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Mortality Investigation
Institute and Faculty of Actuaries

CMI update on longevity modelling and high age mortality

Presentation to the International Mortality and Longevity Symposium 2016

Tim Gordon

Chair of the CMI Mortality Projections Committee

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Chair of the CMI High Age Mortality Working Party

8 September 2016

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The CMI

Tim Gordon
Chair of the CMI

CMI

CMI

- Wholly owned by Institute and Faculty of Actuaries
- Independent executive and management

Funded by subscription but free for academics and non-commercial research

Mission

> *To produce high-quality impartial analysis, standard tables and models of mortality and morbidity for long-term insurance products and pension scheme liabilities on behalf of subscribers and, in doing so, to further actuarial understanding.*

Our vision is to be regarded across the world as setting the benchmark for the quality, depth and breadth of analysis of industry-wide insurance company and pension scheme experience studies

Recent and ongoing work

- Graduation and Modelling Working Party report March 2015 (WP77)
  - Update graduation toolset – no more GM(r,s) / include co-graduation
  - *Software freely available – 'CMI Graduation Software v0.2 (beta)'*
- Investigations
  - Annuities – 08 tables finalised June 2015 (WP81)
  - Assurances – proposed 08 tables: accelerated critical illness released in May 2016 (WP89) and term assurance due September 2016
  - SAPS – S3 targeted for release in 2019
- Projections
  - Proposed model released June/August 2016 (WP90/WP91)
  - *Model and calibration software are freely available*
- High Age Mortality Working Party initial report October 2015 (WP85)

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Recent mortality and the proposed CMI Projection Model

Tim Gordon
Chair of the CMI Mortality Projections Committee

1. Recent mortality in England & Wales

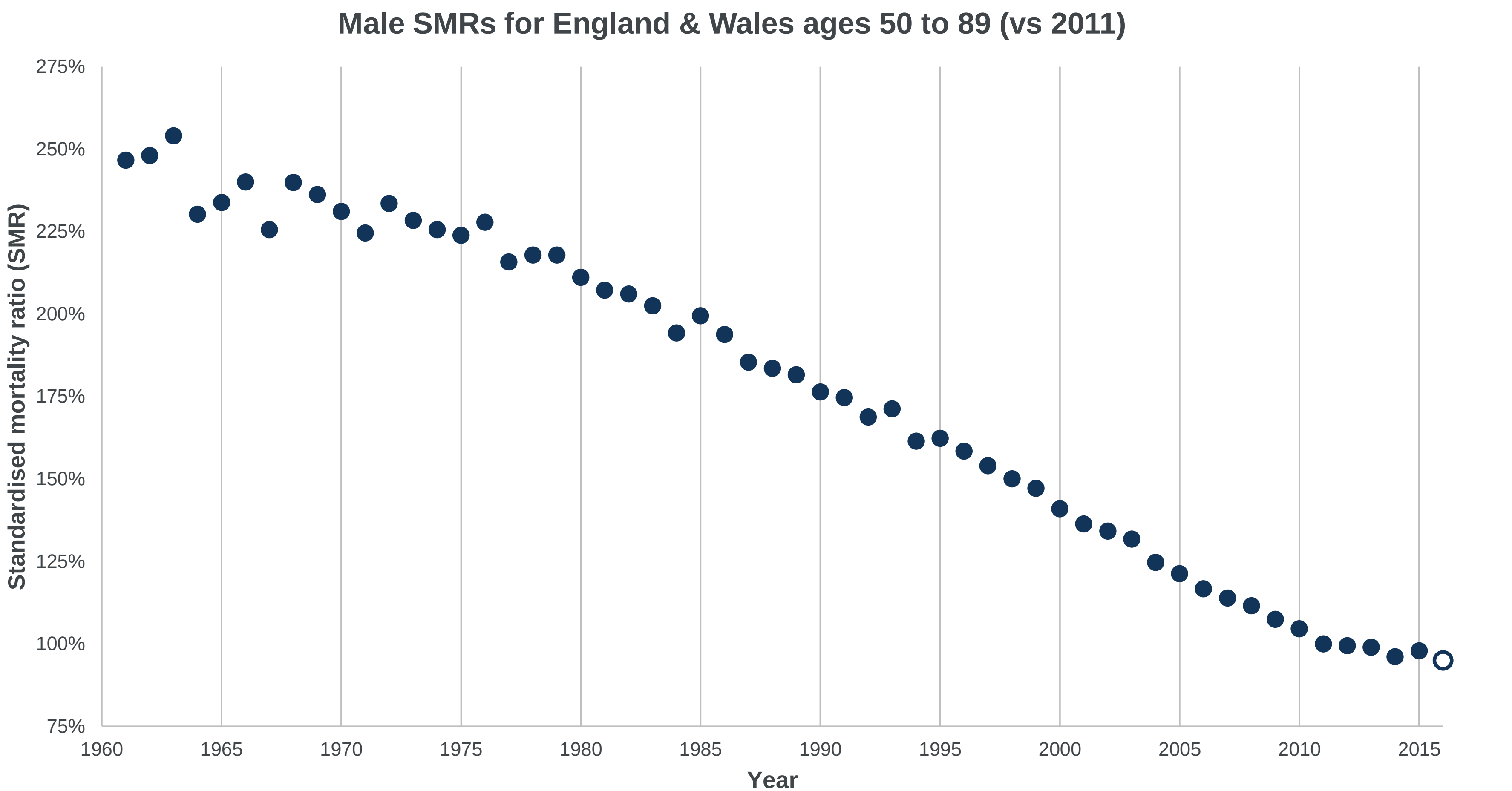
Analysing past mortality using SMRs

- Standardised mortality ratio (SMR):

$$\frac{\sum_{x=50}^{89}\left\{(\text{deaths})_{xt}\times\frac{(\text{exposure})_{x,2011}}{(\text{exposure})_{xt}}\right\}}{\sum_{x=50}^{89}(\text{deaths})_{x,2011}}$$

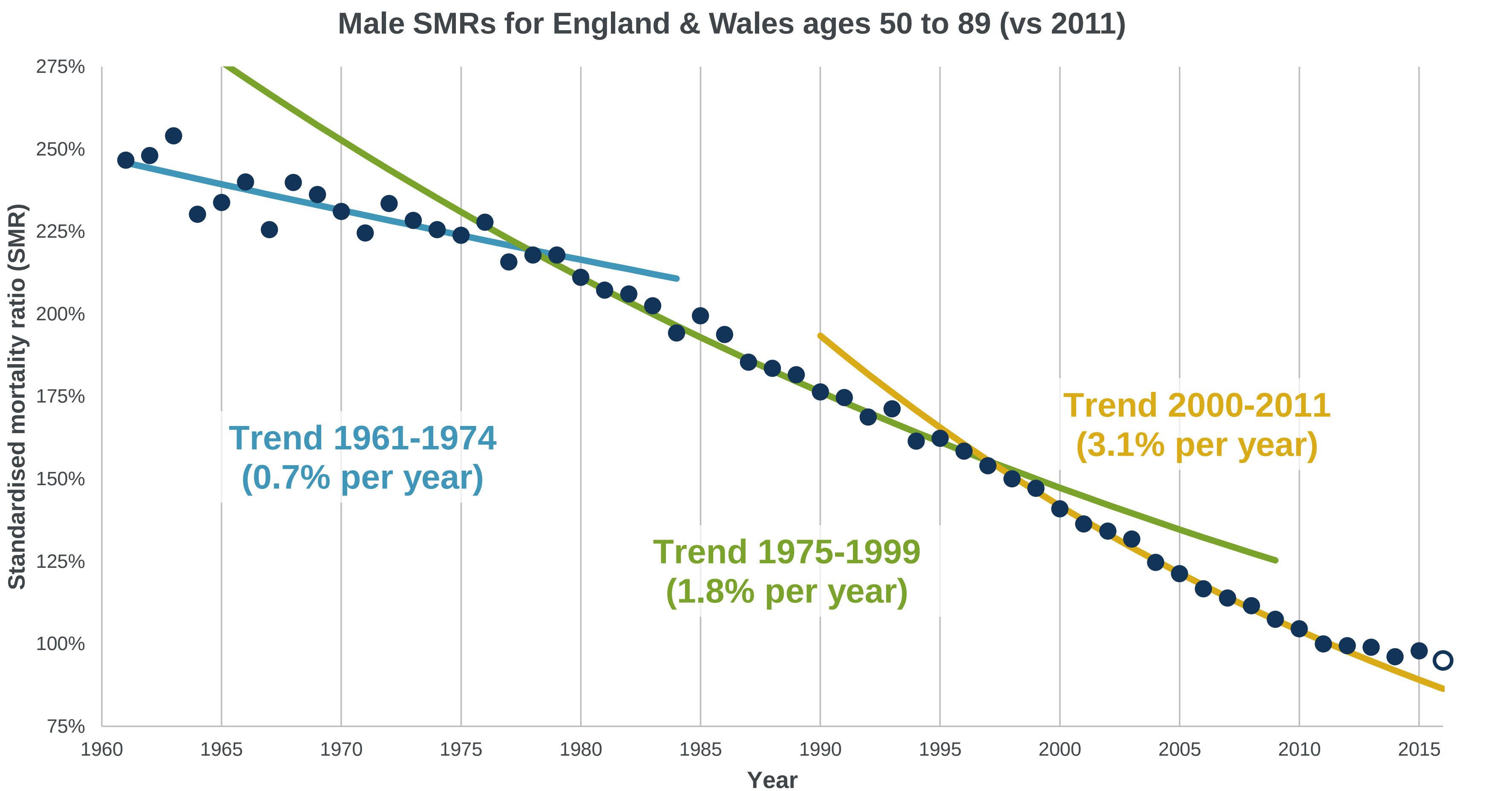
- Measure of 'average mortality' – useful to understand broad trend
- Use ages 50 to 89 – ONS data over age 90 is less reliable
- Comparable year to year – removes population change effects
- Not comparable males vs females – female population is older
- Trend lines chosen by reference to males – deliberately suggestive
- (2016 point is calculated by Aon Hewitt as 'neutral' – don't rely on this)

Male SMR



Calculations by Aon Hewitt using ONS data

Male SMR



Calculations by Aon Hewitt using ONS data

Observation

Apart from very recently – 2012 onwards – relying solely on predictive power would likely select a model that *always* predicted higher future mortality improvements than the past

