Continuous Mortality Investigation
Institute and Faculty of Actuaries

Consultation on the CMI Mortality Projections Model

CMI Mortality Projections Committee

Presentation to the Staple Inn Actuarial Society

11 July 2016

Note: Slides 20, 44, 45 and 46 have been corrected, to reflect revisions made to Working Paper 90.

Consultation process

Date	Item
22 June 2016	Working Paper 90 published
29 June 2016	Edinburgh consultation meeting
11 July 2016	London consultation meeting
July 2016	Publish technical working paper and software
9 September 2016	Responses to the consultation due
November 2016	Working paper summarising responses and revisions
March 2017	Publish CMI_2016 (based on data to 31 December 2016)

Introduction

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

Mortality Projections Committee

Committee members

- Tim Gordon (chair)
- Steve Bale
- Piero Cocevar
- Matthew Fletcher
- Steven Rimmer
- Neil Robjohns
- Brian Sewell
- Jonathan Hughes (ex-member)

Investigation into alternative models

- Kishore Ananda
- Simon Donnelly

Support

- Secretariat
- Jon Palin

This evening

- Assumes some knowledge of the current model
- Not full technical detail – for more information see
  - Working Paper 90
  - Forthcoming technical working paper
  - Forthcoming Excel+VBA software if you want to try it out
- All proposals are subject to consultation

Agenda

1. Overview of proposed changes

2. Determining initial mortality improvements

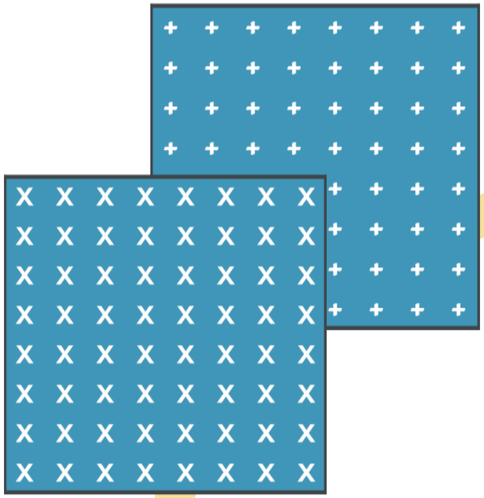
- Age-period-cohort split
- Smoothing
- *Discussion*

3. Projecting future mortality improvement rates

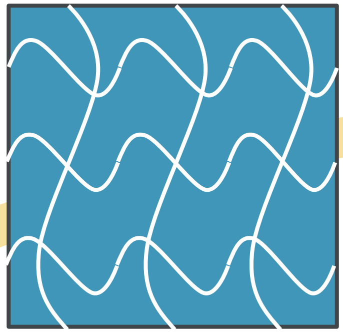
- Direction of travel
- Convergence pattern / period
- *Discussion*

1. Overview of proposed changes

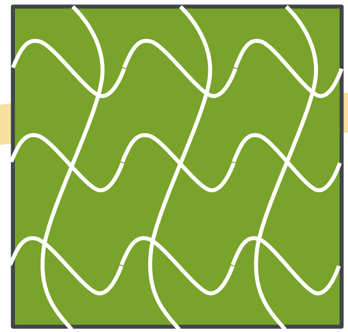
Overview of proposed changes (1/3)



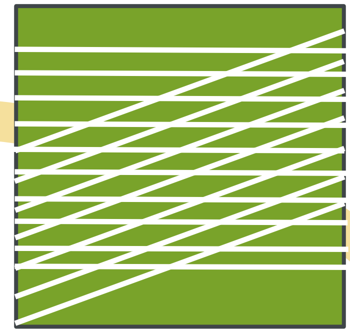
1. Data
(a) Raw death and population data for England & Wales
(b) Population data at high ages constructed by CMI (using ONS methodology)
(c) CMI caps unlikely data points



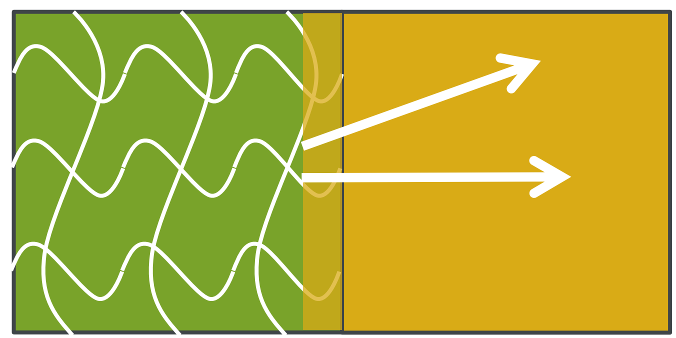
2. Fit P-spline surface to estimate smooth mortality rates



3. Derive annual rates of mortality improvements

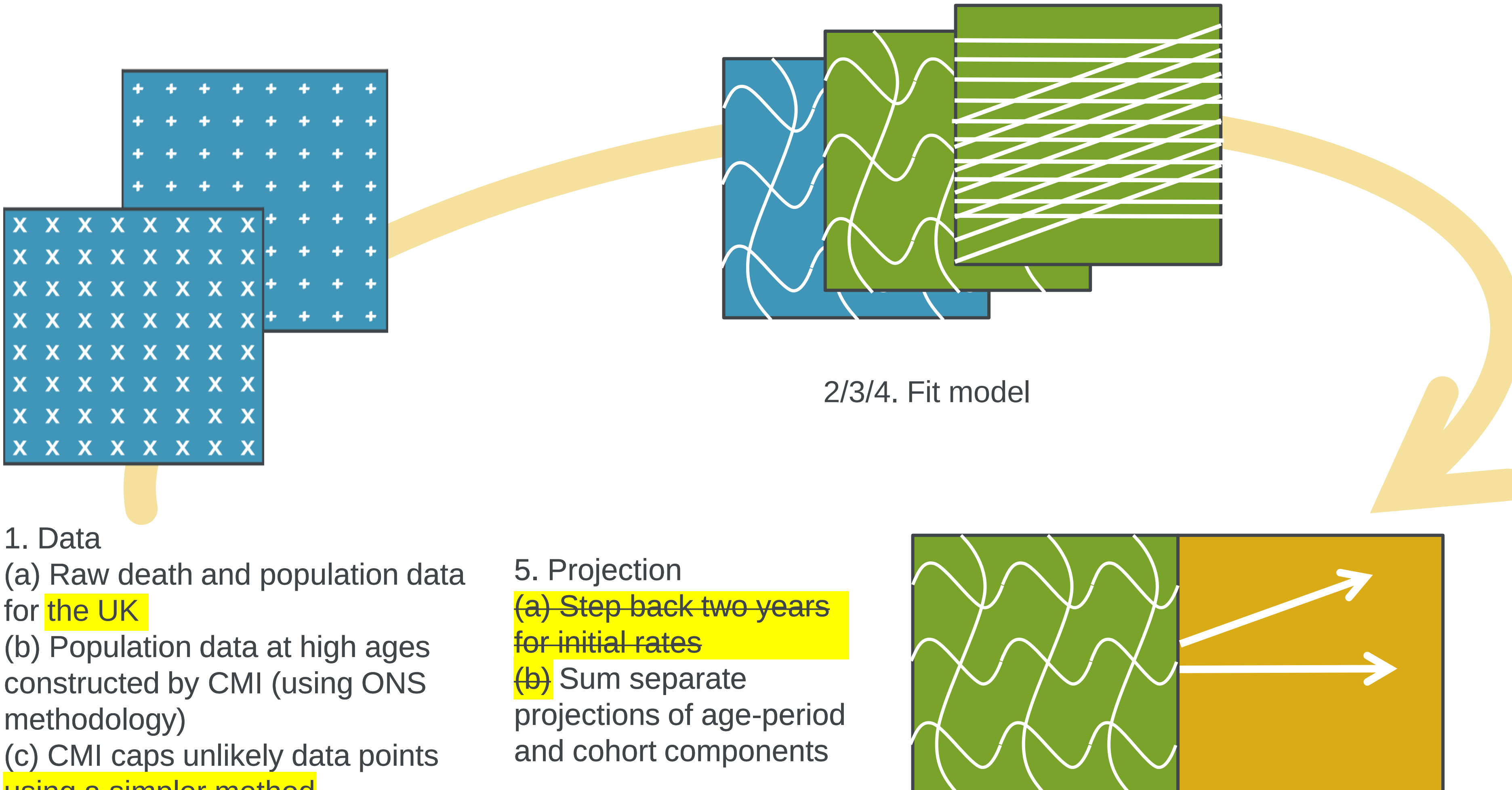


4. Determine age-period / cohort decomposition



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

Overview of proposed changes (1/3)



2/3/4. Fit model

1. Data
(a) Raw death and population data for the UK
(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

Overview of proposed changes (2/3)

Current	Proposed
BIC-determined smoothing criterion	Judgement-based
Age-cohort smoothing axes	All axes of variation smoothed
Identifiability constraint on the AP-C split pinned cohort improvements to zero at low and high ages	New identifiability constraints do not guarantee zero cohort improvements at high and low ages (which affects projections)
Mortality improvement = $1 - q_{x,t}/q_{x,t-1}$	Revised to $\log m_{x,t-1} - \log m_{x,t}$ (internally only) • Age 80: 1.45% (current) ≈ 1.50% (revised) • Age 100: 0.47% (current) ≈ 0.60% (revised)
Smoothed past ➔ initial rates, *then* separate projection	No change – inconsistent-behaviour on inclusion of new data is not the major worry
Projection method	Little changed • Still defaults to nil allowance for direction of travel • But easier for users to tweak

Overview of proposed changes (3/3)

- **Core** – remove the ‘constant addition to mortality improvement’
- **Advanced** – add smoothing parameters S_α, S_β, S_κ, and S_γ
- **Intermediate parameters introduced:**
  – A way to express the advanced parameters succinctly.
  – Not changing what the model does, but aiding communication.
  – e.g. a concise way to express the long-term rate ‘(1.5%@85,0%@110)’
- **Naming** – use the name ‘CMI_2016’ for the March 2017 release.
  – Model version numbers will continue to be consecutive; and will refer to the final year of the calibration data (from CMI_2014 onwards).
  – Add the ‘Period smoothing parameter’ to the name of the Model
    - e.g.**CMI_2016_M [LTR; S_κ]**

2. Determining initial mortality improvements

Key motivations

- Simplify the process
  - The current method has multiple steps and pieces of software.
- Allow users to control the responsiveness of the Model
  - Including views on recent mortality.

