Risk Margin for a Non-Life Insurance Run-Off

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Non-life insurance claims prediction problem

- **Insurance claims generate claims liability cash flows:**
  1. reporting delay
  2. claims settlement process (generates claims liability cash flows)
  3. possible re-opening (generates more claims liability cash flows)

- **Actuarial task:** Predict and value the outstanding claims liability cash flows based on all available information!

  ➞ These predictions give the claims provisions.

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Claims development triangle in non-life insurance

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- \( X_{i,j} \) denote the payments for accident year \( i \) in development year \( j \), thus they are paid in accounting year \( k = i + j \).

- Observed payments \( D_I = \{ X_{i,j}; \ i + j \leq I \} \) at time \( I = 2010 \).
Claims prediction in non-life insurance

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- **Predict** and **value** the cash flows in the lower triangle

$$
\mathcal{D}_I^c = \{ X_{i,j}; \ i + j > I \}.
$$

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(Nominal) best-estimate reserves

- Model the payments $X_{i,j}$ within a stochastic framework.

- The nominal best-estimate reserves at time $I$ for the outstanding loss liabilities $X_{i,j} \in D^c_I$ (lower triangle) are defined by

$$R_I = \sum_{i+j>I} \mathbb{E} [X_{i,j} | D_I].$$

This is the probability-weighted average of all future cash flows based on the latest information available (see Solvency II guidelines).

- Predictors $\mathbb{E} [X_{i,j} | D_I]$ have minimal prediction variance (optimal).

- For (stochastic) discounting we refer to W.-Merz [5].
Bayesian chain-ladder (CL) model

Define cumulative payments \( C_{i,j} = \sum_{l=0}^{j} X_{i,l} \).

**Model assumptions.**

- Conditionally, given \( F = (F_0, \ldots, F_{J-1}) \),
  - \( (C_{i,j})_{j=0,\ldots,J} \) are independent (in \( i \)) Markov processes (in \( j \)),
  - \( C_{i,j+1} \) only depends on \( F_j \) and \( C_{i,j} \), and
  - for \( j = 0, \ldots, J-1 \)
    \[
    \mathbb{E} \left[ C_{i,j+1} \mid F, C_{i,j} \right] = F_j \, C_{i,j}.
    \]

- \( F_0, \ldots, F_J \) are independent and positive.

- \( F \) and \( \{C_{i,0} ; \ i \leq I\} \) are independent.
Bayesian chain-ladder (CL) model

Define cumulative payments $C_{i,j} = \sum_{l=0}^{j} X_{i,l}$.

**Model assumptions.**

- Conditionally, given $F = (F_0, \ldots, F_{J-1})$,
  
  $\triangleright$ $(C_{i,j})_{j=0,\ldots,J}$ are independent (in $i$) Markov processes (in $j$),
  $\triangleright$ $C_{i,j+1}$ only depends on $F_j$ and $C_{i,j}$, and
  $\triangleright$ for $j = 0, \ldots, J-1$

  $\mathbb{E} [C_{i,j+1} | F, C_{i,j}] = F_j C_{i,j}$.

- $F_0, \ldots, F_J$ are independent and positive.

- $F$ and $\{C_{i,0}; i \leq I\}$ are independent.
Remarks on the Bayesian CL model

- Conditionally, given $F$, we have the CL model of Mack (1993).
- Difficulty in practice: $F$ is not known and needs to be estimated.
- Bayesian solution: assume $F$ is part of the stochastic model and model it with a prior distribution.

Bayesian CL model $\Rightarrow$ Bayesian CL model.

- Modeling $F$ stochastically expresses our uncertainty about its true value. This parameter uncertainty will then naturally appear in the prediction uncertainty analysis.
Best-estimate reserves in the Bayesian CL model

• Within the Bayesian CL model the best-estimate reserves are given by, see Bühlmann et al. [1],

\[
\mathcal{R}_I = \sum_{i=I-J+1}^{I} C_{i,I-i} \left( \prod_{j=I-i}^{J-1} \widehat{f}_j^{(I)} - 1 \right),
\]

where

- \( \widehat{f}_j^{(I)} = \mathbb{E} [F_j | D_I] \) posterior CL factors given information \( D_I \),
- \( F_j \) unknown CL factors (modeled stochastically with priors).