Renormalised SMR

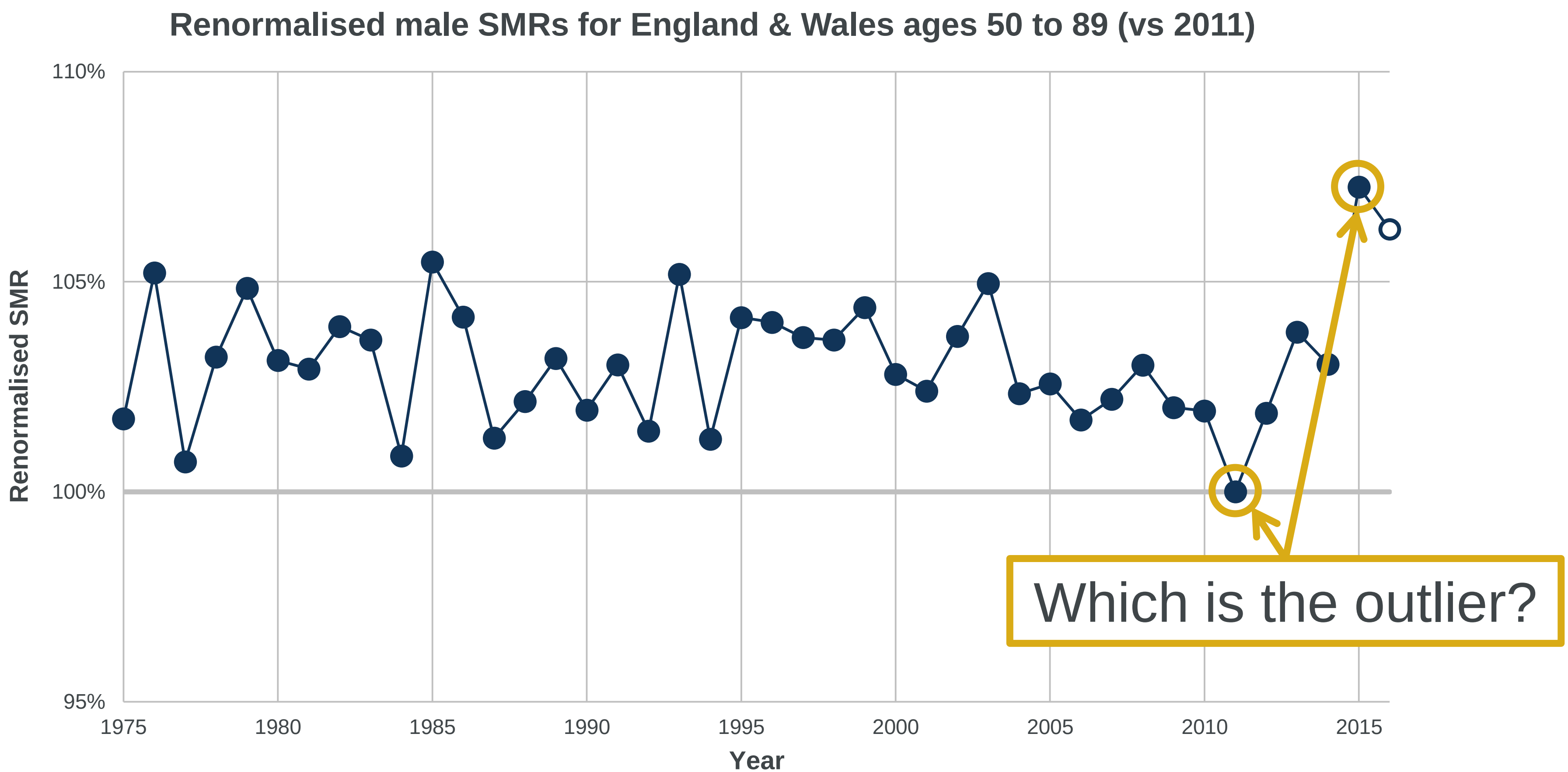
- What about the cohort effect?
- Renormalised SMR:

$$\frac{\sum_{x=50}^{89}\left\{(\text{deaths})_{xt} \times \frac{(\text{exposure})_{x,2011} \times \boxed{m_{x,2011}}}{(\text{exposure})_{xt} \times \boxed{m_{xt}}}\right\}}{\sum_{x=50}^{89}(\text{deaths})_{x,2011}}$$

  where m_{xt} is the mortality rate in the proposed CMI model calibrated to end 2015 (or any other slowly varying reasonable model)

- Residual is change in 'average annual mortality' vs 'average' expected deaths on chosen mortality – useful to understand deviation from trend
- (2016 point is calculated by Aon Hewitt as 'neutral' – don't rely on this)

Male SMR – renormalised



Calculations by Aon Hewitt using ONS data and the proposed CMI projection model calibrated to data to end 2015

2. Proposed CMI Projection Model

Consultation process

Date	Item
22 June 2016	Working Paper 90 published
29 June 2016	Edinburgh consultation meeting
11 July 2016	London consultation meeting
31 August 2016	Working Paper 91 published and **model software released**
30 September 2016	**Responses to consultation due**
November 2016	Working paper summarising responses and revisions
March 2017	Publish CMI_2016 (based on data to 31 December 2016)

Approach

This is an *evolution* of the model

This is *not the answer* – it's a flexible tool that's been made reasonable by

- building on the existing model, and
- exposure to actuarial review

This is *not a predictive model*

- Wide age range mitigates against a *simple* predictive model
- We're short on test data (by the nature of mortality improvement)

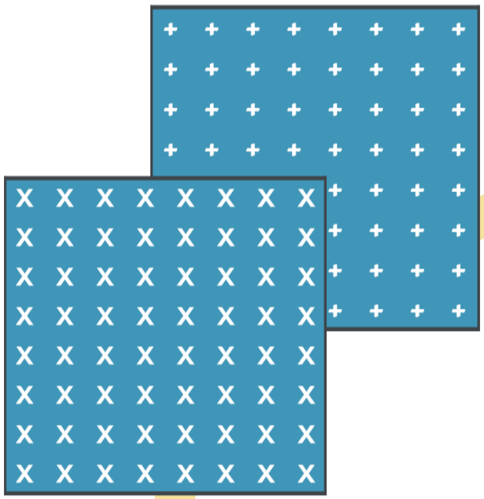
We have simplified where possible

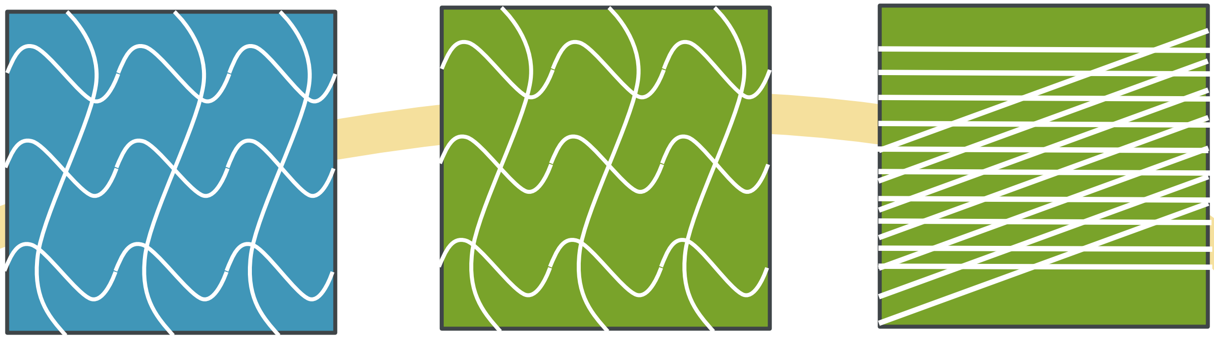
- One step calibration vs smooth *plus* APC improvement split
- One software environment vs Excel/VBA *plus* R
- One smoothing step vs smooth *plus* step back

We have focussed on ease of use

- Allow users to incorporate views e.g. short term responsiveness
- Real time calibration

What's changed – big picture





2. Fit P-spline surface to estimate smooth mortality rates

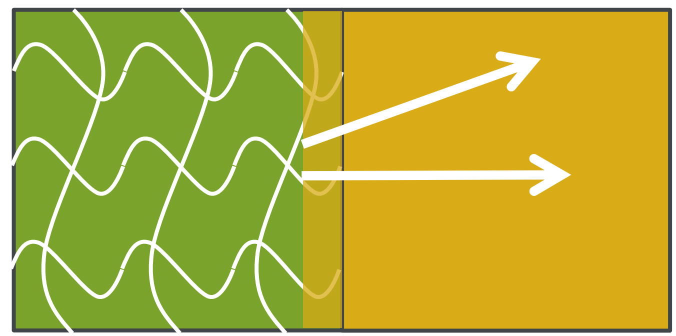
3. Derive annual rates of mortality improvements

2/3/4. Fit model

4. Determine age-period / cohort decomposition

1. Data
(a) Raw death and population data for the UK England & Wales
(b) Population data at high ages constructed by CMI (using ONS methodology)
(c) CMI caps unlikely data points using a simpler method

5. Projection
~~(a) Step back two years for initial rates~~
~~(b)~~ Sum separate projections of age-period and cohort components



3. Proposed CMI Projection Model – initial improvements

Age-Period-Cohort Improvement model

- Definition of the model:

$$\log m_{xt} = \alpha_x + \beta_x(t - \bar{t}) + \kappa_t + \gamma_{t-x}$$

  where:
  - x and t are age and calendar year
  - α_x and β_x are sets of parameters indexed by age
  - κ_t is a set of parameters indexed by calendar year (period)
  - γ_{t-x} is a set of parameters indexed by birth year (cohort)
  - $\bar{t}$ is the midpoint of the period used to calibrate the model
- Mortality improvement is *not* q_{xt}-based, but $\log m_{xt}$-based:

$$\boxed{MI_{xt} = -\left(\log m_{xt} - \log m_{x,t-1}\right)}$$

Age-Period-Cohort Improvement model

- Definition of the model:

$$\log m_{xt} = \alpha_x + \beta_x(t - \bar{t}) + \kappa_t + \gamma_{t-x}$$

- Mortality improvement (reduction in $\log m_{xt}$) is:

$$MI_{xt} = \underbrace{\boxed{-\beta_x}}_{\text{Age}} + \underbrace{\boxed{(\kappa_{t-1} - \kappa_t)}}_{\text{Period}} + \underbrace{\boxed{(\gamma_{t-x-1} - \gamma_{t-x})}}_{\text{Cohort}}$$

- Gives us mortality rates / improvements and APC split *in one step*

- Fit by minimising
  - deviance (aka $-2 \times \log \text{likehood}$) for goodness-of-fit, plus
  - multiples of squared 3rd differences of α_x, β_x and γ_{t-x}, plus
  - multiple of squared 2nd differences of κ_t – tends to flatten MI_{xt},

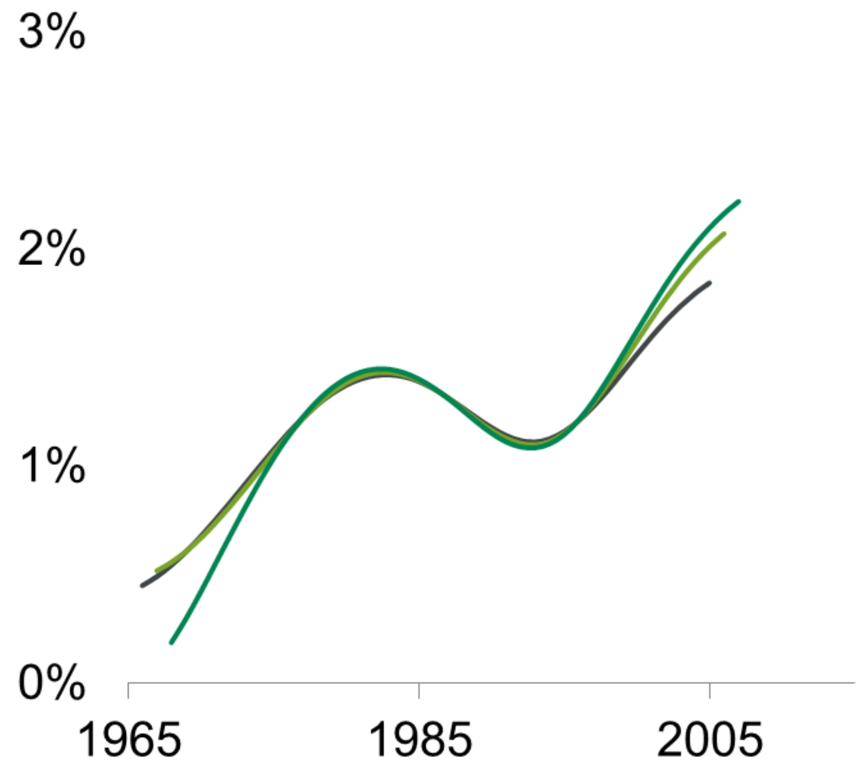
  and applying identifiability

4. Proposed CMI Projection Model – projection

Apparent direction of travel

Chart shows period components of mortality improvements from the (old) p-spline model fitted to male data for various 41-year periods

