Micro Simulation Study of Life Insurance Business

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Agenda

- Modelling Framework
  - Design
  - Computations

- The Life Business
  - Company Overview
  - Company Policies
  - Modelling Approach

- Results & Conclusions

- Some details of Model and ESG in Appendix
Background

- Quoting England and Verrall, 2002: "With the continuing increase in computer power, it has to be questioned whether it would not be better to examine individual claims rather than use aggregate data."
- Here we utilize micro-level insurance data for better informed decisions by performing large simulations
- **Example:** Standard PC + Graphic Cards => Tens of Billions $(10^9)$ Black Scholes per Second
- *Now it is 2013!* Individual simulation is feasible, but fast computers, large memories and efficient algorithms are still crucial
- Fast development each year: Both algorithms and hardware. **Future** looks even better!
I Technical model - Simulation

• **Task 1:** Measuring the effect of management policies on profitability and solvency (under Solvency II)
  • Full stochastic real world policy-by-policy simulation
  • Customer behavior modeling
  • Multiple policy types with embedded options
  • Path-dependent mark-to-market balance sheet simulation

• **Task 2:** Dynamic management actions
  • Profit sharing between dividends, customer benefits, equity
  • Investment strategy changes based on financial position and expected liability cash flows
  • New sales policy (run-off ➔ going concern)
I Technical model - Simulation cycle & High performance computing

1. Simulate or import economic scenarios
2. Go through all years $T$
   1. Go through all customers $N$
      1. Simulate customer’s random events (death, disability ...)
      2. Go through all customer’s contracts (usually 1)
         1. Simulate contract’s random events (surrender, payment, ...)
         2. Go through all time steps in a year (1-12)
            1. Calculate contract’s cash flows for $M$ simulations
            2. Terminate contracts that have encountered a termination condition for $M$ simulations
   2. Generate company balance sheet and make company decisions for $D$ simulations

- The biggest loop (customers, $N$) can be distributed to a computing cluster
  - Local multicore, Computing cluster, Cloud computing

- Computations performed by Matlab (MathWorks) and mSII (Model IT)
I Technical model - ORSA features

• Accurate calculation of mark-to-market technical reserves without nested stochastic simulation
  ➔ Regression approach taken

• Short term simulations with mark-to-market balance sheet can be run with very high simulation count
  • Up to 1 000 000 simulations with 1 year horizon
  • Up to 10 000 simulations with 1-10 year horizon
  ➔ Accurate tail risk calculation

• Real World ESG has two regimes – boom and recession

• Full simulation of the hypothetical company takes ~ 1 hour. In this presentation small samples ~ 1 minute
II The Life business – Company overview (1)

- A publicly listed (hypothetical) life insurance company
- Solo structure with policyholders and investors as the main interest group
- All liabilities are euro denominated
- Solvency II and MCEV are closely followed
- Policy groups are:
  - Pure risk policies
  - 0% and 4% guaranteed rate savings products with all life pension payments and options to switch between guaranteed fund and unit linked funds
- All three policy groups have 100,000 policyholders each
- Estimated year premium from the insurance portfolio including new sales is around 500 million euro
The Life business – Company overview (2)

Age distribution of policyholders

- Policyholders in 4% & UL
- Policyholders in 0% & UL

Age distribution of risk policies

Number of policyholders based to amount of savings

- Savings 4% & UL
- Savings 0% & UL

Number of Risk Policies by risk amount

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2013
### II The Life business – Company overview (3)

**Interest rates quite low,**
Future profits diminished
→ EOF < BS equity
→ SII rate declines

<table>
<thead>
<tr>
<th>31.12.2012 Million €</th>
<th>Life Company</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Assets</strong></td>
<td></td>
</tr>
<tr>
<td>Investments</td>
<td></td>
</tr>
<tr>
<td>Equities</td>
<td>784</td>
</tr>
<tr>
<td>Bonds</td>
<td>6,045</td>
</tr>
<tr>
<td>Loans</td>
<td>536</td>
</tr>
<tr>
<td>Cash</td>
<td>160</td>
</tr>
<tr>
<td>Investment backing unit-linked liabilities</td>
<td>6,218</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>13,743</td>
</tr>
<tr>
<td><strong>Equity</strong></td>
<td></td>
</tr>
<tr>
<td>Core equity</td>
<td></td>
</tr>
<tr>
<td>Share capital</td>
<td>350</td>
</tr>
<tr>
<td>Retained earnings</td>
<td>936</td>
</tr>
<tr>
<td>Sub-Ordinated loans</td>
<td>100</td>
</tr>
<tr>
<td><strong>Liabilities</strong></td>
<td></td>
</tr>
<tr>
<td>Insurance liabilities</td>
<td></td>
</tr>
<tr>
<td>Profit sharing business</td>
<td>6,125</td>
</tr>
<tr>
<td>Pure risk policies</td>
<td>42</td>
</tr>
<tr>
<td>From policies where policyholder bears the investment risk</td>
<td>6,190</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>13,743</td>
</tr>
</tbody>
</table>