• In many cases the best-estimate reserves \( \mathcal{R}_I \) can be calculated analytically.
Conjugate priors

For conjugate prior distributions for $F_j$ we often obtain

$$\hat{f}_j^{(I)} = \alpha_j^{(I)} \frac{\sum_{i=0}^{I-j-1} C_{i,j+1}}{\sum_{i=0}^{I-j-1} C_{i,j}} + \left(1 - \alpha_j^{(I)}\right) \mathbb{E}[F_j],$$

or

$$\hat{f}_j^{(I)} = \alpha_j^{(I)} \sum_{i=0}^{I-j-1} \frac{C_{i,j+1}}{C_{i,j}} + \left(1 - \alpha_j^{(I)}\right) \mathbb{E}[F_j],$$

thus, the posterior CL factor $\hat{f}_j^{(I)}$ is a credibility weighted average between observations in $D_I$ and the prior mean $\mathbb{E}[F_j]$, see Bühlmann et al. [1] and W.-Embrechts-Tsanakas [4].
Technical provisions

deterministic best-estimate reserves $\iff$ stochastic claims payments

- Solvency II Directive 2009/138/EC:
  
  "liabilities shall be valued at the amount for which they could be transferred, or settled, between knowledgeable willing parties in an arm’s length transaction."

- The resulting amount is called technical provisions.

- The technical provisions are the sum of the best-estimate reserves and the market-value margin (MVM) (also called risk margin).

- The MVM is a reward for risk bearing of the (non-hedgeable) run-off risks in the outstanding loss liability cash flows.
Market-value margin (MVM)

• Technical provisions (market-consistent value) for the outstanding loss liabilities are given by

\[ R_I^+ = R_I + \text{MVM}_I. \]

• How should we calculate \( \text{MVM}_I \)?

• It should reflect the uncertainties in the prediction of \( \sum_{i+j>I} X_{i,j} \) when using the predictor \( R_I \).

• A risk-averse financial agent asks for a reward (MVM) for bearing possible shortfalls in the run-off of the outstanding loss liabilities.
Different MVM approaches

• The full **cost-of-capital approach** is rather **complex**: uses multi-period risk measures and leads to nested simulations. Therefore, approximations are used:

  ★ **expected run-off scaling approach** (used in Solvency II) is **NOT** risk-based;
  ★ **split of total uncertainty approach** (see Salzmann-W. [2]).

• **Expected utility theory approach**

• **Probability distortion approach**, see W.-Embrechts-Tsanakas [4],
  ★ straightforward,
  ★ well-known in life insurance,
  ★ consistent with risk neutral pricing in financial mathematics.
Probability distortion approach

The technical provisions at time $I$ for the outstanding loss liabilities $X_{i,j} \in D_I^c$ (lower triangle) are defined by

$$R^+_I = \sum_{i+j>I} \frac{1}{\varphi_I} \mathbb{E} \left[ \varphi_{i+j} X_{i,j} \mid D_I \right] = \sum_{i+j>I} \mathbb{E}^* \left[ X_{i,j} \mid D_I \right],$$

where $(\varphi_k)_{k \geq 0}$ is a probability distortion satisfying:

1. $(\varphi_k)_{k \geq 0}$ is a density process, i.e.
   - $\varphi_k$ is strictly positive, $\mathbb{P}$-a.s.,
   - $(\varphi_k)_{k \geq 0}$ is $(\sigma\{D_k\})_{k \geq 0}$-adapted,
   - $(\varphi_k)_{k \geq 0}$ is a martingale, i.e. $\mathbb{E} \left[ \varphi_{k+1} \mid D_k \right] = \varphi_k$, with $\varphi_0 \equiv 1$ (normalization).

