Continuous
Mortality Investigation

Institute and Faculty of Actuaries

The Future of the CMI Mortality Projections Model

CMI Mortality Projections Committee

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26 October 2015

Introduction

Tim Gordon

The CMI Mortality Projections Model

- The Model has been successful
  - Close to universal UK adoption for disclosure and benchmarking
  - Widely used for actual mortality improvements analysis
- Expectations of mortality modelling are increasing
- Possible concerns with the current model
  - Not a statistically-based model – disconnect past v future
  - Difficult to analyse the ∂PV / ∂(new information) question
  - Cumbersome to calibrate
  - Lots of parameters – only Core+LTR is a meaningful disclosure
- Aim: improved model

CMI Model timeline

Date	Model	Activity
2004 to 2008		Research and consultation
Nov 2009	CMI_2009	First version of the Model
Nov 2010	CMI_2010	Annual update
Sep 2011	CMI_2011	Annual update – CMI estimate of high age population to accelerate publication
Feb 2013	CMI_2012	Annual update
Apr 2013		Consultation on the Model
Sep 2013	CMI_2013	Annual update
Nov 2014	CMI_2014	Annual update incorporating revisions to calibration method
Mar 2015		Consultation on the release date of future updates to the Model
Sep 2015	CMI_2015	Annual update plus paper on recent mortality
Oct 2015		*Public meetings on the future of the Model*
Mar 2016		*Consultation on the future of the Model*
Mar 2017	*CMI_2016*	*First version of revised model*

Agenda

- Introduction
- Recent mortality and impact on projections
- Data
- Responsiveness, stability and prediction
- Updating for new information
- Other issues
- Open discussion

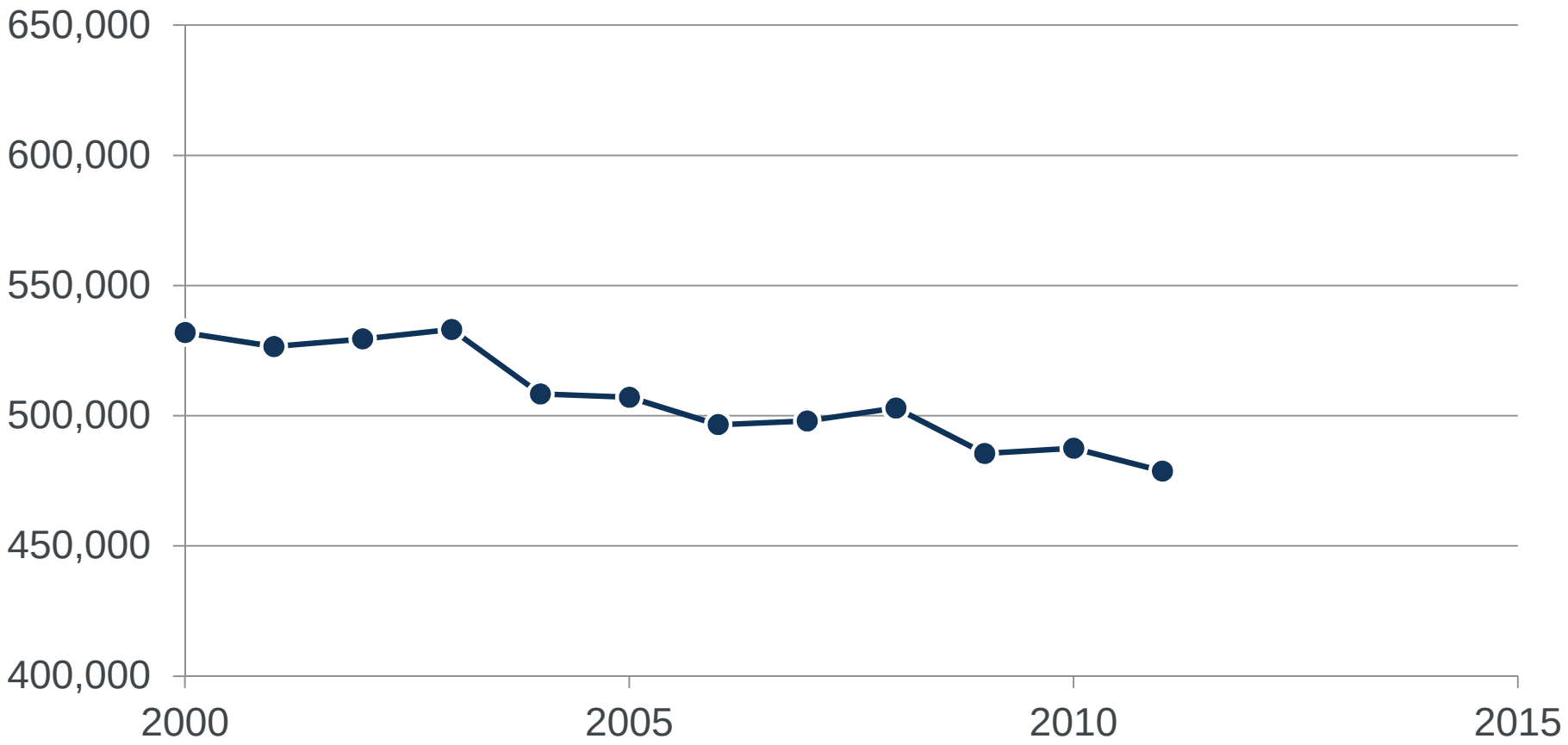
Recent mortality and impact on projections