- We developed the “Age-Period-Cohort Improvement” (APCI) model to satisfy these.

Age-Period-Cohort Improvement model

- Definition of the model:

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

- 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 (e.g. if we calibrate to data from 1975-2015 then $\bar{t}$ is 1995)

Age-Period-Cohort Improvement model

- Definition of the model:

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

- Using our definition of mortality improvement (reduction in $\log m_{x,t}$) gives:

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

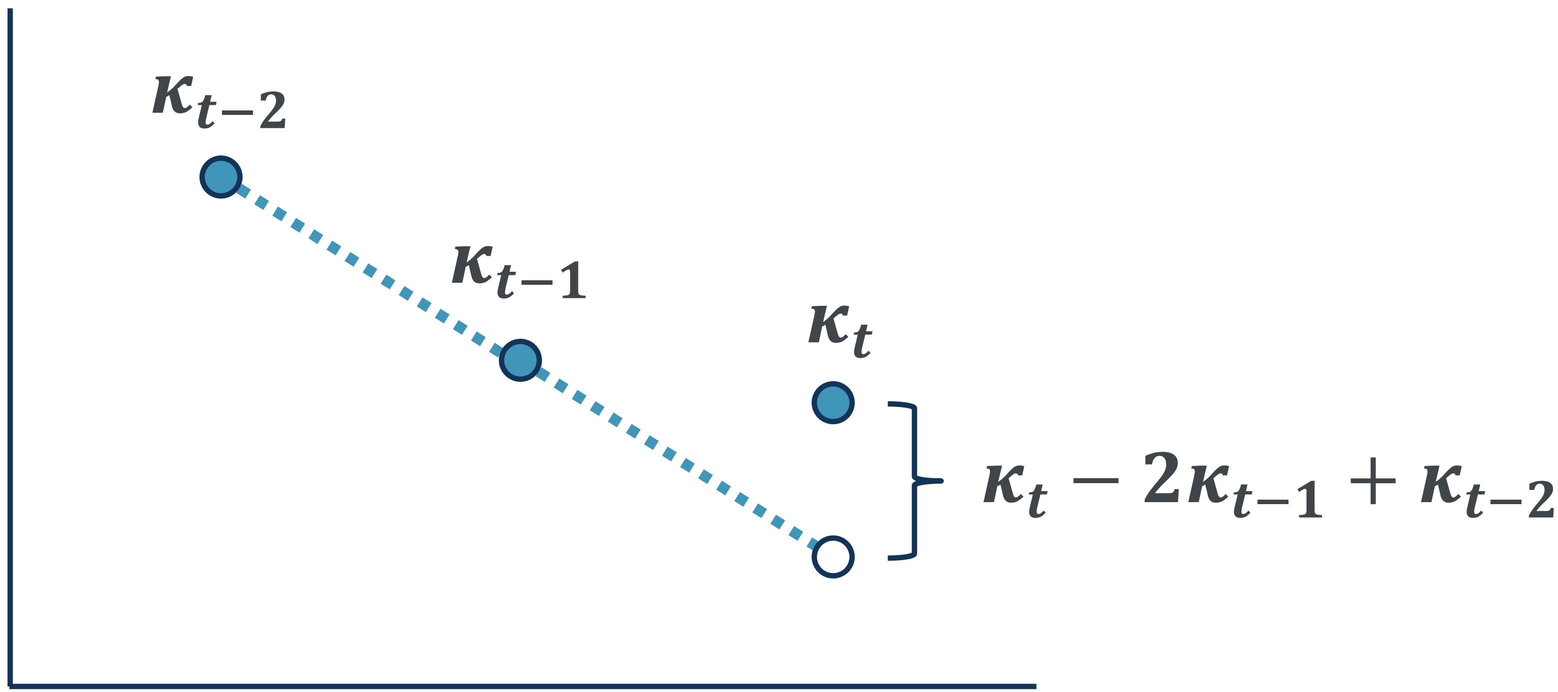
- Fitting the model automatically gives us mortality rates, mortality improvements, and their age, period and cohort components; in one step.

Smoothed improvements

- We could fit the APCI model and use it as a stochastic model.
- For the CMI Model we are interested in underlying smooth mortality improvements, so we want the parameter values to be smooth.
- To achieve this, we minimise an objective function that combines:
  - Deviance (for goodness-of-fit)
  - Four penalty functions (for smoothness of each set of parameters)

Period penalty function

- Period penalty function: $\lambda_\kappa \sum_t (\kappa_t - 2\kappa_{t-1} + \kappa_{t-2})^2$



Period penalty function

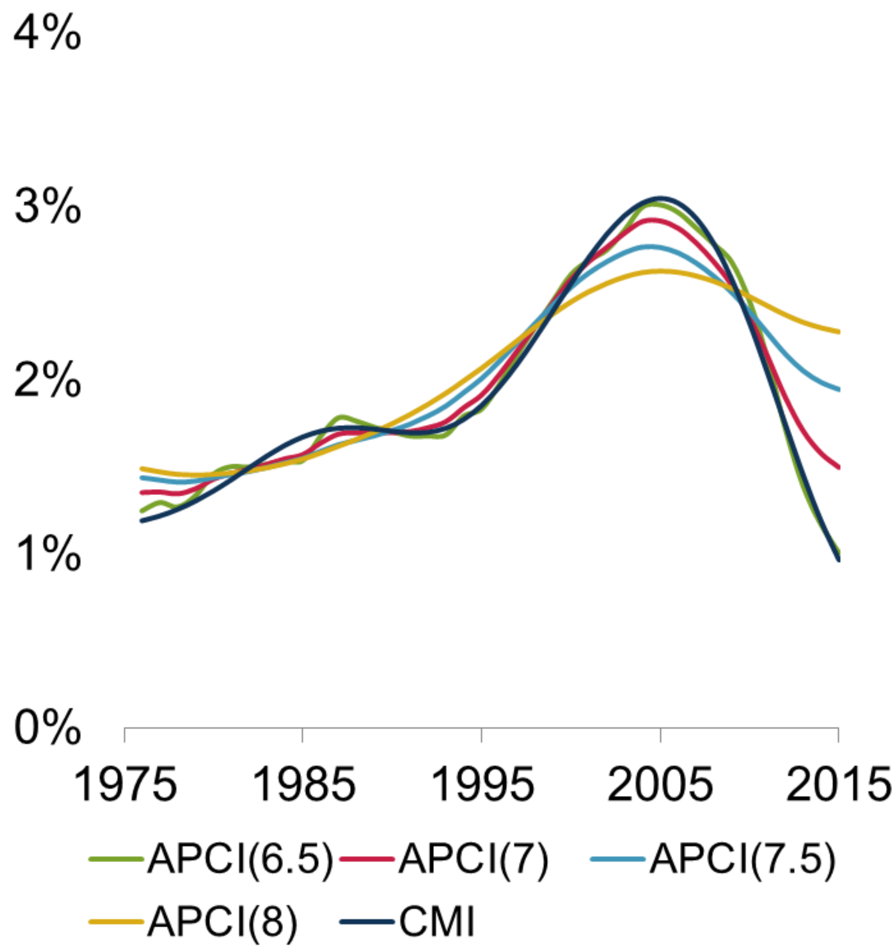
- Period penalty function: $\lambda_\kappa \sum_t (\kappa_t - 2\kappa_{t-1} + \kappa_{t-2})^2$

- This penalty is zero when κ_t is linear.
- Period components of improvements are $(\kappa_{t-1} - \kappa_t)$ so they are constant when κ_t is linear.
- So increasing λ_κ leads to flatter improvements.
- **Changing λ_κ allows control of the responsiveness of the Model.**

- As λ_κ is large we define $S_\kappa = \log_{10} \lambda_\kappa$ and refer to S_κ instead.

Impact of changing S_κ

- The chart shows mortality improvements based on standardised mortality ratios, fitted to data for males, 1975-2015.
- Increasing S_κ flattens the fitted mortality improvements:
  - Lower peak in 2004/2005
  - Smaller fall since then
- Improvements under the CMI method are closest to $S_\kappa = 6.5$.
- But the step-back means that initial improvements are closest to $S_\kappa = 7$.



Note: This slide shows corrected values; not those presented at the meeting.

Choice of S_κ

- A value of 7 or less makes the model more responsive than the current method.
- A value of 8 or more gives higher female improvements in 2015 than 2011 – this seems unrealistic.
- We propose a Core assumption of $S_\kappa = 7.5$.

Fall in life expectancy at age 65 between 2011 and 2015

Model	Males	Females
APCI(6.5)	1.55	1.70
APCI(7)	1.22	1.29
APCI(7.5)	0.89	0.87
APCI(8)	0.58	0.51
CMI	1.06	1.15

Based on S2PMA and S2PFA and current projection assumptions with a long-term rate of 1.5% p.a.

Summary – Determining initial improvements

- A revised "m-based" definition of mortality improvements.
- Using the APCI model lets us:
  - Fit $\log m_{x,t}$ and components of mortality improvements in one step
  - Remove the two-year step-back
  - Run the calculations quickly, entirely within Microsoft Excel
- Users can control responsiveness of the Model by varying the "period smoothing parameter" S_κ.
- We propose a Core value for S_κ of 7.5.

