Estimating future trends in mortality plays a significant part in life (re)insurers’ product development and portfolio valuation. Like other business metrics, there are many ways to study and view mortality trends. For example, mortality trends viewed over the past 10 years, the past 50 years or projected over the next 30 years likely will show very different results. To support prudent decisions, analysis of only a single view of past or future trends is insufficient. It requires selecting and matching an appropriate view for a specific purpose.

There are at least three important factors in framing an appropriate view of mortality trends:

- Time frame (10-year period, 30-year period, etc.)
- Methodology (average annual change, moving average change, etc.)
- Certainty (deterministic or stochastic)

Without clarifying these basic factors, a mortality trend may be misinterpreted and/or used inappropriately. The following information addresses the certainty factor, and the role of deterministic and stochastic views of past mortality.

A Deterministic View

Figure 1 represents a sample of US population mortality from 1933-2007 by five-year age groupings. This view reflects what has already happened and cannot change. Therefore, it is a deterministic view. Examples of observations from this view include:

- Mortality improvement over time varied dramatically by age group
- For ages 95 and older, there was no significant improvement over the entire period as a whole
- A post-war cohort effect may have caused a more significant mortality decrease for age groups younger than 40

Without appropriate context, it is difficult to translate these conclusions into appropriate pricing and valuation assumptions.

Semi-deterministic View. To better understand and quantify long term trends, we developed a regression model (or a trend line) using the following formula:

\[ q_t = q_0 \cdot e^{(b \cdot t)} \]

where \( t \) is time, \( q \) is mortality, and parameter \( b \) approximates the annual improvement.

This approach allows us to define and measure average annual mortality improvement and to use it to better represent the mortality trend.
According to this analysis, the US population age 35-69 mortality trends improved approximately 1.3 percent annually from 1950 to 2007 ($b = -0.013$, Figure 2). The negative value of $b$ indicates mortality is declining in general. (Similar analysis can be done for any age group.)

We call this type of trend view “semi-deterministic,” because while the analysis is based on deterministic experience, the choice of a regression model, the definition of trend and number of years of data to be covered can vary and alter the conclusion. For instance, if we use data from 1970-2007 rather than 1950-2007 for the mean calculation, the annual improvement would be about 1.5 percent instead of 1.3 percent.

This view has a clearly defined time frame, methodology and semi-deterministic nature. The big question is: Can we assume future mortality improvement will be consistent with what we see here?

A stochastic view associates each forecast with a statistically calculated probability that the forecast will become reality. For example, for mortality portfolio reserving or capitalization purposes, actuaries need to estimate the minimum future mortality improvement. We can formulate an estimate by applying appropriate statistical theories to analyzing the US population data (Figure 3).

Meaningful insights can be obtained from this stochastic view of future mortality improvement. For illustrative purposes, let’s assume that (1) the insured population will have the same future mortality improvement as the general population and (2) the mortality improvement assumption is the major factor driving our capital needs. The following observations can be made:

- **The best-estimate mortality improvement has a 50 percent chance of over-estimating future improvement:** Actuaries use past average improvement (Column A) to serve as their best estimate of future improvement. The 50 percent confidence level means that the probability that the population will have an annual mortality decrease on average at least 1.26 percent is one-in-two. However, the probability of mortality decreasing less than 1.26 percent is also 50 percent (1-confidence). A mortality portfolio reserved by assuming a minimum 1.26 percent annual mortality decline would have a 50-50 chance that the portfolio was under-reserved.

- **Match pricing/valuation assumptions with risk appetite:** A company with a conservative risk appetite may require at least 90 percent confidence on all assumptions used. In such an instance, its actuaries may choose the estimated improvements associated with 90 percent confidence level (1 percent in total, Column E), rather than the best estimate (1.26 percent in total), as their improvement assumptions for pricing or valuation. This concept can also be applied to other assumption choices and for setting mortality provisions for adverse deviation (PADs) or solvency capital.

- **Meeting new regulatory requirements:** Unlike statutory requirements, new regulations such as PBA and Solvency II measure risks by using concepts or measurements like VaR(99.5%) (Value at Risk) or TVaR(90%)
These are essentially risk forecasts associated with specified confidence levels. They are stochastic views of risks. When forecasts are derived as in Figure 3, they deliver various levels of VaRs for mortality trends.

**Conclusion**

Estimating mortality trends is only one consideration in assessing future claim liabilities for mortality/longevity portfolios. Prudent business decisions require appropriate quantification and integration of many other risk factors including random fluctuation, rare events such as pandemics, etc. Statistical analysis and stochastic modeling as introduced in this article are among the techniques for deriving integrated stochastic views of multiple risk factors.

SCOR is committed to using our research and development expertise to help clients make fact-based risk management decisions and fulfill regulatory requirements. For more information please contact the authors.