**Solvency position**

<table>
<thead>
<tr>
<th>Eligible Own Funds (Solvency II)</th>
<th>Life Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCR</td>
<td>919</td>
</tr>
<tr>
<td>MCR</td>
<td>306</td>
</tr>
<tr>
<td>Solvency rate</td>
<td>88%</td>
</tr>
</tbody>
</table>

**SCR (31.12.2012 Million €)**

| Adjustments                      | -245         |
| Operational risk                 | 69           |
| Basic Solvency Capital Requirement | 1,096    |
| Diversification benefits         | -297         |
| Sum of risk components           | 1,393        |
| **Market risk**                  | 843          |
| Interest rate                    | 350          |
| Equity                            | 280          |
| Property                          | 0            |
| Spread                            | 356          |
| Concentration                     | 60           |
| Currency                          | 38           |
| CCP                               | -            |
| Counterparty default risk         | 60           |
| **Life Underwriting risks**      | 490          |
| Mortality                         | 122          |
| Longevity                         | 244          |
| Disability                        | 121          |
| Expense                           | 119          |
| Revision                          | -            |
| Lapse                             | 207          |
| Life catastrophe                  | 48           |
| Health underwriting risk          | -            |
| Non-Life underwriting risk        | -            |
II The Life business – Company policies (1)

• Overall strategy:
  • Main business area is insurance and capital is primarily budgeted for it
  • Investments are seen as secondary business area getting the residual capital
  • Now solvency position is challenging 88%. Company aims to get its solvency II position over 140% in the strategy period (5 years)
  • It is extremely important to give benefits for the policyholders
  • Also it is crucial to increase the share value and pay dividends.
• Sub strategies will be used to specify and bring the strategy to business level actions
II The Life business – Company policies (2)

- Main Strategy
- Policy for writing new business
- Investment policy
- Capital management policy
- Policy for overall solvency position
- Re-insurance policy
- Profit sharing policy
- Company decision making
- MCEV
- Solvency II
- P & L + Balance Sheet

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II The Life business – Modelling approach (1)

- Policy-by-policy surrenders and lapses are modelled
- In ESG there is a general model that estimates lapse and surrender probabilities using macro-economic data
- Company specific distribution is used (not real data in this exercise)

The distribution of Lapse Probabilities for Savings policies

100% means the same lapse probability as in ESG for a individual

<table>
<thead>
<tr>
<th>Policy Duration</th>
<th>Age</th>
<th>18 - 30</th>
<th>30 - 40</th>
<th>40 - 50</th>
<th>50 - 60</th>
<th>60 - 65</th>
<th>Over 65</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 2</td>
<td></td>
<td>537.60 %</td>
<td>470.40 %</td>
<td>184.80 %</td>
<td>151.20 %</td>
<td>252.00 %</td>
<td>84.00 %</td>
</tr>
<tr>
<td>3 - 5</td>
<td></td>
<td>403.20 %</td>
<td>352.80 %</td>
<td>138.60 %</td>
<td>113.40 %</td>
<td>189.00 %</td>
<td>63.00 %</td>
</tr>
<tr>
<td>6 - 10</td>
<td></td>
<td>107.52 %</td>
<td>94.08 %</td>
<td>36.96 %</td>
<td>30.24 %</td>
<td>50.40 %</td>
<td>16.80 %</td>
</tr>
<tr>
<td>11 - 15</td>
<td></td>
<td>94.08 %</td>
<td>82.32 %</td>
<td>32.34 %</td>
<td>26.46 %</td>
<td>44.10 %</td>
<td>14.70 %</td>
</tr>
<tr>
<td>16 - 20</td>
<td></td>
<td>40.32 %</td>
<td>35.28 %</td>
<td>13.86 %</td>
<td>11.34 %</td>
<td>18.90 %</td>
<td>6.30 %</td>
</tr>
<tr>
<td>21 - 30</td>
<td></td>
<td>53.76 %</td>
<td>47.04 %</td>
<td>18.48 %</td>
<td>15.12 %</td>
<td>25.20 %</td>
<td>8.40 %</td>
</tr>
<tr>
<td>Over 30</td>
<td></td>
<td>107.52 %</td>
<td>94.08 %</td>
<td>36.96 %</td>
<td>30.24 %</td>
<td>50.40 %</td>
<td>16.80 %</td>
</tr>
</tbody>
</table>
Approximating the Solvency II position:
- Assets and liabilities are valued using ESG
- Liabilities with future benefits as in next slide
- There is assumed to be no issues about eligibility of Tier classes (all BOF counts as EOF).
- SCR market risk components are calculated separately:
  - Both interest risk and spread risk are calculated more precisely as the cash-flow structure and rating classes can’t be ignored
  - For equity risk the risk dampener is set to zero
  - Other market risks these are assumed to develop hand-in-hand with the overall asset fluctuations.
- SCR life risks are estimated separately for risk-, guarantee rate savings- and unit linked policies.
- As life SCR risk components are calculated stressing the best estimate liabilities it is assumed that all SCR life risks follow the certain proportion (of market value liabilities) of what they are at the starting point.
- Total SCR is calculated based to different modules and adjustments.
Approximating market consistent technical reserves without nested stochastic simulation