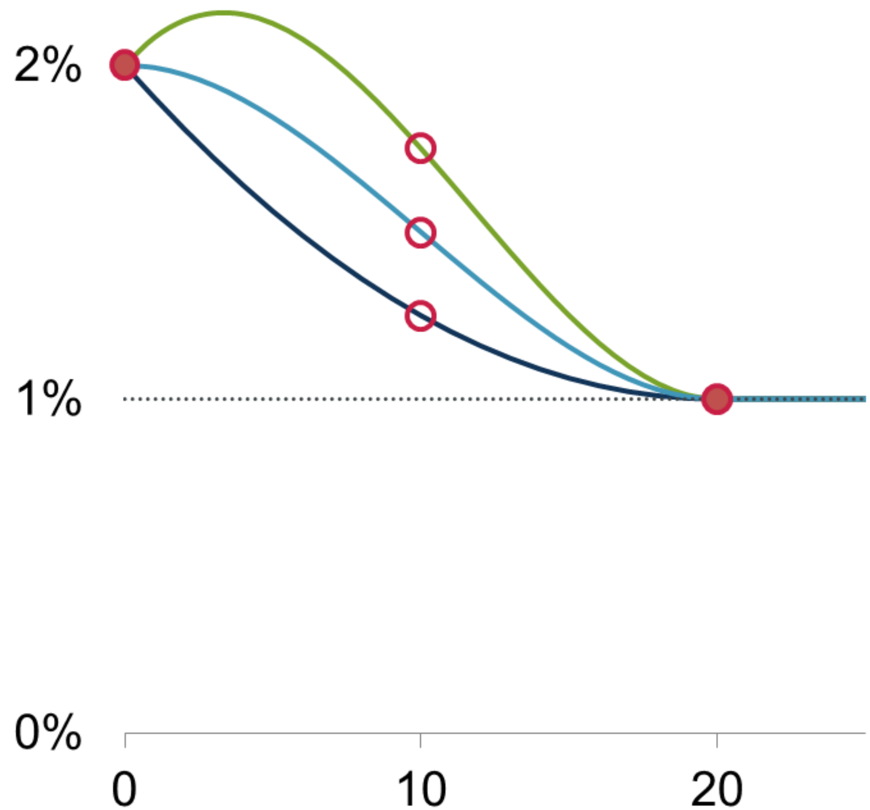
3. Projecting future mortality improvements

Topics in this section

- Convergence and direction of travel
- Shape of the long-term rate
- Cohort convergence periods
- Comparison of results under current and proposed approaches

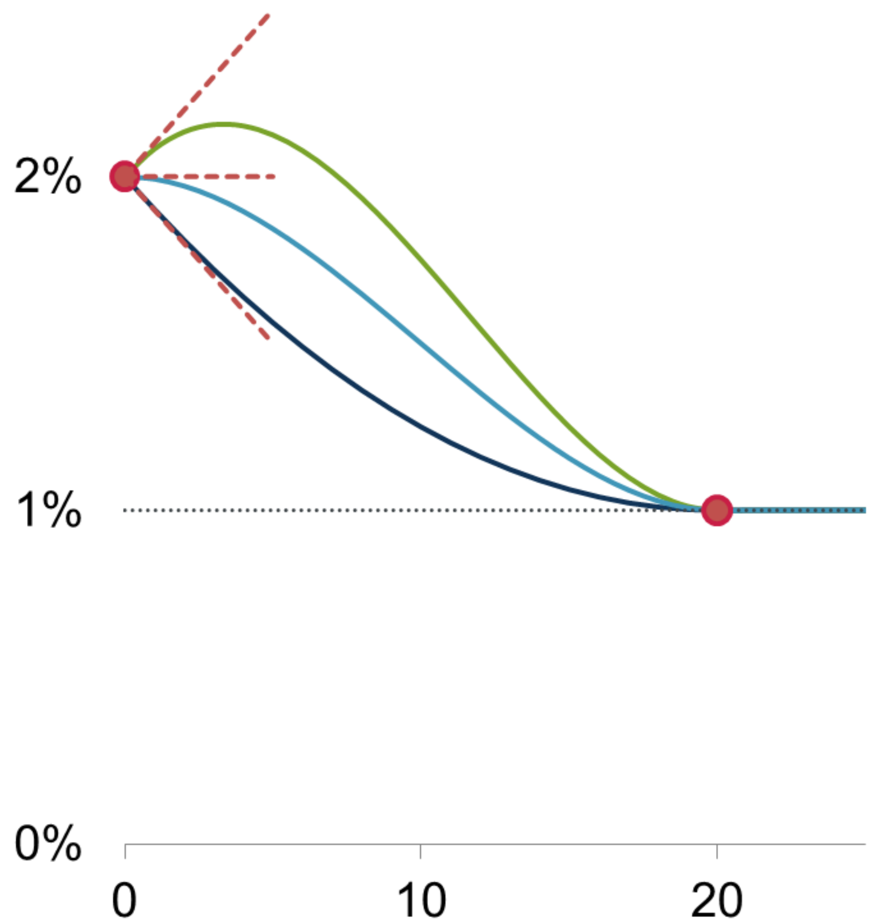
Current approach to convergence

- Project age-period and cohort components of improvements, and then sum them.
- For each age and cohort, use a cubic convergence function with four parameters (sample values used in the chart):
  - initial rate (2%)
  - convergence period (20 years)
  - long-term rate (1%)
  - proportion remaining at midpoint (25%, 50%, 75%)



Additional approach to convergence

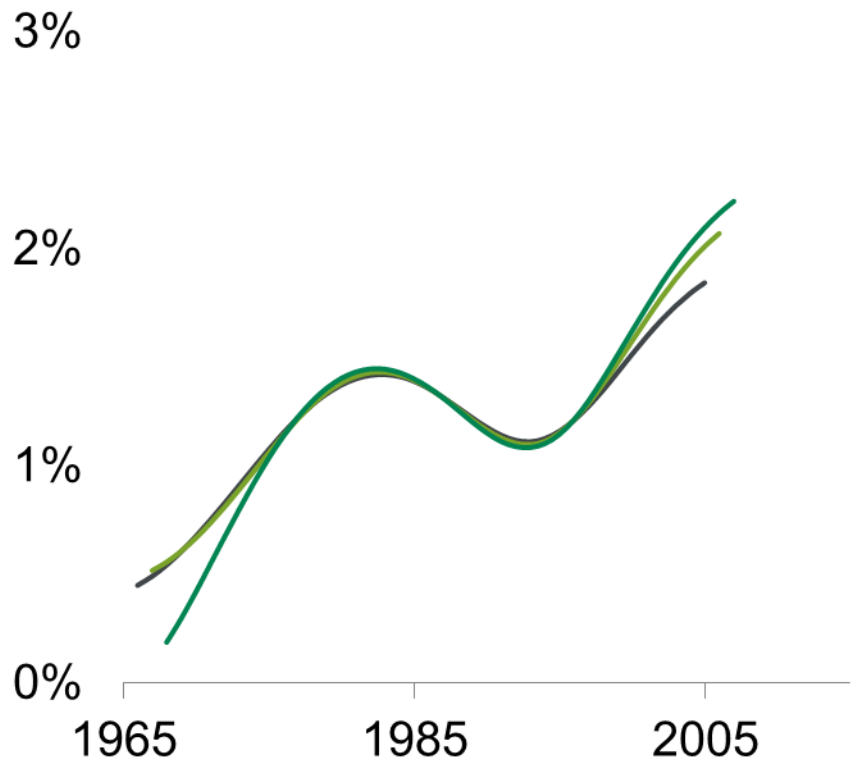
- Project age-period and cohort components of improvements, and then sum them.
- For each age and cohort, use a cubic convergence function with four parameters (sample values used in the chart):
  - initial rate (2%),
  - convergence period (20 years)
  - long-term rate (1%)
  - **"direction of travel" (−0.1%, 0%, +0.1%)**