2. The sequence $\frac{1}{\varphi_k} \mathbb{E} \left[ \varphi_{i+j} X_{i,j} \mid D_k \right], k \geq 0$, is a super-martingale.
Probability distortion MVM

The technical provisions at time $I$ for the outstanding loss liabilities $X_{i,j} \in D^c_I$ (lower triangle) are defined by

$$R^+_I = \sum_{i+j>I} \frac{1}{\varphi_I} \mathbb{E} \left[ \varphi_{i+j} X_{i,j} | D_I \right] = \sum_{i+j>I} \mathbb{E}^* \left[ X_{i,j} | D_I \right],$$

these assumptions on the probability distortion $(\varphi_k)_{k \geq 0}$ imply

$$R^+_I \geq R_I \quad \text{and} \quad \text{MVM}_I \stackrel{\text{def.}}{=} R^+_I - R_I \geq 0.$$

Thus, we obtain a positive MVM reward for risk bearing (that should reflect (i) prediction uncertainty and (ii) risk-aversion).
Explicit probability distortion choice for CL

- In W.-Embrechts-Tsanakas [4] we provide an explicit choice for the probability distortion \((\varphi_k)_{k \geq 0}\) in a Bayesian CL model.

- This choice provides technical provisions

\[
\mathcal{R}_I^+ = \sum_{i=I-J+1}^{I} C_{i,I-i} \left( \prod_{j=I-i}^{J-1} \hat{f}_j^{(I+)} - 1 \right),
\]

where

\[
\hat{f}_j^{(I+)} = \left( \hat{f}_j^{(I)} - 1 \right) h_j^{(I)}(\alpha_1, \alpha_2) + 1 \geq \hat{f}_j^{(I)},
\]

with

- distortion function \(h_j^{(I)}(\alpha_1, \alpha_2) \geq 1\) such that
- \(\alpha_1\) risk-aversion parameter for **process uncertainty**,
- \(\alpha_2\) risk-aversion parameter for **parameter uncertainty**.
Properties of the distortion function

The risk-aversion adjusted CL factor is given by

\[
\tilde{f}_j^{(I+)} = \left( \tilde{f}_j^{(I)} - 1 \right) h_j^{(I)}(\alpha_1, \alpha_2) + 1 \geq \tilde{f}_j^{(I)},
\]

and the distortion function \( h_j^{(I)}(\alpha_1, \alpha_2) \) satisfies

- increasing in the process uncertainty parameter \( \alpha_1 \),
- increasing in the parameter uncertainty parameter \( \alpha_2 \),
- decreasing in time \( I \) (more information becoming available reduces the uncertainty).
Interpretation non-life vs. life insurance

• CL factors $\hat{f}_j^{(I)}$ correspond to a second order life table,

• risk-aversion adjusted CL factors $\hat{f}_j^{(I+)} \geq \hat{f}_j^{(I)}$ to a first order life table (with safety margin).

• Technical provisions satisfy

$$\mathcal{R}^+_I = \sum_{i=I-J+1}^{I} C_{i,I-i} \left( \prod_{j=I-i}^{J-1} \hat{f}_j^{(I+)} - 1 \right)$$

$$\geq \sum_{i=I-J+1}^{I} C_{i,I-i} \left( \prod_{j=I-i}^{J-1} \hat{f}_j^{(I)} - 1 \right) = \mathcal{R}_I.$$
Probability distortion and MVM calibration

- Market-value margin is given by

\[
\text{MVM}_I = \sum_{i=I-J+1}^{I} C_{i,I-i} \left( \prod_{j=I-i}^{J-1} \hat{f}_j^{(I+)} - \prod_{j=I-i}^{J-1} \hat{f}_j^{(I)} \right) \geq 0.
\]

- Note that the MVM can only be calculated as a difference!

- Calibration and comparison:
  - Choose \( \alpha_1 \) (for process uncertainty) and \( \alpha_2 \) (for parameter uncertainty) so that the MVM has a similar size as the one from Solvency II.
  - Study qualitatively the expected run-off/release of the MVM.

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Expected run-off in private liability insurance

MVM(1) = Solvency II approach
MVM(2) = split of total uncertainty approach, Salzmann-W. [2, 3]
MVM(3) = probability distortion approach, see [4]
Conclusions

- Probability distortions provide a straightforward and simple framework for the modeling of the MVM.

- Risk-aversion corresponds to a prudent choice of the CL factors.

- Most practical examples show that the Solvency II approach underestimates the run-off uncertainties, see also W. [3].

- However, the MVM is relatively small compared to other positions and risk management should concentrate on the important issues!
References


