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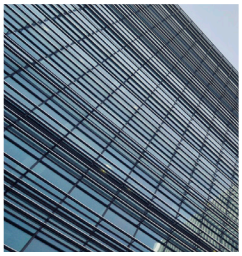
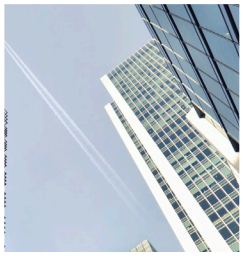
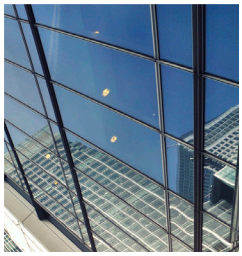
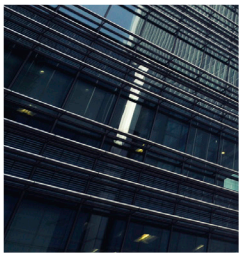

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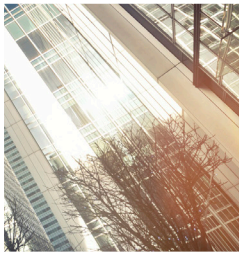

MORTALITY IMPROVEMENT MODELING IN THE UNITED STATES

By Bruce Rosner and Francisco Orduña

In the United States, longevity across all ages has improved almost continuously over the past century. In 1900, according to the Social Security Administration, a 45-year-old was likely to live another 22 years, to age 67. Today, a 45-year-old is likely to live another 38 years, to age 83—a 72 percent increase in life expectancy.

In this same time period, the Social Security Administration reported that mortality improved at an average rate of 1.10 percent per year. That mortality will continue to improve into the next century is considered a given. But will the improvement continue at this rate or an even faster rate? Or will mortality improvement eventually flatten out or perhaps drop? Making the right assumptions regarding mortality and its rate of improvement is critical to the effective pricing and financial management of many forms of insurance and annuity contracts, in addition to determining the ongoing funding of pension plans and other retirement provisions. In the second half of the 1900s, actual improvement rates have outpaced the projections used to value pensions and other retirement products, contributing to pension plan funding deficits as people lived longer than anticipated post-retirement.

Consequently, North American actuaries are in the midst of examining different techniques and models used to forecast short-term and long-term mortality improvement rates. The Society of Actuaries has undertaken a review of the literature to assess techniques, models and assumptions used for these forecasts. The report "Literature Review and Assessment of Mortality Improvement Rates in the U.S. Population: Past Experience and Future Long-Term Trends" is

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CONTINUED ON PAGE 7

available on the SOA's website.[1] This article discusses those findings, describing techniques and models used to forecast mortality improvement and the considerations that underlie long-term mortality improvement projections.

TECHNIQUES FOR FORECASTING MORTALITY IMPROVEMENT

Demographers and actuaries use a variety of techniques to forecast mortality improvement rates and reflect the embedded uncertainty of such forecasts. The primary techniques can be classified into the following broad categories:

- ***Extrapolative:*** projects historical trends in mortality into the future—includes parametric methods and targeting methods
- ***Process-based:*** focuses on the underlying causes of death and attempts to model mortality rates from a bio-medical perspective

The following section indicates some of the most common techniques available to practitioners.

Extrapolative

- **Lee-Carter.** Developed by Ronald Lee and Lawrence Carter in 1992, this is a basic time-series technique that uses historical mortality data to predict future trends by age and period. Because the technique is purely extrapolative, its accuracy depends on patterns from the past continuing into the future, which they rarely do. Surprisingly, however, back-testing data from 1900–1989 showed a highly linear improvement in mortality, even with the period's significant medical, behavioral and societal changes. This result gives some researchers confidence that the technique will continue to produce accurate forecasts.
- **Lee-Carter APC.** The Lee-Carter Age-Period-Cohort (APC) technique adds cohort effects to the original Lee-Carter technique. Rather than by period, it is possible to specify mortality improvement by year of birth. The implication of a factor based on year of birth is that, in future years, the associated mortality improvements affect only the people born during a particular period, rather than everyone passing through a certain age.
- **P-spline.** The penalized spline (P-spline) technique uses interpolation to create a smooth curve from noisy historical mortality data. This curve can then be extrapolated to project future mortality rates by age and period. Back-testing data for the years 1984–2003 has shown this technique to produce accurate short-term forecasts.

Process-based

- **Cause-of-death.** Future mortality improvements may be developed from a composite of anticipated changes in mortality attributable to various causes of death. These models may reveal patterns around causes of death that can better inform and educate the user on the trends underlying the aggregate mortality rates. The disadvantages of this technique are the lack of credible and sufficient data, and an assumption that each cause of death to be independent of the others when, in reality, the causes are often interrelated.

The SOA report provides more detail on each of these techniques, including advantages and disadvantages, back-testing results, practitioner insights, and a comparison of modeling approaches.

