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Development and Use of Stochastically Generated Mortality Scenarios in VM-20

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As written, VM-20 allows for the use of stochastically generated mortality scenarios in developing reserves. There are some issues pertaining to the use of stochastic mortality scenarios that the framers of VM-20 might not have foreseen that need to be addressed. I will discuss these issues in this article.

STOCHASTICALLY GENERATED MORTALITY SCENARIOS ARE ALLOWED

It may come as a surprise that VM-20 allows you to use stochastically generated mortality scenarios. Your surprise may be due to the focus of the educational efforts of the American Academy of Actuaries (the Academy), the National Association of Insurance Commissioners (NAIC), and others close to VM-20. They have justifiably focused on the methodology for setting prudent estimate mortality assumptions. I would like to bring to your attention the following paragraphs in subsection 9.A of VM-20:

> The company shall use prudent estimate assumptions in compliance with this section for each risk factor that is not prescribed or is not stochastically modeled by applying a margin to the anticipated assumption for the risk factor.
>
> If the company elects to stochastically model risk factors in addition to those listed in A.3 above [interest rates and equity returns], the requirements in this section for determining prudent estimate assumptions for these risk factors do not apply.

These paragraphs clearly show that you can choose to model any assumption stochastically, as long as it is not prescribed.

These paragraphs also make a clear distinction between prudent estimate assumptions and prescribed assumptions. For example, the NAIC has published tables, included in VM-20 appendices, for the baseline default cost factors, current benchmark spreads and long-term benchmark spreads. You are required to use these tables to set the asset default assumption. The mortality assumption, on the other hand, is a prudent estimate assumption. Like other non-prescribed assumptions, the methodology for setting the prudent estimate assumption is described in Section 9. And like the other non-prescribed assumptions, you can instead model this assumption stochastically.

A review of the Reinsurance Section provides additional evidence that the use of stochastic analysis for risk factors other than interest rates and equity returns is not alien to VM-20. Paragraph C.2 of this section states:

> To the extent that a single deterministic valuation assumption for risk factors associated with certain provisions of reinsurance agreements will not adequately capture the risk the company shall … stochastically model the risk factors directly in the cash flow model when calculating the stochastic reserve.

The guidance note to this section mentions that you may be required to perform a stochastic analysis for stop-loss reinsurance.

CONSIDERATIONS IN DEVELOPING STOCHASTIC MORTALITY SCENARIOS

Below is an approach for developing stochastic mortality scenarios. All the major topics to be considered when developing stochastic mortality models are touched upon. Overall, the approach is as follows:

1. Use a stochastic model to generate scenarios for the U.S. population.

2. Adjust the U.S. population mortality scenarios to reflect the current best estimate for the company.
3. Take into account the additional random fluctuations in the mortality due to the smaller sample size for the company experience compared to that of the U.S. population.
4. Reflect the uncertainty in the estimates due to the lack of credibility and relevance of the data used to develop the current best estimate for the company.

Extrapolative stochastic mortality models of the Lee-Carter type are discussed here. Extrapolative models are based purely on historical mortality data and do not take into account any knowledge about the medical, societal or behavioral influences on mortality. A recent publication by the Society of Actuaries (SOA), "Literature Review and Assessment of Mortality Improvement Rates in the U.S. Population: Past Experience and Future Long Term Trends," provides a summary of the various mortality models. It mentions that the Lee-Carter-type models are well suited for generating future mortality paths. Typically, these models are calibrated to several decades of mortality experience of a population, e.g., the United States. These models capture the general volatility in mortality by age and sex and the uncertainty in mortality improvements.

The data needed to calibrate these models is readily available from the Human Mortality Database.[1] For U.S. population mortality, the experience from 1933 to 2010 is available. Once calibrated, these models can be used to simulate mortality rates that vary by age, sex, projection year and scenario.

Relationship Between Population Mortality and Insured Mortality

Next you need to convert the population mortality rates into company mortality rates. Company mortality rates could differ from population mortality rates for many reasons. Company mortality rates are select and ultimate, whereas population mortality rates are clearly not. Furthermore, depending on the markets that the company focuses on, there could be differences due to socioeconomic status, race distribution, age distribution, etc. There has been some research on the relationship between population mortality and the insured mortality based on statistical analysis. See, for example, Li, Hardy and Tan.[2]

… Lee-Carter-type models are well suited for generating future mortality paths.

Here I suggest a simplified approach. First, convert the simulated mortality rates into projected to current (P/C) ratios. You can set the current mortality to be the 2010 mortality rate for the U.S. population. The P/C ratio is then:

Population P/C ratio (age, sex, year) = Projected Mortality (age, sex, year) ÷ 2010 Mortality (age, sex)

Next, apply the population P/C ratios to the current company mortality table. If you have generated 1,000 scenarios and 30 projection years, then this step has given you 30,000 mortality tables. This approach assumes that the company's true mortality rates move proportionately with the population mortality. It also assumes that company mortality is as volatile as the U.S. population mortality and the company's true mortality rates are known with certainty. Both of these assumptions can be relaxed.

