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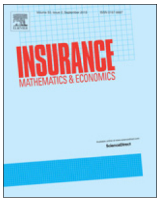

Do actuaries believe in longevity deceleration?[☆]

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As more and more people believe that significant life extensions may come soon, should commonly used future mortality assumptions be considered prudent? We find here that commonly used actuarial tables for annuitants – as well as the Lee–Carter model – do not extrapolate life expectancy at the same rate for future years as for past years; instead they produce some longevity deceleration. This is typically because their mortality improvements decrease after a certain age, and those age-specific improvements are constant over time. As potential alternatives (i) we study the Bongaarts model that produces straight increases in life expectancy; (ii) we adapt it to produce best-practice longevity trends (iii) we compare with various longevity scenarios even including a model for "life extension velocity". (iv) after gathering advances in biogerontology we discuss elements to help retirement systems cope with a potential strong increase in life expectancy.

1. Introduction

During an online interview with more than 200 attendants, the biogerontologist Aubrey de Grey indicated that he estimates at 60% the probability that people currently aged 40 reach "Longevity Escape Velocity" (de Grey, 2015), a set of scenarios where one's remaining life expectancy increases as one ages, because therapies gradually come to restore health faster than the rate of body deterioration due to biological aging (de Grey, 2004). There is so far evidence of strong life expectancy improvements in animal models (see for example Bartke et al., 2008 or Bernardes de Jesus et al., 2012) but little (Bannister et al., 2014) or no evidence of such medical advances in humans so far. We are still far from curing some diseases where one single gene is the source of the problem. Therefore, it may take longer than de Grey's estimate to strongly slow or reverse aging. Besides, one would need to think more about the social and economical issues that would appear in such a world and about their negative impacts on longevity improvements. Nevertheless, given the increasing number of scientists who believe that the human lifespan may soon increase at an unprecedented pace, one may wonder if retirement systems are built in a way that could cope with such scenarios if they were to take place. In particular, currently used mortality projections for retirement systems are very different from the concept of Longevity Escape Velocity:

A widely used basis for mortality projections is the Lee–Carter model (Lee and Carter, 1992). It has led to the development of numerous models (Cairns et al., 2011). In their original paper, Lee and Carter (1992) present a forecast of US life expectancy that first continues at the historical trend and then decelerates over time. Their confidence intervals are presented that are below a linear extrapolation of life expectancy. The authors write: "While many methods assume an upper limit to the human life span (...) our method allows (...) the deceleration of life expectancy (...) without any special additional assumption". At that time indeed, a sort of "longevity deceleration" was expected.

A widely known view is that life expectancy grossly increases by one quarter per year. Such a view was introduced by Oeppen and Vaupel (2002) ten years after the publication of the Lee–Carter model, in the context of maximal life expectancy across countries. They indicate that it has increased fairly linearly for more than 150 years – a "best practice line" – and has broken various predictions and limits imagined by actuaries, such as a 1928 computation of a putative ultimate human life expectancy of... 64.75 years (Dublin, 1928). Along those lines, Bongaarts (2014) questions longevity decelerations embedded in the Lee–Carter model and develops a simple mortality projection model that produces straight life expectancy increases.

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Vallin and Meslé (2010) recomputed maximal life expectancy with other data and find that it is better represented by several portions of lines than by one line: the trend can change over time in particular due to various medical and social progresses. As they indicate, maximal life expectancy has increased by up to 4 months per year during several decades after the work of Louis Pasteur, the trend is now lower than "one quarter per year" and is more and more driven by improvements at later ages, in particular depending on how age-related frailty and age-related pathologies are addressed. Along those lines, Li et al. (2013) produce an extended version of the Lee–Carter model that allows for age patterns of mortality decline to rotate in the future towards higher ages, thereby reducing the longevity deceleration of the Lee–Carter model. Note that Ronald Lee was one of the coauthors of that paper.

One might interpret the latter as a convergence of views that a decelerating pattern of the Lee–Carter model is inadequate and that a trend of linear increases of life expectancy, which would be slower than one quarter per year for the next decades to come, makes sense. In this paper we name such a scenario the "Best Practice Trend" following the strong-worded vocabulary of Oeppen and Vaupel (2002), even if it is of course not clear at all what the best practice is, and we model it in this paper. However, views are far from uniform. There have typically been debates whether general improvements will outweigh changes in lifestyle, pollutions and climate, whether age-specific risks of chronic diseases will increase or decrease for a given age, and whether lifespan should consecutively increase or decrease and also whether a limit of human lifespan exists (Aubert et al., 2010; Cambois et al., 2009; Debonneuil et al., 2011).