Jon Palin

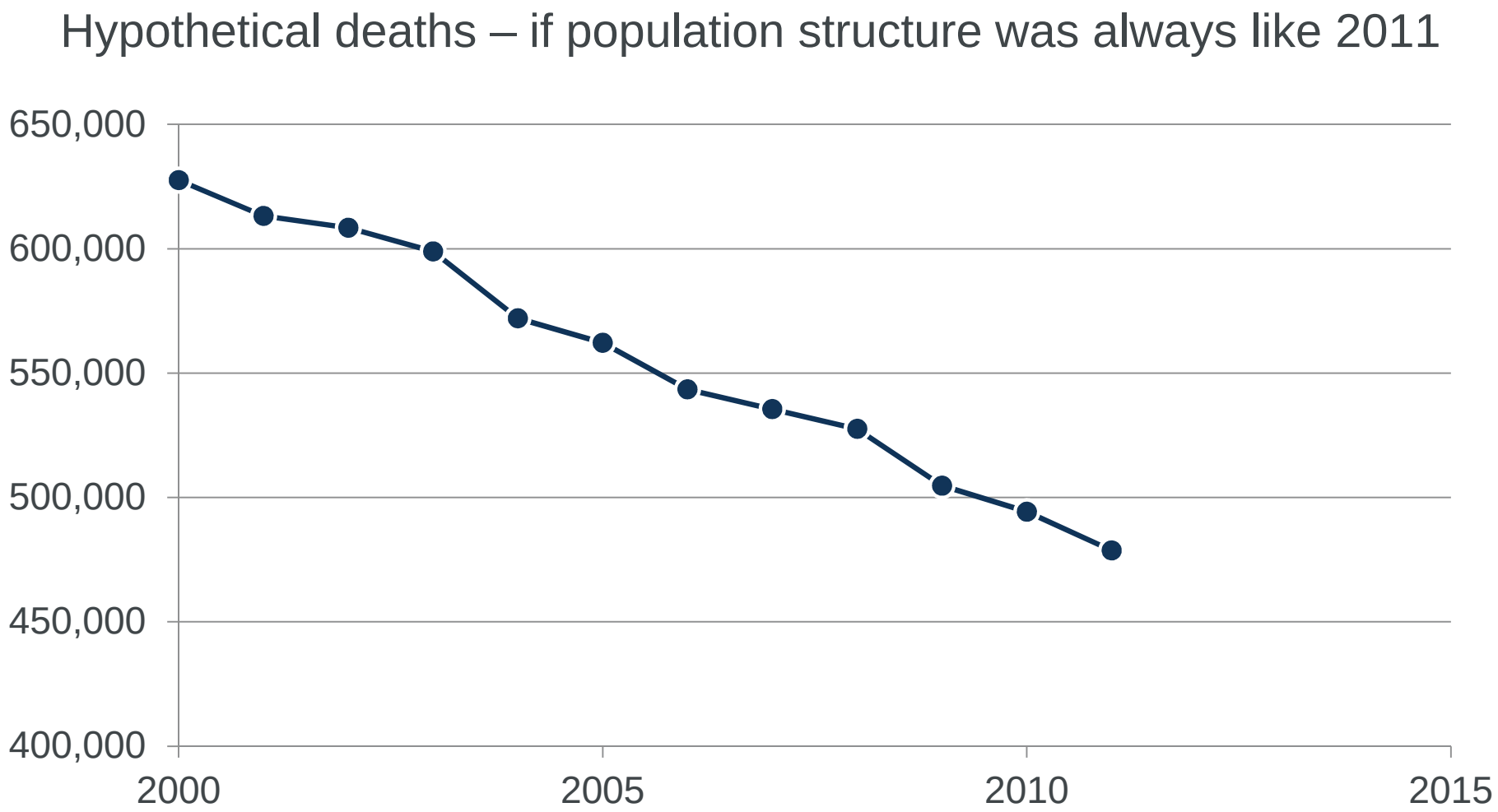
Recent mortality

Recent mortality

Deaths in England & Wales, 2000-2011, ages 18-102, males and females

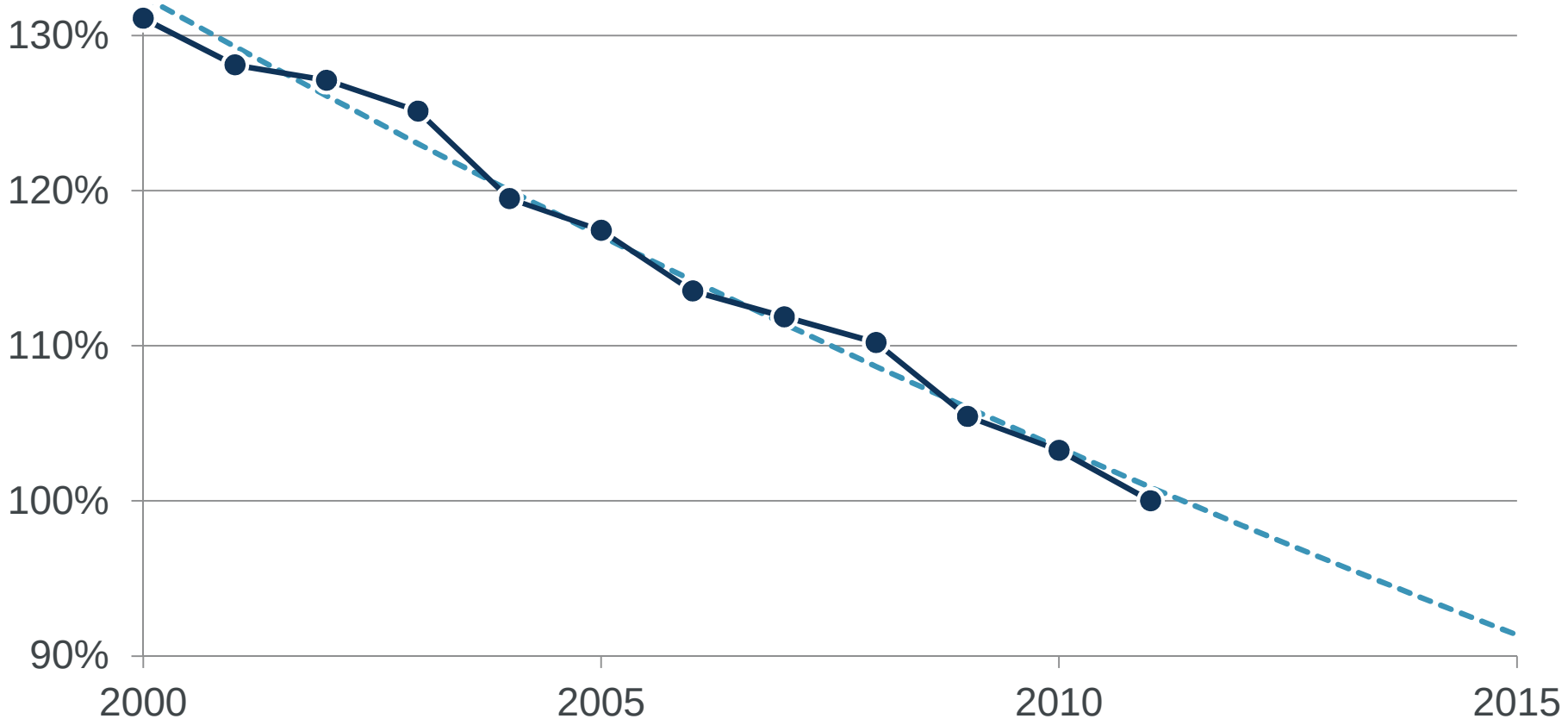


Recent mortality



Recent mortality

Standardised mortality ratio, England & Wales, and 2000-2011 trend



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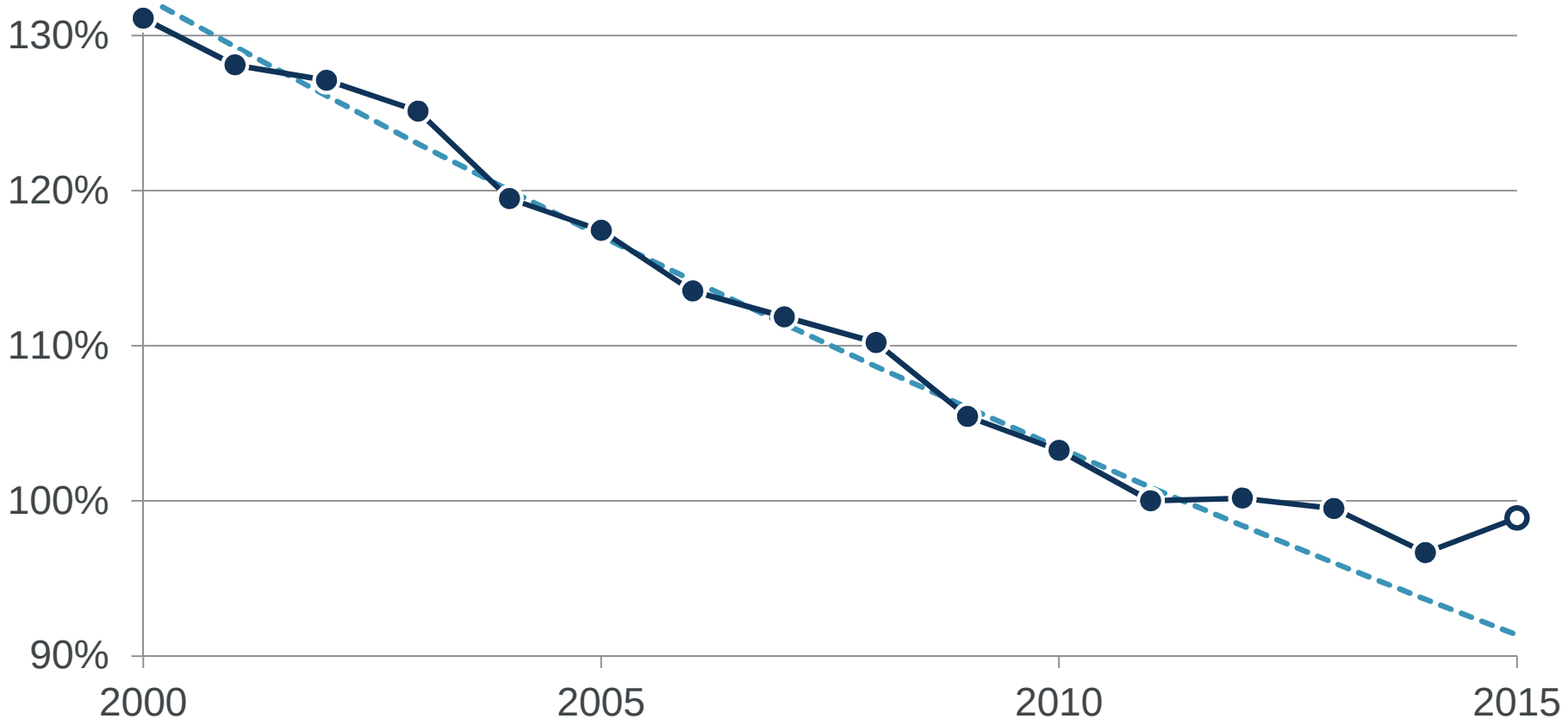
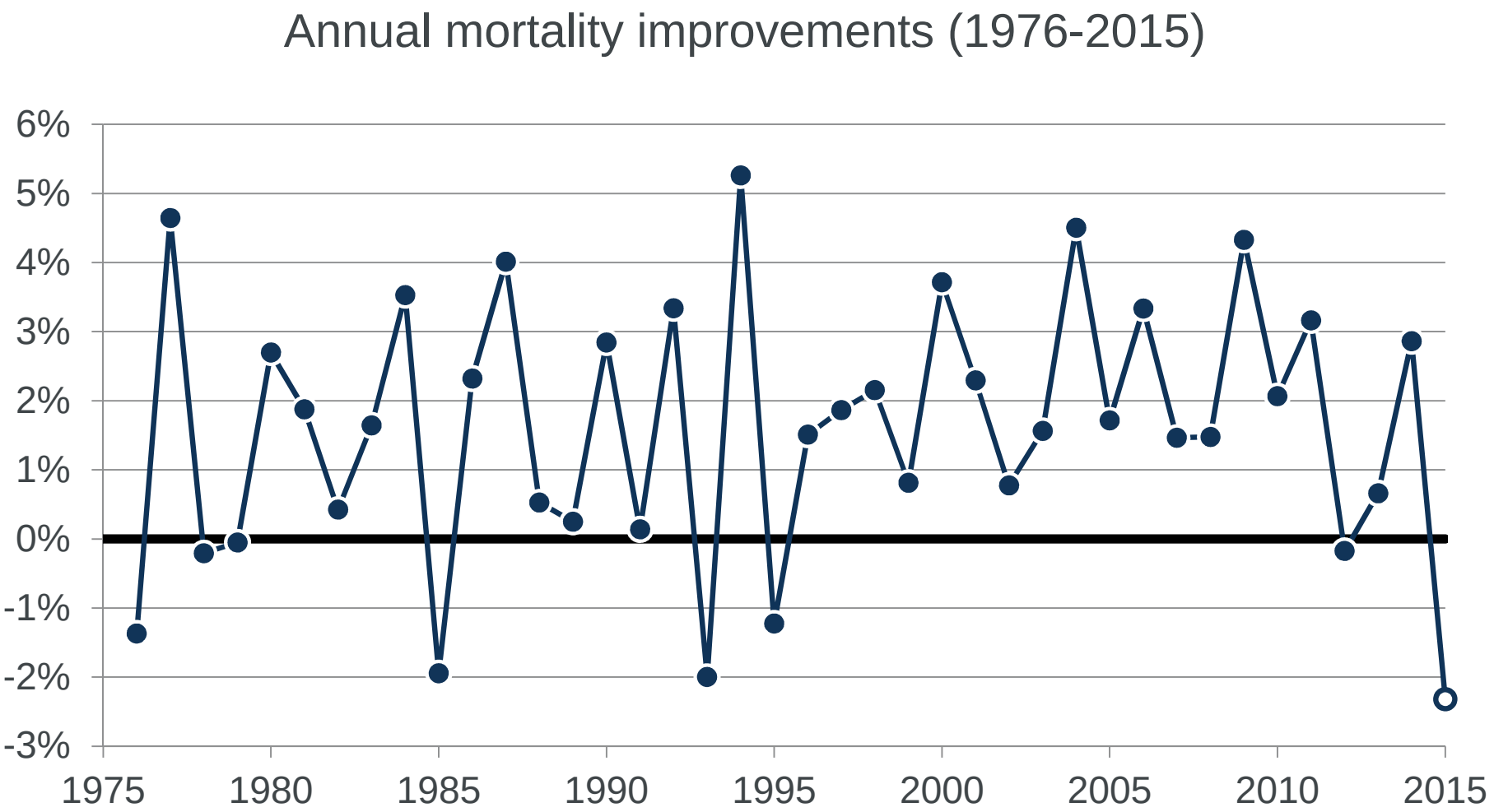


Note: 2015 data has been estimated based on actual deaths to 31 July.

Recent mortality improvements



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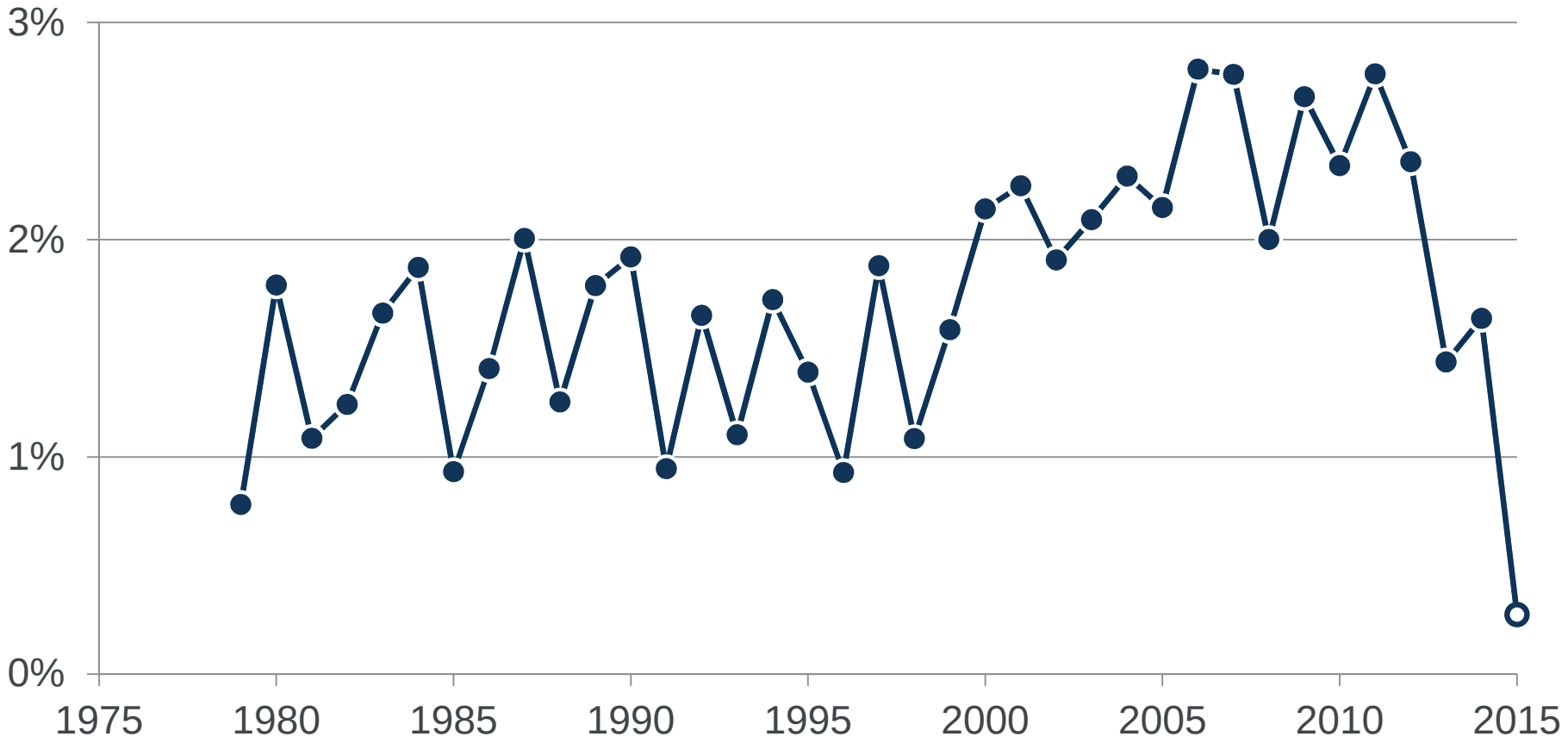
Recent mortality improvements

Four-year average annualised mortality improvements (1979-2015)