The uncertainty in the company mortality rates can be estimated using bootstrapping methods. Standard use of bootstrapping can be studied from a textbook on simulation. For an example of the use of bootstrapping to estimate uncertainty in the estimates of mortality rates, see Alkema and New.[3] For an example of its use in mortality projections, see Li, Hardy and Tan. These methods can be adopted for taking into account the uncertainty in the company mortality rates for the model outlined here. The result would be a wider range of projected mortality rates.

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Due to its smaller size, the company's simulated mortality experience should be more volatile than the U.S. population's. This can be taken into account with standard Monte Carlo analysis. Guth[4] provides a step-by-step guide to Monte Carlo analysis of mortality in the context of X factors. This can be adopted for the model outlined here. The result should be a greater volatility in the projected mortality experience.

Pandemic Events

Should the stochastic model take into account pandemic events? If the stochastic mortality model being used for VM-20 will be used for internal capital calculations, then it might make sense to include pandemics in the model. If properly modeled, because of the rarity of pandemics, reserves should not be impacted significantly by including pandemics in the model.

Aggregation of the Mortality Scenarios with Other Scenarios

The final item that needs to be considered is how to aggregate the stochastically generated mortality scenarios with the scenarios for other risks. This topic is well researched. If one believes that 1,000 scenarios are sufficient to discover the CTE 70 portion of the distribution of the asset requirement for each risk, then 1,000 interest/equity scenarios multiplied by 1,000 mortality scenarios would require the company to run 1,000,000 scenarios! Sampling 2,000 scenarios from the 1,000,000 scenarios would be a reasonable compromise. Other variance reduction techniques could also be applied to reduce the number of scenarios that need to be run.

OBSTACLES TO OVERCOME IN THE CONTEXT OF VM-20

VM-20 Language Regarding No Mortality Improvements after Valuation Date

To summarize this stochastic mortality model approach, a mortality table that reflects the current company mortality experience is needed, which should then be adjusted for various items, including any population mortality improvements. VM-20 requires that for the anticipated mortality assumption, no mortality improvements be assumed beyond the valuation date. It would be a difficult task, and not a scientific one, to solve for the parameters in this model to ensure that at CTE 70 there are no mortality improvements in every single projection year. Therefore, the discussion regarding the mortality improvements after the valuation date has to morph into a discussion about the parameters of the stochastic model. How do we adjust the volatility parameter calibrated to historical values to reflect actuarial judgment and satisfy regulatory requirements?

Prescribed Margins

Currently there are prescribed margins for setting the prudent assumption. The margins are prescribed separately for the company experience rates and the industry table. The prescribed margins for the company experience are based on the credibility of the experience. It seems that the margins reflect the random fluctuations and the uncertainty due to low credibility. The prescribed margins for the industry table seem to be for the uncertainty in the estimates due to the potential difference between a company's own experience and the average industry experience.

The model outlined above would take into account the random fluctuations and the various sources of uncertainty. The discussion between the industry, the profession, and the regulators would have to shift from the right level of margins to the right level of uncertainty and volatility to be incorporated into the stochastic model. The method for taking into account random fluctuation is less contentious than the methods for taking into account the uncertainty in anticipated mortality estimates.

Under a stochastic mortality model approach, applying a credibility adjustment is optional. If the company has not adjusted for credibility, then there is a greater amount of uncertainty arising from the use of a small sample size. This greater uncertainty would be reflected in the model outlined. If the company has adjusted for credibility, then the company has reduced the amount of uncertainty arising from the sample size but may have increased the uncertainty from the industry table to the extent industry data is not relevant. In order to capture the uncertainty from the variation in the company by company experience, you would need to know certain statistics backing the industry experience, e.g., distribution of mortality experience by companies of similar size and underwriting/sales practices. Hardy and Panjer[5] suggest an approach, but further research is needed.

VM-20 Language Does Not Mention Aggregation
There is no language in VM-20 regarding the aggregation of stochastically generated mortality scenarios with the scenarios for interest rates and equity returns. The language in Section 5 needs to be tweaked because it is clear that the author of this section was not thinking of scenarios being an aggregation of interest rates/equity return and mortality (or any other stochastically modeled assumption). For example, paragraph A of Section 5 states:

> Project cash flows in compliance with the applicable requirements in Sections 7, 8 and 9 using the stochastically generated scenarios described in Section 7.G.2.

