SOCIETY OF ACTUARIES

Article from:

Reinsurance News

August 2008 – Issue No. 63

LONGEVITY: MORTALITY IMPROVEMENT

by John Kingdom

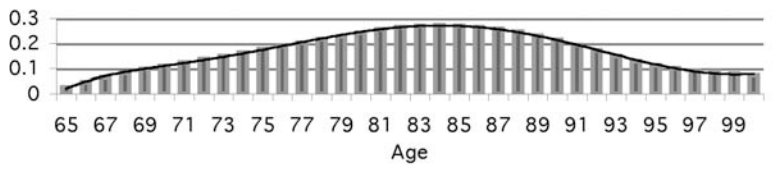
Editor's note: *This article appears with kind permission of The Actuary, Staple Inn Actuarial Society, London, United Kingdom.*

Over the last few years, the issue of longevity risk has gained prominence as mortality rates, and therefore life expectancies, have been improving at an accelerating and faster than anticipated pace.

In 2001, the Continuous Mortality Investigation (CMI) released the interim cohort projections, an extension of the 92-series projections which incorporated the so-called cohort effect.[1] Following that, the Medium Cohort (MC) projection was adopted by much of the industry for the valuation and pricing of annuity products. However, it is now generally accepted that the MC projection, unadjusted, is underestimating future improvements in mortality.

This article shares this view. In particular, the MC projection does not factor in material improvements in mortality rates for older ages. For example, consider Figure 1, which plots the cumulative improvement for males aged 65-100 under the MC projections in 2007.[2] As we can see, cumulative improvements for older ages are set to decelerate under the MC, and peak around the age of 85.

Figure 1: Cumulative improvement for males aged 65-100



I also discuss the notion of date thresholds which separate trends in mortality into two distinct periods: an early period with stable mortality rates and a later period with positive improvements taking place. These date thresholds tend to occur later on in time for older ages. Furthermore, it is not yet clear whether such a threshold has occurred for males currently aged 90 and above—given this, the potential exists for significantly greater improvements in mortality at such high ages.

I present a simple high-level theory for this pattern in mortality improvements which focuses on the effectiveness of medical advances on reducing mortality rates at different ages. I also suggest a possible way to model this which is based on the Lee-Carter methodology, a popular model for stochastic mortality.

Patterns In Mortality Improvements

Upon examination of past mortality trends, we can distinguish two inherent features, as briefly mentioned above.

The first feature is that, initially, mortality rates follow a path of no improvements; this is then followed by a cycle of accelerating and then decelerating improvements, before finally reverting again to a path of no improvements.

The second feature is that mortality improvements start to occur at a later date as we move up the age scale. For example, Figure 2 plots smoothened improvements in mortality rates since 1920 for males aged 45, 70 and 95.[3] We can see that, for males aged 70, improvements in mortality started to occur around 1955 and have been accelerating since. On the other hand, improvements for age 45 started to occur before 1920 and peaked around 1965, while at the other end, improvements

1 The cohort effect describes the phenomenon in the U.K. whereby population cohorts born between 1925 and 1945 have experienced faster improvements in mortality over their lifetime than adjacent generations. See, for example, Willets (1999) and Willets et al. (2004) for a description of this.

2 This plots the annual rate of improvement in mortality for someone aged 65 in 2007 versus the mortality rate of someone aged 65 in 2006, the improvement of someone aged 66 in 2008 versus someone aged 66 in 2006, someone aged 67 in 2009 versus someone aged 67 in 2006 and so on.

for age 95 seem to have picked up from around 1985—although these are not, in a statistical sense, significantly different to zero.

A Simple Theory

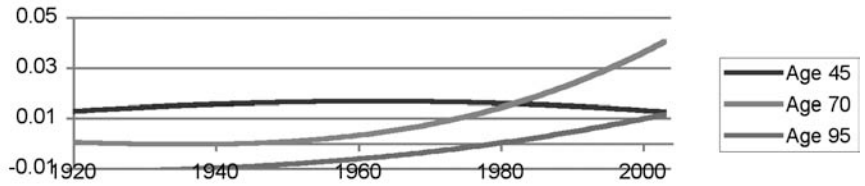
At high levels of mortality, gradual advances in medical science may not have a major impact on reducing mortality rates. For example, at older ages, individuals may suffer from multiple causes of ill-health, so treating one of those causes still leaves them vulnerable to others. Therefore, a significant amount of time and resources may be necessary before the medical knowledge and technology is available to reduce mortality rates. During this time, mortality levels will show little, if any improvement.

