Longevity Risk 101: A review of mortality and improvements through time

Momentum Conference, Bristol,
11:30am, Friday 4th December 2015
Joshua Waters and David Alison, KPMG
A review of mortality and improvements through time

1. Longevity experience around the world
2. Modelling longevity rates and improvements
3. The future of longevity
4. The regulatory view
Longevity experience around the world
How has longevity changed over time?

Life expectancy
At birth in the Netherlands. From Leyden Academy data.

Life expectancy (years)
Time (calendar year)

Male  Female
How has longevity changed around the world?
How has longevity changed around the world?
How has longevity changed around the world?
How has longevity changed around the world?
How has longevity changed by age and income level?
### Demographic changes affecting mortality

<table>
<thead>
<tr>
<th>Environmental</th>
<th>Medical</th>
<th>Lifestyle</th>
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<tbody>
<tr>
<td>Access to clean drinking water</td>
<td>Vaccines</td>
<td>Smoking habits</td>
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<tr>
<td>Improved sanitation</td>
<td>Surgical anaesthetic</td>
<td>Drinking</td>
</tr>
<tr>
<td>National Health Service</td>
<td>Antibiotics</td>
<td>Physical exercise</td>
</tr>
<tr>
<td>Changes in pollution</td>
<td>Changes in heart surgery</td>
<td>Improvement to diets</td>
</tr>
<tr>
<td>Decrease in crime rate</td>
<td>Radiological imaging</td>
<td></td>
</tr>
<tr>
<td>Improved efficiency in using natural resources</td>
<td>Organ transplants</td>
<td></td>
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<td></td>
<td>Increased ability to identify symptoms</td>
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- **Environmental**: Access to clean drinking water, Improved sanitation, National Health Service, Changes in pollution, Decrease in crime rate, Improved efficiency in using natural resources
- **Medical**: Vaccines, Surgical anaesthetic, Antibiotics, Changes in heart surgery, Radiological imaging, Organ transplants, Increased ability to identify symptoms
- **Lifestyle**: Smoking habits, Drinking, Physical exercise, Improvement to diets
Individual factors affecting mortality

1st tier factors
- Age
- Gender
- Medical condition
- Genetic factors

Socio-economic
- Marital status
- Occupation
- Income
- Education

Lifestyle
- Smoking
- Drinking
- Physical exercise
- Diet

Life Expectancy at Birth
2002 - 2006

Source: CBS

Conditional Probability of Death \( q(x) \) for Males in the U.S. (U.S. Non-Hispanic White, Insured with $1 Million+ Policies, and Whites with College Education (2005))

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Modelling longevity rates and improvements
How can we model historic mortality improvements?

Too many dimensions for ages 60 to 100. Need a dimension reduction technique that fits the historic data. Then we can project forward.

<table>
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<tr>
<th></th>
<th>Lee Carter</th>
<th>Cairns Blake Dowd</th>
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<tr>
<td><strong>Year</strong></td>
<td>1992</td>
<td>2006</td>
</tr>
<tr>
<td><strong>Focus</strong></td>
<td>Whole lifetime</td>
<td>Retirement</td>
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<tr>
<td><strong>Formula</strong></td>
<td>$\log q_{x,t} = \alpha_x + \beta_x \kappa_t + error$</td>
<td>$\text{logit } q_{x,t} = A_t + (x - \bar{x})B_t + error$</td>
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Lee Carter (1992)

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<tr>
<td><strong>Additive term</strong></td>
<td>Base mortality curve</td>
<td>Level of mortality through time</td>
</tr>
<tr>
<td><strong>Time dependent term</strong></td>
<td>Fully parameterised</td>
<td>Intuitive form</td>
</tr>
<tr>
<td><strong>Parameters</strong></td>
<td>≈ 300</td>
<td>≈ 200</td>
</tr>
<tr>
<td><strong>Strengths</strong></td>
<td>Captures infant mortality</td>
<td>Better fit in retirement</td>
</tr>
<tr>
<td><strong>Weaknesses</strong></td>
<td>Doesn’t tell you how to project forwards</td>
<td></td>
</tr>
<tr>
<td><strong>Transformation</strong></td>
<td>Logarithm, $\log q$</td>
<td>$\logit q := \log(q) - \log(1 - q)$</td>
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## How can we project forward future mortality improvements?

The past is no guide to the future. We need a way of informing expert judgement.

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<th>Cause of Death</th>
<th>Cause of Improvements</th>
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<td>Overall improvements</td>
<td>Split by disease e.g. cancer</td>
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CMI Model

Current improvement rates

- Convergence path

Long term improvement assumption

- e.g. 2.00%pa males
- and 1.75%pa females
Reduce dimensions using Principal components analysis, Lee Carter model or age standardised mortality rates
## Cause of Improvements Model

<table>
<thead>
<tr>
<th>Developing countries</th>
<th>Working age population</th>
<th>Retired population</th>
</tr>
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<tr>
<td>Children</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Developing countries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>More developed countries</td>
<td></td>
<td></td>
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Cause of Improvements Model

Source: http://riskinc.com/Publications/Longevity_Risk_brochure.pdf
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<td>Assumptions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Long term improvements rate</td>
<td>• Future improvements in each cause</td>
<td>• Future path of drivers</td>
</tr>
<tr>
<td></td>
<td>• Convergence path</td>
<td>• Interdependency between causes</td>
<td>• Impact of drivers on mortality</td>
</tr>
<tr>
<td>Strengths</td>
<td>Low data requirements Quicker to build</td>
<td>Easier to justify expert judgements</td>
<td>Allows for interdependency</td>
</tr>
<tr>
<td>Weaknesses</td>
<td>Difficult to validate expert judgements</td>
<td>Higher number of expert judgements</td>
<td>Difficult to validate expert judgements</td>
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How can we underwrite annuities?

