Living forever with Solvency II: A closer look at mortality stresses

Alexandre Boumezoued

Milliman

In recent Consultation Papers, the European Insurance and Occupational Pensions Authority (EIOPA) proposed an alternative calibration of the Standard Formula mortality and longevity stresses. This white paper proposes two alternative and complementary views on the mortality and longevity shock calibration: a prospective approach in the spirit of one-year calculations as well as a retrospective analysis based on historical data from corrected mortality tables.

The study derives significantly lower shocks compared to the Standard Formula using an approach similar to EIOPA's, but accounting for a proper one-year view of risk. In addition, this paper argues for enhancement to account for other sources of risk.

After the Solvency II Directive came into effect on 1 January 2016, the European Commission asked EIOPA in July 2016 for technical advice on the review of specific items in the Solvency II Delegated Regulation. In November 2017, EIOPA first released a Consultation Paper (CP-17-006) providing a second set of advice to the European Commission and submitted on 28 February 2018 the final technical paper (BoS-18/075). Among the various risks at stake in the Standard Formula that have been studied, this white paper focusses on the standard parameters for mortality and longevity risks in the life and health underwriting modules.

In the Consultation Paper, EIOPA calculates the mortality and longevity shocks on an ultimate basis-- that is, the random time factors driving the mortality rates evolution are simulated from the current year until a limit age is reached. Recall that the famous Article 101 of the Solvency II Directive states:

"The Solvency Capital Requirement shall correspond to the Value-at-Risk of the basic own funds of an insurance or reinsurance undertaking subject to a confidence level of 99.5% over a one-year period".

In this context, we propose an alternative method in line with the one-year view to calibrate the mortality and longevity stresses. We highlight the main differences between the ultimate and the one-year approaches to the calibration of mortality and longevity risks. Firstly, we describe EIOPA's ultimate approach and interpret it for each stochastic mortality model. Secondly, we introduce an alternative prospective approach consistent with the one-year view. Finally, we put the results into perspective with a retrospective analysis based on historical mortality improvements.

EIOPA results on longevity/mortality shocks re-calibration

In this part, we introduce the method used in the Consultation Paper released by EIOPA. We present the different assumptions made, the simulation-based method used and the outputs.

DATA SELECTION AND MODEL FITTING

- **Mortality data:** The data used comes from the Human Mortality Database (HMD) for the following countries: France, Germany, the Netherlands, Italy, Poland, Spain, the UK, Denmark, Belgium, Sweden and Greece. Note that we consider the February 2018 update of the HMD providing revised mortality tables. The demographic data covers more than 80% of the global European population. The period chosen for calibration is 1985-2014 except for Germany because the west and east data were combined only in 1990, and Greece, whose data is available up to year 2013. To make a proper comparison, both models are fitted using the age range 40 to 90. Mortality tables are extrapolated up to 120-years-old thanks to the Kannisto rule, similar to EIOPA's approach.
- **Model selection:** Mortality rates are forecast thanks to the widely used stochastic mortality models by Lee & Carter (1992) and Cairns, Blake & Dowd (2006) as in the EIOPA study. Each model provides a different view on mortality dynamics: the model by Lee & Carter allows getting a refined age structure for mortality rates but assumes that a single risk factor drives their time dynamics. On the other hand, the Cairns, Blake & Dowd model depends on two time risk drivers while assuming a simple log-linear age structure for the mortality rates; therefore, no parameters in age have to be estimated. Note that alternative approaches like the Age- Period-Cohort-Improvement (APCI) model of the Continuous Mortality Investigation (CMI) Bureau could have been considered, although we suspect that similar conclusions hold in terms of comparison between the one-year and the ultimate view as discussed in the present paper.

EIOPA'S CALIBRATION METHOD

The calibration method used in the Consultation Paper is described as follows:

- Based on the parameter estimates for each stochastic mortality model and each country, 5000 future mortality tables are simulated at an ultimate horizon – in particular, the simulation of underlying risk factors is performed at each projection year.
- Life expectancies are calculated for each attained age given the survival function determined by the simulated mortality tables. The 99.5 and 0.5 percentile realisations of the cohort life expectancies are then computed.
- For each age, the optimal mortality and longevity shocks are defined as the shocks that minimise the distance between the life expectancy in the central scenario and the quantile realization.

