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DEVELOPING A STOCHASTIC MORTALITY FRAMEWORK TO SUPPORT THE REINSURANCE MARKET

by Matthew Clark and Chad Runchey

This article is taken from a recent research paper on stochastic decrements released by the Society of Actuaries. The focus of the research was on the techniques that can be applied to perform stochastic analysis on non-market risks, not the specific parameters or distributions used for the risks. The full version of this paper can be found on the SOA Web site at www.soa.org.

As risk management matures in the insurance industry, the universe of risks measured and modeling techniques used to measure them will continue to advance. Likewise, insurance products have evolved to include sophisticated embedded options and guarantees. However, traditional deterministic regulatory, valuation and risk measurement techniques provide a limited view of the risk profile of such products or of the life insurer issuing them. The introduction of stochastic modeling techniques—which to date has focused on market risks, including interest, equity and credit risk—has aided in the quantification of market risks, including low-incidence, high-severity tail events, while the industry has continued to value non-market risks using traditional valuation techniques. Given the advances in recent years in modeling techniques and computing power, there is no reason to be limited to a deterministic approach to valuing non-market risks. Furthermore, the increasing complexity of pending changes to financial reporting and capital requirements will demand more sophisticated analysis.

Specifically, this article will look at the stochastic techniques actuaries can employ to quantify the non-market risks in insurance products, and how stochastic techniques can be used in the evaluation of reinsurance arrangements.

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Background—Modeling Approach

A 20-year level term life insurance product was selected for this analysis to illustrate the quantification techniques for non-market risks. Term life insurance is an example of a product with significant exposure to non-market risks, and with minimal market risk exposure. A mature in-force block of term business was constructed assuming 20 years of sales across a simplified population of male non-smokers (including nine different age/face amount cohorts). For additional modeling assumptions, please refer to the complete research paper on the SOA Web site.

Generating Stochastic Mortality Scenarios

For this article, we will address the non-market risk of mortality. Traditionally, the measurement of non-market risks in life insurance products relied on sensitivity testing, with limited attention to generating a distribution of the economic results.

The introduction of stochastic analysis requires the creation and calibration of a scenario generator. Borrowing from the techniques employed to generate multiple random market risk scenarios, and carefully applying an understanding of the risk composition of mortality risk, stochastic generators can be created to reflect the non-market risks incurred by insurance companies. The parameterization of these generators needs to be performed with consideration for the current and evolving risk profile of the insurer. When selecting parameters for the scenario generator, historical experience must be balanced along with the complete potential risk universe. Historical experience typically understates the extreme tail events that tend to be one of the most important insights provided by stochastic analysis.

The selected distributions and parameters for the analysis that follows in this article should be viewed as illustrative.

To create a mortality scenario generator, it is important to understand the elements inherent in mortality risk. Note that for some insurance products, the risk of longevity (living longer than expected) versus the risk of increased mortality introduces the risk of economic loss for the insurer. Within this article, any references to mortality risk will be to the risk of higher than expected mortality, which is the relevant risk for level term life insurance.
Mortality risk is composed of four primary risk elements, including:

- Underwriting process error (systematic deviations in the underwriting process).
- Volatility around the best estimate.
- Catastrophic events (e.g., pandemic, natural disaster, terrorist attack).
- Trend in mortality (improvement or deterioration).

The generator that was created to support this illustration focused on the first three risks and did not address the trend element, because mortality improvement is not a material risk to term insurance. Table 1 presents the distributions that were used for this analysis. The practitioner should work to set both the distribution and parameters that are reflective of their specific risk exposures.

Table 1
Stochastic Mortality Risk Element Distributions

Stochastic Element	Underlying Distribution	Mean	Standard Deviation
Underwriting factor	Lognormal	1.00	5%
Annual mortality volatility	Lognormal	1.00	5%
	Underlying Distribution	Incident	Probability
Catastrophic shock	Binomial	300%	1 in 100 years event

The stochastic mortality generator produces a matrix of risk factors that are then applied to each of the projection years for each of the scenarios. For this exercise, 10,000 scenarios were generated. Each of the three mortality risk elements mentioned above contributes to the risk factor matrix. The risk associated with underwriting is reflected with a single factor applied across each scenario to reflect the systematic underwriting error that would be reflected in all of the issue years modeled. The volatility and catastrophic elements are reflected as factors generated each projection year for each scenario. The catastrophic events were simulated such, that for each year, either an event occurred or did not. The baseline assumption is that there is no deviation from expected mortality. The table below illustrates how the factors were applied to the base mortality assumption to generate the mortality scenarios.

Table 2
Stochastic Mortality Factor Example

Stochastic Element	Best Estimate	Illustrative Scenario 1	Illustrative Scenario 2
Underwriting factor	1.00	0.99	1.02
Annual mortality volatility	1.00	1.02	1.01
Catastrophic shock	1.00	1.00	3.00
Cumulative mortality factor	1.00	1.01	3.09

When generating a set of risk scenarios, it is important to understand how the risks contribute and interact to produce a cumulative risk profile. An important step in the process is the evaluation of the stochastic results to gain an understanding of the risk profile and the impact that parameterization has on the results. This will enable the company to identify which of the mortality risk elements presents the largest exposure to risks, and, once identified, to target risk management resources and programs at those risk elements. For example, if the company finds out that the risk of poor underwriting has a materially larger impact than that of the other mortality risk elements, it can focus the available resources towards improving the underwriting process.