1. Run 60 year market consistent simulation to calculate technical reserves at $t=0$
   1. Store contract-level means of net cash flows and account values for each savings account and time step separately
   2. Calculate time dependent regression analysis of net cash flows’ deviation from mean for each product segment for each decision point against each systematic risk factor in the model

2. Run 5 year real world simulation and at given time $t$ in given simulation path $k$
   1. For each contract that’s alive, accumulate expected future cash flows and adjust with evolved account values
   2. Apply regression coefficients based on current systematic risk factor values for projected net cash flows for each product segment
   3. Discount the projected net cash flows with current yield curve
## II The Life business – Modelling approach (3)

### Company decision making - Algorithmic approach

<table>
<thead>
<tr>
<th>No</th>
<th>Solvency &amp; business trigger</th>
<th>Profit sharing</th>
<th>Risk tolerance</th>
<th>Capital management</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>(EOF/SCR &gt; 300%)</td>
<td>As in No 2 or No 3 depending of dMCEV but after the payments an extra dividend amounting EOF - 3SCR (if positive) will be payed.</td>
<td>This will automatically work through re-allocation processes</td>
<td>Overcapitalization is taken care in profit sharing part</td>
</tr>
<tr>
<td>2.</td>
<td>(140% &lt; EOF/SCR) &amp;&amp; dMCEV &gt; 1.1</td>
<td>As in No 3 but with extra 20% into dividends</td>
<td>Normal stage - no changes</td>
<td>Normal stage - no changes</td>
</tr>
<tr>
<td>3.</td>
<td>(140% &lt; EOF/SCR)</td>
<td>If profit before benefits &amp; taxes is positive, 30% from this will be for benefits and 30% into dividends. Benefits increases the guaranteed funds and shares are just out of the company (but will be taken into account when measuring the company)</td>
<td>Normal stage - no changes</td>
<td>Normal stage - no changes</td>
</tr>
<tr>
<td>4.</td>
<td>100% &lt; EOF/SCR &lt; 140%</td>
<td>As in 3. but benefits are only 15% and dividends zero</td>
<td>Re-allocation (by Euler) takes care of reduction of market risk as there will not be any changes into the amount of Life risk</td>
<td>No changes at this stage</td>
</tr>
<tr>
<td>5.</td>
<td>2/3 &lt; EOF/SCR &lt; 100%</td>
<td>No benefits or shares</td>
<td>The proportion invested into B rated bonds are allocated into less risky (A rated) bonds. The proportion in equities is reduced automatically towards zero as EOF reaches 2/3 SCR.</td>
<td>Sub-ordinated loans will grow and amount of (EOF - 1.1 SCR) assuming that there has not been any other new loan in current simulation (one time event in strategy period 5 years).</td>
</tr>
<tr>
<td>6.</td>
<td>MCR &lt; EOF/SCR &lt; 2/3</td>
<td>No benefits or shares</td>
<td>The parameter controlling the maximum amount of new policies will stop all sales of new policies. Proportion invested into A rated bonds will be allocated into AAA class.</td>
<td>Share capital will increase by an amount of (EOF - SCR) assuming that there has not been any other new share capital in current simulation (one time event in strategy period 5 years).</td>
</tr>
<tr>
<td>7.</td>
<td>EOF/SCR &lt; MCR</td>
<td>Insolvency</td>
<td>Insolvency</td>
<td>Insolvency</td>
</tr>
</tbody>
</table>
III Simulation results – ESG

- Stock returns
- Probability intervals
- Correlation: Solvency ratio vs. Stock return
- Outliers?
III Simulation results – Solvency II measures

- Equity is 1.4 x SCR and 4 x MCR as a mean level in year four (2016)