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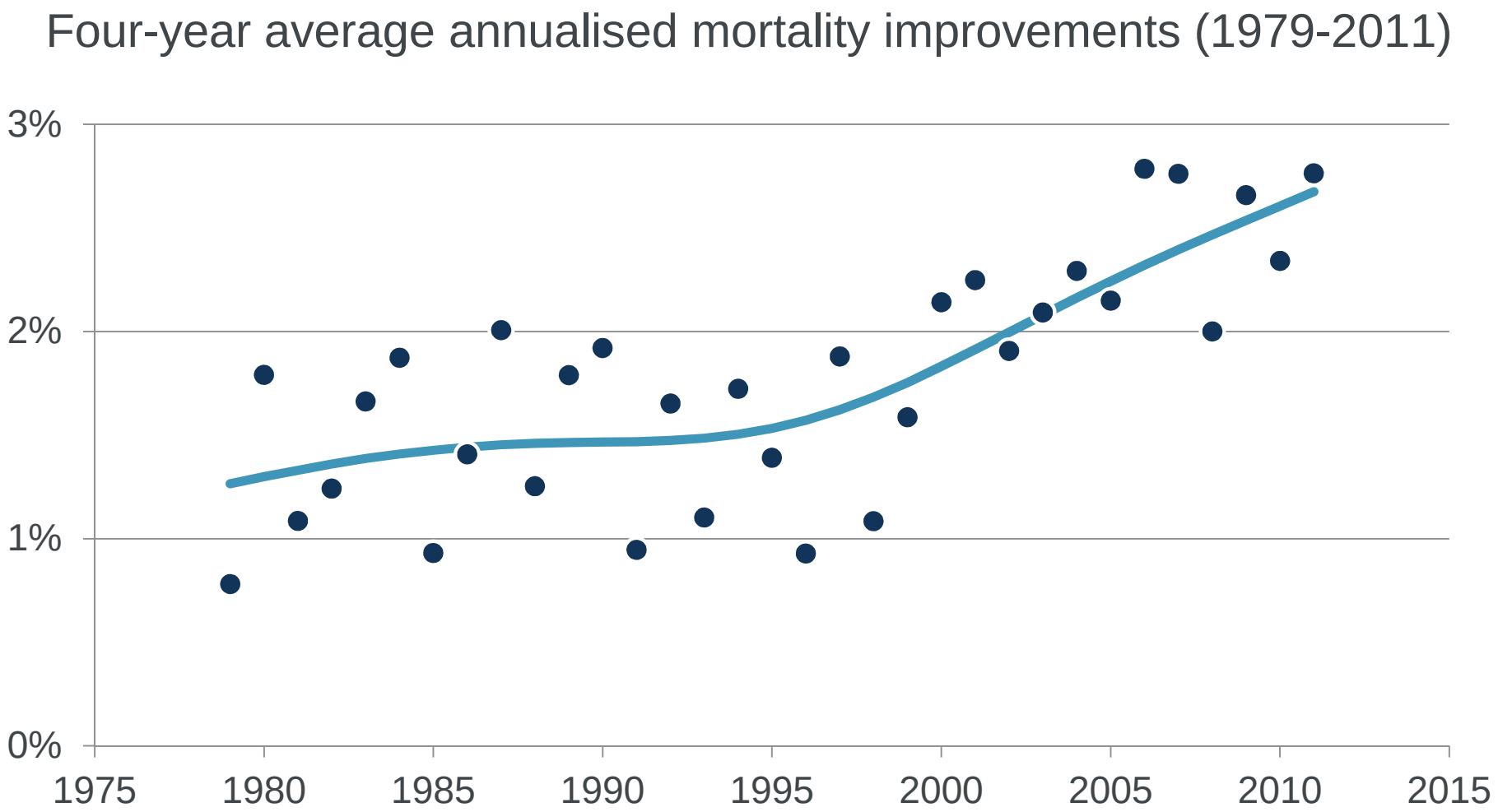
Recent mortality improvements



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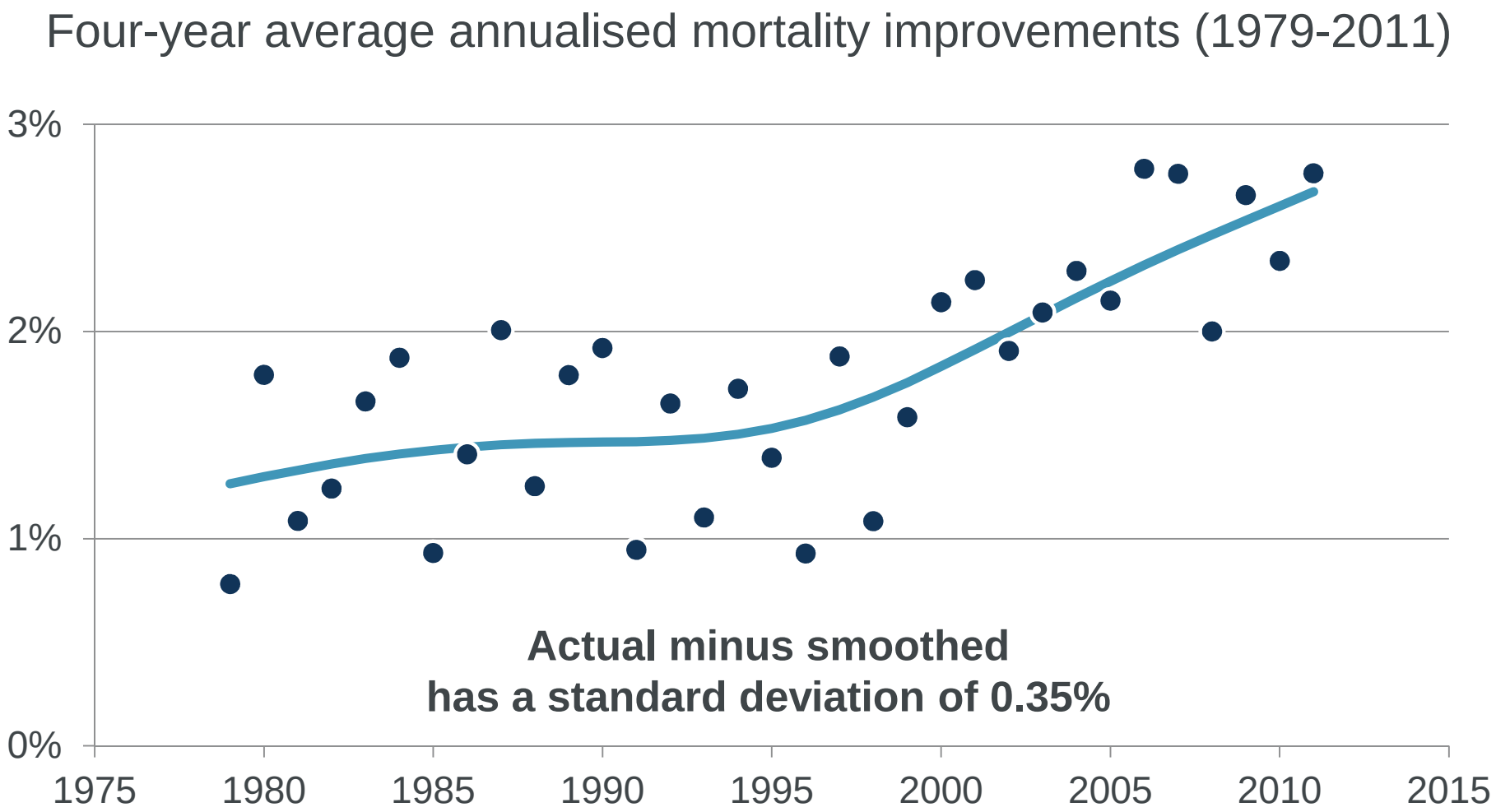
Recent mortality improvements



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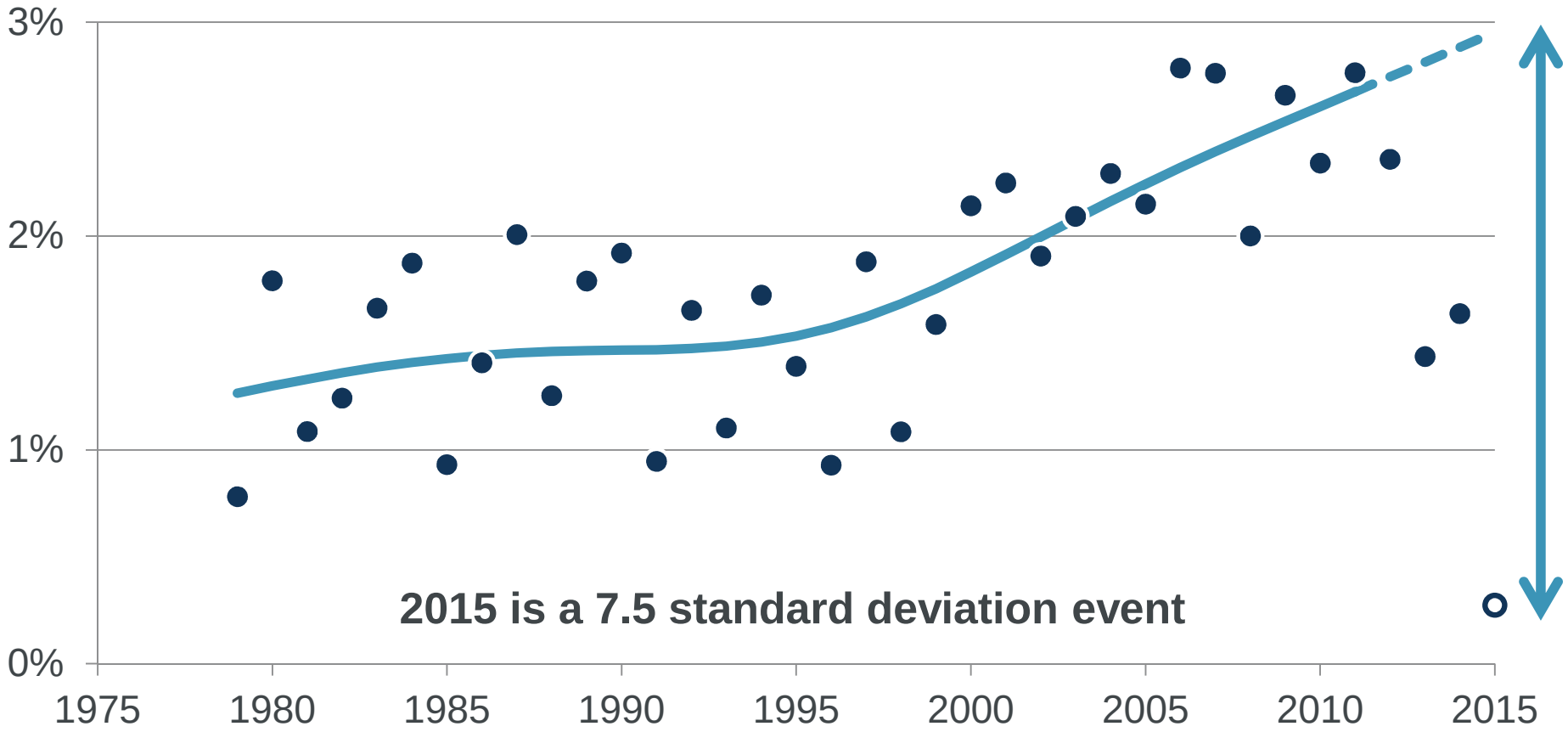