Once a breakthrough point is reached and mortality rates start to improve, more research may be required before substantial reductions in mortality are achieved. Therefore, mortality rates will start to improve slowly but at an accelerating pace as further innovations occur.

Finally, as medical advances continue, it takes an increasing amount of new medical advances to further reduce mortality rates. For example, it may not be very easy to reduce mortality rates of 0.4 percent for males aged 50. At this point therefore, mortality improvements start to slow down before stabilizing at a low level, perhaps close to zero.

As Figure 2 suggests, this cycle of accelerating improvements, decelerating improvements and stabilization occurs later for older ages. Arguing along the same lines, this is because mortality rates for older ages are more difficult to improve and so more time and medical progress is necessary to start this process. The necessary medical advances for this could start to occur in the near future, fuelled perhaps by large financial investments from pharmaceutical firms.

Figure 2: Smoothened improvement in males mortality for England and Wales



To model this, I estimate a Lee-Carter model with time-varying coefficients, using ONS data on male mortality in England and Wales. This approach is now described below.

A Lee-Carter-Based Approach

The standard Lee-Carter approach constructs a mortality index from the underlying data and models age-specific mortality rates as a function of this index. Each age-specific mortality rate then has a beta coefficient which measures its sensitivity to changes in the overall mortality index over the period analyzed.[4]

For any given age and time, the age-specific (log) mortality rate is given as:

$$\ln q_{x,t} = \alpha_x + \beta_x k_t + \varepsilon_{x,t}$$

where α is a constant, k is the mortality index, and ε denotes normally and independently distributed errors. Future mortality rates are then derived by projecting the mortality index k forward in time.

One drawback of the standard Lee-Carter approach is that the estimated coefficients remain constant within the projection period. As a result, ages which have experienced relatively high mortality improvements in the past and hence have high beta estimates will have relatively high projected future improvements. Likewise, ages which have experienced lower improvements in the past (e.g. ages greater than 80) will have

3 Source: Own calculations using data from the Office of National Statistics (ONS).

4 An analogy perhaps would be to think of the return on an individual stock and how it is related to the return on the market portfolio through its beta.

continued on page 16

low projected improvements. If, as argued above, mortality improvements for older ages are set to accelerate, this approach will underestimate life expectancy and hence will undervalue annuity products.

Table 1: Estimated Lee-Carter beta coefficients

	Age 30	Age 60	Age 75
1841-2003	0.0158	0.0053	0.0029
1920-2003	0.0132	0.0057	0.0044
1970-2003	-0.0004	0.0139	0.0109

For example, consider Table 1, which gives the beta coefficients obtained from running the Lee-Carter model using the time periods 1841-2003, 1920-2003 and 1970-2003. This shows how the beta coefficients can vary considerably as the estimation period is shortened.

At age 30, the beta coefficient starts off at a relatively high level and declines to a negative value (although this is not statistically different to zero). For older ages however, the beta coefficients increase as the time period is shortened. As discussed, this occurs because younger-age mortality showed most improvement in earlier years while in later years it was older-age mortality which improved the most.

In order to take this into account in my own estimates for life expectancy, I use the Lee-Carter approach but with time-varying coefficients. To do this I first examine the trends in the alpha and beta coefficients of the Lee-Carter model for ages 50-100 by estimating these for consecutive and rolling 30-year sub-periods.[5] Then, when projecting forward the mortality index k, I also extrapolate the alpha and beta coefficients of the model in a way that is consistent with previous trends in these.

In brief, the model projects an increase in the beta coefficients for ages above 80 and, in parallel, a fall in these for ages 50-80. At the same time, there is little change in the projected alpha coefficients—taken together, this implies an accelerating pace of mortality improvements for older ages and a fall in the rate of improvement for younger ages. The results are detailed below.

Table 2: Estimated life expectancy, males aged 65

Year	e(65)	Change
2004	18.7	0.19
2005	18.8	0.19
2006	19.0	0.18
2007	19.2	0.18
2008	19.4	0.18

Table 3: Estimated Average Improvement

Age group	This model	MC projection
65-69	2.0%	2.2%
70-74	1.7%	1.8%
75-79	1.9%	1.7%
80-84	2.1%	1.7%
85-89	2.8%	1.3%
90-94	2.5%	0.7%
95-100	2.0%	0.3%

Results

Using this method of projection to estimate mortality rates from 2004 onwards, I estimate life expectancy for males aged 65 in 2007 at 19.2 years. In contrast, using the standard Lee-Carter specification yields a life expectancy for 2007 of 18.3 years—0.9 years less.