Estimating direction of travel

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

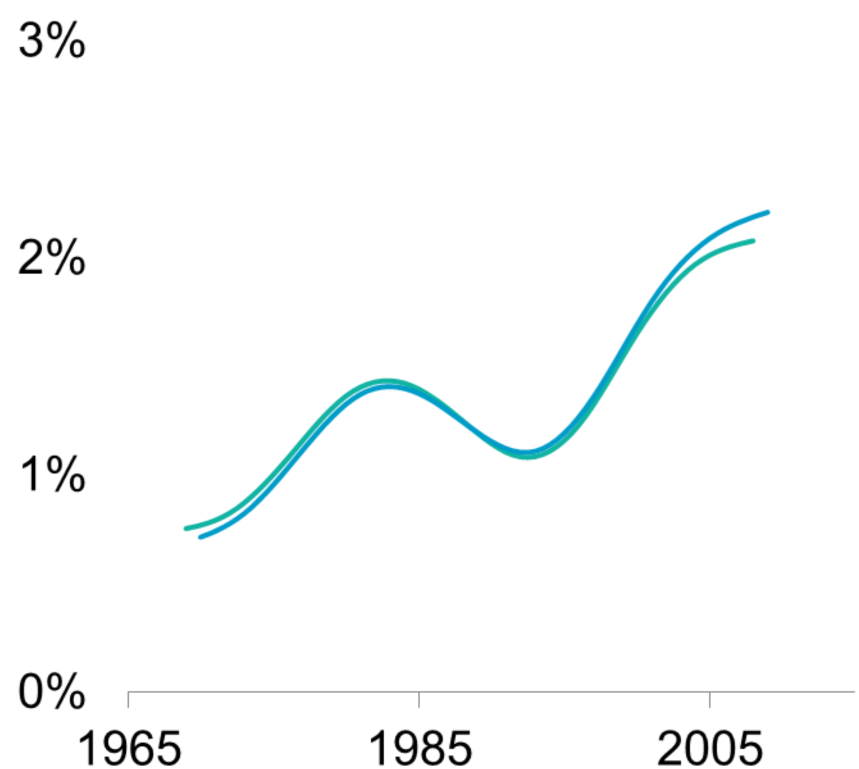
Periods ending in 2005, 2006, 2007



Estimating direction of travel

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

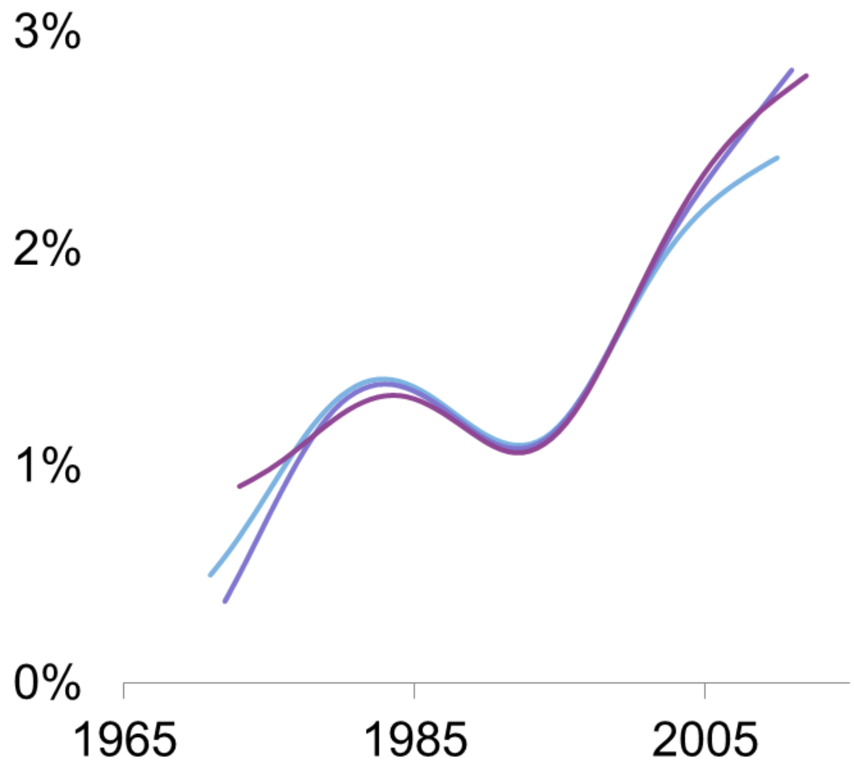
Periods ending in 2008, 2009



Estimating direction of travel

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

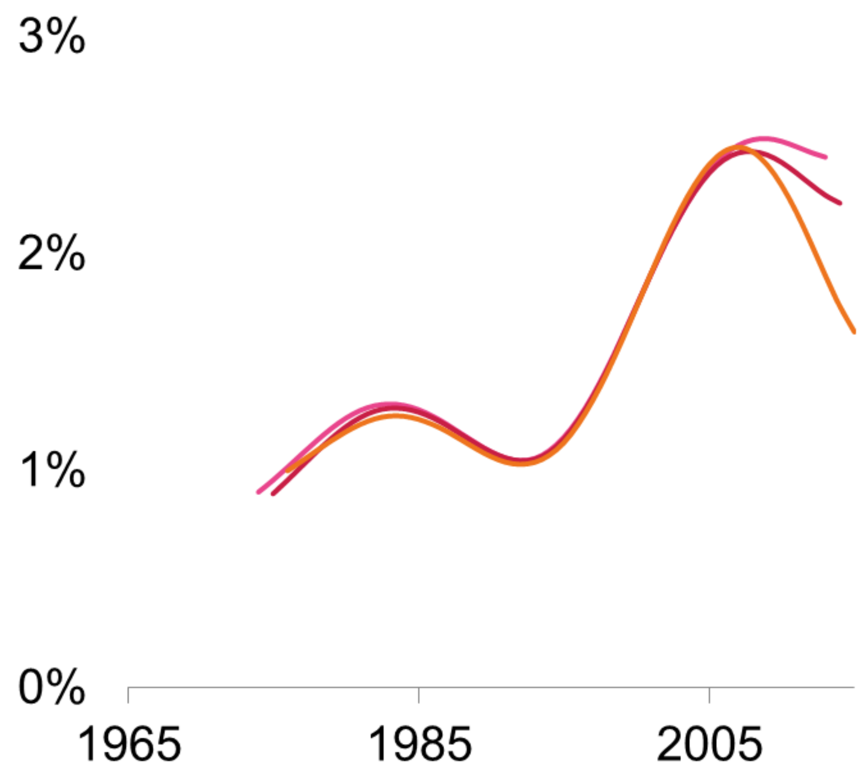
Periods ending in 2010, 2011, 2012



Estimating direction of travel

- The 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

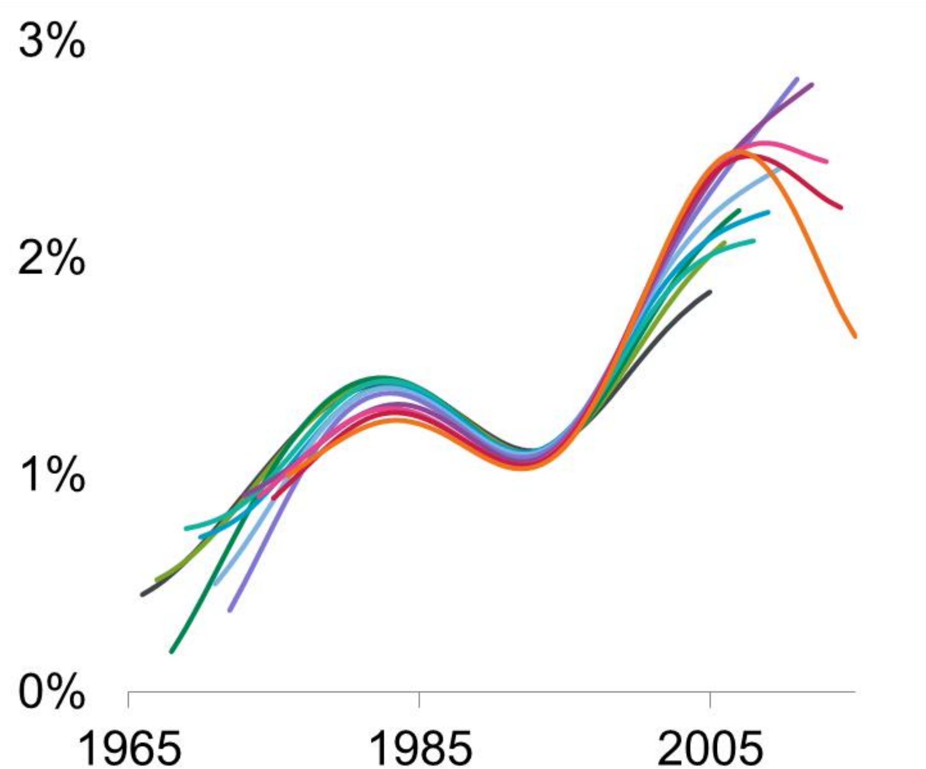


Estimating direction of travel

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

Period ending	Direction of travel
2005-2007	Continuing to rise
2008-2009	Starting to peak
2010-2012	Continuing to rise
2013-2015	Turning down

Periods ending in 2005 to 2015



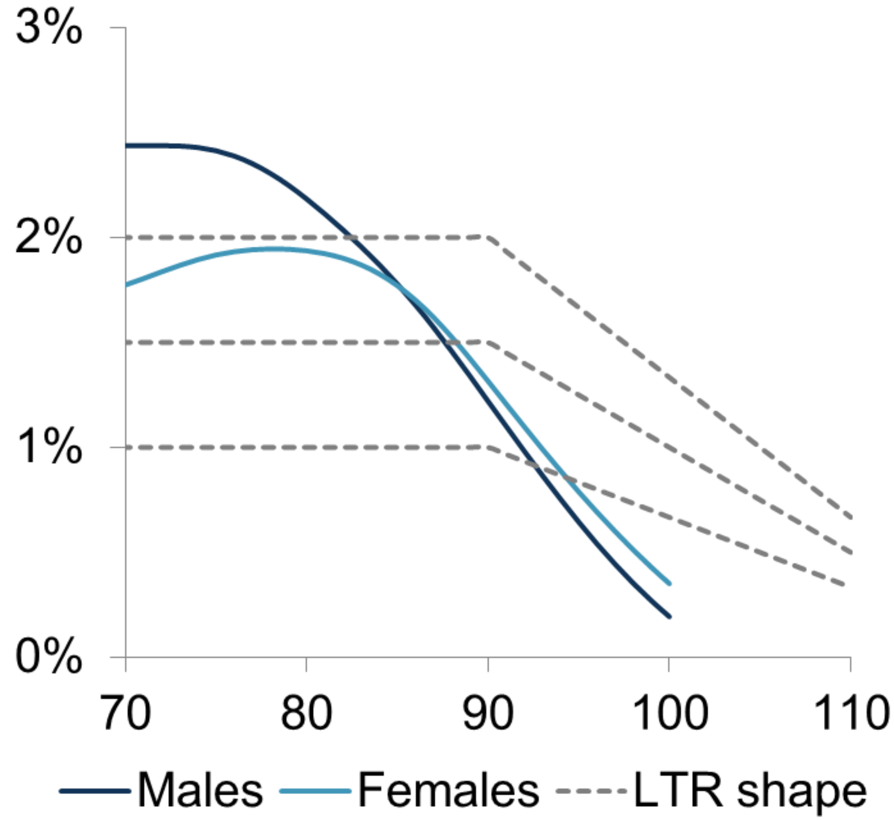
Direction of travel

- Users will have the option of specifying direction of travel or proportion remaining at midpoint.
- The APCI model will output a value of direction of travel.
- Given the uncertainty of direction of travel, the Core assumption will remain as now – nil direction of travel.