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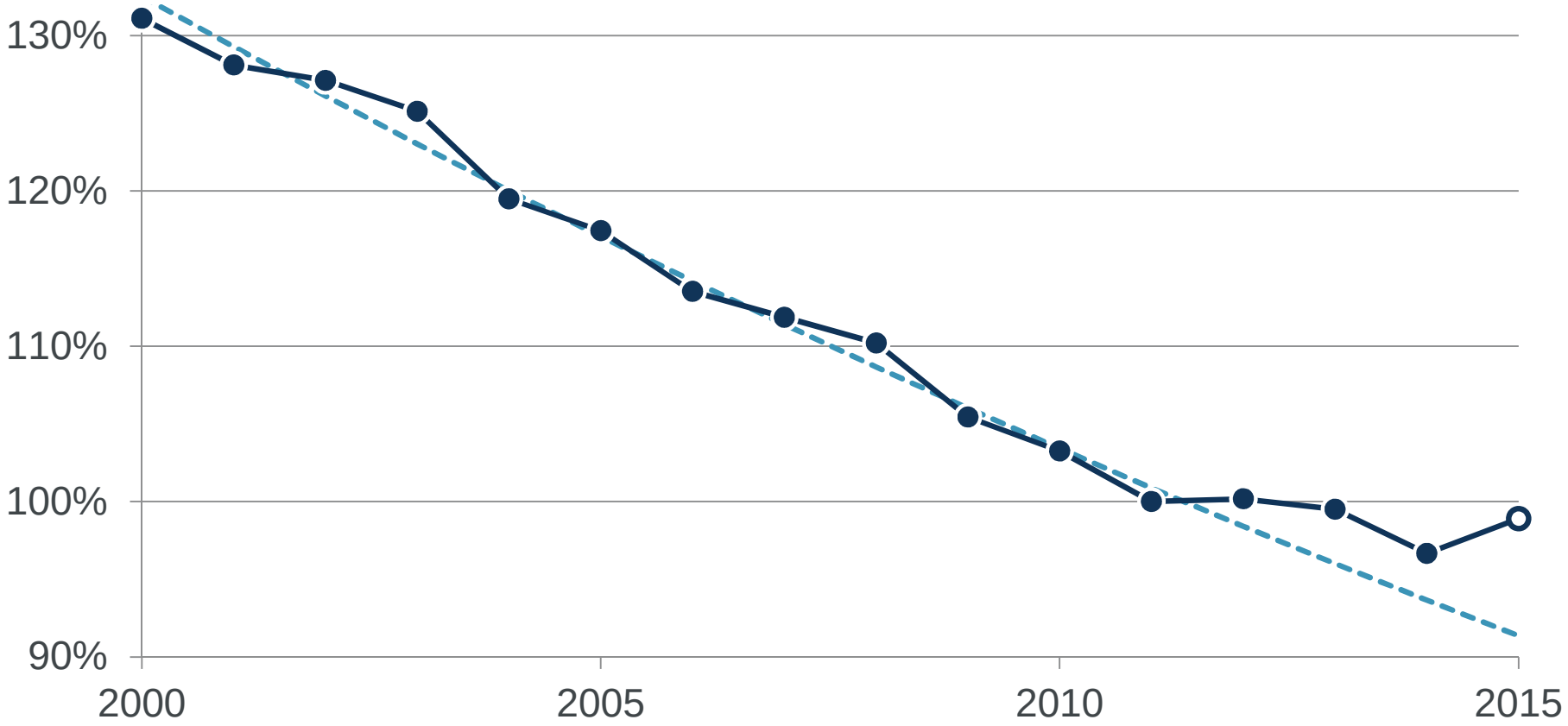
Annual mortality (revisited)

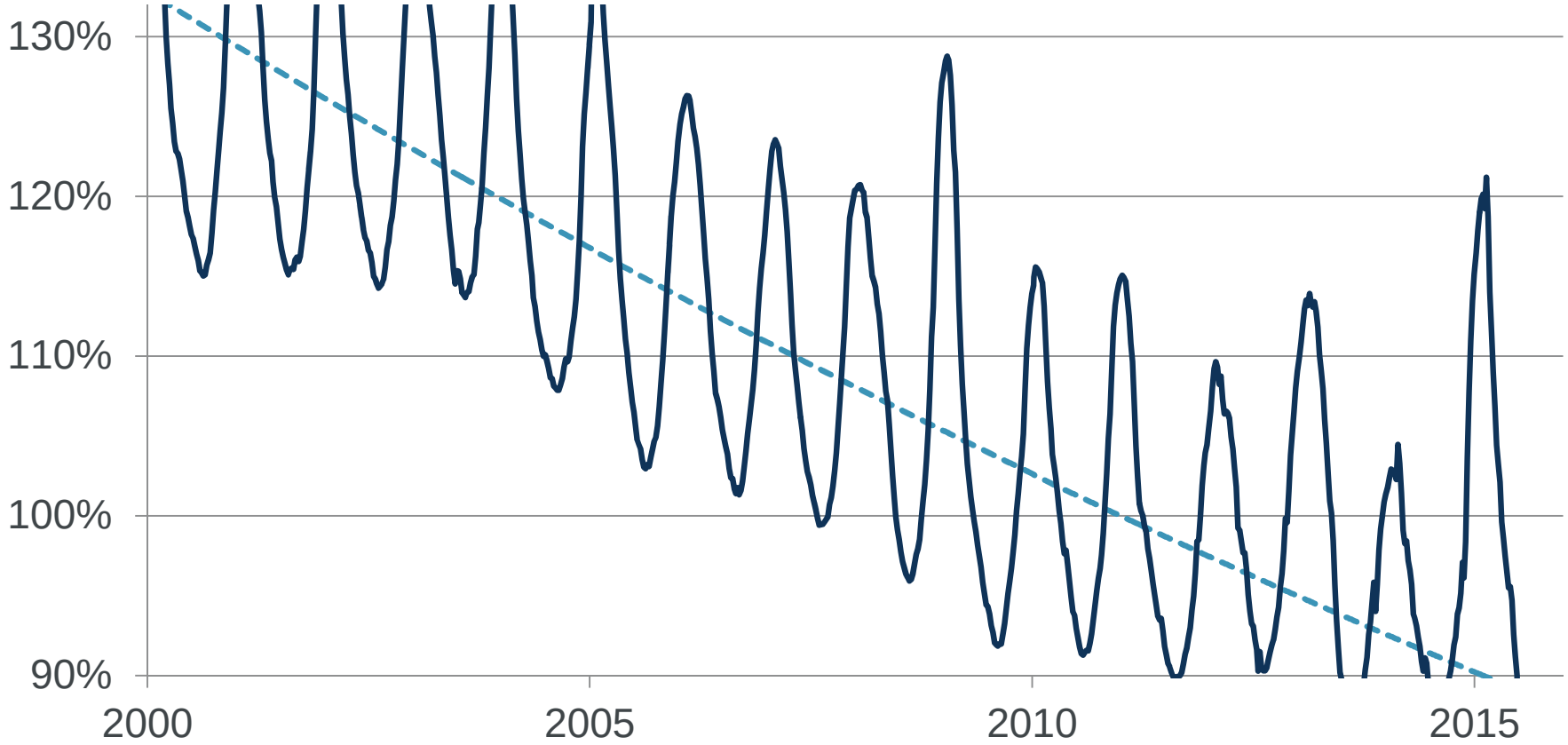
Standardised mortality ratio, England & Wales, and 2000-2011 trend



Note: 2015 data has been estimated based on actual deaths to 31 July.