This paragraph makes a specific reference to Section 7.G.2. Because the paragraph already states that cash flows should be projected in compliance with the applicable requirements of Sections 7, 8 and 9, the reference to 7.G.2 is extraneous. It was apparently done to emphasize that 7.G.2 develops the stochastically generated scenarios that must be used. However, it is open to interpretation. It could be interpreted to be limiting the stochastic scenarios to 7.G.2. This does not seem to be the intent and such interpretation would contradict Section 9. This language would have to be ignored or removed via an amendment proposal.

The issue then is that none of Sections 7, 8 and 9 describes the appropriate and reasonable approach to aggregating scenarios. This leaves this topic open to interpretation by the company actuary. The options for the regulators and the actuarial profession would be to leave this hole as it is (which could lead to comparability issues), or the regulators could put some guardrails on the aggregation and scenario reduction techniques to ensure comparability. Another possibility is for the actuarial profession to come up with acceptable or standardized practices to be used by the actuaries.

Stochastic Exclusion Test
It is doubtful there is any need to change the stochastic exclusion test. The exclusion test requires the use of anticipated mortality based on the absence of mortality improvements after the valuation date. The purpose of the stochastic exclusion test is to determine if a company has any material tail interest rate or equity risk. The way mortality is being handled here, in my opinion, is fine.

Expectations of the Regulators
If the industry and the profession move toward developing principle-based reserves (PBR) using stochastic mortality, could some companies have an easier time with the regulators in terms of their interpretation of the valuation law than other companies? Would different state regulators have different interpretations and different requirements for the setting of parameters of mean, volatility and uncertainty? Would some regulators disallow the use of stochastic mortality in the calculation of PBR because they believe there is a prescribed way to determine mortality in VM-20 without exception?

Comparability is an important issue for regulators. In the absence of a standard mortality scenario generator, different companies could use different models and approaches. Regulators, the industry, or the actuarial profession would need to address this. The actuarial profession could address this via research, practice notes, or an Actuarial Standard of Practice (ASOP) on stochastic mortality. It could also be addressed by developing a standard stochastic mortality model, akin to the interest/equity model that the Academy developed for VM-20.

CURRENT STATE OF RESEARCH, DEVELOPMENT AND EDUCATION

From my review of the literature, my impression is that stochastic mortality research has mostly focused on developing population models for dealing with longevity risk. More recent focus has been on pricing and managing longevity risk via structured transactions. The issues related to reserving for the mortality risk are somewhat different. The SOA needs to encourage research into the development of stochastic mortality models for life insurance reserving purposes.

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Investment in such research could pave the way for the use of stochastic mortality in developing reserves under the PBR regime.

The SOA also needs to bring back linear algebra topics on the syllabus. Some of the current scientific research on extrapolative mortality models requires understanding of topics such as singular value decomposition, which is a topic you find in intermediate undergraduate level textbooks and is not on the SOA syllabus.

Companies that can develop their stochastic mortality modeling capabilities can change the nature of their conversations with the regulators and potentially get greater reserve relief than the prudent estimate assumption approach affords.

CONCLUSION

Earlier versions of VM-20 required a more rigorous actuarial approach to setting the mortality assumption than it does today. The authors of VM-20 attempted to describe the method for developing the credibility-adjusted mortality assumption. During the Impact Study, it became apparent that the instructions were confusing. Actuaries seemed to be having trouble with a very actuarial topic—credibility. Trying to get the same actuaries to use stochastic mortality to set reserves seems like a herculean task. But I am hopeful. I am hopeful for many reasons. One reason is that, because I can do it, I believe other actuaries can do it as well. I am also hopeful because of the industriousness of our profession and of the insurance regulators. I am also hopeful because perhaps there would be a financial incentive for companies to explore stochastic mortality solutions for setting their life reserves. ■

ENDNOTES

[1] *Available on www.mortality.org.*

[2] *Li, S.H., M. Hardy and K.S. Tan. 2010. "Developing Mortality Improvement Formulas: The Canadian Insured Lives Case Study." North American Actuarial Journal 14(4): 381-99.*

[3] *Alkema, L., and J.R. New. 2012. "Progress toward Global Reduction in Under-Five Mortality: A Bootstrap Analysis of Uncertainty in Millennium Development Goal 4 Estimates." PLoS Med 9(12): e1001355, doi:10.1371/journal.pmed.1001355.*

[4] *Guth, R.W. December 2000. "Using Monte Carlo Simulation to Understand Mortality." Small Talk Newsletter Issue No. 16: 6–7. Society of Actuaries.*

[5] *Hardy, M.R., and H.H. Panjer. November 1998. "A Credibility Approach to Mortality Risk." ASTIN Bulletin: A Journal of the International Actuarial Association. Volume 28, No. 2: 269–283.*