INTEGRATED MODELS TO PROJECT MORTALITY IMPROVEMENT

In addition to each of the techniques described above, in practice, researchers may combine those techniques and expert opin-

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ions to project mortality improvement rates. The two integrated models considered in our study are the Social Security Administration's model and the Continuous Mortality Investigation (CMI) model currently used in the United Kingdom.

The Social Security Administration uses a model based on a cause-of-death forecasting technique. The primary input is an historical analysis of trends by five causes of death: cardiovascular disease, cancer, violence, respiratory disease and "other" causes. The secondary input is a sampling of expert opinions about anticipated changes in each cause of death, including risk factors, medical breakthroughs and environmental factors—changes that might affect long-term mortality improvement. The cause-of-death forecast and expert opinions are then mapped together to develop long-term mortality improvement estimates, which are then used to determine mortality improvement rates.

The CMI model is a sophisticated yet easy-to-use model for forecasting mortality improvements by gender, age, cohort and projection year. It uses two components:

- Short-term rates of mortality improvement, determined using P-spline smoothing
- A long-term rate of mortality improvement, as determined by the user

The model then generates mortality improvement rates through the convergence of the short-term rate to the user-selected long-term rate. The long-term mortality improvement rate is the heart of the model and makes it an easy-to-use tool for comparing outcomes across a range of long-term mortality improvement scenarios. It also helps to overcome some of the weaknesses of a purely extrapolative model, since socioeconomic and lifestyle factors that affect life expectancy can be reflected in the long-term rate selected, as well as the basic assumption on whether or not humans are approaching a fundamental limit to lifespan. This model may be useful to actuaries in the United States as well.

HOW WILL MORTALITY IMPROVEMENT CHANGE IN THE FUTURE?

Is it reasonable to assume that mortality improvement will continue into the future indefinitely? Or will it slow, eventually stop improving and perhaps even reverse as negative external factors come more and more into play?

In projecting mortality improvement researchers tend to fall into two extremes, with little middle ground. At one extreme, many see a practically unlimited human lifespan, arguing that every component of mortality has the potential to be reduced by human intervention. At the other extreme, some researchers believe the human life span is limited. Although they predict that life expectancy will continue to lengthen for some time into the future through medical advances and other factors, these researchers believe the inevitable processes of aging and damage accumulation will create a limit to the average life span.

The two camps have not attempted to arrive at a consensus. In reviewing available literature, we found that the implied annual mortality improvement rate of 1.26 percent, as reported to the Social Security Administration in the 2011 Technical Panel on Assumptions and Methods, represents an approximate middle ground for the range of long-term rate assumptions found in our review (Figure 1). The literature review provides a detailed review of the range of opinions on human longevity.

Socioeconomic status—driven by wealth, education and occupation, as well as other lifestyle factors—also has a significant impact on mortality improvement and creates

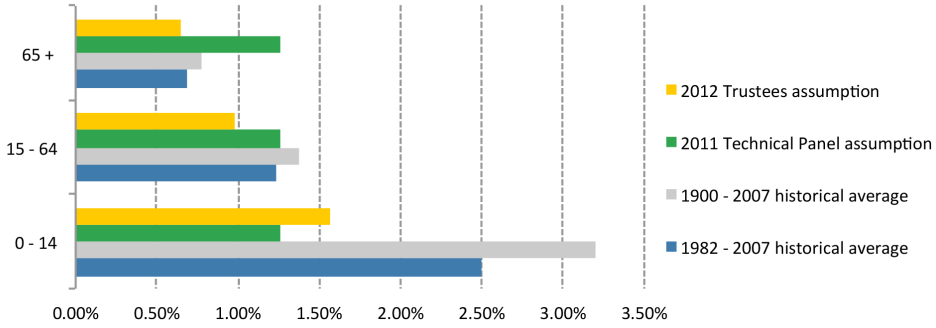
subgroups within a population. The literature review provides some context for actuaries to understand how certain subpopulation mortality improvement rates may compare to the general population.

CONCLUSION

Understanding mortality improvement is critical to the ongoing financial health of pension plans and retirement benefit programs, as well as insurance and annuity coverage. As professionals in life contingencies, we encourage actuaries to become more aware of the various considerations in developing mortality improvement assumptions and the modeling techniques that are available for this purpose.

The opinions expressed in this article reflect the opinions of the authors and are not necessarily those of Ernst & Young LLP. ■

Figure 1. Historical and assumed annual rates of reduction in aggregate mortality Source: Social Security Administration, Office of the Chief Actuary 2012



* Ultimate intermediate assumption for period 2036–86 in Board of Trustees, Federal Old-Age and Survivors Insurance and Federal Disability Insurance Trust Funds 2012

** Derived from the 2011 Technical Panel on Assumptions and Methods unisex period life expectancy at birth in 2085 in Office of the Chief Actuary 2012

*** Historical average annual percent reductions in age-adjusted death rates are based on 2000 Census resident population and are "ultimate" rates of reduction after year 2036

ENDNOTES

[1] http://www.soa.org/Research/Experience-Study/Pension/research-2013-lit-review.aspx