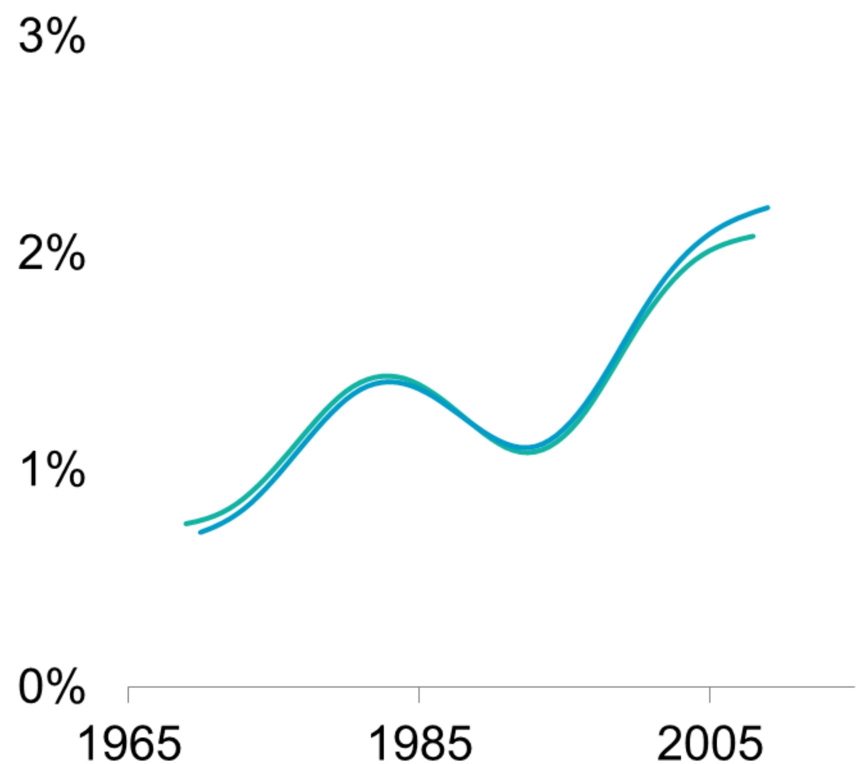
Periods ending in 2005, 2006, 2007



Apparent direction of travel

Chart shows period components of mortality improvements from the (old) p-spline model fitted to male data for various 41-year periods

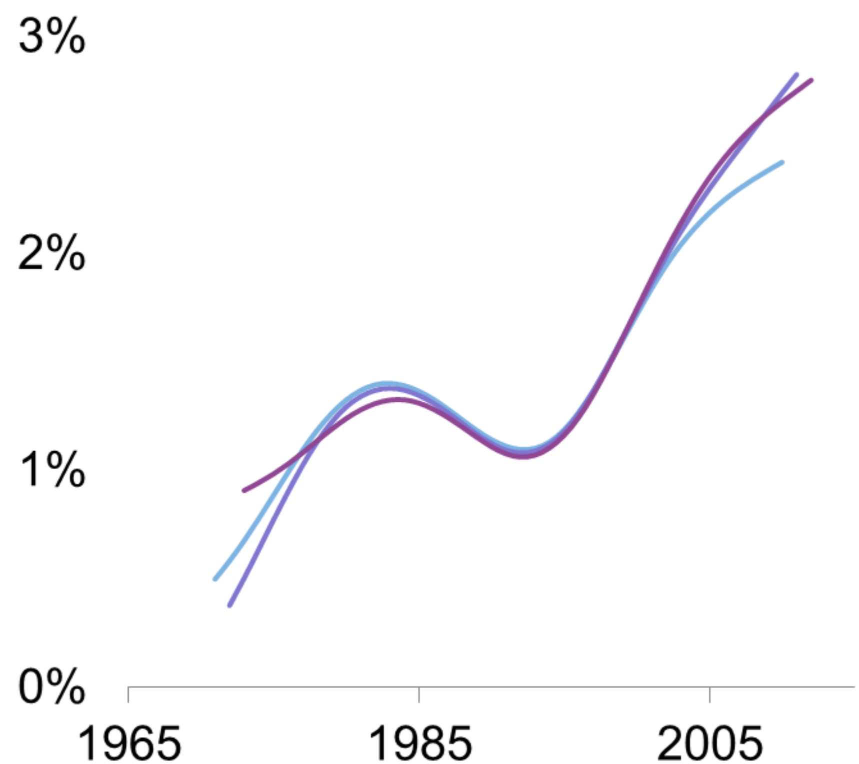
Periods ending in 2008, 2009



Apparent direction of travel

Chart shows period components of mortality improvements from the (old) p-spline model fitted to male data for various 41-year periods

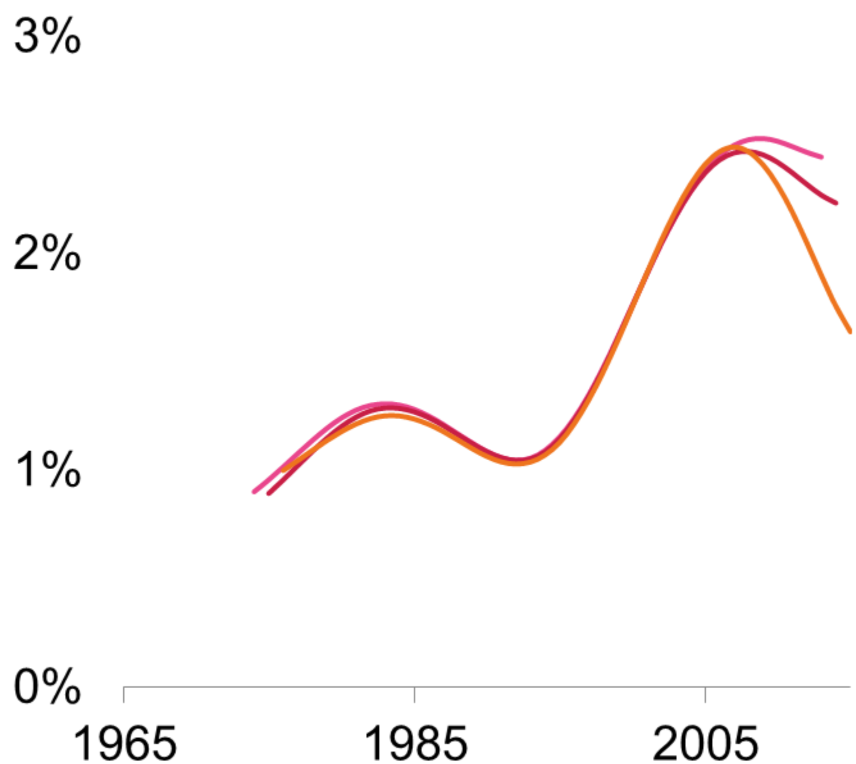
Periods ending in 2010, 2011, 2012



Apparent direction of travel

Chart shows period components of mortality improvements from the (old) p-spline model fitted to male data for various 41-year periods

Periods ending in 2013, 2014, 2015



Apparent direction of travel

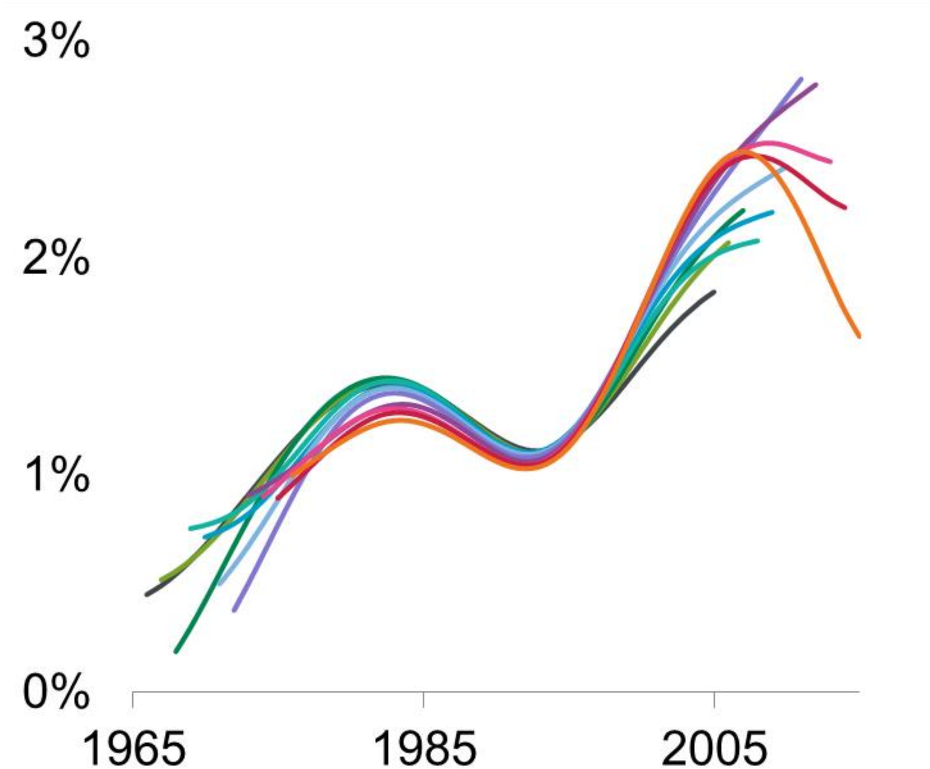
Lesson:

Apparent direction of travel from period component is uncertain

CMI proposed approach

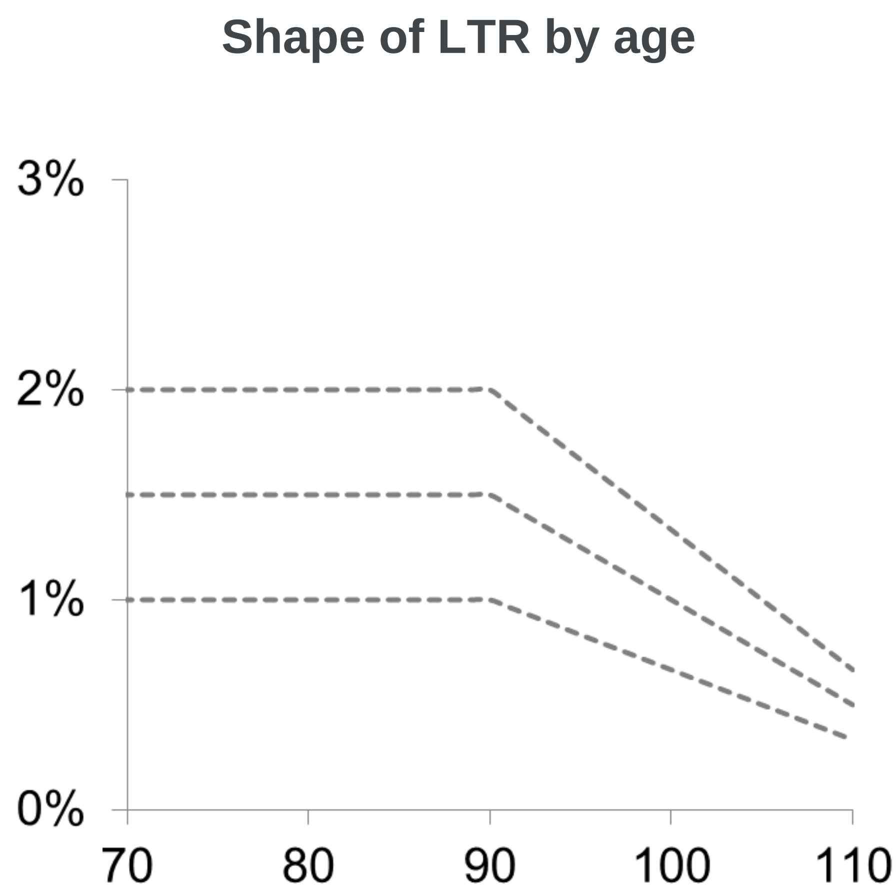
- Core assumption to remain as nil allowance for direction of travel
- Give users option to specify direction of travel
- Model to output direction of travel