Insight into the Value of Reinsurance

Stochastic analysis will also enable the company to evaluate various forms of risk management, including reinsurance. Reinsurance is a common tool used by insurance companies to limit their exposure to mortality risk. Integrating reinsurance agreements with a stochastic decrement model provides insight into the net impact reinsurance has on the risk profile of a term insurance port-

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folio. For this analysis we looked at three different types of reinsurance contracts—excess, experience refund and multi-year stop-loss. The following table details the contracts used.

Table 3
Reinsurance Contract Assumptions

Contract	**Coverage**	**Cost**
Excess	Caps all claims at $750,000	110% of expected claims
Experience Refund	Claims in excess of 150% of expected claim	150% of expected claims, with refund after 5% margin if claims are less than 150%
Multi-Year Stop-Loss	Cumulative claims over 120%	3% of annual premium

Companies do not purchase reinsurance simply to protect against best-estimate events. Evaluating reinsurance on a deterministic basis limits the cost-benefit analysis associated with the nature of the reinsurance arrangement. Table 4 illustrates this by showing the present value of cash flows for the various reinsurance arrangements under a deterministic scenario, where actual experience is consistent with expectations.

The difference in the net cash flows is a result of the net reinsurance cash flows. The deterministic run without reinsurance results in a present value of future cash flows of ($178 million). As expected, for the deterministic scenario with mortality and lapse events consistent with best estimate assumptions, the net impact of reinsurance is negative, in short, because the reinsurance premiums exceed the reinsurance receivables. Note that the terms of the multi-year stop-loss contract do not result in any reinsurance receivables in this deterministic scenario.

Table 4
Present Value of Future Cash Flows ($ Millions) – Deterministic

	No Reinsurance	Excess Reinsurance	Experience Refund	Multi-Year Stop-Loss
Premium	1,196.4	1,196.4	1,196.4	1,196.4
Death Claims	(1,338.9)	(1,338.9)	(1,338.9)	(1,338.9)
Other Expenses	(35.9)	(35.9)	(35.9)	(35.9)
Gross Cash Flows	(178.4)	(178.4)	(178.4)	(178.4)
Reinsurance Premiums	–	(976.8)	(2,008.6)	(35.9)
Reinsurance Receivables	–	894.8	1,941.7	–
Net Reinsurance Cash Flows	–	(82.0)	(66.9)	(35.9)
Net Cash Flows	(178.4)	(260.4)	(245.3)	(214.3)

Expanding the analysis to include the stochastic mortality scenarios provides a distribution of events that allows a better understanding of the impact that reinsurance has on the overall risk profile. To examine this impact, two scenarios were selected from the population of stochastic scenarios—one at each end of the distribution. First, a poor mortality scenario was selected. This scenario had an average mortality factor of 123 percent, driven primarily by three catastrophic events over the 30-year horizon.

Table 5
Present Value of Future Cash Flows ($ Millions) – Poor Mortality – Scenario #7629

	No Reinsurance	Excess Reinsurance	Experience Refund	Multi-Year Stop-Loss
Premium	1,134.3	1,134.3	1,134.3	1,134.3
Death Claims	(1,591.5)	(1,591.5)	(1,591.5)	(1,591.5)
Other Expenses	(35.5)	(35.5)	(35.5)	(35.5)
Gross Cash Flows	(492.7)	(492.7)	(492.7)	(492.7)
Reinsurance Premiums	–	(928.4)	(1,914.7)	(34.0)
Reinsurance Receivables	–	1,060.1	2,027.9	89.9
Net Reinsurance Cash Flows	–	131.7	113.2	55.9
Net Cash Flows	(492.7)	(361.0)	(379.5)	(436.8)

In this scenario, the difference between reinsurance premiums and receivables caused the net cash flows with each of the reinsurance arrangements in place to be higher than those without reinsurance arrangements. Also, because mortality experience was worse than expected in this scenario, the benefit of each reinsurance contract outweighed the cost.

In this next scenario, the mortality experience was better than expected. The average mortality factor used was 97 percent, and no catastrophic events occurred.

Table 6
Present Value of Future Cash Flows ($ Millions) – Good Mortality – Scenario #8801

	No Reinsurance	Excess Reinsurance	Experience Refund	Multi-Year Stop-Loss
Premium	1,226.2	1,226.2	1,226.2	1,226.2
Death Claims	(1,202.1)	(1,202.1)	(1,202.1)	(1,202.1)
Other Expenses	(36.2)	(36.2)	(36.2)	(36.2)
Gross Cash Flows	(12.1)	(12.1)	(12.1)	(12.1)
Reinsurance Premiums	–	(1,000.4)	(2,054.6)	(36.8)
Reinsurance Receivable	–	804.2	1,986.1	–
Net Reinsurance Cash Flows	–	(196.2)	(68.5)	(36.8)
Net Cash Flows	(12.1)	(208.3)	(80.6)	(48.9)

Similar to the deterministic run, the reinsurance contracts result in lower net cash flows than the results without a contract in place. This is once again driven by the differential of the reinsurance premiums to receivables.

