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Market-Consistent Valuation and Capital Assessment for Demographic Risk in Life Insurance: A Cohort Approach

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Overview

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Solvency Capital Requirement

- Risk measure: Value-at-Risk
- Level of confidence: 99.5%
- Time horizon: 1 year

Inflows and outflows over a 1-year time horizon

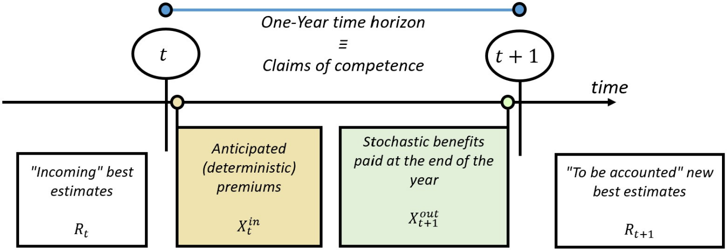

Figure: A graphical representation of the book entries in a generic year t and considering an annual time horizon

Cash-flows definition

We examine a cohort composed (at the inception) of l_0 policyholders. Considering a generic valuation instant t, we define $\mathbf{X}_{(t)} = [X_\tau]_{\tau=t,\dots,n}$ where each element X_τ is defined as follows:

$$X_\tau := \begin{cases} -X_\tau^{in} & \text{if } \tau = t, \\ X_\tau^{out} - X_\tau^{in} & \text{if } t < \tau < n, \\ X_\tau^{out} & \text{if } \tau = n \end{cases} \tag{1}$$

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where

$$X_\tau^{out} := (\mathbf{S}_{\tau-1})^\intercal \cdot \mathbf{\Lambda}_{\tau-1}^B \cdot U_\tau^{out,\ \tau} \tag{2}$$

and

$$X_\tau^{in} := (\mathbf{S}_\tau)^\intercal \cdot \mathbb{1} \cdot U_\tau^{in,\ \tau} \tag{3}$$

Example: Out-flows representation

We defined

$$X_{\tau}^{out} := (\mathbf{S}_{\tau-1})^{\intercal} \cdot \mathbf{\Lambda}_{\tau-1}^{B} \cdot U_{\tau}^{out,\ \tau} \tag{4}$$

or, analogously,

$$X_{\tau}^{out} := \begin{pmatrix} S_{1,\tau-1} & S_{2,\tau-1} & \dots & S_{l_0,\tau-1} \end{pmatrix} \cdot \begin{pmatrix} \mathbb{I}_{1,\tau-1}^{D} \\ \mathbb{I}_{2,\tau-1}^{D} \\ \dots \\ \mathbb{I}_{l_0,\tau-1}^{D} \end{pmatrix} \cdot U_{\tau}^{out,\ \tau} \tag{5}$$

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$$X_{\tau}^{out} := (\mathbf{S}_{\tau-1})^{\mathsf{T}} \cdot \mathbf{\Lambda}_{\tau-1}^{B} \cdot U_{\tau}^{out,\ \tau} \tag{4}$$

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- $(\mathbf{S}_{\tau-1})^{\intercal}$ is a $l_0 \times 1$ vector of insured sums,
- $\mathbf{\Lambda}_{\tau-1}^{B}$ is a $l_0 \times 1$ $\mathbb{T}$-adapted matrix of insurance technical variables which elements are i.i.d. Bernoulli r.v. $\mathbb{I}_{k,\tau-1}^{D}$ (with $k \in [1, l_0]$) with parameters equals to the **r.v.** probabilities the beneficiaries become *eligible* for benefit in $[\tau - 1, \tau]$,

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- $\left(U_{\tau}^{out,\ t}\right)_{t\in[0,n]}$ is a $\mathbb{G}$-adapted stochastic process and represents the process of the financial portfolio $\mathcal{U}_{\tau}^{out}$ used to replicate the outflow at time τ;

The Cohort Valuation Portfolio construction (1/2)

Step 1: Choice of financial instruments

In the most generic way, here we define with $\mathcal{U}_t^{out}$ the portfolio of financial instruments to replicate the outflow X_t^{out}. The $\mathcal{U}_t^{out}$ portfolio can be understood as a linear combination of weights $y_{i,t}^{out}$ of financial instruments available on the market $\mathcal{M}$:

$$\mathcal{U}_t^{out} = \sum_{i \in \mathcal{M}} y_{i,t}^{out} \cdot \mathcal{U}_{i,t}^{out} \tag{6}$$