Current shape of long-term rate (LTR)

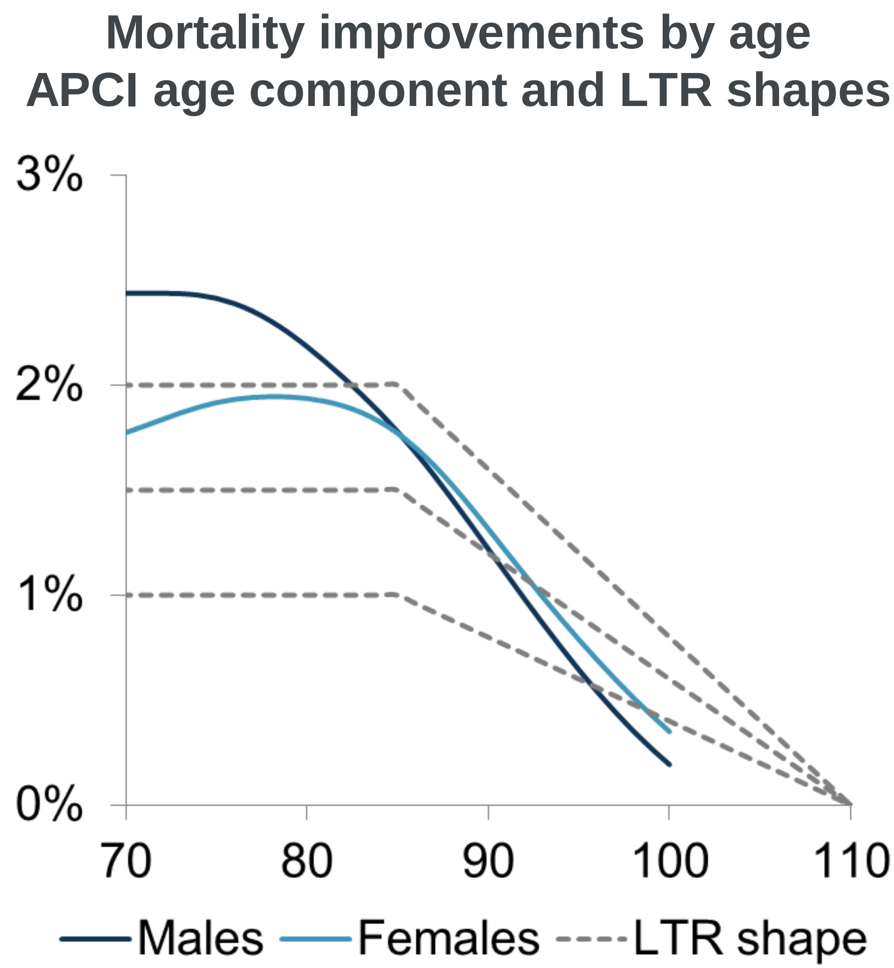
- Under the current Core assumption, the LTR applies up to age 90, and tapers to zero at 120.
- This implies a sharp rise in improvements for centenarians in future; and is out of line with typical insurer assumptions.

Mortality improvements by age
APCI age component and LTR shapes



Proposed shape of long-term rate (LTR)

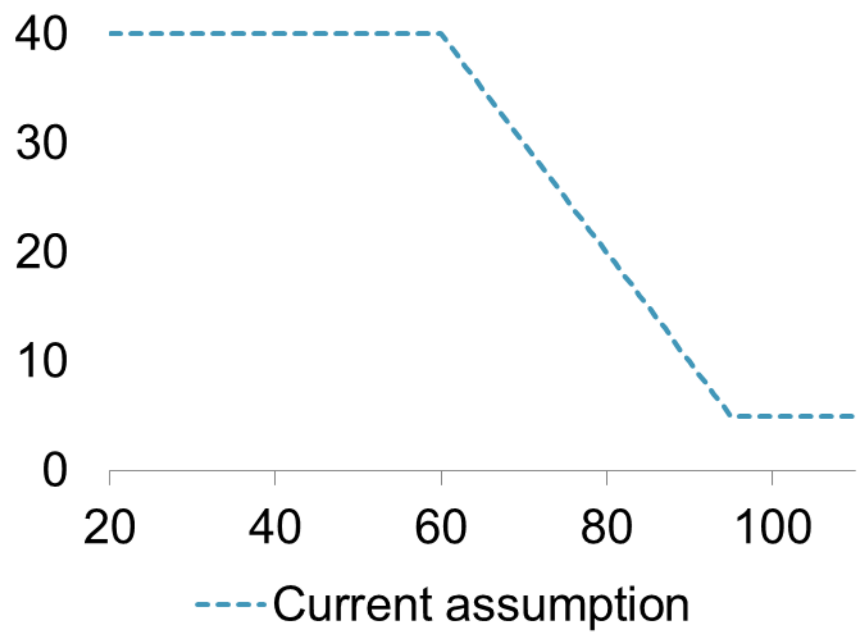
- We propose that the LTR applies up to age **85**, and tapers to zero at age **110**.
- This implies a more modest rise in improvements for centenarians.



Cohort convergence periods

- Cohort convergence periods are currently 40 years below age 60.
  - This assumption is more material in the APCI model as cohort improvements at young-adult ages are higher.
  - Causes of death at young-adult ages are different to older ages; so current influences of improvements may not persist.
  - Net migration may make young-adult age exposure estimates less reliable.

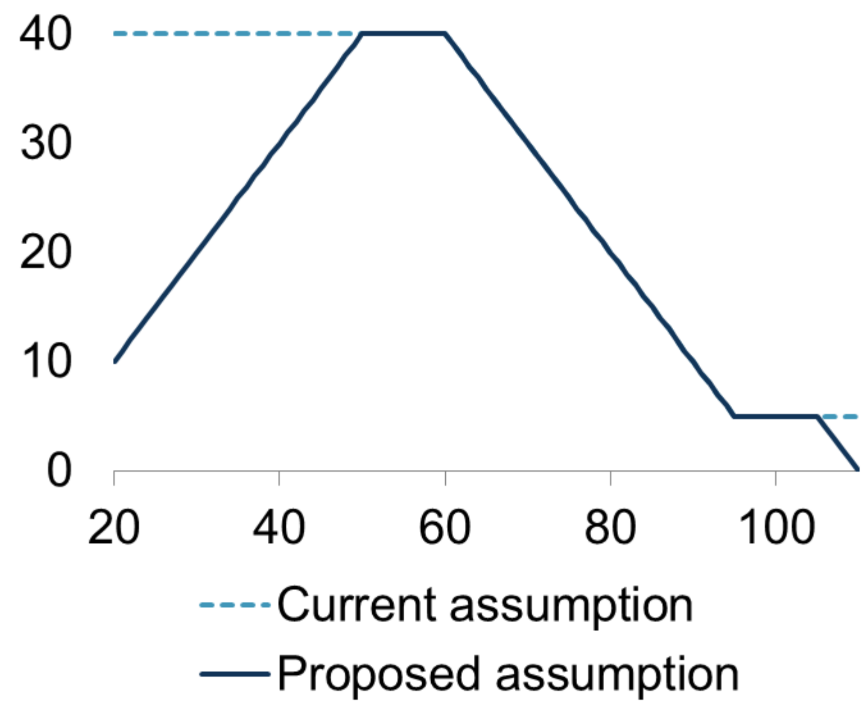
Cohort convergence periods by age at the start of the projection



Cohort convergence periods

- Cohort convergence periods are currently 40 years below age 60.
- We propose to reduce cohort convergence periods for ages below 50.
- At old ages, “tidying up” so improvements are nil at age 110+, consistent with the LTR shape.

Cohort convergence periods by age at the start of the projection



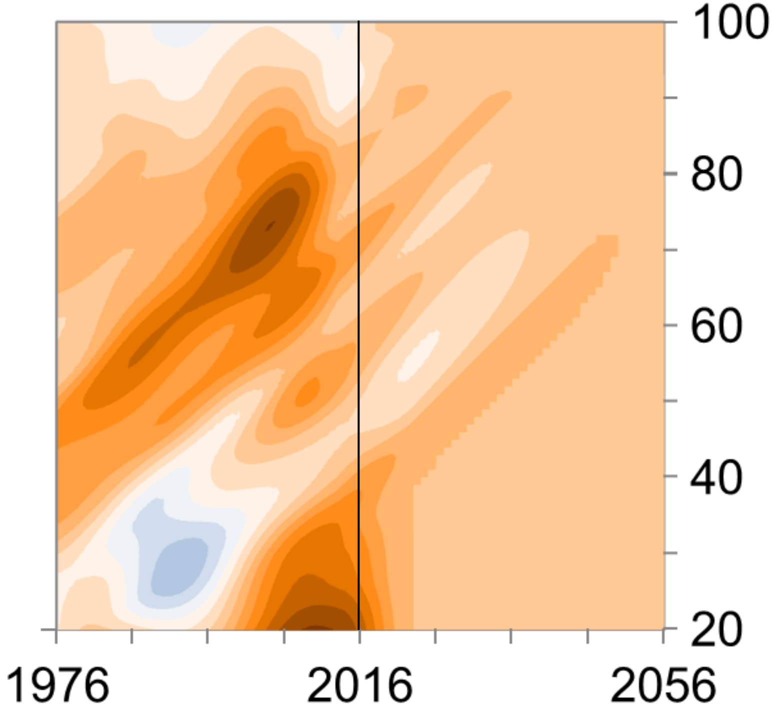
Comparison of current and proposed methods

- The next few slides compare the current and proposed methods on a like-for-like basis, using data for 1975-2015.
- We use a sample long-term rate of 1.5% p.a.
- Note that the “current” method shown is not the same as CMI_2015, and is not an official release of the Model.