- Distributions widen quite much

- The cumulative probability of going insolvent (EOF < MCR) is sufficiently low
III Simulation results – future dividends

- The amount company is able to pay dividends (according to its policy)
  - Negligible in 2013
  - Grows as its solvency position recovers
III Simulation results – Correlations

- Surender vs. Inflation in 2016
  OBS.: Two regimes in inflation

- Stock investment vs. Benefits
Conclusions I

• Individual level simulation is feasible computational tool for life insurance modeling
  • Flexibility to model the future cash flows realistically
  • Better information can potentially lead to better decisions
    • Effective communication critical!
• Computational power needs to be focused on essential tasks: most demanding or frequent; Full data or small sample?
• **Specific / tailored** algorithms needs to be developed for (e.g.):
  • Contract level cash-flows
  • Avoiding nested simulations in ERM/ORSA
  ➔ Parallel algorithms
    Fast data structures
    Tailored versions of known computational statistics / finance algorithms + know new methods
• Interactive tools needed for interactive model development / use
Conclusions II

- For business decisions
  - It should be clarified which metrics to follow (here SII and MCEV levels)
  - well-defined strategy and harmony between sub strategies appropriately taken into account in the model will help

- Causality structure drives results
  - Interactive modeling a tool for scrutinizing stochastic causality
  - Stochastic sensitivity analysis

- All model components need to be realistic enough so that the overall process complexity can be separated into understandable parts.

- The link between policyholder behavior and company was here approached via economic scenarios resulting lapses → more interrelationships (like other events that cause lapses) could have also been needed

- For Solvency II purposes this kind of modeling would probably cover many of the ORSA requirements.
Thank You!

• Modeling is not always easy, but it makes actuaries real all-around experts!
Appendix: Technical model - Overview

External input
Economic scenarios

Asset Valuation
Company decisions
Liability Simulation

Full yearly distribution of
Cash Flows
Income Statement
Balance Sheet

SII Pillar 1
MCEV
SCR

ERM and ORSA
Business Decisions
Appendix: Technical Model - Balance Sheet

**Liabilities**
- Equity
- SCR
- MCR
- Technical reserves

**Assets**
- Fixed income investments
- Equity and other investments
- Unit Link investments
- Priced with current* yield curve
- Modeled as a basket of ESG indices
- Sum of current* unit link policy savings

- Based on policy-level SCR attribution and current* investment risk
- Expected value of future cash flows
  - For policies still active in current* simulation
  - Adjusted with evolved short rate and current* yield curve
  - Discounted with current* yield curve

* Current = current simulation path and current time step
Appendix: Technical Model – Contract Definitions

Random events
- Death
- Switch
- Retirement
- Payment
- Surrender

Triggered cash flows
- Savings to be paid to customer with life coverage multiplier
- Switch between savings accounts
- Pension calculation
- Cash flow to savings
- Payment fee
- Surrender fee

Recurring cash flows
- Administration fee
- Unit link returns
- Benefits
- Pension
- Pension fee

Economic scenarios
Company decisions

Contract termination
With delay
If full surrender
Appendix: ESG Part 1

• Quite simple ESG is used / not exact statistical fit. Published research articles => Parameters for the ESG model.

• A more sophisticated feature: ESG is its dependence on business cycle. Homogenous Markov process $S(t)$ where the probability to stay in expansion regime $S(t) = 1$ is $0.97$ and the probability to stay in recession regime $S(t) = 1$ is $0.40$.

• We assume that the primary process is that related to GDP development. This drives the other processes inflation and equity return. Inflation in turn drives nominal interest rates.

• Yield-curve modeling methodology relies on a stochastic state space formulation of the Nelson-Siegel. Here model follows autoregressive processes. Interest rates incorporate regime-switching behavior in the time-series evolution through the above inflation process.
Appendix: ESG Part 2

- Monthly inflation follows autoregressive process
  - \( y(t) - 0.01 = 0.63 \times [ y(t-1) - 0.01 ] + 0.013 \times e(t), \) when \( S(t) = 1 \) (expansion regime)
  - \( y(t) - 0.08 = 0.4 \times [ y(t-1) - 0.08 ] + 0.038 \times e(t), \) when \( S(t) = 2 \) (recession regime)

- Monthly stock returns \( p(t) \) by a two-regime mixture model.
  Interpretation: regime one produces bubble periods and regime two periods which bring prices back to fundamentals.
  - \( p(t) = 0.027 + 0.027 \times e(t) \) when \( S(t) = 1 \) (expansion regime)
  - \( p(t) = -0.3 + 0.059 \times e(t) \) when \( S(t) = 2 \) (recession regime)