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Step 2: Determination of the number of portfolio shares to be held to replicate the cash flows

It is necessary to identify the best estimate of the number of such instruments that the insurance company must hold to replicate the general future cash flows $\mathbf{X}_{(t)}$. Coherently with [Wüthrich, 2010], we have:

$$\begin{aligned} \mathbf{X}_{(t)} \rightarrowtail & VaPo_t\left(\mathbf{X}_{(t)}\right) = \\ & = \mathbf{E}\left(\mathbf{S}_t \middle| \mathcal{T}_t\right)^{\intercal} \cdot \mathbf{E}\left[\left(\mathbf{\Lambda}_{(t)}^{L} \circ \mathbf{\Lambda}_{(t)}^{B}\right) \middle| \mathcal{T}_t\right] \cdot \boldsymbol{\mathcal{U}}_{(t+1)}^{out} \\ & - \mathbf{E}\left(\mathbf{S}_t \middle| \mathcal{T}_t\right)^{\intercal} \cdot \mathbf{E}\left[\left(\mathbf{\Lambda}_{(t)}^{L}\right) \middle| \mathcal{T}_t\right] \cdot \boldsymbol{\mathcal{U}}_{(t)}^{in} \end{aligned} \tag{7}$$

The Cohort Valuation Portfolio (VaPo) construction (2/2)

Step 3: The account principle to evaluate financial instrument

This last step presents an accounting principle which associates a monetary value to each financial instrument. We choose to use a fair value valuation consistent with the Solvency II framework. We indicate this accounting principle with $\mathcal{E}_t$ with $t \in [0, n]$ and we define the accounting value of the cash-flows as

$$\begin{aligned} \mathbf{X}_{(t)} \rightarrowtail \mathcal{Q}_t\left(\mathbf{X}_{(t)}\right) &= \mathcal{E}_t\left(VaPo_t\left(\mathbf{X}_{(t)}\right)\right) = \mathcal{R}_t \\ &= \mathbf{E}\left(\mathbf{S}_t \middle| \mathcal{T}_t\right)^{\intercal} \cdot \mathbf{E}\left[\left(\boldsymbol{\Lambda}^L_{(t)} \circ \boldsymbol{\Lambda}^B_{(t)}\right) \middle| \mathcal{T}_t\right] \cdot \mathcal{E}_t\left(\boldsymbol{\mathcal{U}}^{out}_{(t+1)}\right) \\ &- \mathbf{E}\left(\mathbf{S}_t \middle| \mathcal{T}_t\right)^{\intercal} \cdot \mathbf{E}\left[\left(\boldsymbol{\Lambda}^L_{(t)}\right) \middle| \mathcal{T}_t\right] \cdot \mathcal{E}_t\left(\boldsymbol{\mathcal{U}}^{in}_{(t)}\right) \end{aligned} \tag{8}$$

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Filtrations

$$\begin{aligned} &\mathbb{F} = (\mathcal{F}_t)_{t\in[0,n]} \text{ is the filtration containing all information} \\ &\mathbb{T} = (\mathcal{T}_t)_{t\in[0,n]} \text{ is the filtration containing demographic information} \\ &\mathbb{G} = (\mathcal{G}_t)_{t\in[0,n]} \text{ is the filtration containing financial information} \\ &\mathbb{T} \text{ and } \mathbb{G} \text{ are independent w.r.t. the probability measure } P \end{aligned} \tag{9}$$

Claims Development Results (CDRs) - Definition

The starting point therefore coincides considering the quantity V_{t+1} (value generated by the portfolio composed of reserves and inflows of year t) defined as

$$\begin{aligned} V_{t+1} := & (\mathbf{S}_t)^\intercal \cdot \mathbf{E}\left[\left(\boldsymbol{\Lambda}^L_{(t)} \circ \boldsymbol{\Lambda}^B_{(t)}\right) \middle| \mathcal{T}_t\right] \cdot \mathbf{U}^{out,\ t+1}_{(t+1)} \\ & - (\mathbf{S}_t)^\intercal \cdot \mathbf{E}\left[\left(\boldsymbol{\Lambda}^L_{(t+1)}\right) \middle| \mathcal{T}_t\right] \cdot \mathbf{U}^{in,\ t+1}_{(t+1)} \end{aligned} \tag{10}$$