Periods ending in 2005 to 2015



Current shape of long-term rate (LTR)

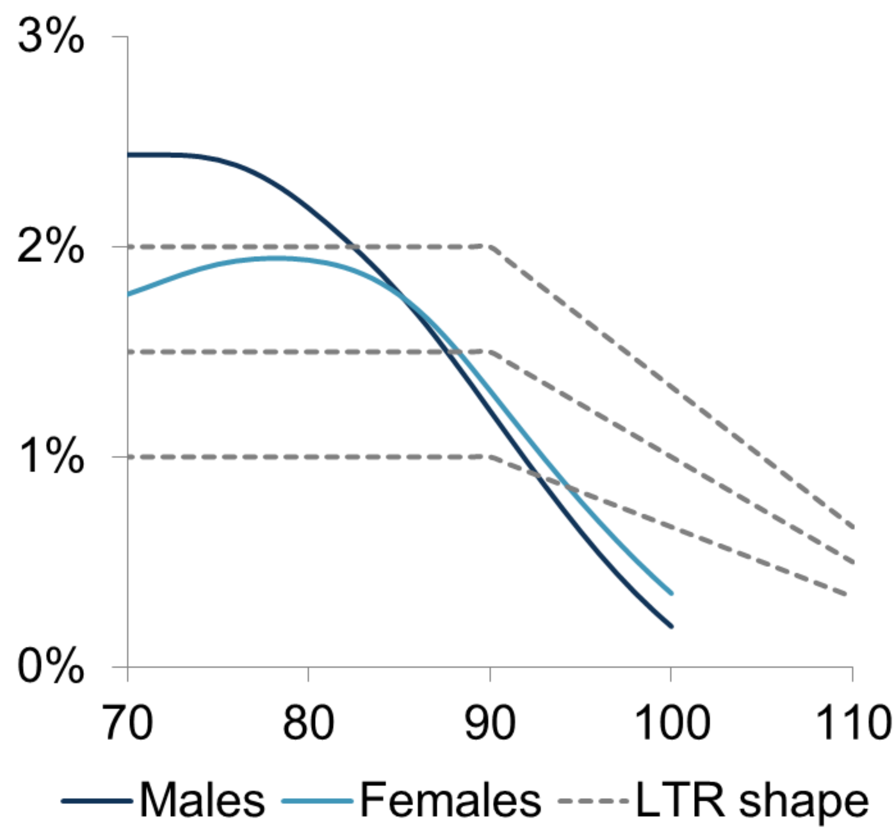
- Under the current Core assumption, the LTR applies up to age 90, and tapers to zero at 120



Current shape of long-term rate (LTR)

- Under the current Core assumption, the LTR applies up to age 90, and tapers to zero at 120
- This implies a sharp rise in improvements for centenarians in future, which is out of line with past experience

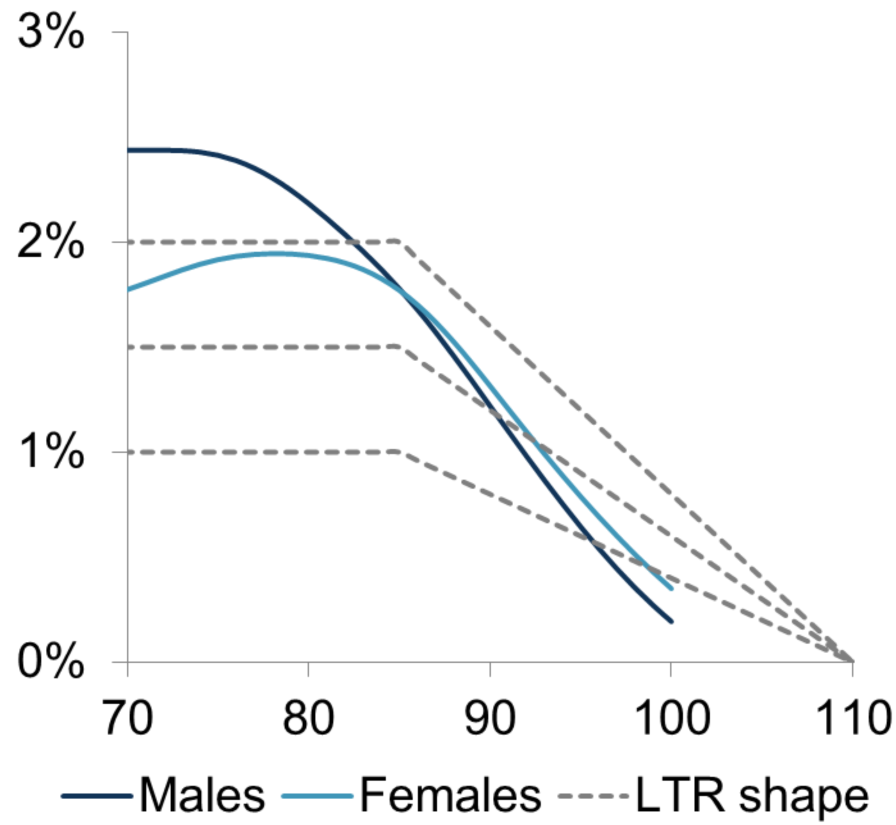
Mortality improvements by age
APCI age component and LTR shapes



Proposed shape of long-term rate (LTR)

- We propose that the LTR applies up to age **85**, and tapers to zero at age **110**
- This implies a more modest rise in improvements for centenarians

Mortality improvements by age
APCI age component and LTR shapes



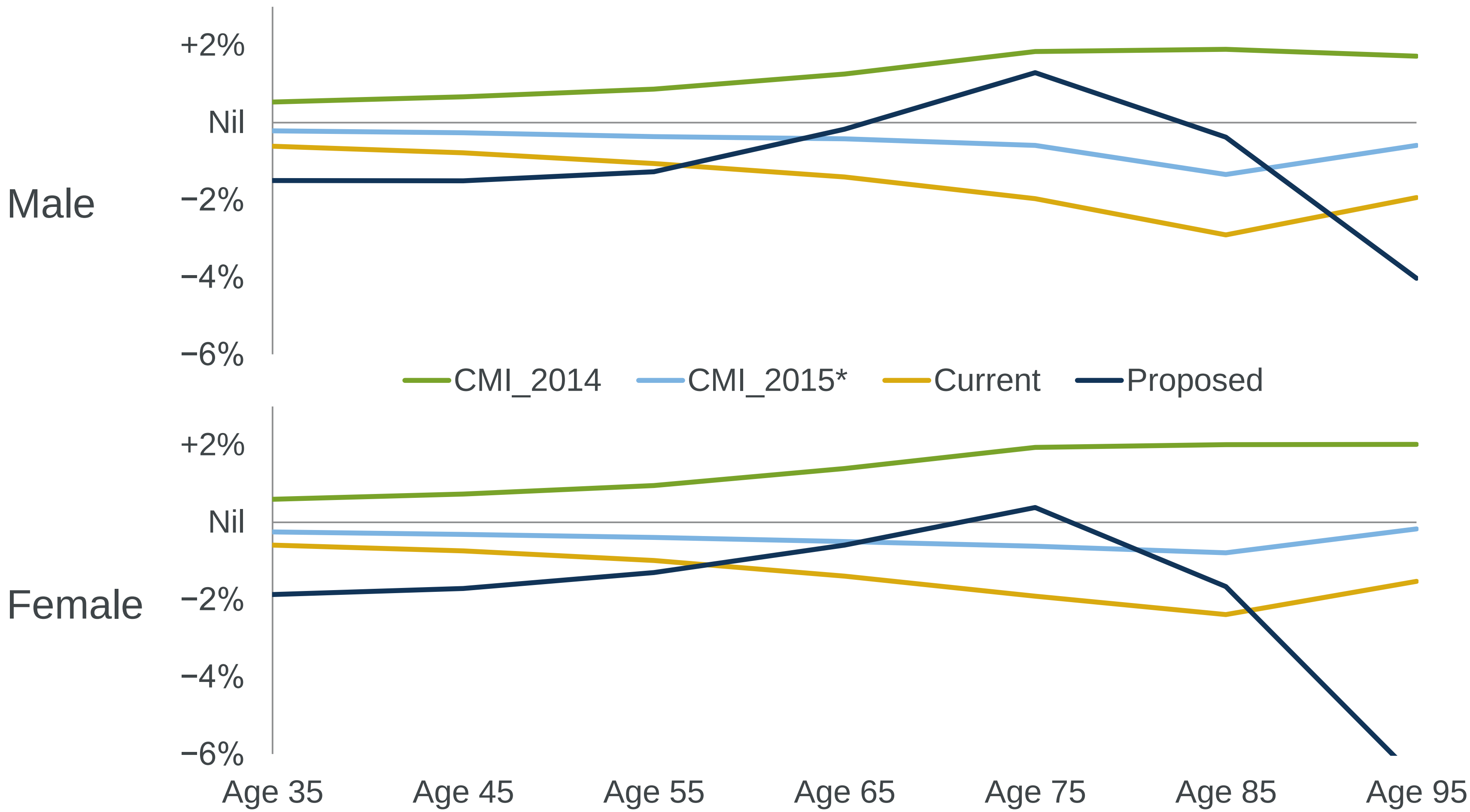
5. Proposed CMI Projection Model – impact

Life expectancy at end 2015 vs CMI_2015

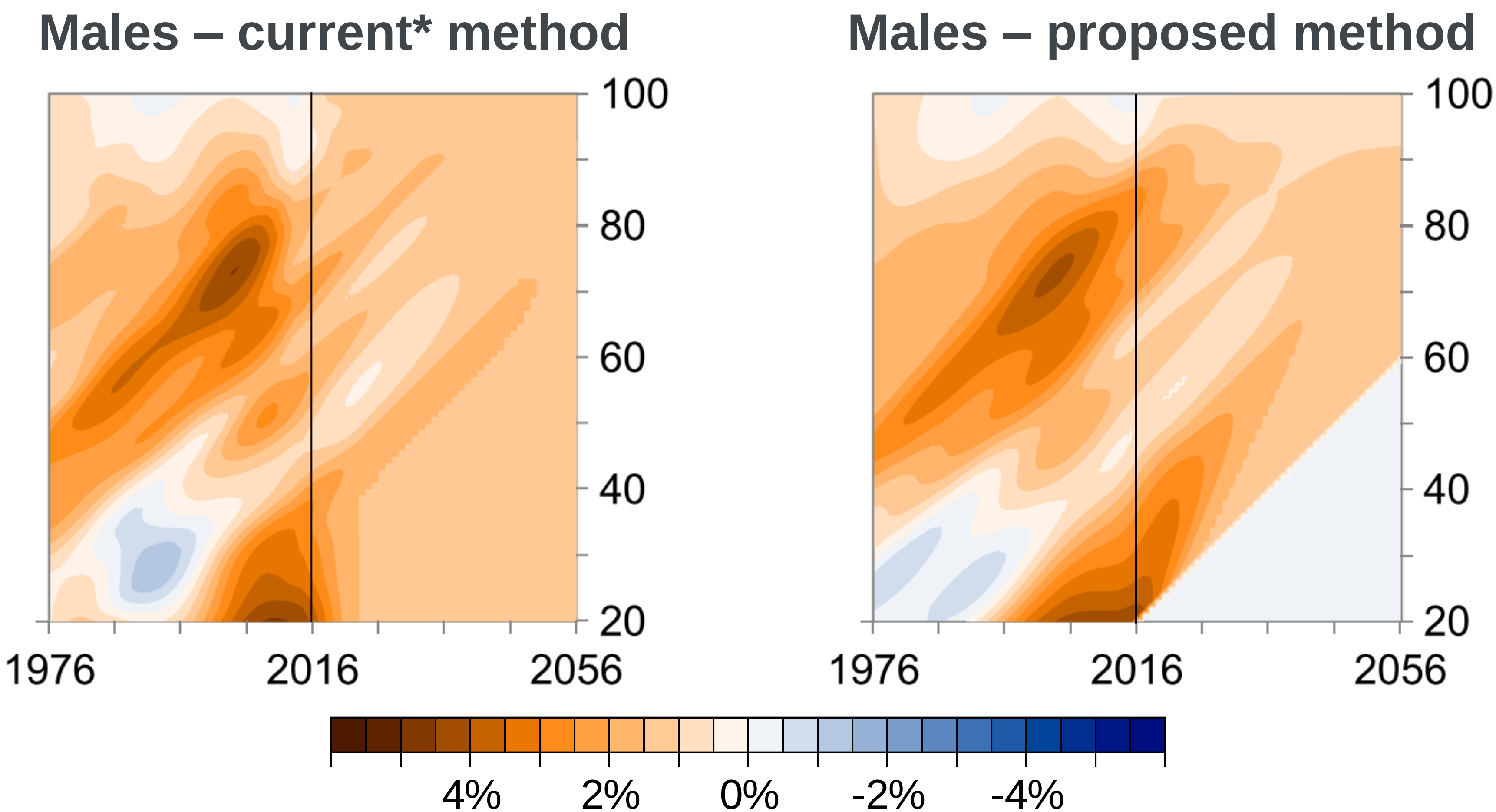
Sex	Method	Age 35	Age 45	Age 55	Age 65	Age 75	Age 85	Age 95
Male	CMI_2014	+0.53%	+0.67%	+0.87%	+1.26%	+1.84%	+1.90%	+1.72%
	CMI_2015*	−0.21%	−0.26%	−0.36%	−0.42%	−0.59%	−1.34%	−0.59%
	Current	−0.61%	−0.78%	−1.06%	−1.41%	−1.97%	−2.91%	−1.94%
	Proposed	−1.50%	−1.51%	−1.27%	−0.17%	+1.29%	−0.38%	−4.03%
Female	CMI_2014	+0.60%	+0.73%	+0.95%	+1.39%	+1.94%	+2.01%	+2.02%
	CMI_2015*	−0.25%	−0.31%	−0.39%	−0.50%	−0.62%	−0.79%	−0.17%
	Current	−0.59%	−0.74%	−0.99%	−1.39%	−1.91%	−2.39%	−1.53%
	Proposed	−1.87%	−1.71%	−1.30%	−0.59%	+0.38%	−1.66%	−6.63%