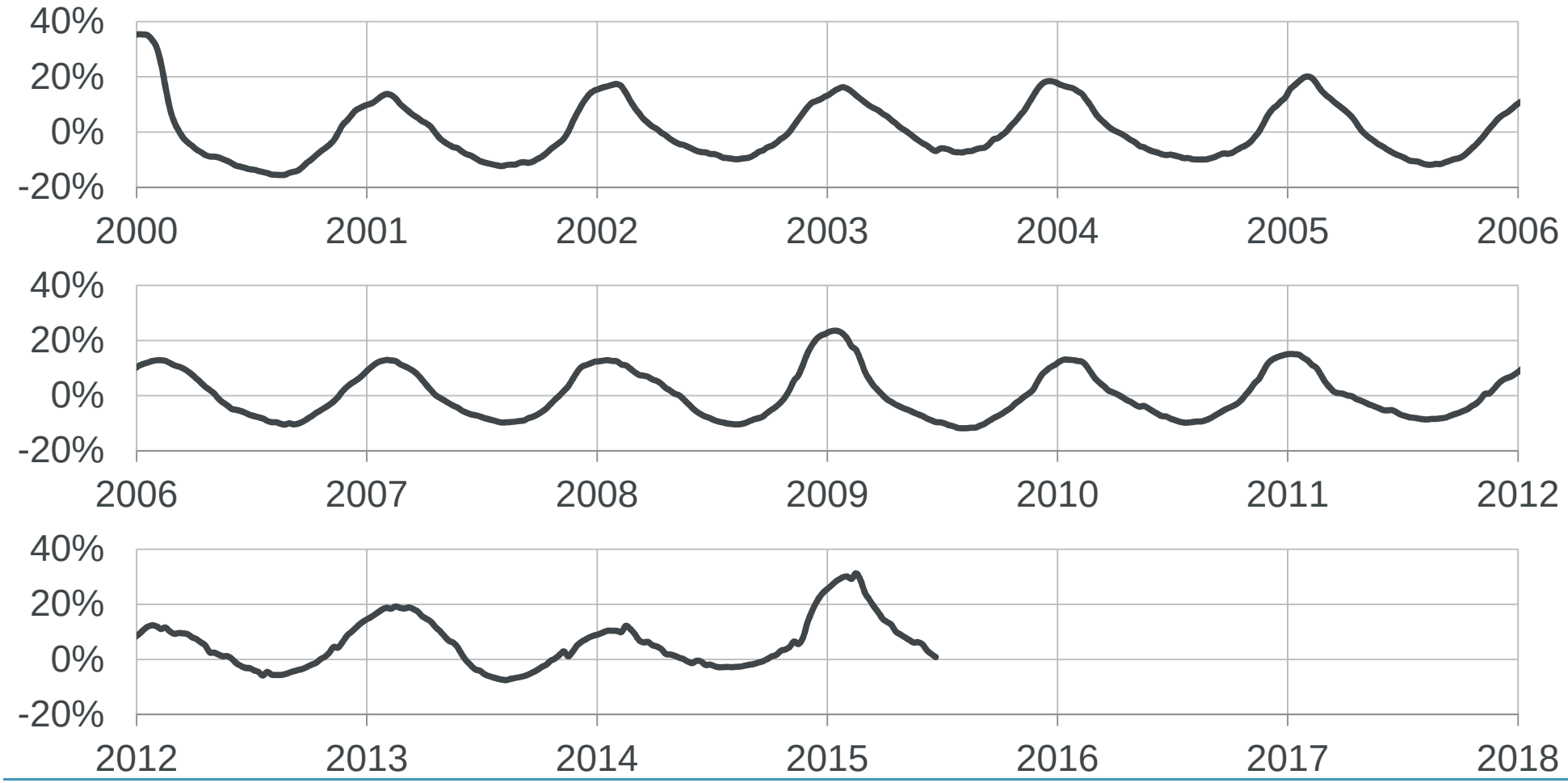
Seasonal mortality

13-week average standardised mortality ratio, and 2000-2011 trend



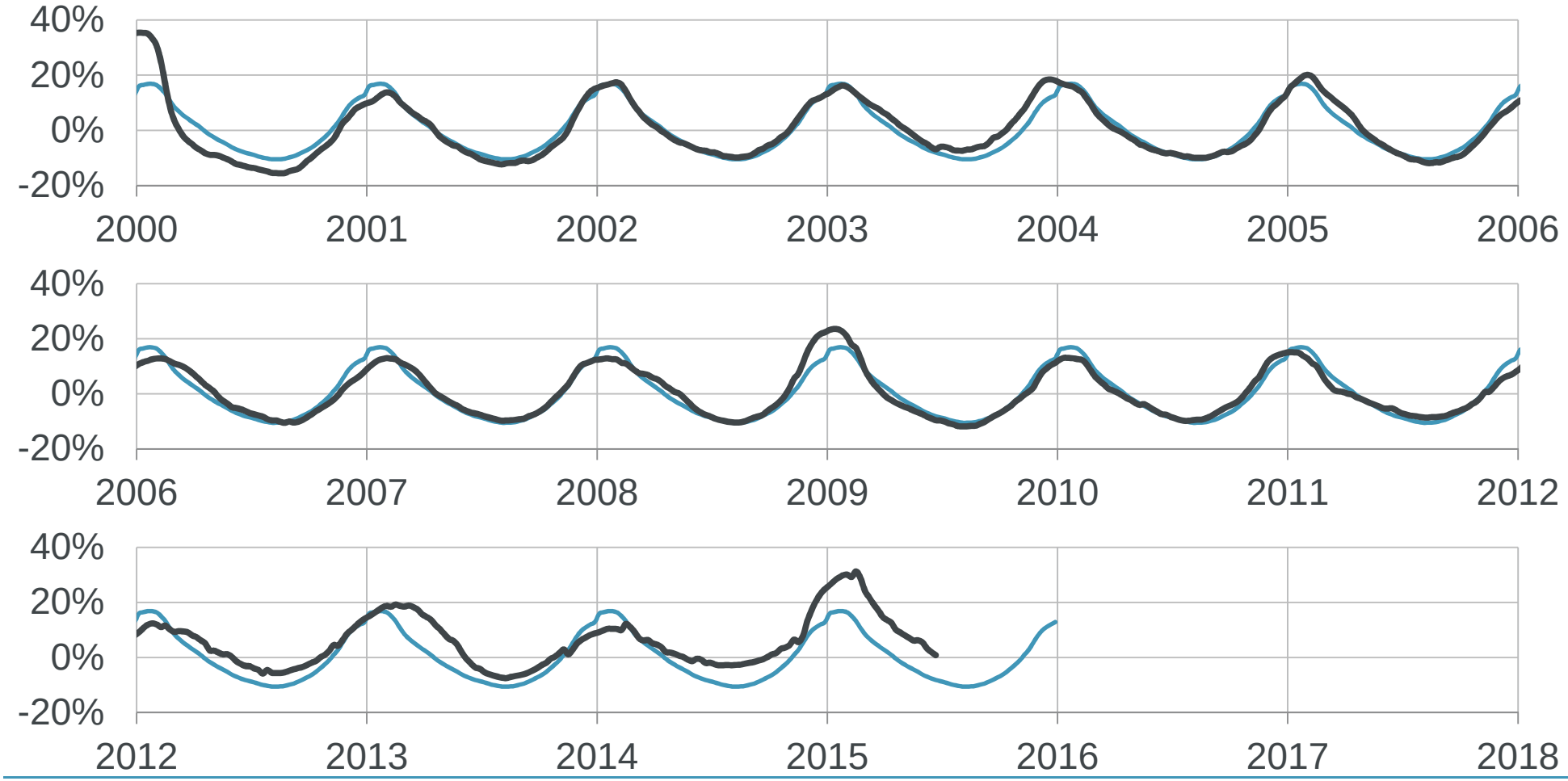
Seasonal mortality

13-week average standardised mortality ratio, relative to 2000-2011 trend



Seasonal mortality

13-week average standardised mortality ratio, relative to 2000-2011 trend, compared to seasonal average



Impact on projections

Components of crude mortality rates

1. Smooth, persistent, underlying long-term trends
   - e.g. lifestyle, medical, economic influences
2. Transient, short-term influences
   - e.g. infectious diseases, temperature
3. Poisson / individual / idiosyncratic risk
   - e.g. tossing a fair coin 100 times probably won't give 50 heads
4. Artefacts of the data
   - e.g. exposure data for 1919/1920 cohorts, and older ages

For long-term projections we typically want to extract the long-term trends.

Is 2011-2015 a new trend or a blip?

Trend: “A general direction in which something is developing or changing”

- e.g. lifestyle, medical, economic influences

Blip: “An **unexpected**, **minor**, and typically **temporary** deviation”

- e.g. infectious diseases, temperature

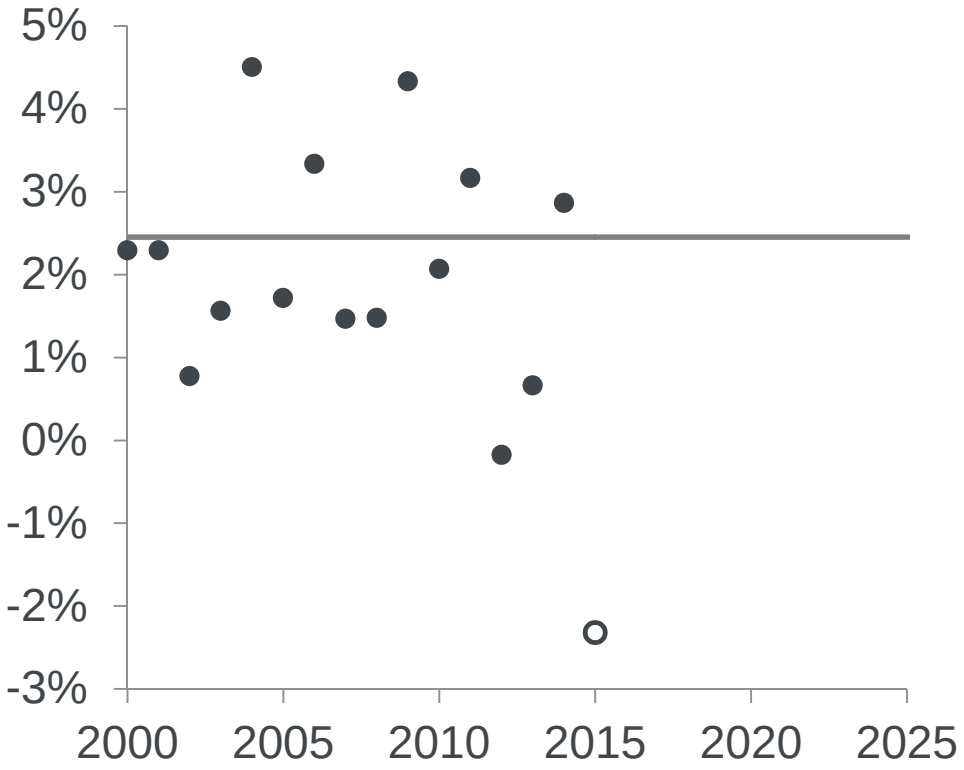
How might we project mortality if we think it is a new trend or just a blip?

Sources of definitions: oxforddictionaries.com

Historical mortality

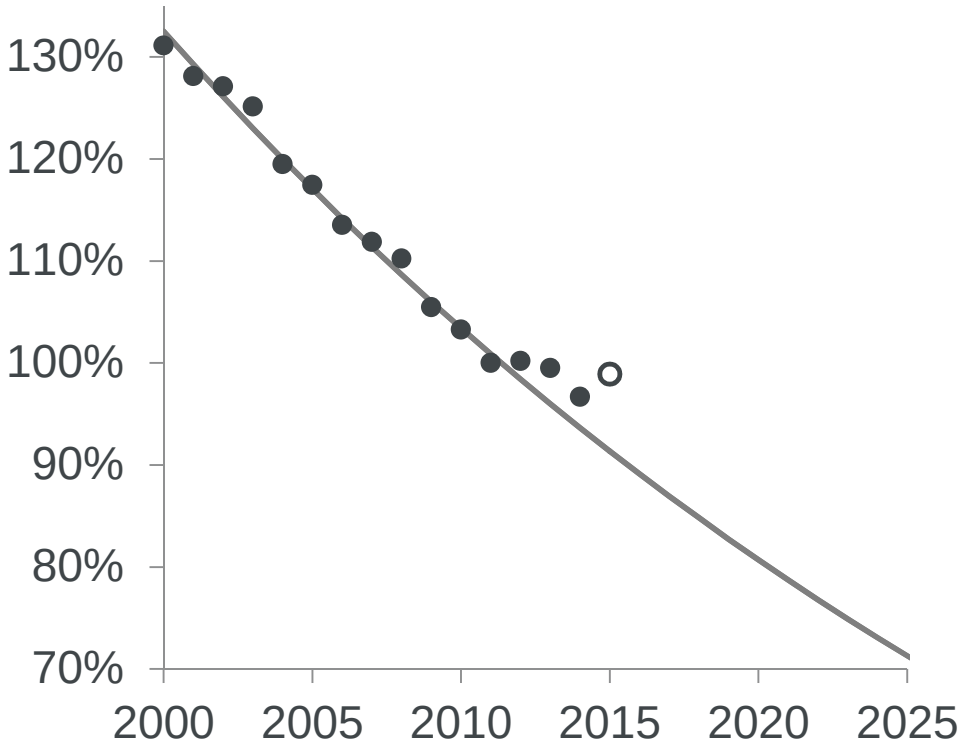
Mortality improvements

Lower in recent years



Standardized mortality ratio

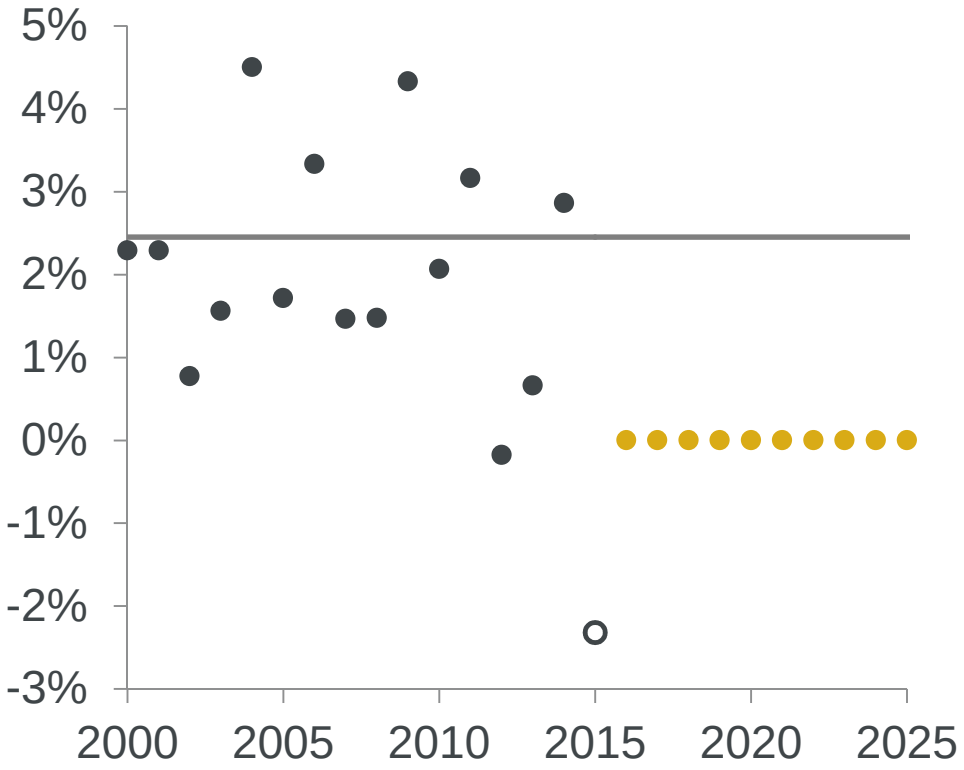
Starting to plateau or just a blip?