The results imply an increase in life expectancy of 0.18 years per annum between 2004 and 2008. Compared to the cohort projections, this is equivalent (in value but not in shape) to assuming that improvements follow the MC with a floor of 1.8 percent. If we re-base mortality rates in 2007 and project these forward,[6] these projections are in fact equivalent to assuming the MC with a floor of 2.1 percent. What's more, unlike the MC projection, the bulk of these improvements occur for older ages—this is highlighted in more detail in Table 3.

5 In other words, I first estimate the model using data from 1841-1870, then 1842-1871, then 1843-1872, and do this for all 30-year sub-periods up to 1974-2003.

6 That is, if both my model and the MC model project from a common set of mortality rates in 2007.

The Cohort Effect

Although the model does not explicitly model cohorts, the projections suggest the presence of a cohort effect after 2003 which is centered around the 1935 cohort. For example, the 1935 cohort has an average projected lifetime improvements of 2.51 percent, against average projected lifetime improvements of 1.8 percent and 1.85 percent for the 1920 and 1950 cohorts.

That the model projects a cohort effect despite not modelling cohorts explicitly also presents another possible explanation for such phenomena on the basis of medical advancements and changes in lifestyle alone. Having said that, this does not invalidate other possible explanations which may also contribute to this effect in the U.K., such as, for example, the introduction of the NHS in 1948.

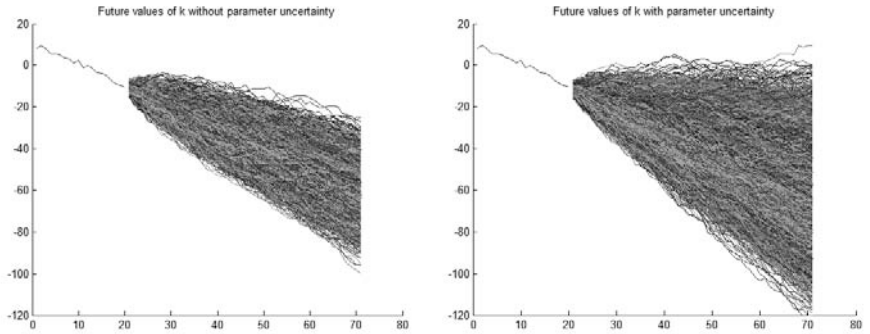
The Extent Of Uncertainty

There is a considerable amount of uncertainty in the model's projections. I derived a 1-in-200 stress test scenario by running a large number of stochastic simulations in the mortality index and capturing the 99.5th percentile for male life expectancy at 65 in 2007. The result is a life expectancy of 22.1 years, nearly 2.9 years higher than the best estimate of 19.2 years. This is equivalent to applying the MC with a floor of 3.7 percent.

These stress tests included two sources of uncertainty: straightforward statistical volatility arising from the random error terms in the model and parameter uncertainty, which is the risk that the estimated parameters of the model do not necessarily reflect the true underlying values.[7]

The simulations show that parameter uncertainty is an important risk that should be accounted for—if this is excluded from the model's simulations, the resulting stress test is equivalent to applying the MC with a floor of just 3.4 percent and yields a life expectancy of half-a-year less. The extent of this effect is illustrated in Figure 3, which plots possible future paths for the mortality index k with and without parameter uncertainty—as we can see, the projections which include parameter uncertainty have a considerably larger funnel of doubt.

Figure 3: Future projections of the mortality index with and without parameter uncertainty



Conclusion

In this article I argue that mortality trends are not stable over time and that mortality rates for the more advanced ages are set to accelerate in the near future.

I propose a model for this by using a Lee-Carter framework with time-varying coefficients. Based on this method, the best estimate for life expectancy for males in England and Wales is considerably stronger than that of the standard Lee-Carter approach and is equivalent to applying the MC projection with a floor of 1.8 percent in 2003 and 2.1 percent in 2007.

To conclude, the one central message of this article is that, when estimating life expectancy, care should be taken to account for how trends in mortality can change over time—by assuming that trends remain constant, one can underestimate life expectancy and therefore undervalue annuity products. ✺

John Kingdom, Ph.D., joined the Financial Services Authority, London, U.K., as a research associate in 2007 after completing a Ph.D. in Economics at the University of Southampton. The views expressed in this article are strictly his own personal ones. He can be reached at *john.kingdom@fsa.gov.uk*.

7 This is not to be confused for mis-estimation risk of current mortality rates, which is not included in this analysis.