- CMI_2014 = actual data to 30 September 2014 + initial year 2011
- CMI_2015 = actual data to 31 July 2015 + initial year 2012
- CMI_2015* = CMI_2015 + data to end 2015 (but still initial year 2012)
- ‘Current’ = CMI_2015* + initial year 2013
- ‘Proposed’ = data to end 2015 (no step-back applicable)

Life expectancy at end 2015 vs CMI_2015

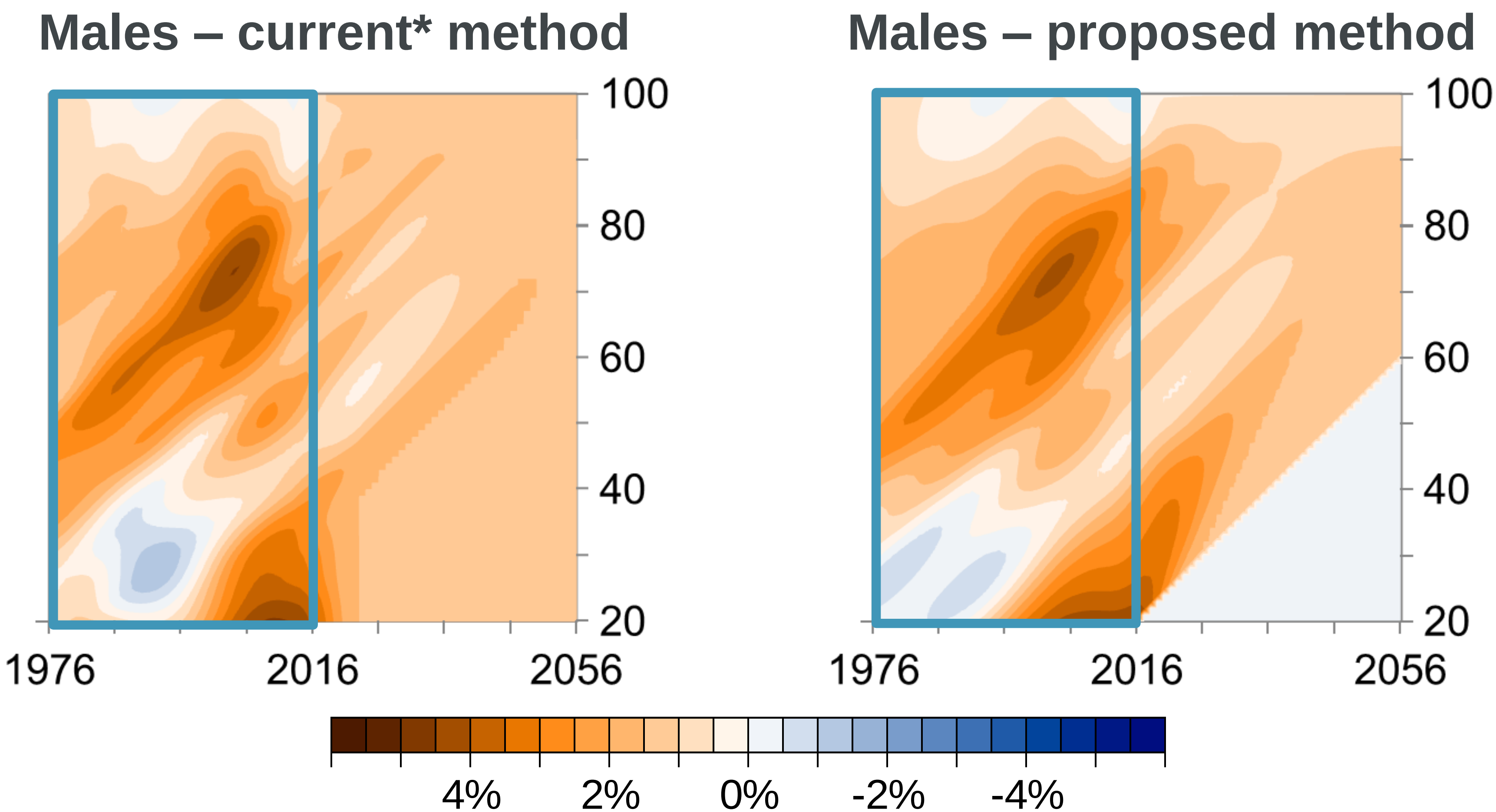


Comparison of male mortality improvements



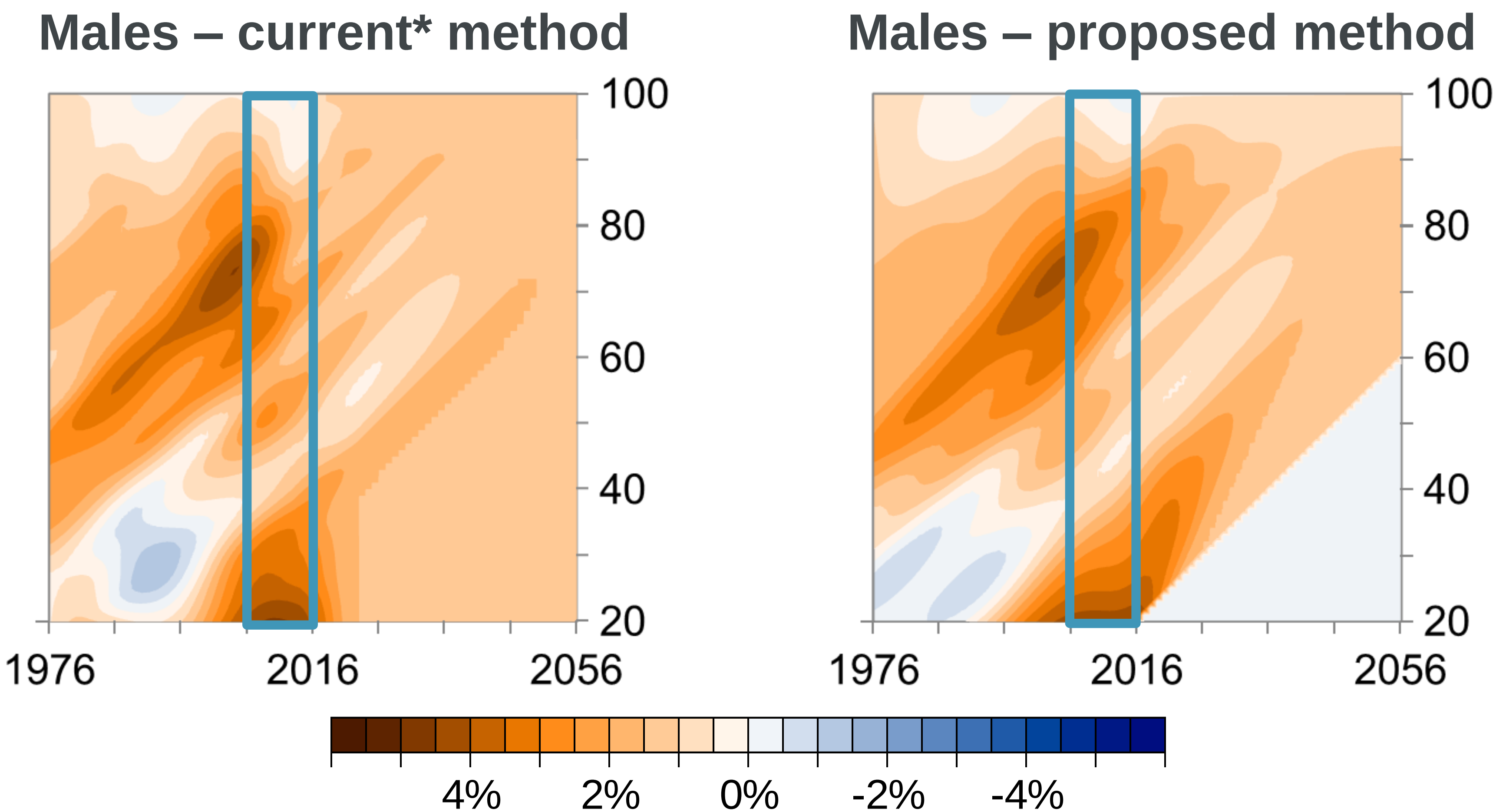
*Note that "current" is not the same as CMI_2015