Possible future mortality scenarios

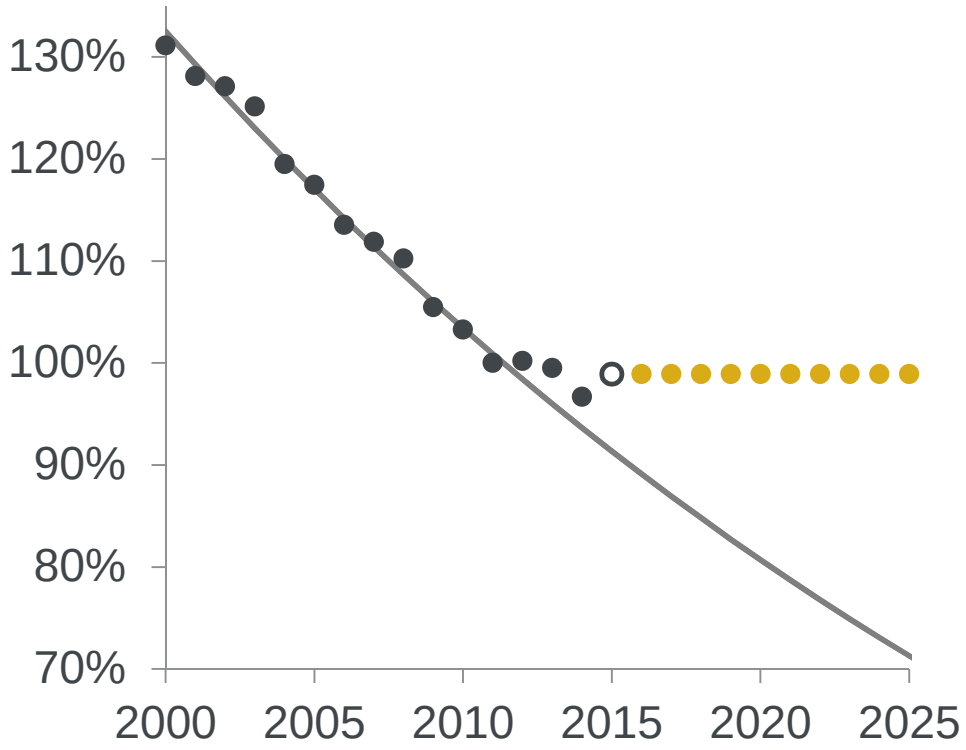
Mortality improvements

- New trend – no improvements



Standardized mortality ratio

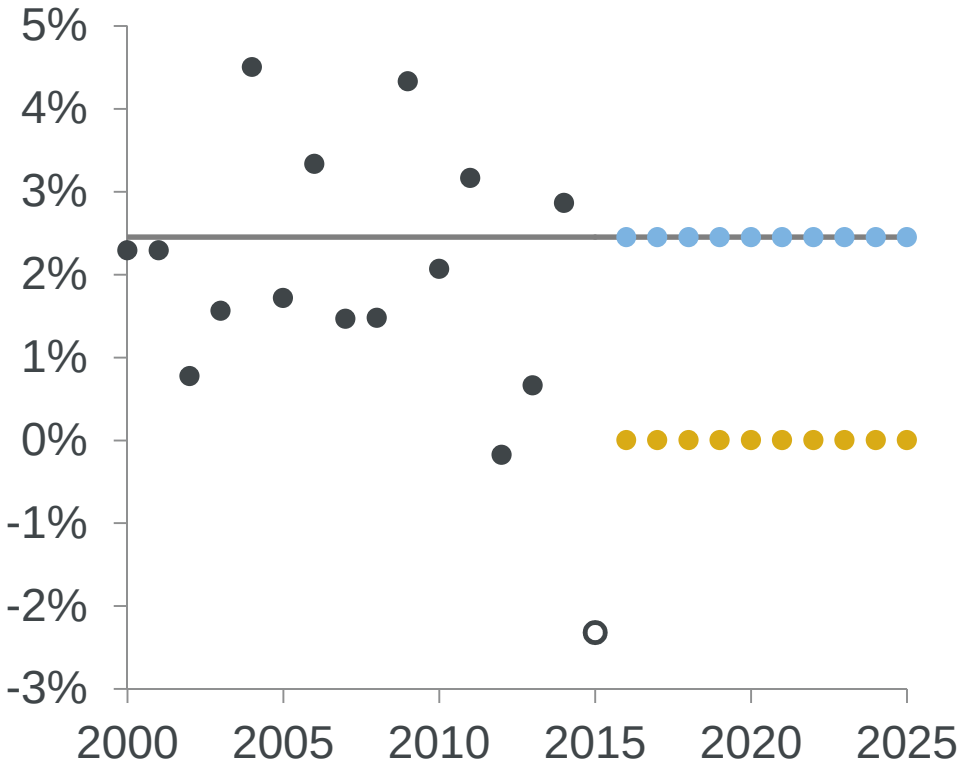
- Plateau continues



Possible future mortality scenarios

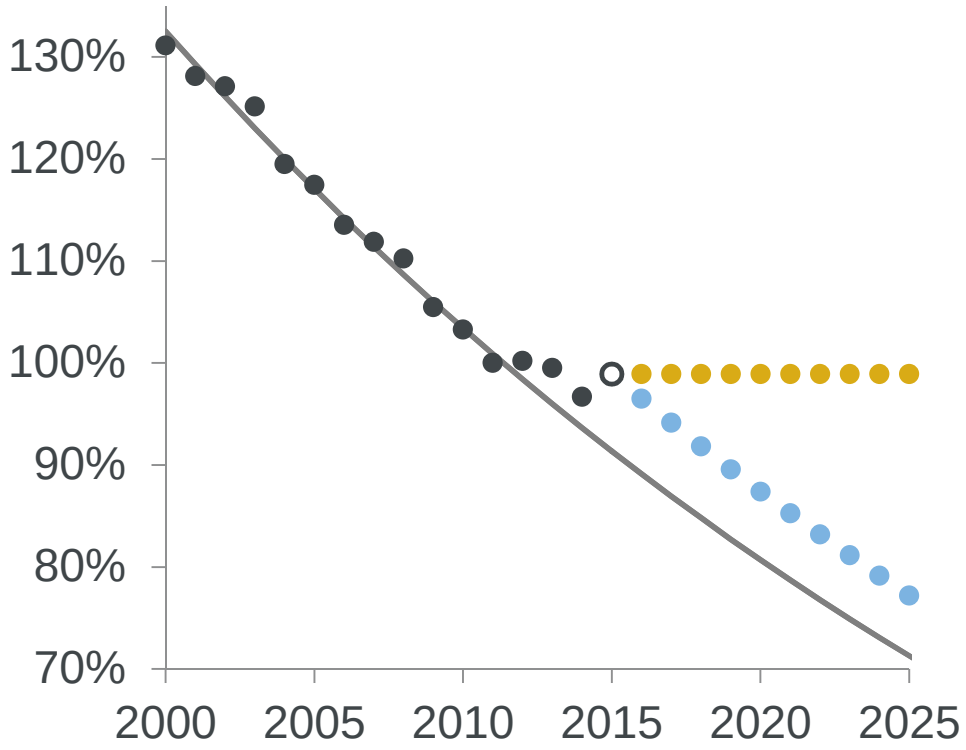
Mortality improvements

- Just a blip; back to 2000-11 trend



Standardized mortality ratio

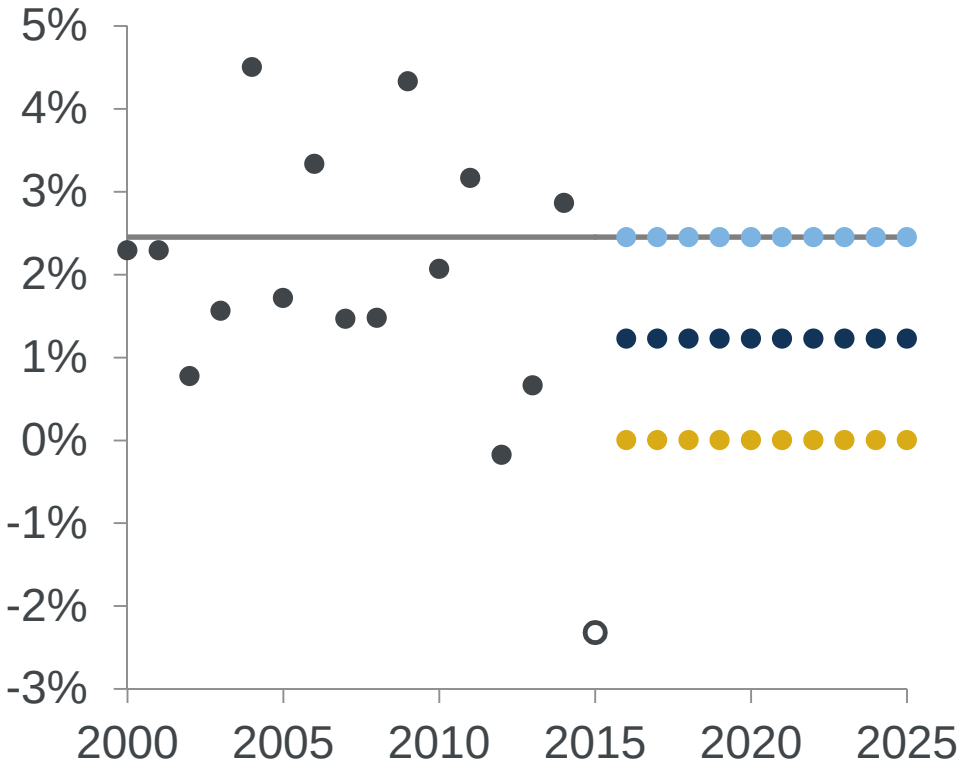
- Constant multiple of trend



Possible future mortality scenarios

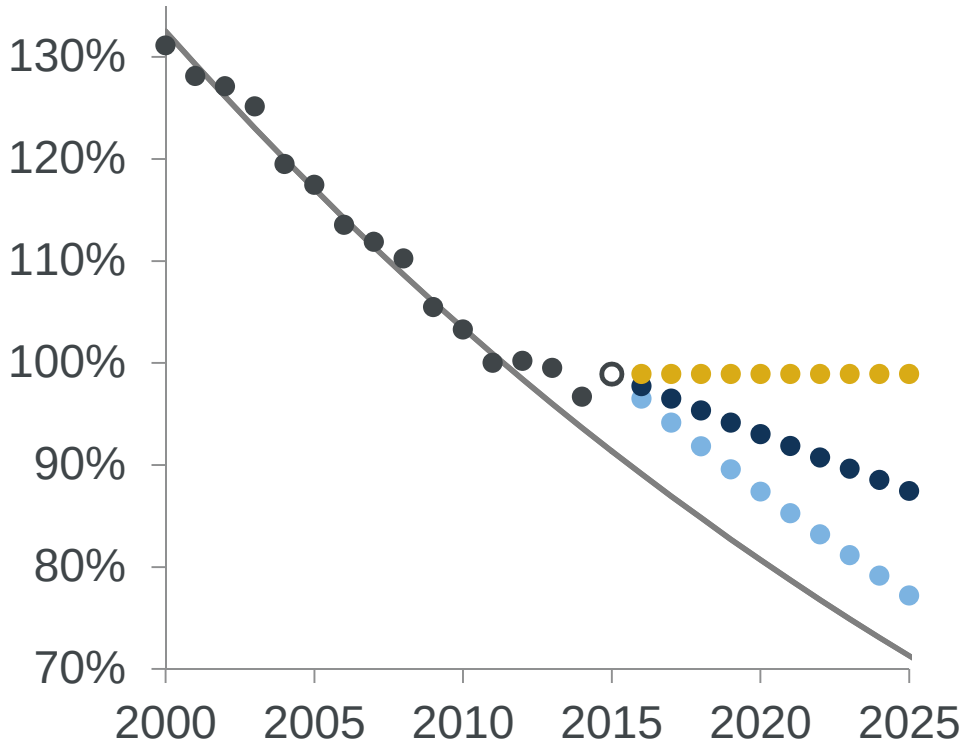
Mortality improvements

- Average of the recent past



Standardized mortality ratio

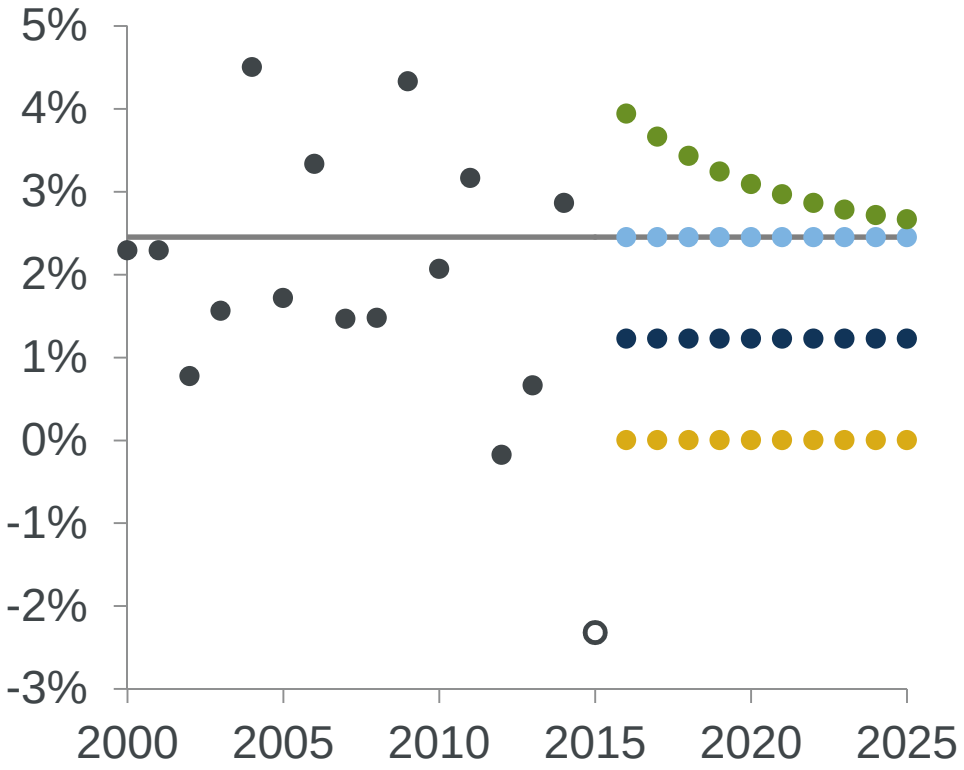
- Falling, but more slowly



