Analysis of Trends in the Age-Specific Shape of Mortality Curves for Populations in the United States and Japan

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Abstract

Life expectancy at birth has improved dramatically over the course of the twentieth century. Over this period there has been a shift in that the highest improvements in mortality rates have been seen in progressively older ages. This paper discusses alternative ways of looking at this trend, fitting models to past trends, and projecting future mortality based on a forward projection of these trends, and calculates annuity values based on these projections.

We consider that the probability of age at death for very advanced ages can best be understood and projected in conjunction with the probability of deaths occurring at younger ages, as changes in mortality rates at younger ages will be correlated with the probability of deaths at very advanced ages.

The work of Jim Oeppen and James Vaupel (2002) influenced our thinking in this area. They concluded that the population life expectancy at birth of the country with the highest life expectancy has followed almost a straight line over the last 160 years with a rate of increase of 0.25 years per annum.

We took the view that in attempting to identify and project trends in mortality the analysis should, if possible, be based on those trends showing significant stability. This led us to investigate whether, in addition to the standard actuarial approach of considering curves of q_x, the following curves may provide a basis for modeling:

The curve of the probability of death at a specified age
The curve of the cumulative probability of death up to a specified age.

We therefore examined the progression over time of each of these curves.

We investigated age-specific mortality curves for population mortality experience for the United States and Japan over the last 40 years. Our investigation was based on population mortality experience from the Human Mortality Database. Japan was chosen as it has seen the highest population life expectancy of any developed nation over the last 20 years. Prior investigators of the Human Mortality Database have suggested that mortality improvements among the higher socioeconomic classes of the United States are not dissimilar to those seen among the general population of Japan.

We have developed models that attempt to relate the age-specific mortality curves for individual calendar years by means of time-dependent variables. The mortality curves that we considered for both males and females in both countries from life tables appropriate to individual calendar years are as follows:

Probability of death at specified age
Age-specific q_x
Cumulative probability of death.

We used these models to project future mortality rates in the United States and Japan. We further consider how these mortality rates may vary according to different future deterministic scenarios. We illustrate the impact of these mortality rates by the calculation of specimen annuity values and projections of age at death for different percentiles of the population.

We discuss the implications of the results for life expectancy and for population age structure. We conclude by providing commentary on the various views being expressed by experts in the fields of demography and medicine as to the likelihood of further improvements in life expectancy and the existence of limits to longevity.