1. Historical fit is broadly similar



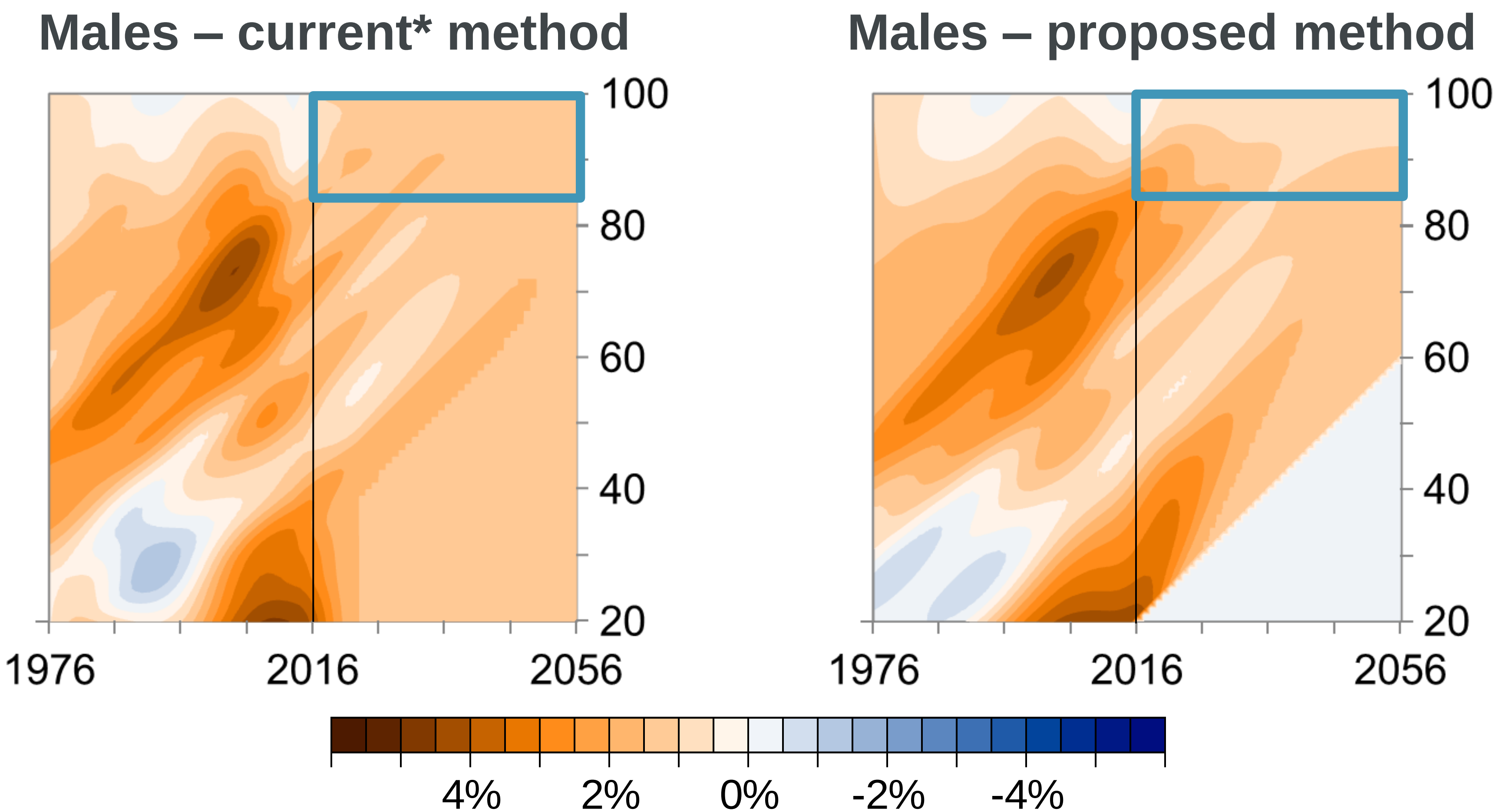
*Note that "current" is not the same as CMI_2015

2. Recent improvements are higher



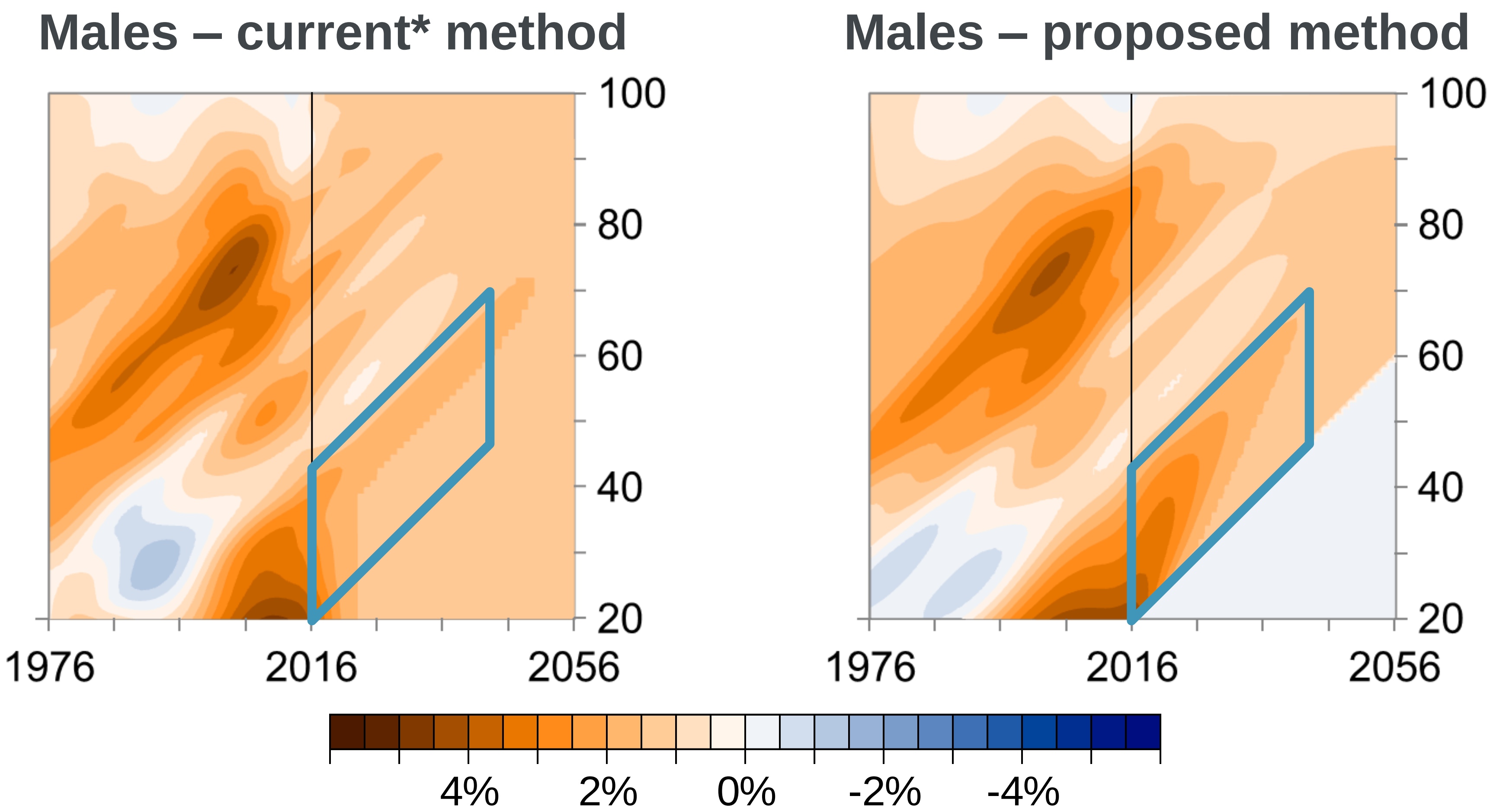
*Note that "current" is not the same as CMI_2015

3. Lower long-term old-age improvements



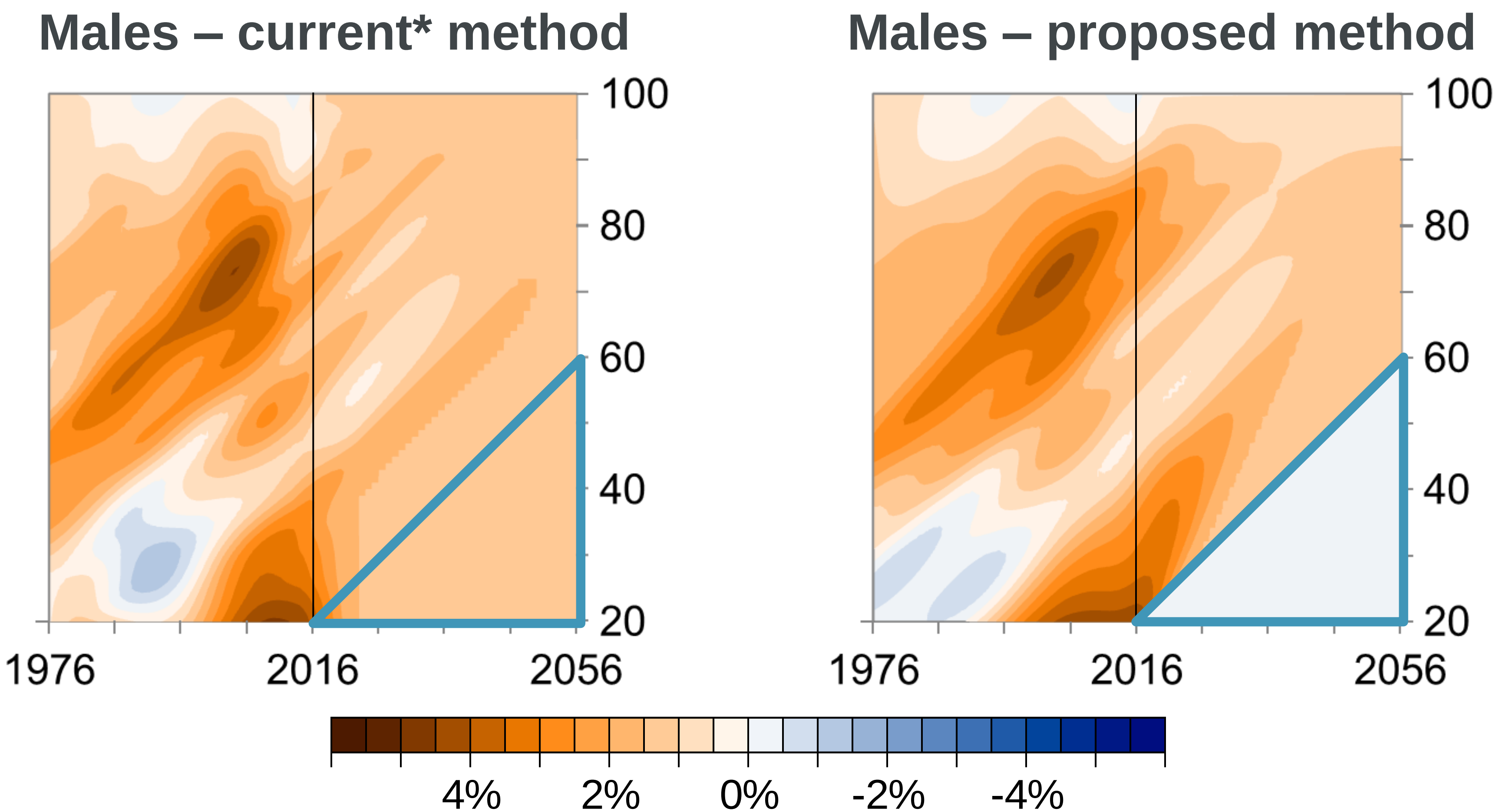
*Note that “current” is not the same as CMI_2015