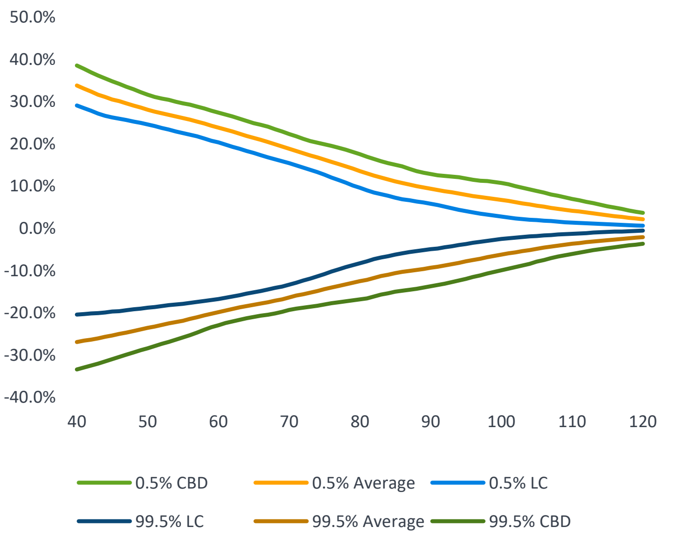
Through this process, mortality and longevity shocks are obtained for each age and each model.

EIOPA'S CALIBRATION RESULTS

To ensure consistency with our complementary analysis, we computed ourselves the shocks on an ultimate basis by sticking to the assumptions and the method previously introduced.

The results are depicted in Figure 1, where we notice that the shocks computed with the Cairns, Blake & Dowd model appear more severe, mainly because two random risk factors are involved, unlike the Lee and Carter model that includes only one time series. On average, taking age 60 as a reference, the longevity shock is close to -20% and the mortality shock is close to +25%.

FIGURE 1: MORTALITY AND LONGEVITY SHOCKS PER AGE USING THE LEE-CARTER AND CAIRNS-BLAKE-DOWD MODELS – ULTIMATE BASIS



Another central point that must be mentioned is the fact that the shock decreases with age. Indeed, the simulation is performed here for each cohort until the limit age, so that as the attained age increases, the number of remaining years to be simulated decreases, and therefore less randomness persists overall.

It is worth mentioning, in light of the precedent statement, that considering a single shock for all ages may be inappropriate depending on the company risk profile. In particular, considering an age-insensitive shock could result in gains for some cohorts and losses for others.

Finally, note that the shock values are sensitive to many assumptions such as structure of the model considered, number of parameters involved and the extrapolation method used at high ages.

In the final technical advice (EIOPA-BoS-18/075), EIOPA introduced an alternative approach that consists in truncating the time horizon in the calculation of life expectancies. That is, the calculation of a partial life expectancy at each age is performed by setting a maximal maturity for the calculation instead of going up to the limit age. The shocks thereby exhibited are lower than the one computed on an infinite time horizon because life expectancies capture less volatility, but still higher compared to a pure one-year approach as detailed in the next section.

Alternative prospective one-year approach

FORECASTING LIFE EXPECTANCIES ON A ONE-YEAR BASIS

For a better comparison of the ultimate and one-year views, we stick to the assumptions formulated in the Consultation Paper (CP-17-006), especially the use of cohort life expectancies based on future developments of mortality rates.