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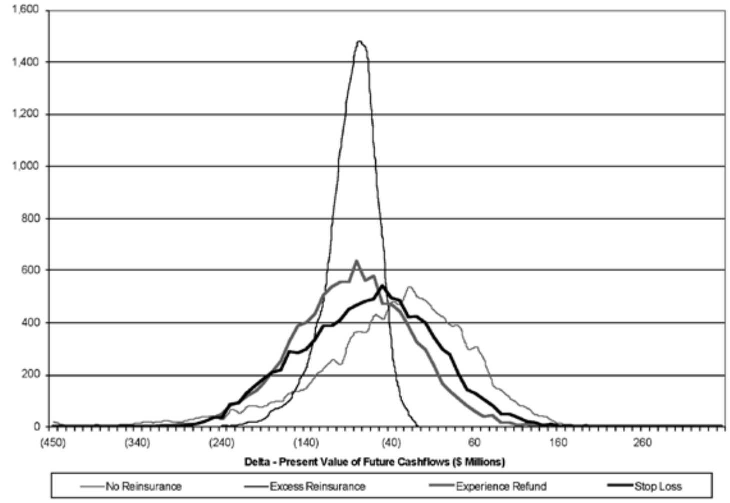
The chart below shows the distribution of a metric called "Delta" for the entire 10,000 scenarios, in which Delta is calculated as the difference in present value of future cash flows relative to the deterministic best-estimate run without reinsurance in place.

Chart 1 – Delta Results for Various Reinsurance Arrangements



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All of the reinsurance agreements reduce the exposure to the tail mortality events, and the structure of each agreement has a different impact on the overall risk profile. Each of the distributions shift to the left relative to the run without reinsurance, reflecting the net reinsurance cash flows as discussed above. The excess reinsurance has the largest impact on the tail events; this comes at a cost, illustrated by the shift in the mean value to the left. The table below presents the results at various points in the distribution.

Table 7
Delta Results – Reinsurance Contract Results ($)

Percentile (or Point)	No Reinsurance	Excess Reinsurance	Experience Refund	Multi-Year Stop-Loss
99%	(345,763,093)	(190,589,904)	(250,137,271)	(244,677,360)
95%	(225,371,960)	(152,140,502)	(205,473,584)	(205,173,089)
90%	(168,636,342)	(133,924,182)	(178,494,502)	(179,002,760)
75%	(95,290,552)	(109,827,409)	(135,803,532)	(126,982,987)
50%	(34,594,325)	(89,302,891)	(88,304,257)	(69,560,000)
25%	17,562,212	(72,617,167)	(42,617,229)	(17,750,003)
10%	59,948,313	(58,095,238)	(2,962,224)	24,165,626
5%	86,418,939	(50,355,793)	21,349,758	50,304,823
1%	134,210,185	(34,366,830)	69,577,543	98,066,727
Average	(46,827,630)	(93,560,270)	(89,909,943)	(73,024,289)
Standard Deviation	96,166,775	31,690,937	68,877,519	77,456,045

The results demonstrate the impact that reinsurance has at both ends of the distribution, and having the full distribution allows for additional insights not available under traditional modeling techniques. Specifically, poor mortality experience is muted when the reinsurance contracts are in place, and the impact of the improved mortality experience is also dampened by the reinsurance premiums. Having the full distribution allows the practitioner to identify the net cash flow crossover point of the reinsurance arrangement, and know the probability of having a positive net cash flow from the reinsurance arrangement. Table 8 provides the crossover points of each of the contracts.

Table 8

Reinsurance Crossover Percentile

Excess Reinsurance	Experience Refund	Multi-Year Stop-Loss
80th	92nd	92nd

The crossover point at the 80th percentile for excess reinsurance means that the present value of future cashflows is higher in 20 percent of the scenarios with the reinsurance contract in place. From the reinsurance company's perspective, in 80 percent of the scenarios they collected more money in premium than they paid out in claims.

Summary

Expanding the use of stochastic modeling techniques to non-market risks like mortality and lapse will provide insurers with a detailed view of risk elements. Insurers will also benefit from integrating non-market and market risks for a more complete picture of their overall risk profile.

The application of stochastic analysis to non-market risks also provides a framework by which companies can evaluate the cost-benefit of risk mitigation techniques like reinsurance. It is useful in comparing various types of reinsurance, and understanding the specific pros and cons of each arrangement. This type of analysis provides both the ceding and assuming company with a framework to fully analyze the net cost and benefits of entering into the agreements. This will help both sides of the reinsurance arrangement gain a better understanding of their revised risk profile. ✺