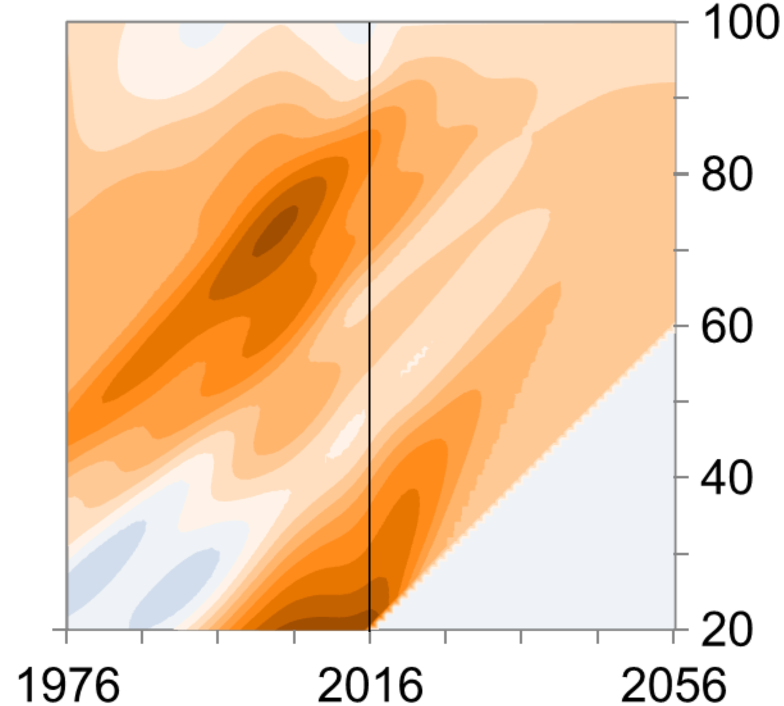
	Release	Actual data to	Estimated data to	Initial year
CMI_2015	September 2015	July 2015	December 2015	2012
Current	[March 2016]	December 2015	n/a	2013
Proposed	[March 2016]	December 2015	n/a	2015

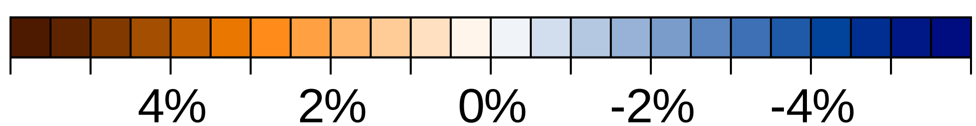
Comparison of male mortality improvements