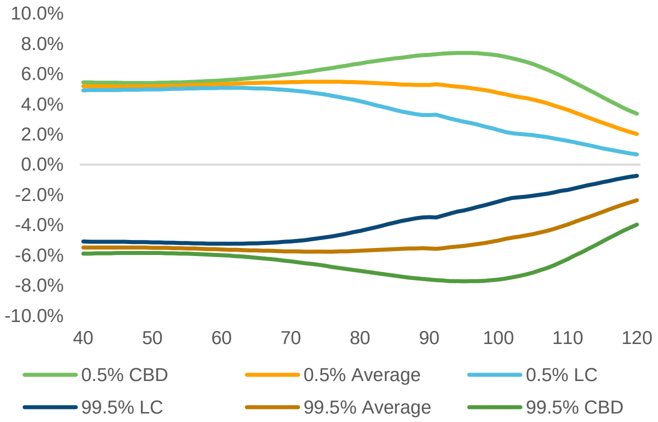
In an approach in line with the one-year view, we simulate numerous realisations of mortality rates at a one-year time horizon. The expected values of times series in the subsequent years are then computed conditionally on their value in the first year. Once the time series are determined for each scenario, we can compute future mortality rates and life expectancies for each simulation, allowing to recover the 99.5 and 0.5 percentile realisations of cohort life expectancies. Then the mortality and longevity stresses are defined for each age as the equivalent deterministic shock that allows to equal the quantile life expectancies.

Thus, this approach differs from the ultimate one because the expected conditional value of time series does not capture the inherent volatility included in the stochastic model after the first year. Note that such approach is naturally closer to the spirit of some Solvency 2 Internal Model practices compared to an ultimate forecast.

REVISED MORTALITY AND LONGEVITY SHOCKS

In Figure 2, we confirm the precedent intuition as the mortality and longevity shocks are significantly reduced using this method. The average of the two models suggests a calibration of the mortality and longevity shocks around 6% that is close, in particular, to the shocks at reference age 60.

FIGURE 2: MORTALITY AND LONGEVITY SHOCKS PER AGE USING THE LEE-CARTER AND CAIRNS-BLAKE-DOWD MODELS – ONE-YEAR BASIS



Interestingly, the shock values firstly increase with age in the Cairns, Blake & Dowd model (green curves in Figure 2), contrary to the ultimate approach (see again Figure 1). In a one-year approach indeed, the volatility of life expectancy for each cohort lies in the first projection year; therefore, the number of years embedding randomness does not increase with the attained age as was the case in the ultimate approach.

Prospective approaches based on stochastic mortality models are a way of capturing the one-year shock arising from an adverse realisation of mortality rates. A question which follows is whether the prospective approach is conservative regarding historical deviations of mortality rates. As in addition to pure risk factor deviations, the historical empirical mortality rates embed sampling variations due to limited population size (especially at high ages), it is prudent to consider as a reference the volatility of past observed mortality rates. In this context, we analyse mortality rates volatility and resulting shocks in the light of past historical variations in the next section.

Retrospective analysis based on historical variations

In this section, we put into perspective the previous results with further historical analysis on mortality improvements. Firstly, we introduce another method to predict mortality rates and life expectancies on a one-year time horizon, which better reproduces historical volatility. Secondly, we present revised shocks and compare the outputs with those obtained under the prospective method.

FORECASTING MORTALITY RATES ON A ONE-YEAR BASIS BASED ON HISTORICAL VOLATILITY

The proposed alternative method consists in forecasting mortality rates using historical mortality improvements as follows:

- **Model fitting:** For each age, we compute the historical mean and standard deviation of mortality improvements on a specific time window.
- **Simulation at one-year horizon:** We assume that for each age, mortality improvements follow a normal distribution whose parameters (mean and variance) are directly estimated using historical data for each country. We suppose that mortality improvements depend on a unique risk factor and are therefore perfectly correlated, which ensures their comonotonicity. Mortality rates at one-year are then simulated for each year, and the 99.5 and 0.5 quantile realisations are computed.
- **Predicting future mortality:** Expected value of mortality rates are computed conditionally on the first year being stressed. Once mortality rates have been estimated, we can compute life expectancies in the same way as in other approaches.

This approach is consistent with the one-year view and includes an additional prudency margin as life expectancies are computed with underlying scenarios where the risk factors reach simultaneously their 99.5 (resp. 0.5) quantile realisation.

For the purpose of capturing historical volatility, it is crucial to benefit from highly reliable historical mortality data. As previously described, the HMD recently provided updated mortality tables. However, this update is not fully satisfactory for our specific purpose because only a subset of historical data has been corrected. Important work has been performed at Milliman (see references) to provide mortality tables corrected from several cohort anomalies for more than 30 countries over the full historical period available for each country. In our retrospective analysis, we consider these revised mortality tables to allow recovering coherent volatility magnitude which does not suffer from data inconsistencies (see the Milliman white papers listed in the References).