We define the Claims Development Result (CDR) CDR_{t+1} as

$$CDR_{t+1} := V_{t+1} - X^{out}_{t+1} - \mathcal{R}_{t+1} \tag{11}$$

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We then introduce the quantity $\hat{\mathcal{R}}_{t+1}$ that represents the **best estimate** in $t+1$ under the assumption that the **technical risk is conditioned on the information contained in $\mathcal{T}_t$**.
Hence, we split the CDR in two components as follows:

$$CDR^{Idios}_{t+1} = V_{t+1} - X^{out}_{t+1} - \hat{\mathcal{R}}_{t+1} \tag{12}$$

and

$$CDR^{Trend}_{t+1} = \hat{\mathcal{R}}_{t+1} - \mathcal{R}_{t+1} \tag{13}$$

CDR Idiosyncratic

It is possible to define the idiosyncratic risk as

$$CDR_{t+1}^{Idios} = \left[\mathbf{E}\left(\mathbf{S}_t \circ \mathbf{\Lambda}_t^B \middle| \mathcal{T}_t\right) - \mathbf{E}\left(\mathbf{S}_t \circ \mathbf{\Lambda}_t^B \middle| \mathcal{T}_{t+1}\right)\right]^{\mathsf{T}} \cdot \mathbb{1} \cdot \eta_{t+1} \tag{14}$$

where $\eta_{t+1} = \left(U_{t+1}^{out,\ t+1} - \beta_{t+1}\right)$ with β_{t+1} best estimate rate of a policyholder of the cohort calculated in $t+1$ with technical bases estimated in t.

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By means of the tower property,

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Moreover, it is possible to prove

$$Var\left(CDR_{t+1}^{Idios} \middle| \mathcal{F}_t\right) = \left(l_t \cdot\ q_{x+t} \cdot (1 - q_{x+t}) \cdot \bar{\mathbf{S}}_t^2 + l_t^2 \cdot \left(\bar{\mathbf{S}}_t^1\right)^2 \cdot \sigma_{Q_{x+t}}^2\right) \cdot \mathbf{E}\left(\eta_{t+1}^2 \middle| \mathcal{G}_t\right) \tag{16}$$

where $\bar{\mathbf{S}}_{2,t}$ is the quadratic average of the sums insured.

Algorithm for CDR_{t+1}^{Trend}

1. Using train data available at time t, fit a projection model to forecast expected mortality rates for the residual coverage period $(q_{x+t}, ..., q_{x+t+n-1})$;
2. Estimate the uncertainty around the central estimates, e.g. by a number H of iterations of a bootstrapping methodology, obtaining the distribution of the r.v. Q_{x+t};
3. In each simulation, generate the deaths of the policyholders from l_t Bernoulli r.v.;
4. In each simulation $h = 1, ...H$, build a new train data set DB_{t+1}^{h} composed by the train data set used at step 1 and by the one-year mortality rates obtained at step 2 in the simulation h.
5. In each simulation, re-fit the mortality model selected at step 1 on the new train dataset DB_{t+1}^{h}, enriched with additional information simulated under real-word probabilities, and estimate new expected mortality rates for the residual coverage period at time $t + 1$.
6. Calculate $\mathbf{U}_{(t+2)}^{out,\ t+1}$ and $\mathbf{U}_{(t+1)}^{in,\ t+1}$ simulating the underlying financial variables $\mathbf{U}_{t+1}$;
7. Compute for each simulation $CDR_{t+1}^{h, Trend}$;
8. Calculate