Males – current* method



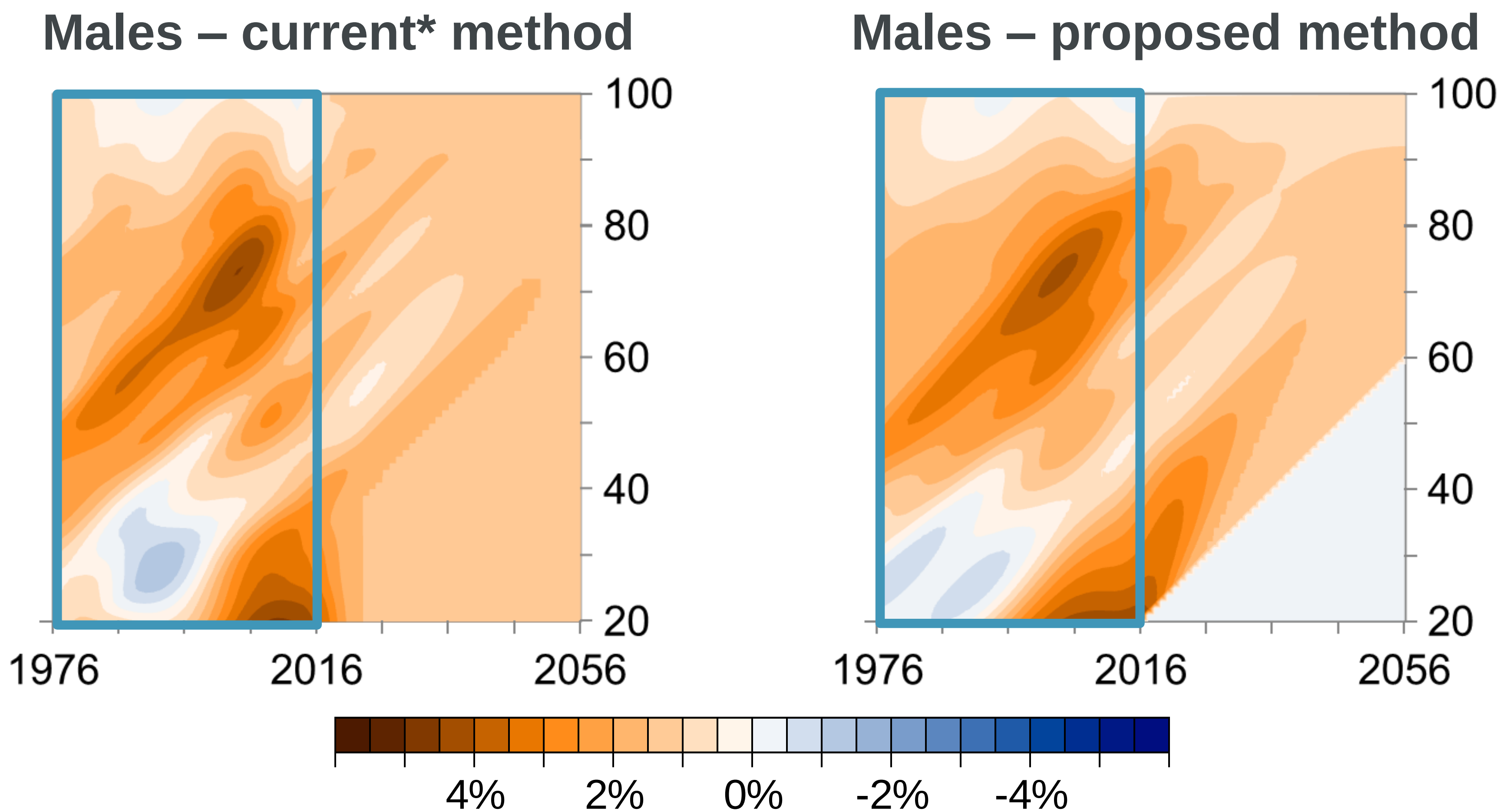
Males – proposed method





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

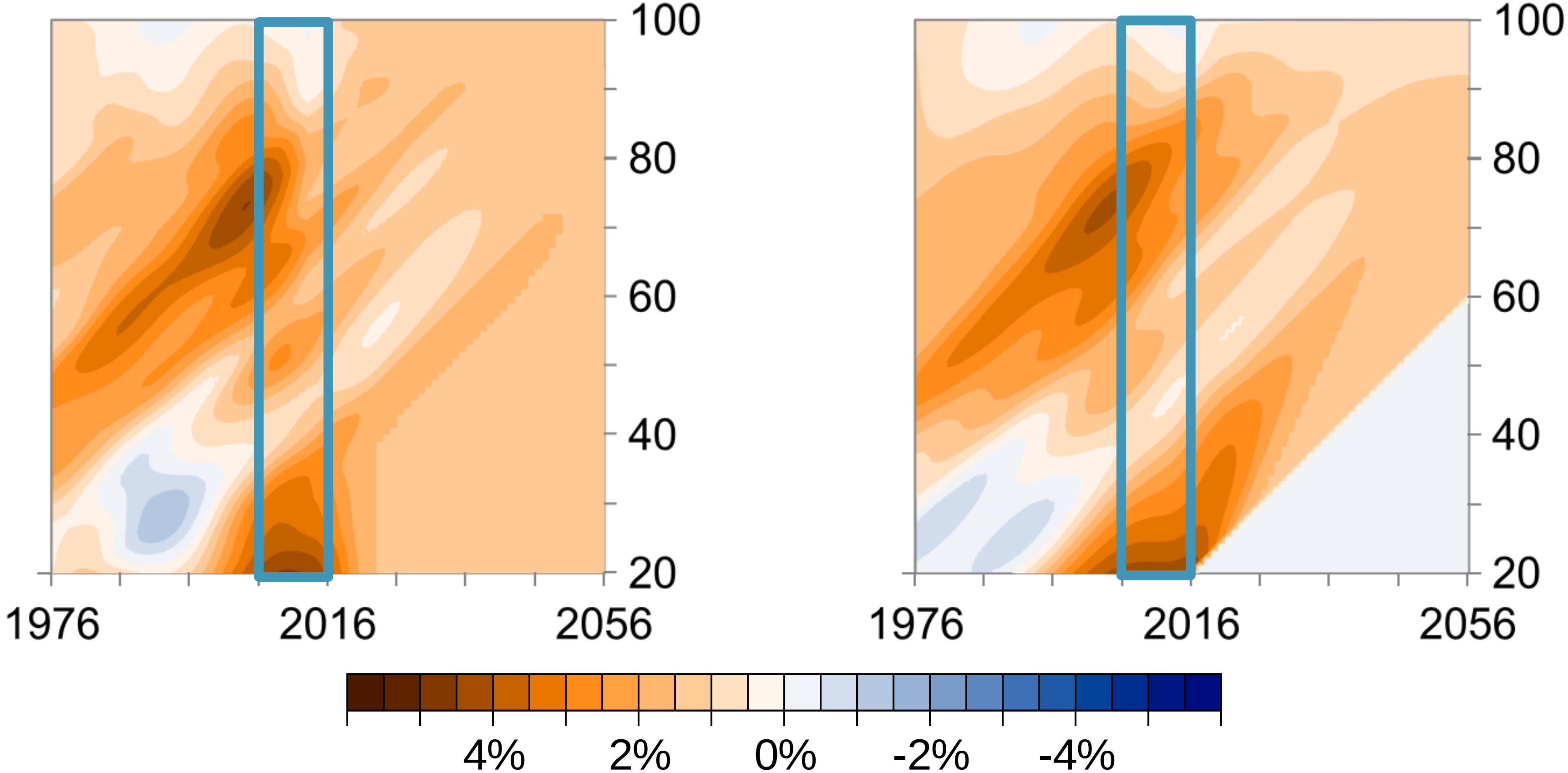
1. Historical fit is broadly similar



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

2. Recent improvements are higher

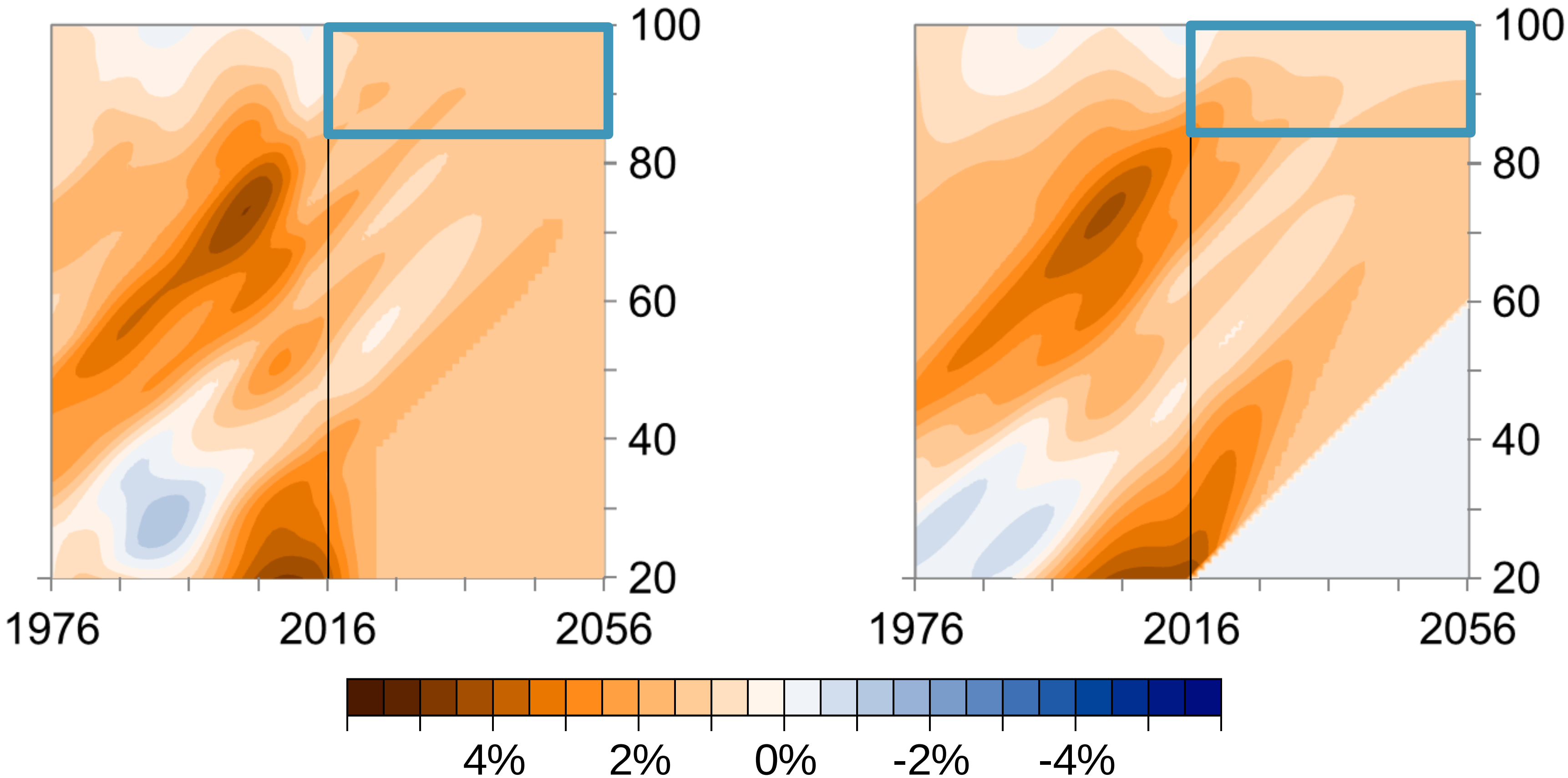
Males – current* method | **Males – proposed method**