REVISED SHOCKS BASED ON HISTORICAL DATA

Figure 3 depicts the mortality and longevity shocks resulting from the method introduced above. For ages under 100 years, mortality shocks range from 8.8% to 10.4% and longevity shocks range from 9% to 11.4%. The main conclusion is that shocks derived under the retrospective method are mostly higher than the ones exhibited under the prospective one-year approach using the Lee & Carter and the Cairns, Blake & Dowd model. Indeed, stochastic mortality models tend to smooth historical year-to-year deviations due to their parametric specification.

FIGURE 3: REVISED SHOCKS BASED ON HISTORICAL DATA ON MORTALITY IMPROVEMENT

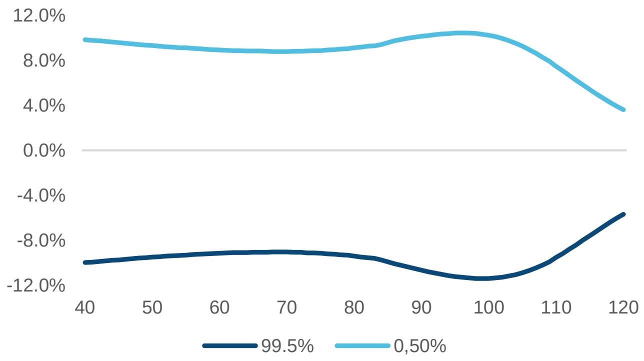
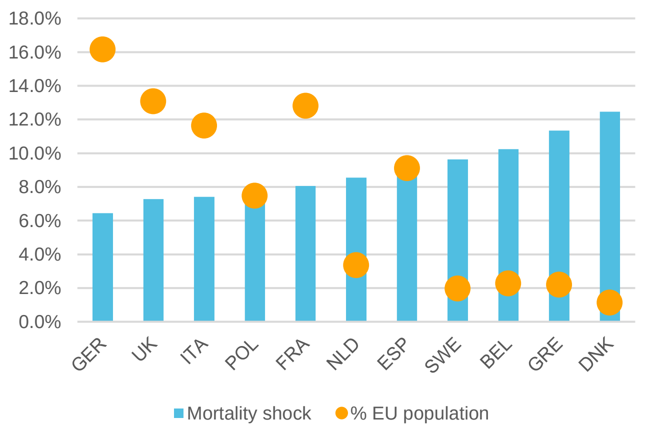


Figure 4 depicts for each country the mortality stress at 60 (corresponding to the reference value used by EIOPA) and the percentage of the European Union (EU) population to quantify the size of the country relatively to the others. We observe that mortality shocks are generally greater for smaller countries, which is mainly due to the sampling variation effect. Note that including Belgium, Denmark, Greece and Sweden in the study, as EIOPA did between the two Consultation Papers, allows considering a larger market but also captures a higher sampling risk resulting in higher shocks for the retrospective approach.

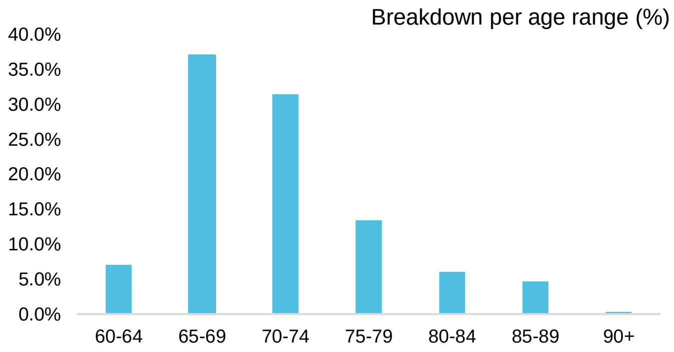
FIGURE 4: REVISED MORTALITY SHOCKS AT 60 YEARS OLD



CASE STUDY: SCR IMPACT

In this section, we compare the impact of different calibration approaches on the calculation of the Solvency Capital Requirement in the case of a portfolio of death benefits, described in Figure 5 (aggregated by five years age classes for presentation purposes).