Possible future mortality scenarios

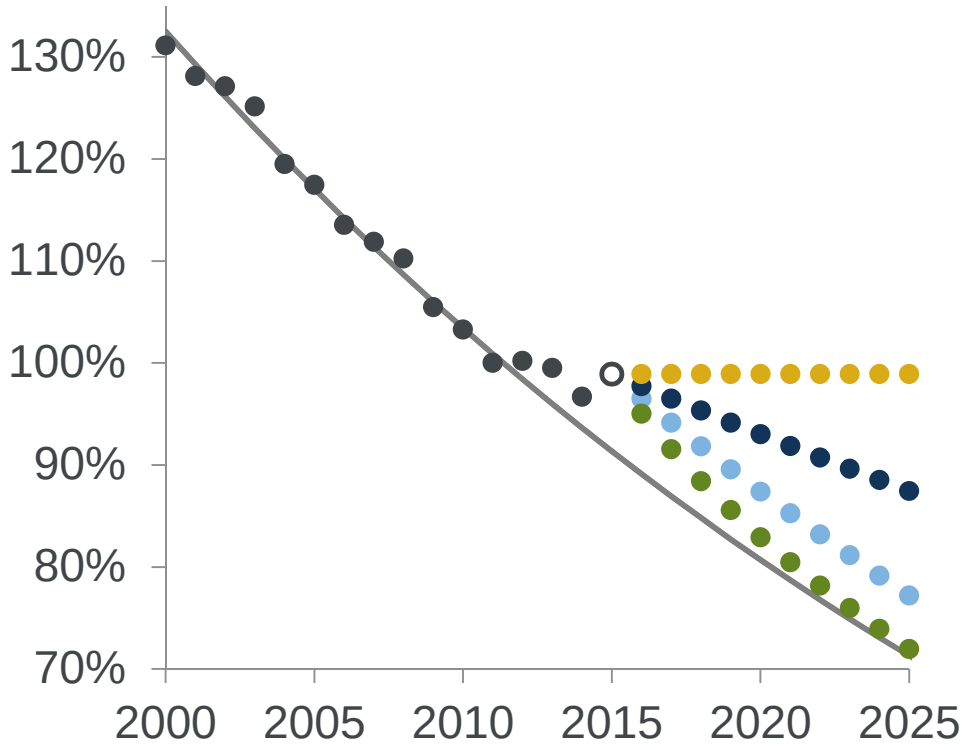
Mortality improvements

- Higher short-term improvements



Standardized mortality ratio

- Gradual return to trend



Changes between CMI Model versions

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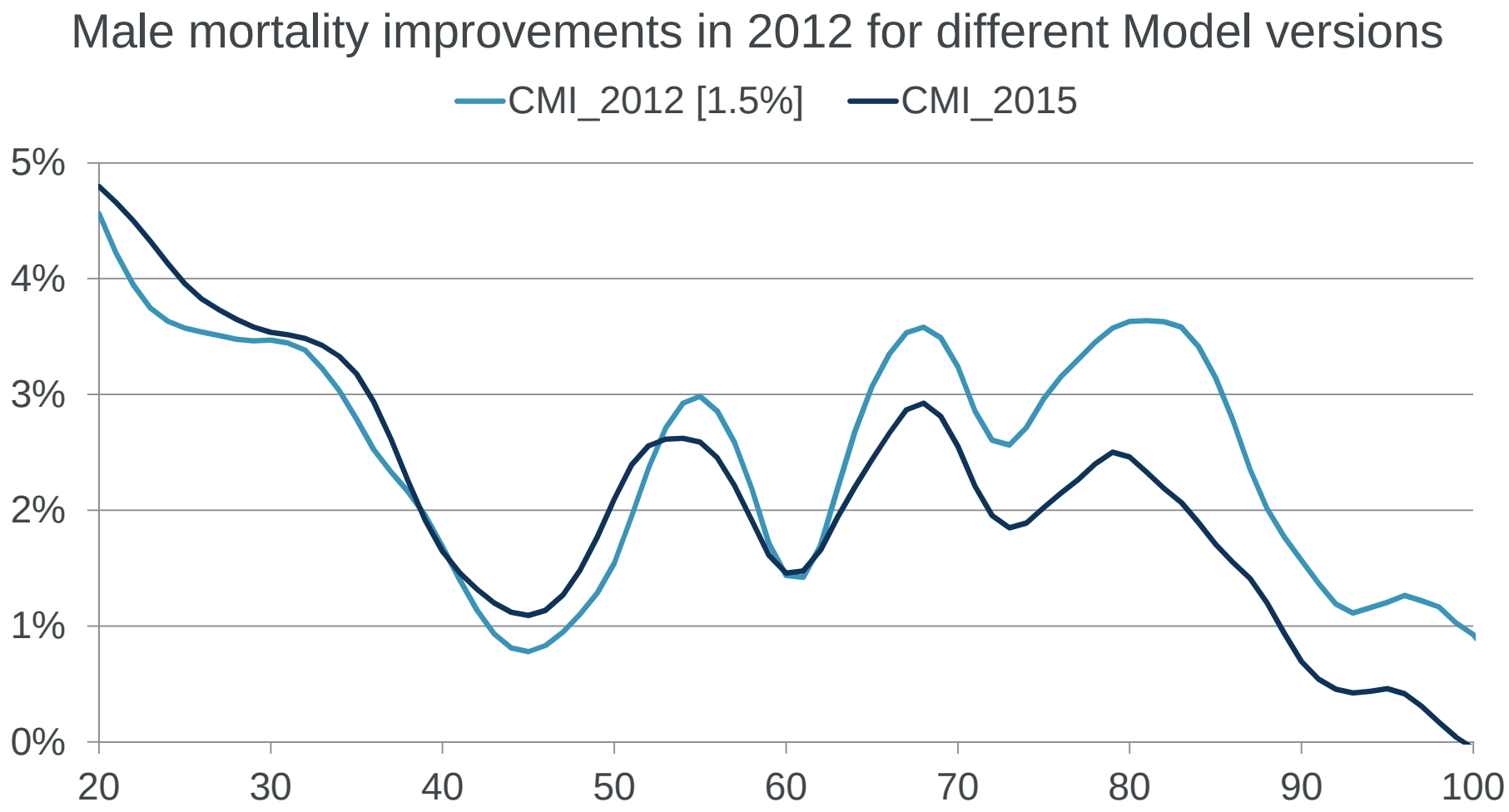
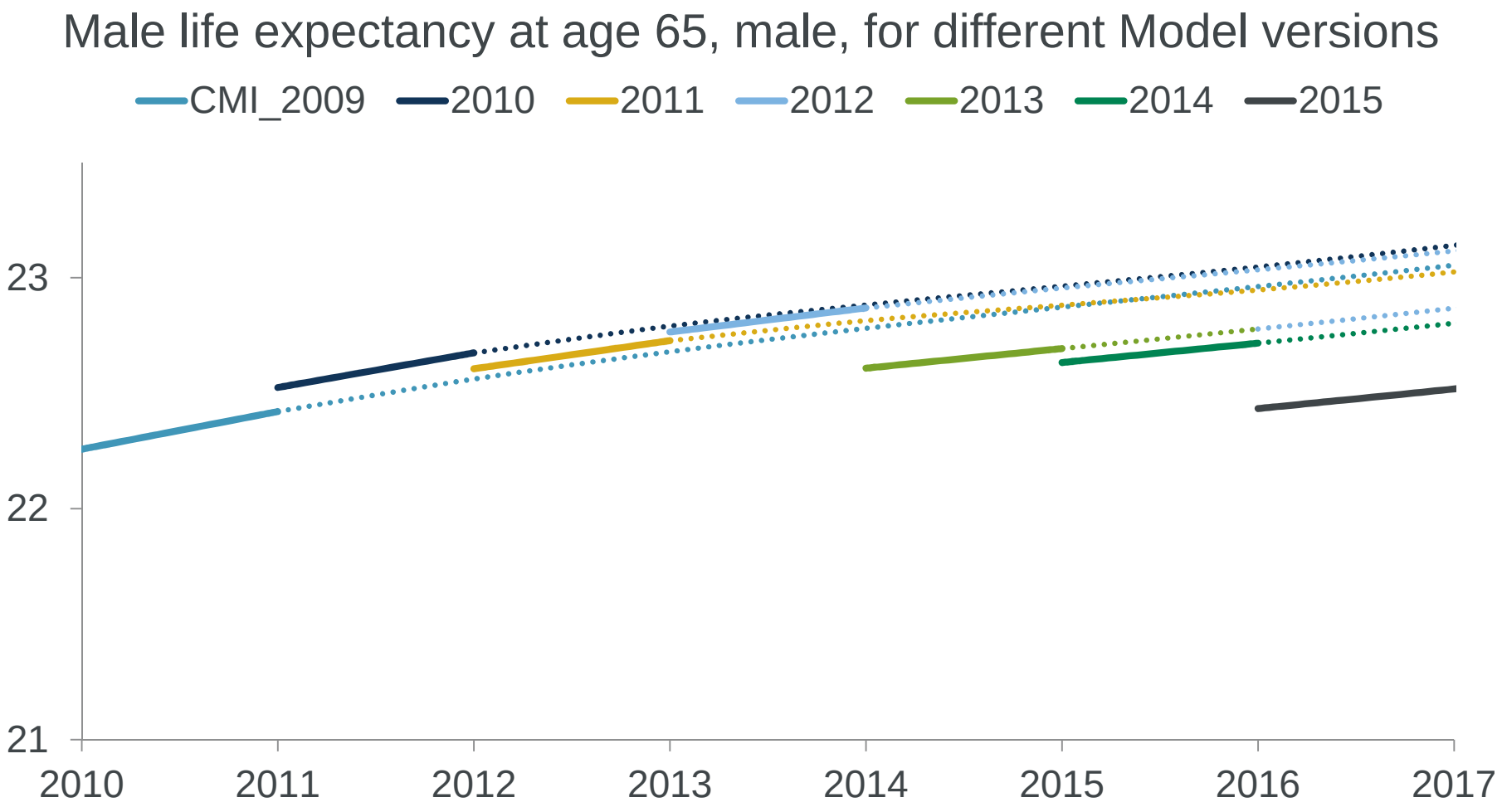


Changes between CMI Model versions



Assumptions: S2PMA at 1 January 2007, projected using CMI_20yy_M[1.5%]

Discussion questions

Discussion questions

- Is the 2011-2015 experience a blip or a new trend?
- How can we tell? What other data or evidence would help?

- Is the response of CMI_2015 to recent experience too strong, too weak, or about right?