4. Young-age cohort improvements



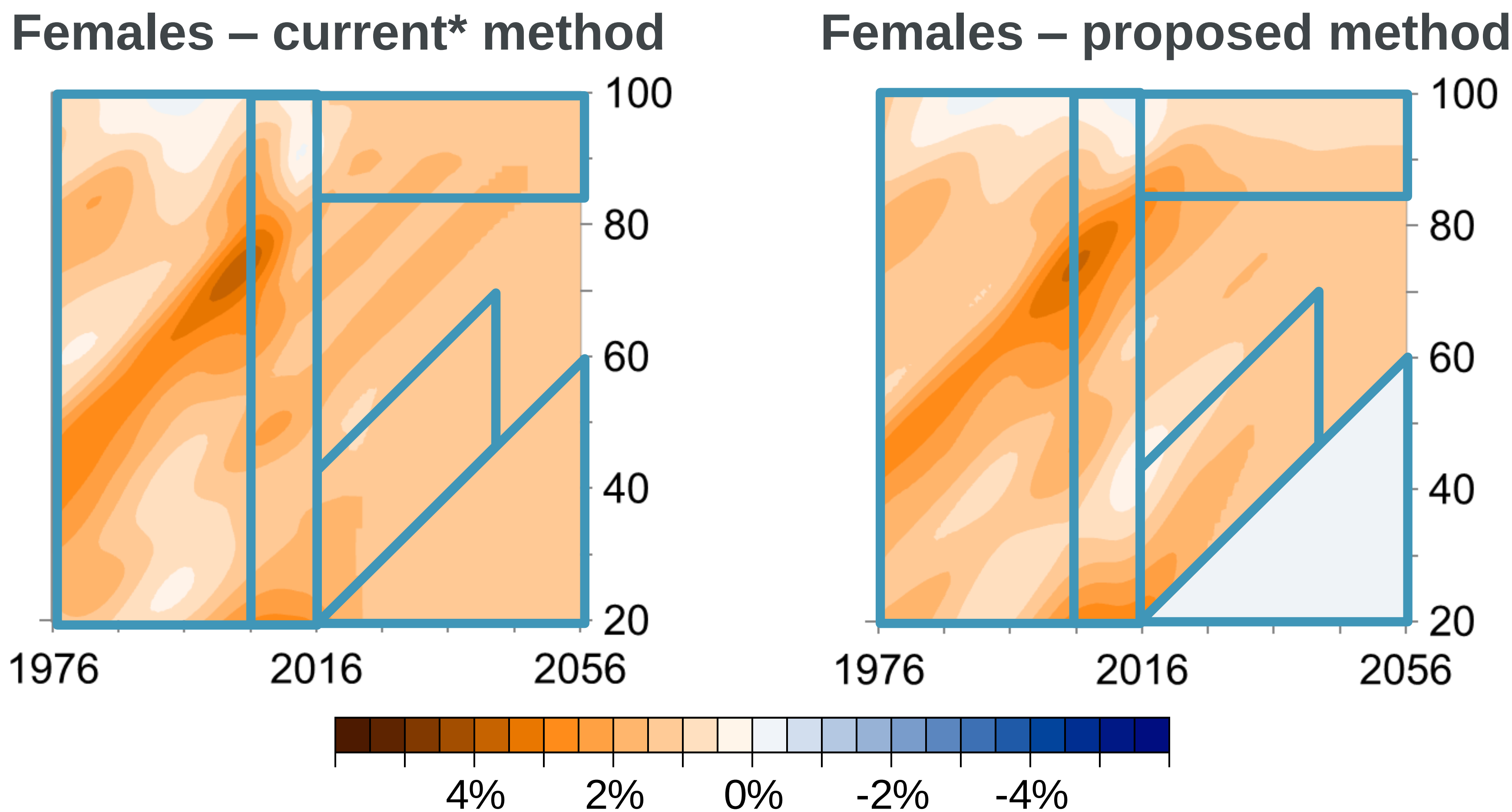
*Note that “current” is not the same as CMI_2015

5. 'New' cohorts not projected



*Note that "current" is not the same as CMI_2015

Comparison of female improvements



*Note that “current” is not the same as CMI_2015

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High age mortality

Steve Bale
Chair of the CMI High Age Mortality Working Party

Phase 1: Initial findings

- Working Paper 85 released October 2015

- Key areas of analysis:
  - Summary of recent research
  - Functional forms for closing mortality rate tables
  - Modelled impacts of late reporting and age mis-statement
  - Closed cohort mortality

- https://www.actuaries.org.uk/learn-and-develop/continuous-mortality-investigation/cmi-working-papers/mortality-projections/cmi-wp-85

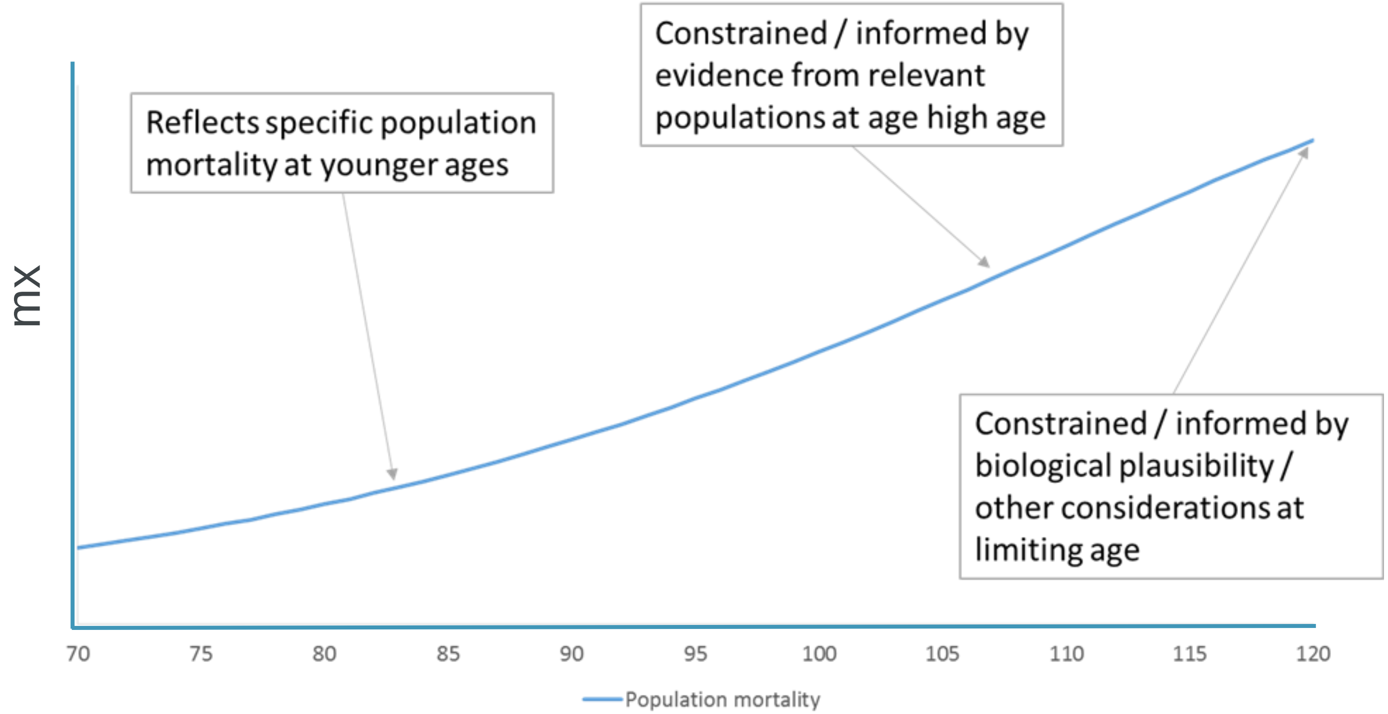
Phase 2: Continued analysis

- Three strands of work

- Strand 1: Principles for closing off mortality tables
- Strand 2: Seek high quality portfolio data for analysis
- Strand 3: How might high age population variants impact the CMI Model?

- Focus today is on Strands 1 and 3
- Work in progress, provisional findings presented

Strand 1: Closing mortality rate tables



- Plausibility
- Data compatibility
- Cohort features
- Robustness of fit
- Uncertainty assessment
- Trend allowance
- Smooth progression

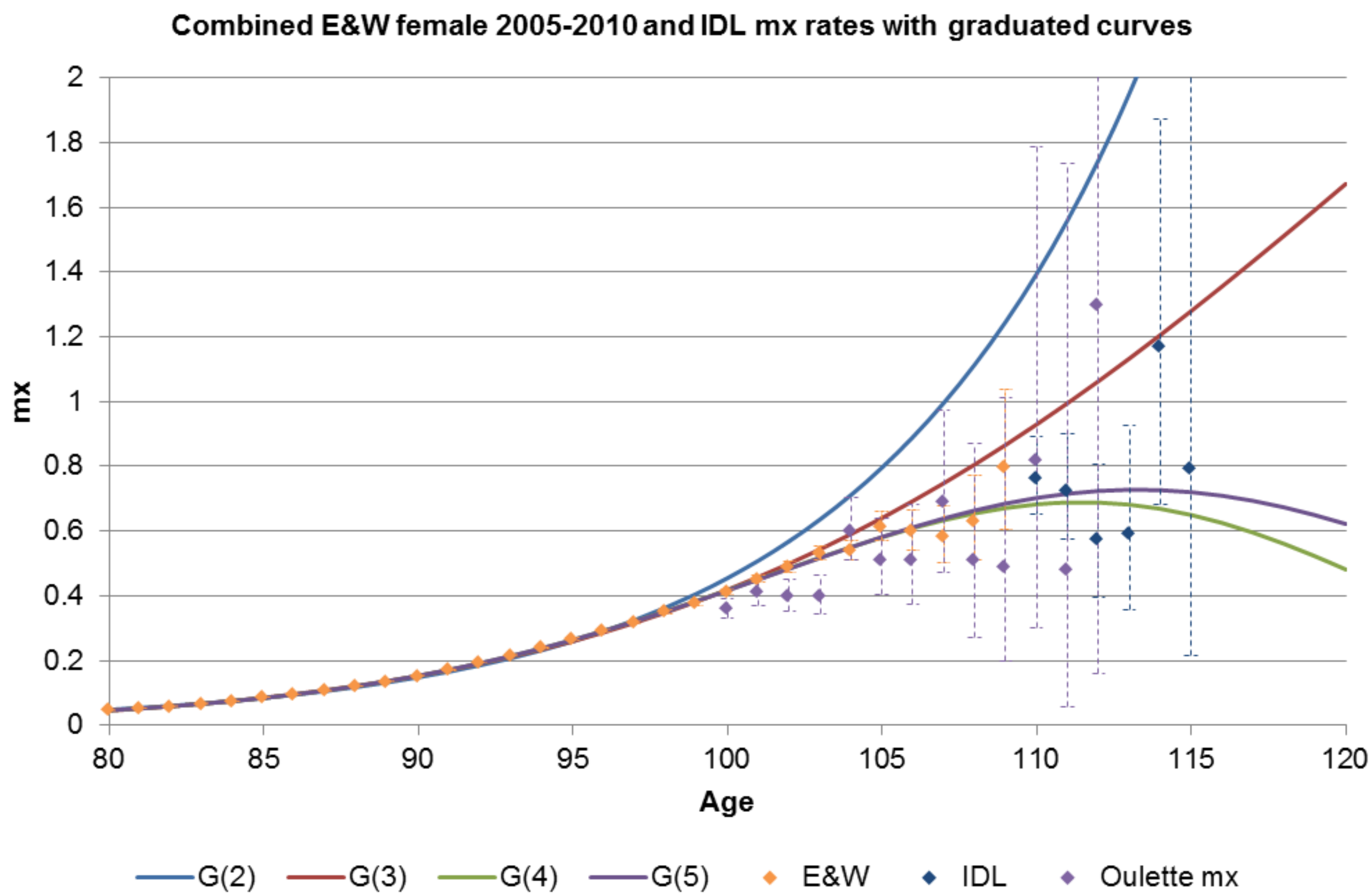
Mortality deceleration

Gavrilov & Gavrilova (2015)

- Little evidence of mortality deceleration at high age in IDL supercentenarian dataset
- Factors explaining observed deceleration include:
  - Aggregation of birth cohorts resulting in homogeneous groups
  - Inaccurate age reporting resulting in downward bias
  - Common assumptions on high age mortality breaking down

- Ouellette and Bourbeau Study (2014)
  - Canadian death rates using church parish registers
  - Greater certainty on DOB information from baptismal certificates

Mortality dataset comparison



Findings

- Wider considerations
  - Need to consider whole age curve, not just 110+
  - IDL dataset may not be complete

- IDL mortality and E&W graduated rates lie within Ouellette CI

- View on mortality deceleration remains inconclusive

Strand 3: Population data modelling

Challenges with England & Wales exposure data

- Unusual birth patterns
- “Phantoms”
- Exposure estimates for ages 90+
- Potential for discontinuity at census dates
- Differences between ONS and HMD data