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

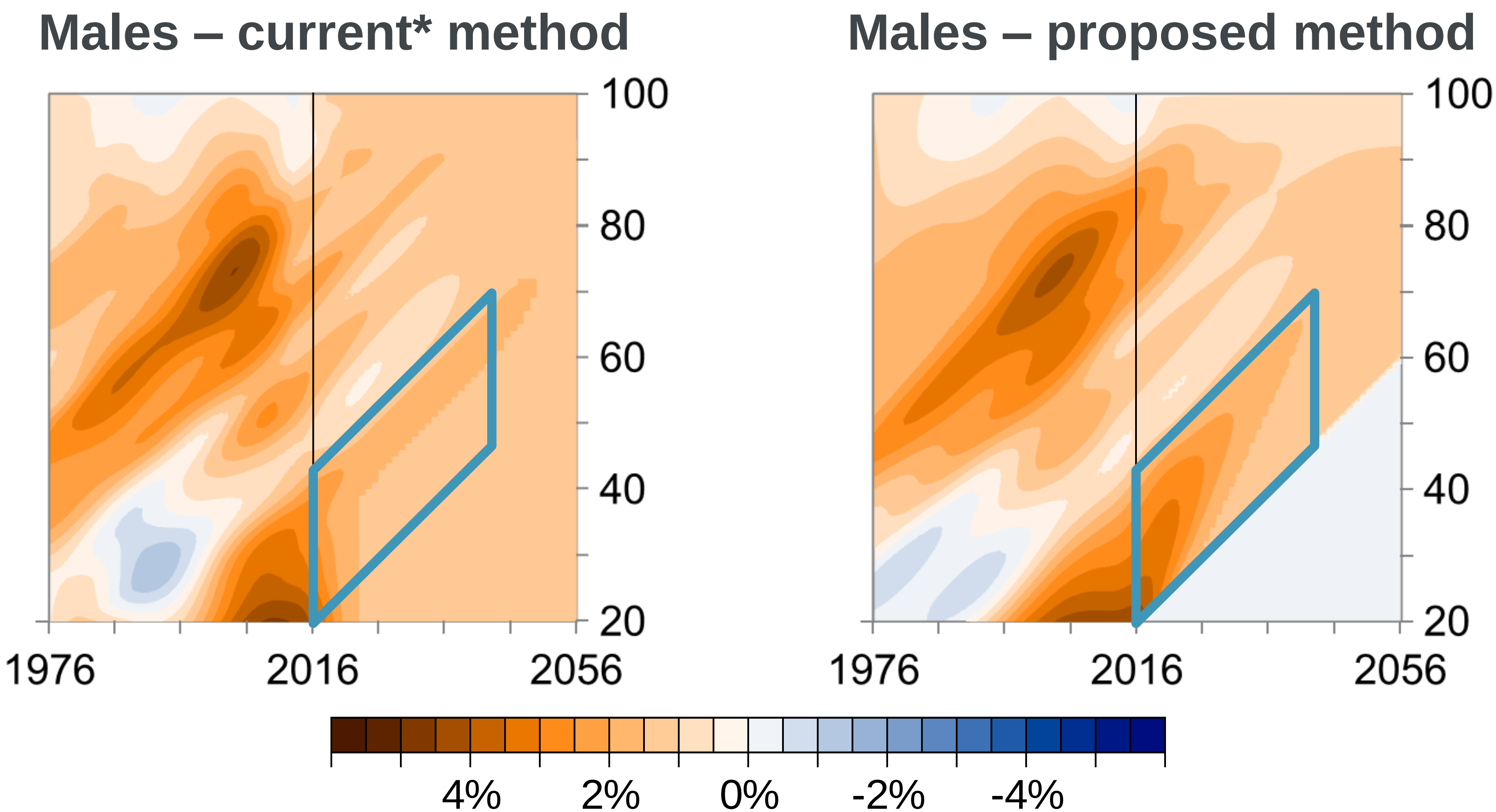
3. Lower long-term old-age improvements

Males – current* method | **Males – proposed method**



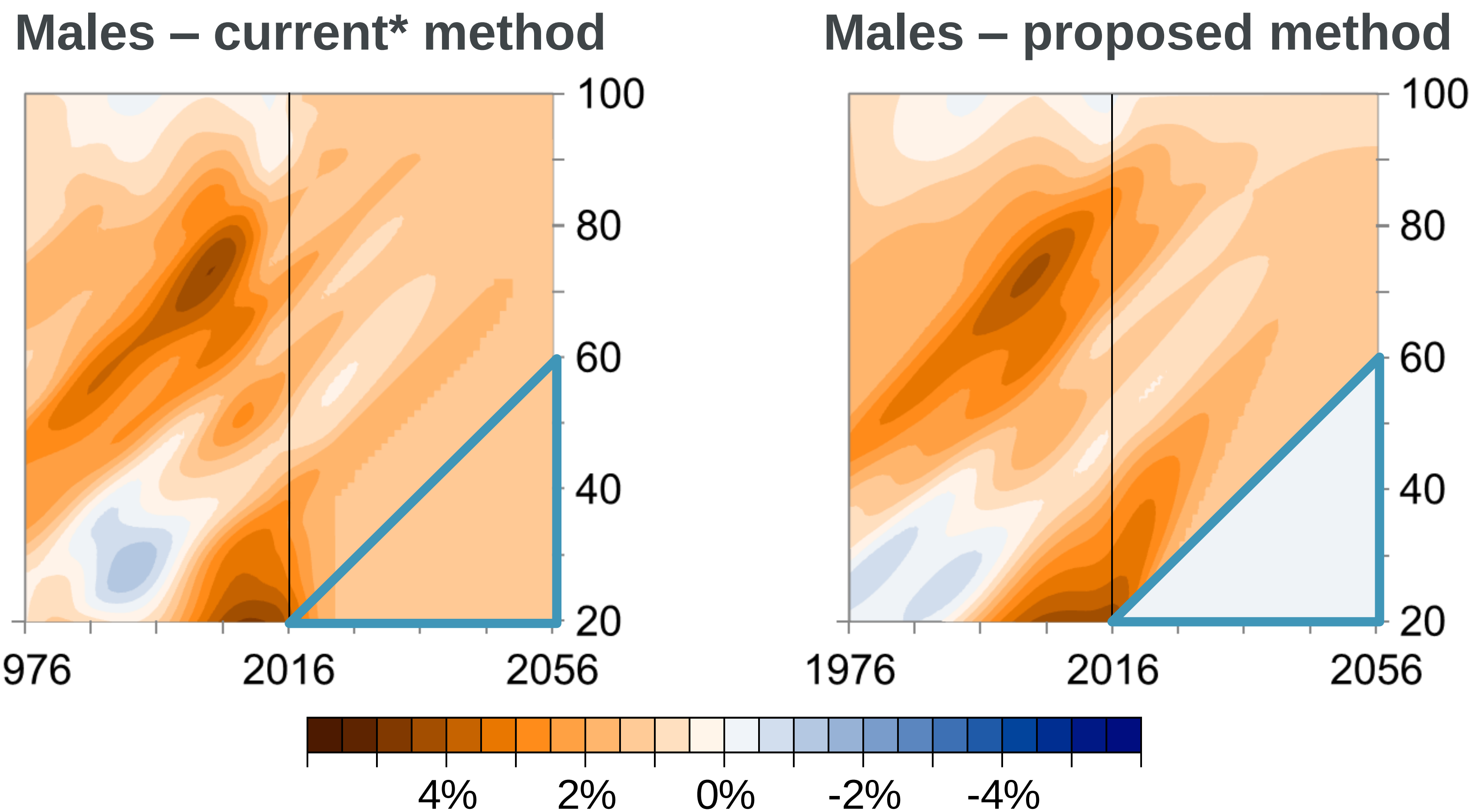
*Note that "current" is not the same as CMI_2015.

4. Young-age cohort improvements



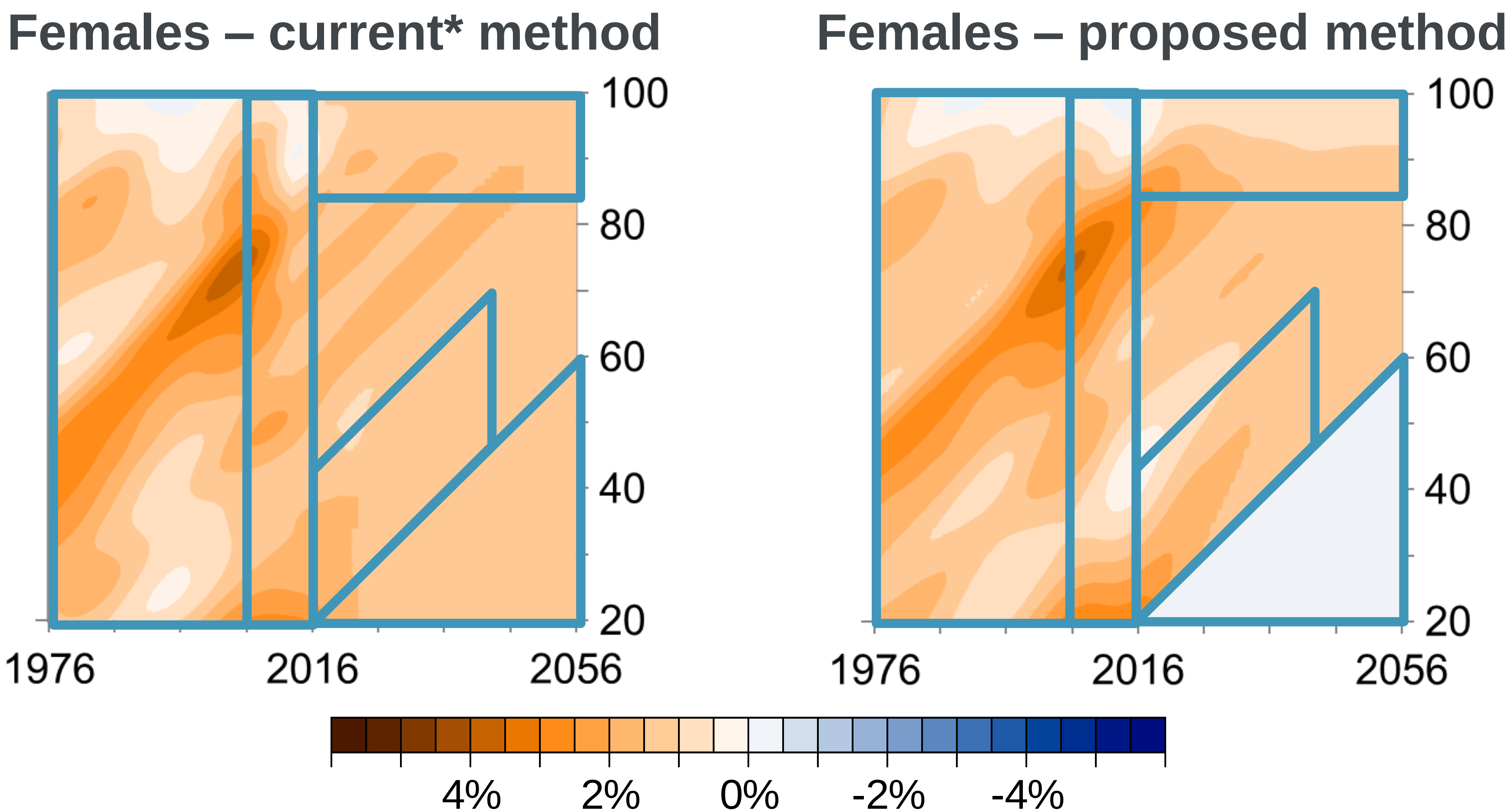
*Note that “current” is not the same as CMI_2015.

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.

Note: This slide shows corrected values; not those presented at the meeting.

Comparison of life expectancies (1)

- This slide compares current and proposed methods on a like-for-like basis.
- The table shows sample life expectancies at 31 December 2015
  - for current and proposed methods fitted to data for 1975-2015
  - using S2PMA and S2PFA base tables and LTR of 1.5%

	M 25	M 45	M 65	M 75	M 85	F 25	F 45	F 65	F 75	F 85
Current*	64.51	42.30	22.12	13.30	6.60	66.65	44.58	24.13	14.90	7.58
Proposed	63.83	41.99	22.40	13.74	6.78	65.68	44.14	24.33	15.24	7.64
% difference	−1.1	−0.7	+1.3	+3.3	+2.6	−1.4	−1.0	+0.8	+2.3	+0.7

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

Note: This slide shows corrected values; not those presented at the meeting.

Comparison of life expectancies (2)

- The previous slide compared current and proposed methods on a like-for-like basis. This slide shows progression over time, as new data emerges.

	Release	Actual data to	Estimated data to	Initial year
CMI_2014	November 2014	September 2014	December 2014	2011
CMI_2015	September 2015	July 2015	December 2015	2012
Current	[March 2016]	December 2015	n/a	2013
Proposed	[March 2016]	December 2015	n/a	2015

Life expectancy as a percentage of CMI_2015

	M 25	M 45	M 65	M 75	M 85	F 25	F 45	F 65	F 75	F 85
CMI_2014	100.4%	100.7%	101.3%	101.8%	101.9%	100.5%	100.7%	101.4%	101.9%	102.0%
CMI_2015	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Current	99.5%	99.2%	98.6%	98.0%	97.1%	99.5%	99.3%	98.6%	98.1%	97.6%
Proposed	98.4%	98.5%	99.8%	101.3%	99.6%	98.1%	98.3%	99.4%	100.4%	98.3%

Note: The final bullet point has been amended.

Summary – Projecting future improvements

- The Model will allow the use of "direction of travel" or "proportion remaining at midpoint".
  - But our Core assumption will still be for no direction of travel.
- Long-term rate tapers to zero between ages 85 and 110 (rather than 90 and 120 as now).
- Shorten the cohort convergence periods for cohorts now aged below 60.
- No projections for "new cohorts" aged under 20 at the start of the projection.
- Life expectancies under the proposed approach are not radically different to those under the current method.
- Under the current method, life expectancies for a March 2016 model release would have been lower than for CMI_2015.

Next steps

Consultation process

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

Continuous
Mortality Investigation

Institute and Faculty of Actuaries

Continuous Mortality Investigation Limited
Registered in England & Wales (Company number: 8373631)
Registered Office: 7th floor, Holborn Gate, 326-330 High Holborn, London, WC1V 7PP

Correspondence address: Cheapside House, 138 Cheapside, London, EC2V 6BW, United Kingdom
Email: info@cmilimited.co.uk
Tel: +44 20 7776 3820

Website: www.cmilimited.co.uk (redirects to www.actuaries.org.uk)

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