**Historical data**
- Public, own data, reinsurer
- Curve fitting, generalised linear model

**Underwriting**
- Smoker status, postcode, BMI, medical conditions, education
- Medical exam, questionnaire

**Other considerations**
- Anti-selection from enhanced annuities
- Seasonality effects
How can we model enhanced mortality?
The future of longevity
History of survival

Survival Curve for Number of Survivors Per 1,000 Births

- 1931-40 Sweden
- 1959
- 1891-1900
- 1916-40
- 1753-63
- Guinea farming villages 1954-55
- Stone age
- Bronze age
- Japan 1977


What next?
Rectangularisation or Methuselah?
Rectangularisation – Life expectancy is reaching a limit

Source: Theories of Longevity – Robert L. Brown, PhD
Rectangularisation – Life expectancy is reaching a limit

Improvements have focussed mainly on the heart

Largest progress in raising life expectancy relates to infants.

No strong evidence that max age is increasing

Current causes of death only impact so much
Methuselah – Life expectancy and maximum life span will continue to grow

Source: Broken Limits to Life Expectancy – Oeppen and Vaupel
Methuselah – Life expectancy and maximum life span will continue to grow

Even experts can be wrong

Not just life span, but health can also be preserved

Natural selection can conquer senescence

Genetic engineering, nano-technologies have all contributed to significant successes

Studies reveal aging can be surprisingly elastic
The Future Will Be Different from the Past

Advancements in Medical Technology

- Regenerating and rejuvenating tissue
- Slowing the rate of aging
- Nanotechnologies
- Replacing deleterious genes

Shifting focus from the past

- Country
- Causes
- Ages
PRA treatment of mortality
The PRA has split longevity risk into two sub-risks: base mis-estimation risk and future improvement risk:

**Base mis-estimation**
- Actual mortality experience differs from the best estimate mortality assumption
- No QI as each firm’s exposure is unique

**Future improvement**
- Actual future improvements differ from best estimate future improvements assumption
- Less heterogeneous and therefore the PRA have derived a QI for future improvement risk
- How much could the best estimate future improvement assumption change over one-year?

**Data Risk**
- Simulating an additional year of data and recalibrating the trend risk model accordingly.

**Event Risk**
- The impact of new information emerging which is not captured by historical data. The PRA has equated this with changing a trend risk model.
Comments from the PRA approach

<table>
<thead>
<tr>
<th>1-year VaR</th>
<th>No Cause-of-Death</th>
<th>Model Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRA is focused on a 1-year VaR</td>
<td>PRA does not consider cause-of-death modelling a robust model</td>
<td>The PRA itself works with: “four commonly used families of stochastic longevity risk models”</td>
</tr>
<tr>
<td>Whereas a catastrophe can occur in an instant, longevity risk takes decades to unfold</td>
<td>None of the models are “cause of death” models due to their greater complexity, data requirements and the need for a greater level of expert judgement to be exercised.</td>
<td>The best way to deal with model risk is to not rely on a single model.</td>
</tr>
<tr>
<td>Mortality shocks are easy to spot. Longevity shocks much less so, since you can only detect a trend change several years after it has already started.</td>
<td>Concerned that the correlations between causes of death were not easily measured and would not be stable over time</td>
<td>Different models produce different capital requirements</td>
</tr>
<tr>
<td>Longevity risk not a natural fit to “1:200 over one year” approach and a run-off may be a more appropriate way to view this risk.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How do you find a multi-year run-off scenario equivalent to a 1:200 event over one year?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This doesn’t stop firms from using these approaches, but the challenge then is to demonstrate consistency with the one-year calibration standard.
How does this compare to the true nature of longevity risk?

<table>
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<tr>
<th>Richards Risk Behaviours*</th>
<th>Comments</th>
<th>Assessment against QIs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basis risk</td>
<td>Uncertainty in the assumptions drawn from “external” experience</td>
<td>Portfolio specific – no QIs proposed</td>
</tr>
<tr>
<td>Idiosyncratic risk</td>
<td>Case of unusually light mortality experience from random individual variation.</td>
<td></td>
</tr>
<tr>
<td>Mis-estimation risk</td>
<td>Statistical error in the calibration of the mortality basis to past experience</td>
<td></td>
</tr>
<tr>
<td>Model risk</td>
<td>It is impossible to know if the selected projection model is correct.</td>
<td>Covered by PRA “event risk”</td>
</tr>
<tr>
<td>Volatility</td>
<td>Case of unusually light mortality experience from seasonal or environmental variation</td>
<td>Covered by PRA “data risk”, but question is whether this is a permanent or temporary increase to life expectancy</td>
</tr>
<tr>
<td>Trend risk</td>
<td>Even if the model is correct and there is no basis risk, an adverse trend may result by chance which is nevertheless fully consistent with the chosen model.</td>
<td>Has this truly been covered by PRA’s VaR approach?</td>
</tr>
</tbody>
</table>

Other risks potentially not considered

- Underwriting risk – uncertainty in the assumptions from the specific information by the individual
- Catastrophe risk – a “catastrophic shift” in mortality rates

*A VALUE-AT-RISK FRAMEWORK FOR LONGEVITY TREND RISK – S. J. Richards et al.*
Summary and questions…

Experience around the world

Modelling longevity

The future of mortality

View of the regulator
Thank you!