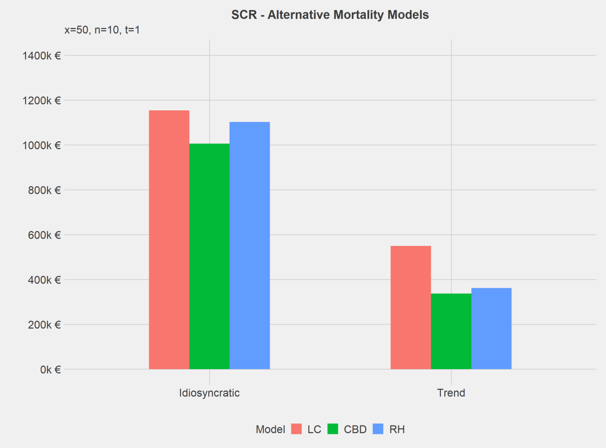
$$SCR_{Trend} = -min \left[CDR_{t+1}^{h, Trend} : \mathbf{F}_{\mathbf{CDR}_{t+1}^{Trend}} \left(CDR_{t+1}^{h, Trend} \right) > 0.5\% \right] \qquad (17)$$

The characteristics of the cohort & the market ones

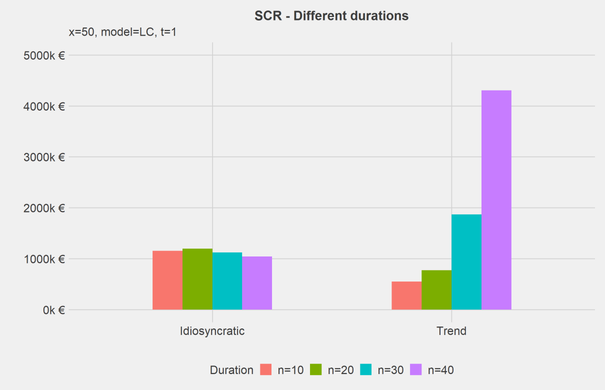
Table: Model parameters

Characteristics	**Value**
Type of policy	Endowment
Number of policyholders in $t = 0$	10,000
Cohort age	50
Policies duration	10 years
1st order demographic base	2nd order q_x increased of 20%
2nd order demographic base	Lee-Carter applied on 1852-2019 Italy data
Risk-free rate	Constant and equals to 2%
Guaranteed rate i_{gar}	1%
Average sum insured	100,000
Coeff.Var. of s_0	2

Alternative Mortality Models



Different Durations



Different Ages and Durations

Conclusions (1/2)

The proposed model incorporates the **market-consistent actuarial valuation provided by Solvency II** and effectively computes the key characteristics of both components of demographic risk: idiosyncratic and trend. The model shows a punctual performance when applied to a single cohort of policyholders.

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One notable advantage of the model is its efficient computational framework, leveraging **matrix notation** to significantly reduce computation times. By utilizing this approach, actuarial calculations can be performed more swiftly, facilitating timely analysis and decision-making processes.

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- The dependence between cohorts,
- The dependence between idiosyncratic risk and trend risk,
- The possibility of obtaining the CDR_{t+1}^{Trend} characteristics in a closed formula.
- To consider other types of guarantees, e.g., Cliquet

References

Clemente, Gian Paolo and Della Corte, Francesco and Savelli, Nino (2022)

A stochastic model for capital requirement assessment for mortality and longevity risk, focusing on idiosyncratic and trend components

Annals of Actuarial Science 16(3), 527-546.

Clemente, Gian Paolo and Della Corte, Francesco and Savelli, Nino (2024)

An undertaking specific approach to address diversifiable demographic risk within Solvency II framework

Decisions in Economics and Finance 1-28.

Clemente, Gian Paolo and Della Corte, Francesco, Savelli, Nino and Zappa, Diego (2024)

Market-Consistent Valuation and Capital Assessment for Demographic Risk in Life Insurance: A Cohort Approach.

North American Actuarial Journal (2024): 1-25 .

Dhaene, Jan and Stassen, Ben and Barigou, Karim and Linders, Daniel and Chen, Ze (2017)

Fair valuation of insurance liabilities: Merging actuarial judgement and market-consistency

Insurance: Mathematics and Economics 76 (2017): 14-27

Wüthrich, Mario V. and Merz, Michael (2013)

Financial modeling, actuarial valuation and solvency in insurance

New York: Springer No. 11390.

Wüthrich, Mario V. and Bühlmann, Hans and Furrer, Hansjörg (2010)

Market-consistent actuarial valuation

Berlin: Springer Vol.2.

Thanks for your attention!

For any comments, do not hesitate to write me at
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