FIGURE 5: PORTFOLIO OF DEATH BENEFITS



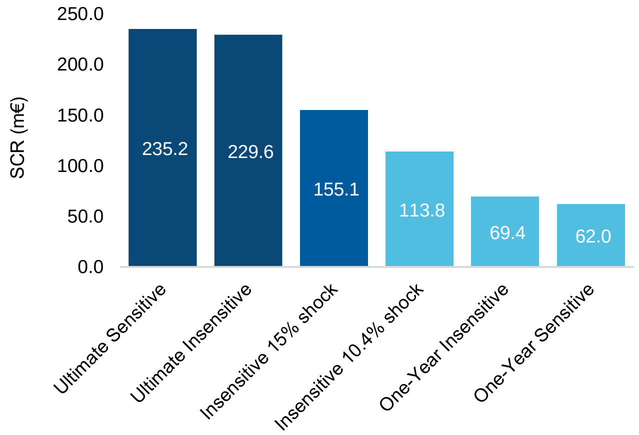
The Solvency Capital Requirement (SCR) is computed under six different scenarios, all based on a reference French mortality table:

- **Ultimate sensitive:** This scenario takes into account the decreasing trend of shocks over ages, while using the ultimate approach.
- **Ultimate Insensitive:** This scenario corresponds to the re-calibration discussed by EIOPA in the first Consultation Paper: an age-insensitive shock of 25%.
- **Insensitive 15% shock:** This scenario corresponds to the current mortality stress set by the regulatory framework.
- **Insensitive 10.4% shock:** We apply a revised age-insensitive shock of 10.4%, the maximum obtained on the historical retrospective analysis.
- **One-year insensitive:** We apply a revised age-insensitive shock of 6% from the prospective one-year approach.
- **One-year sensitive:** Mortality shocks are calculated using the prospective one-year approach, and the decreasing dependence of shocks on ages is taken into account.

The Best Estimate of Liabilities at time zero equals €6.257 million. The SCR for mortality risk is then calculated as the difference between the stressed liability in each scenario and the Best Estimate Liability at time zero.

In Figure 6, we observe that considering a one-year approach in SCR calculation considerably reduces the Solvency Capital Requirement because stressed liabilities are less volatile and closer to the central Best Estimate. In this particular case, the SCR is reduced by 74% on an age-sensitive basis. In addition, considering an age-insensitive 10.4% shock, derived at one-year from historical data, seems to balance the ultimate and the one-year prospective approaches. Note that the impact of an age-insensitive shock at one-year on the SCR is almost linear.

FIGURE 6: SCR CALCULATION WITH DIFFERENT ASSUMPTIONS ON SHOCKS



Moreover, Figure 6 echoes the previous statement that considering a reference age for shock calibration may not be appropriate to fit with the risk profile of an insurance company. It appears that insensitive shocks can lead to overestimated or underestimated SCR depending on products, contracts, portfolio age structure and time horizon.

Concluding remarks

This white paper proposes two alternative and complementary views to the EIOPA's final technical set of advice on the mortality and longevity shock calibration: a prospective approach in the spirit of one-year calculations and a retrospective analysis based on historical data from corrected mortality tables.

The case study exemplifies that the ultimate approach contains a substantial margin while a pure prospective one-year view may underestimate risk. The historical analysis shows that setting mortality shocks at around 10% may appear as a compromise between the two views.

The underlying sources of risk are numerous and go beyond the pure risk driven by a stochastic mortality model (prospective or retrospective). As such, trend risk, parameter uncertainty and model error are risk layers which are to be explored to capture the full range of uncertainty.

How can Milliman help?

Milliman has a depth of experience and expertise on the support of modelling and management of life risks, including the following services:

- Training on life risks concepts and modelling
- Key challenges related to Standard Formula calculations, including risk profile and granularity
- Assistance to internal model development, validation and optimisation
- IFRS 17, including Risk Adjustment calculations

If you have any questions or comments on this paper or any other aspect of life risks, please contact the consultants below or your usual Milliman consultant.

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CONTACT

Alexandre Boumezoued
alexandre.boumezoued@milliman.com