- Raised in Cairns et al 2014 “Phantoms Never Die”

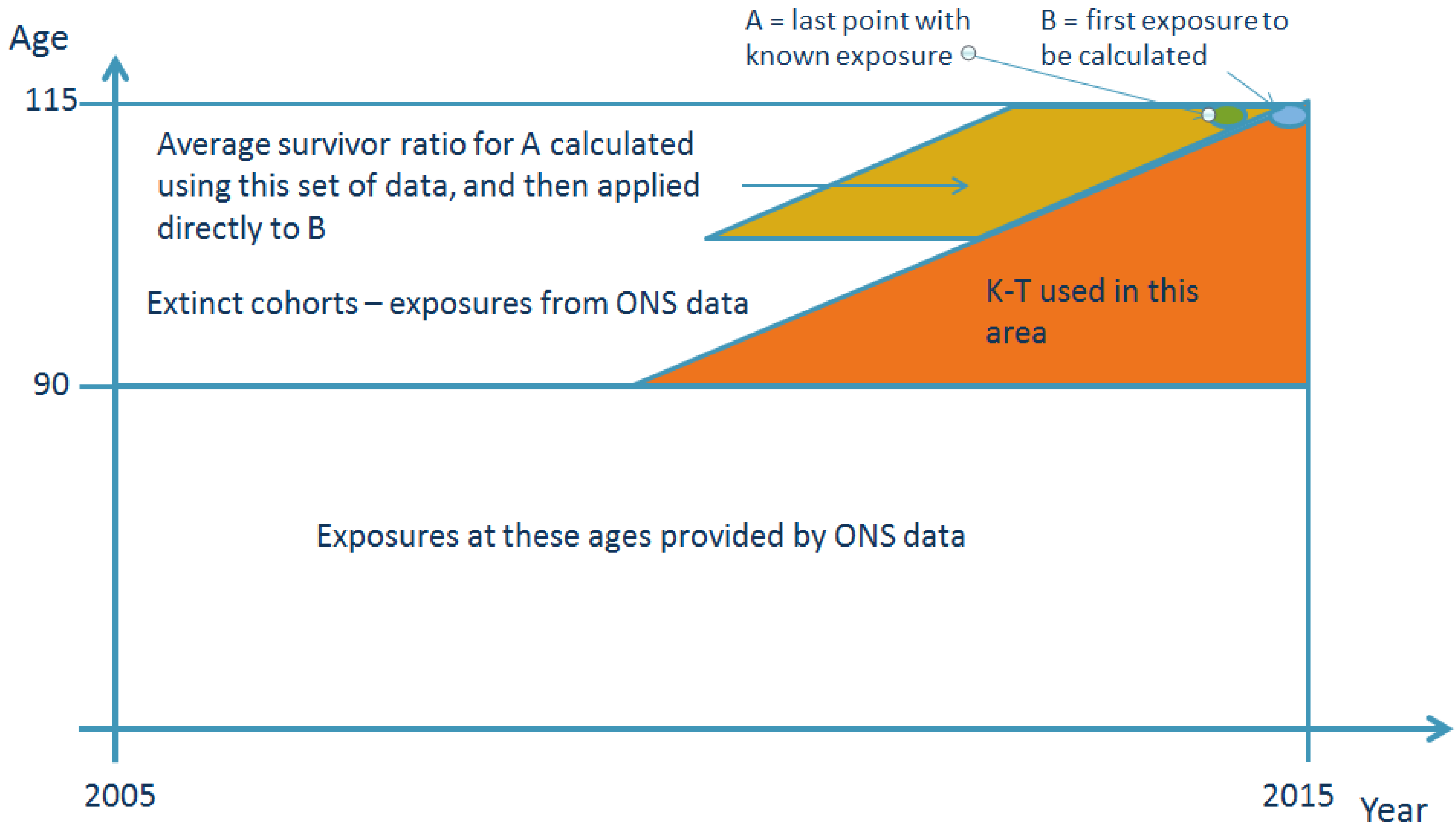
Variants considered

Candidates

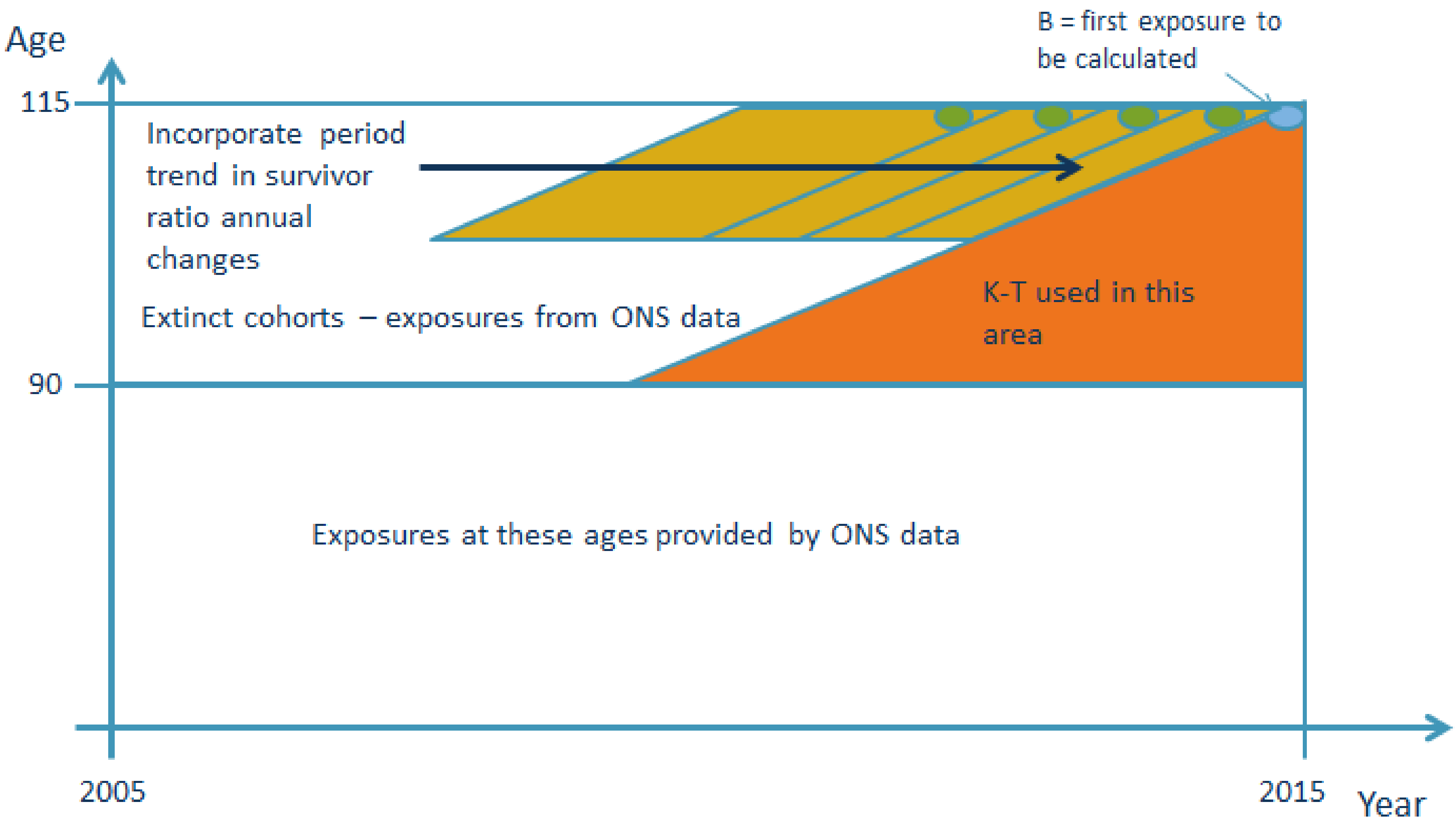
- Current Kannisto-Thatcher with population constraint
- Kannisto-Thatcher with allowance for simple survival ratio trend
- Also currently being considered (not presented):
  - CBD convexity adjustment
  - HMD high age methodology
  - Plus combinations of the above

- Allowance with and without exposure smoothing
- Calculate life expectancies for male lives as at 31/12/2015

Current Kannisto-Thatcher methodology

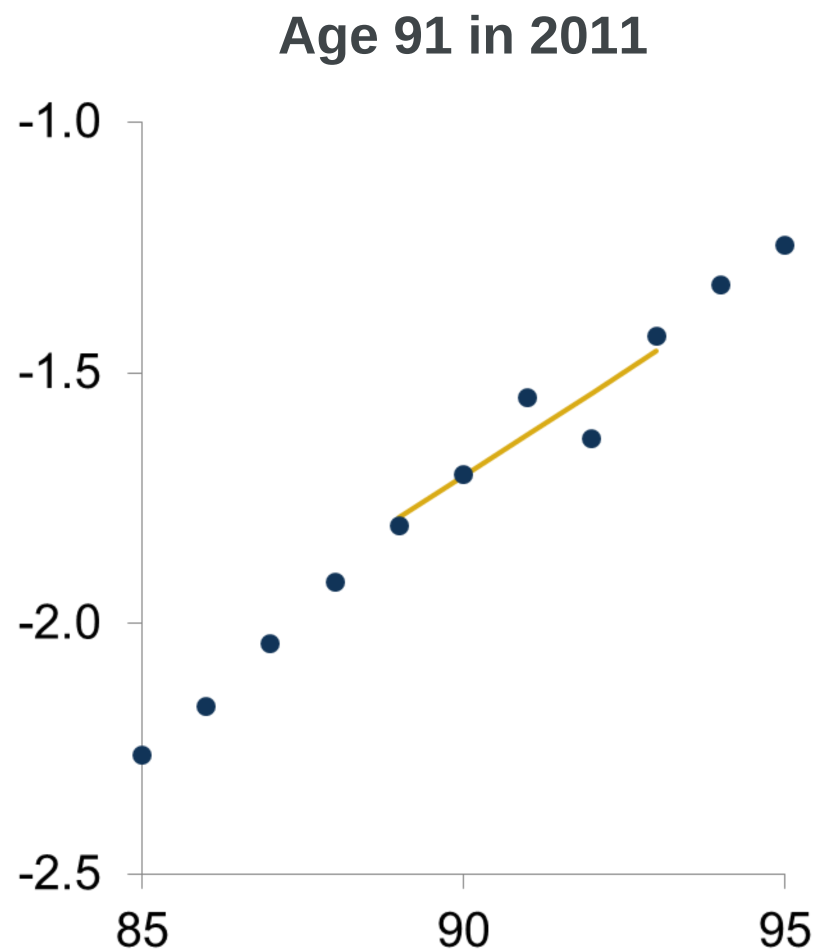


Variant 1: Kannisto-Thatcher + improvements



CMI exposure adjustment

- For a given age X and year T
  - Work with crude $\log m_{x,T}$
  - Smooth by fitting a straight line to data for ages $X-2$ to $X+2$
  - If the crude and smoothed rates for age X are far apart, then adjust exposure to match the smoothed mortality rate
  - We assess “similar” and “far apart” using deviance residuals.
- Exposure is adjusted for age 91 in 2011 (and for age 92).



Provisional findings – cohort life expectancy

	Issue addressed				Life expectancy impact relative to current Kannisto-Thatcher approach			
Analysis of change	Unusual birth patterns	Phantoms	Trend allowance	Constrained to ONS 90+ estimate	65	75	85	95
Start: Current Kannisto-Thatcher	✗	✓(partial)	✗	✓	22.31	13.62	6.68	2.81
Allowance for trend	✗	✓(partial)	✓	✓	–0.00	–0.00	–0.00	–0.01
Allowance for smoothed exposures	✓	✗	✓	✗	–0.02	+0.00	+0.01	–0.01

Negligible impact on projections model from variants considered

Questions

Comments

The views expressed in this presentation are those of the presenter.

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