Facing uncertainty, actuarial assumptions should be prudent rather than aggressive. Antolin and Mosher (2014) review the sufficiency of actuarial mortality tables that are commonly used for retirement systems, country by country. For that purpose, they compare mortality tables with projections obtained with models that extrapolate log-mortality rates, such as the Lee–Carter model. They find in most of the cases that the mortality table leads to lower provisions than the model (Antolin and Mosher, 2014)—thereby generating a general warning: are actuarial mortality tables sufficient? Antolin and Mosher (2014) also suggest that governments help set up a framework to financially hedge longevity risk.

Here, further than comparing commonly used mortality tables with commonly used actuarial models, we compare them with models that extrapolate life expectancy linearly. Placing then the results in the context of potentially even far different futures than generally investigated we gather facts of advances in biogerontology and elements of solutions to help retirement systems cope with strong increases in human lifespans.

2. Mortality projection methods

2.1. Overview

We here limit the modeling scope in order not to disperse into too many aspects. Complex longevity risk estimations that would consider country-specific and system-specific risk absorption mechanisms and amounts at stake are not considered. Rather, the quantitative parts of this paper focus on life expectancies (period and generational life expectancies starting at different ages) and values of immediate annuities for people aged 65. The sole data we use here are general population data and actuarial tables, the results of which are compared without modeling complex basis risk between general and insured populations. Similarly, results for males and females are superimposed without modeling correlations between the two. For the sake of simplicity, we consider life expectancy at age 20 (and above) rather than at birth because some actuarial tables do not provide mortality rates for lower ages. Of course, this oversimplification would prevent one from accurately estimating longevity risk. However, it enables us to illustrate our conclusions with little complexity.

The interest of the analysis then lies in the use of models with various trends and some first order comparison with commonly used actuarial assumptions.

Briefly, for a given country and a given gender, five mortality projection models ("Lee–Carter", "Bongaarts", "BestPractice", "Fast", "Flat", "LEV"). Indicators are calibrated from the general population data. Indicators are then computed for various dates, both based on those models and based on an actuarial table for the same country and gender: [period] life expectancy at age 20 and 65, generational life expectancy at age 65 and immediate annuity value at age 65.

2.2. Standard methods

Regarding data, the general population data consist in deaths and expositions taken from the Human Mortality Database for various countries (Human Mortality Database, 2015). It is split by gender, age "x" and calendar year "t". We consider data up to calendar year 2009 only as more recent data is currently only available for a limited number of countries. The actuarial mortality tables are those commonly used in insurance according to a recent report from the OECD about the insufficiency of current actuarial assumptions (Antolin and Mosher, 2014).

Regarding indicators, annual mortality rates $q_{x,t}$ are computed from central mortality rates $m_{x,t}$ using

$$q_{x,t} = 1 - e^{-m_{x,t}}.$$

The remaining [period] life expectancy at age x is computed using $e_{x,t} = 0.5 + \sum_{y=x}^{170} \prod_{z=x}^{y} \left(1 - q_{z,t}\right)$.

The expected lifespan of people aged 65 at year t is computed using

$$e^t_{g\,65} = 65.5 + \sum_{x=65}^{\infty} \prod_{y=65}^{x} \left(1 - q_{y,t+(y-65)}\right).$$

In practice we replace ∞ by 170 (except for the LEV model where we use 10 000). Immediate annuities at age 65 are calculated similarly, with an interest rate of 2%:

$$\ddot{a}^t_{65} = 65.5 + \sum_{x=65}^{\infty} \frac{\prod_{y=65}^{x} \left(1 - q_{y,t+(y-65)}\right)}{1.02^{x-64}}.$$

We will compute them with standard mortality tables ($\ddot{a}^t_{65(table)}$) and various models ($\ddot{a}^t_{65(model)}$).

Regarding the Lee–Carter model, parameters are calibrated for ages 0 to 89 with the LifeMetrics "fitmodels.r" functions (see Cairns et al., 2007), which is an implementation of an adjustment of the original Lee–Carter model (see Brouhns et al., 2002). The longevity trend is obtained by extrapolating kappa with a simple linear regression (slope defined by least square linear regression, and applied to the last known kappa; for further refinements, it could be possible to apply trends to an average of the last 3 years for example): we obtain central mortality rates $m_{x,t}$ for ages 0 to 89 and at any future date. For any given date t we then extrapolate $m_{x,t}$ from ages 60–89 to ages 90–170 using a logistic regression: $logit\ m_{x,t} = a_t x + b_t$. This is simple and sufficient for the gross indicators that we use in this paper such as life expectancies at age 20 and 65. To smooth mortality rates along age and time one may extrapolate mortality rates at high ages in a coherent manner across consecutive years following Planchet (2006).

Regarding the "Bongaarts" model, sometimes called "shifting logistic", we carry out a standard logistic regression on deaths and

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