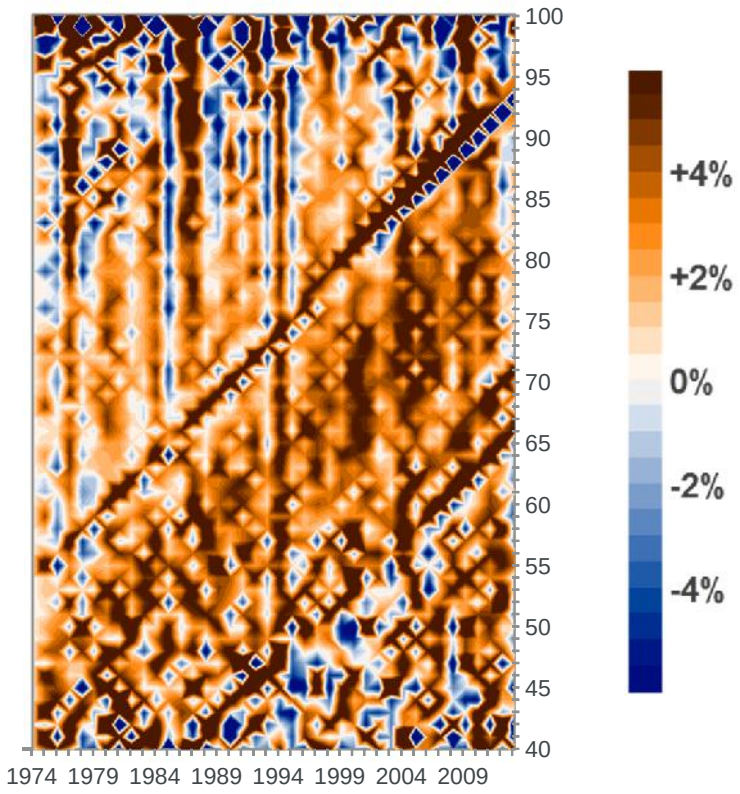
Data

Brian Sewell

Data Behind the Current Model

- ONS population data for England & Wales
  - Mid-year population estimates
  - Registered deaths
- 40 year period
- Ages 18 to 102
- Males and females
- Over 90's derived using a Kannisto-Thatcher based approach (as used by ONS)

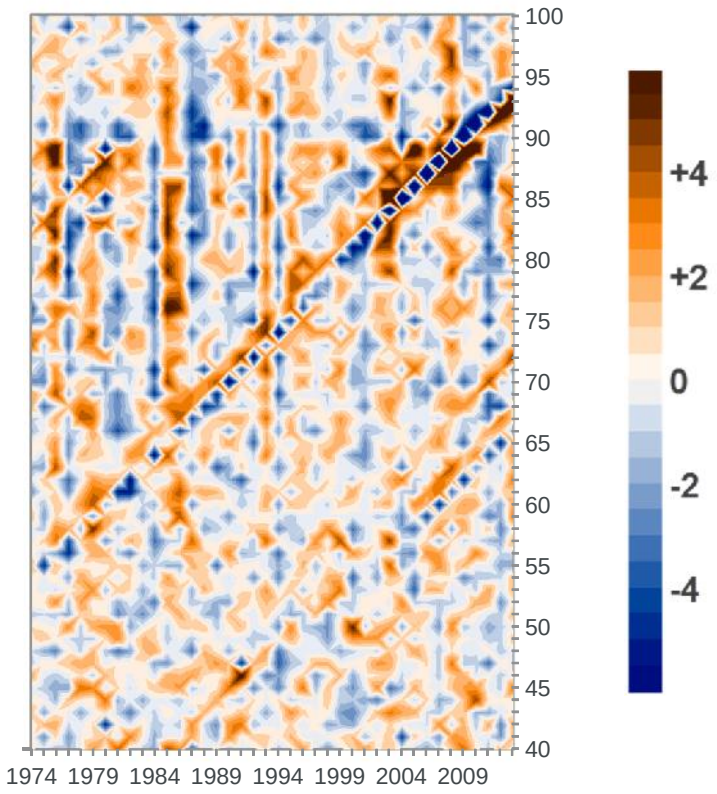
Raw Mortality Improvements



Data Behind the Current Model

- Model fitting
  - P-Spline Age Cohort Model
- Overdispersion
  - Variance Inflation Factor : 2.27
- Strongest patterns mimic patterns seen in mortality improvements

Deviance Residuals



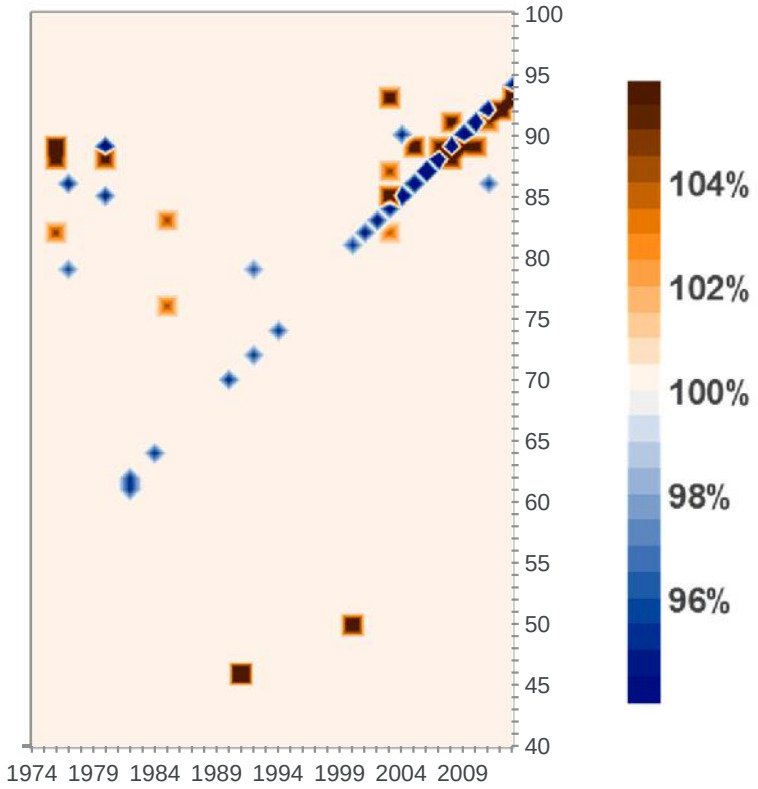
Phantoms Never Die

- Andrew J G Cairns, David Blake, Kevin Dowd, Amy Kessler
  - *http://www.pensions-institute.org/workingpapers/wp1410.pdf*
- Covers:
  - Propagation of Errors in Population Estimates Through Time
  - Linear run-off of those Errors over Inter-censal Periods
  - Census Date to Mid Year Shift in 2001
  - Mid Year Population Estimates not always a Good Proxy for Exposure
- Develops:
  - Graphical Techniques for Identifying Issues
  - Generic Approach to ‘correcting’ Exposure Data

Method used in CMI_2014 and CMI_2015

- Fitted p-spline age cohort model as normal
- Identified cells resulting in extreme residuals (p<=0.01%) after the first fit
- Adjusted exposures in those cells so that raw rate equals fitted rate
- Re-fitted the model using adjusted exposures

Adjustments to Exposures



Other Issues – Age 90+ Method?

- 1919 cohort entered the 90+ group in 2009
  - CMI mirrors ONS approach to deriving individual year estimates for 90+
    - For closed cohorts simply rolls back from deaths
    - For open cohorts incorporates survivor ratio's from previous cohorts
  - Still a significant adjustment required to tie this in with the 90+ total

- Ideas to Investigate…
  - Investigate effect of distribution of births on the 90+ method
  - Investigate suitability of applying with a lower age bound?
    - High age methodology based on registered deaths *potentially* more reliable than population estimates? (Assuming minimal migration at older ages.)

Discussion questions

- Should we continue trying to investigate and fix suspected issues with the ONS E&W data set?
  - Will give more comfort in the results of our initial model fitting
  - Ties in with, and may help, the work of the High Age Mortality Working Party

- Or should we be looking at developing and implementing techniques to ‘fix’ any data set when used with the CMI Mortality Projections Model?
  - So that users could apply them, for example, to other countries population data

Responsiveness, stability and prediction

Matthew Fletcher

How should a model respond to new data?

- Two questions:
  - **Does mortality show a pattern over time?**
    - Do heavy years of mortality follow light years?
    - Do years of high improvement follow years of low improvement?
    - If so, should we allow for this in fitting and projecting mortality rates?
  - **How much smoothing should be applied in building a predictive model?**
    - Are ‘better fitting’ models the same as ‘better predicting’ models?
    - Are Information Criteria a useful guide?

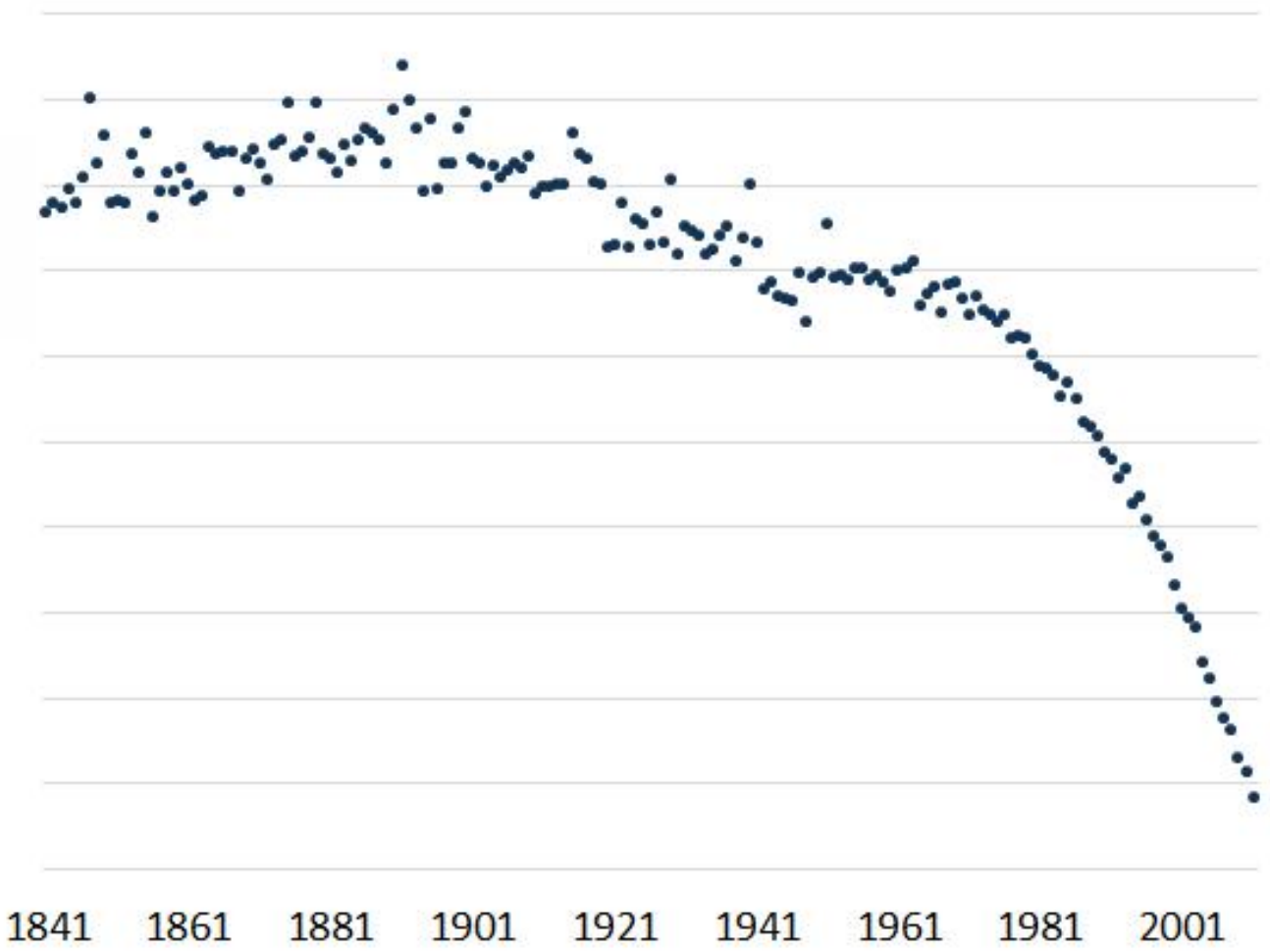
Source for all data used in this section: *Human Mortality Database*. University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany) www.mortality.org

How to interpret a new year of data?

- Fit a Lee-Carter model based on E&W male data:

$$\ln m_{at} = \alpha_a + \beta_a \kappa_t + \varepsilon_{at}$$

- Extract the period element, κ_t **(blue dots)**



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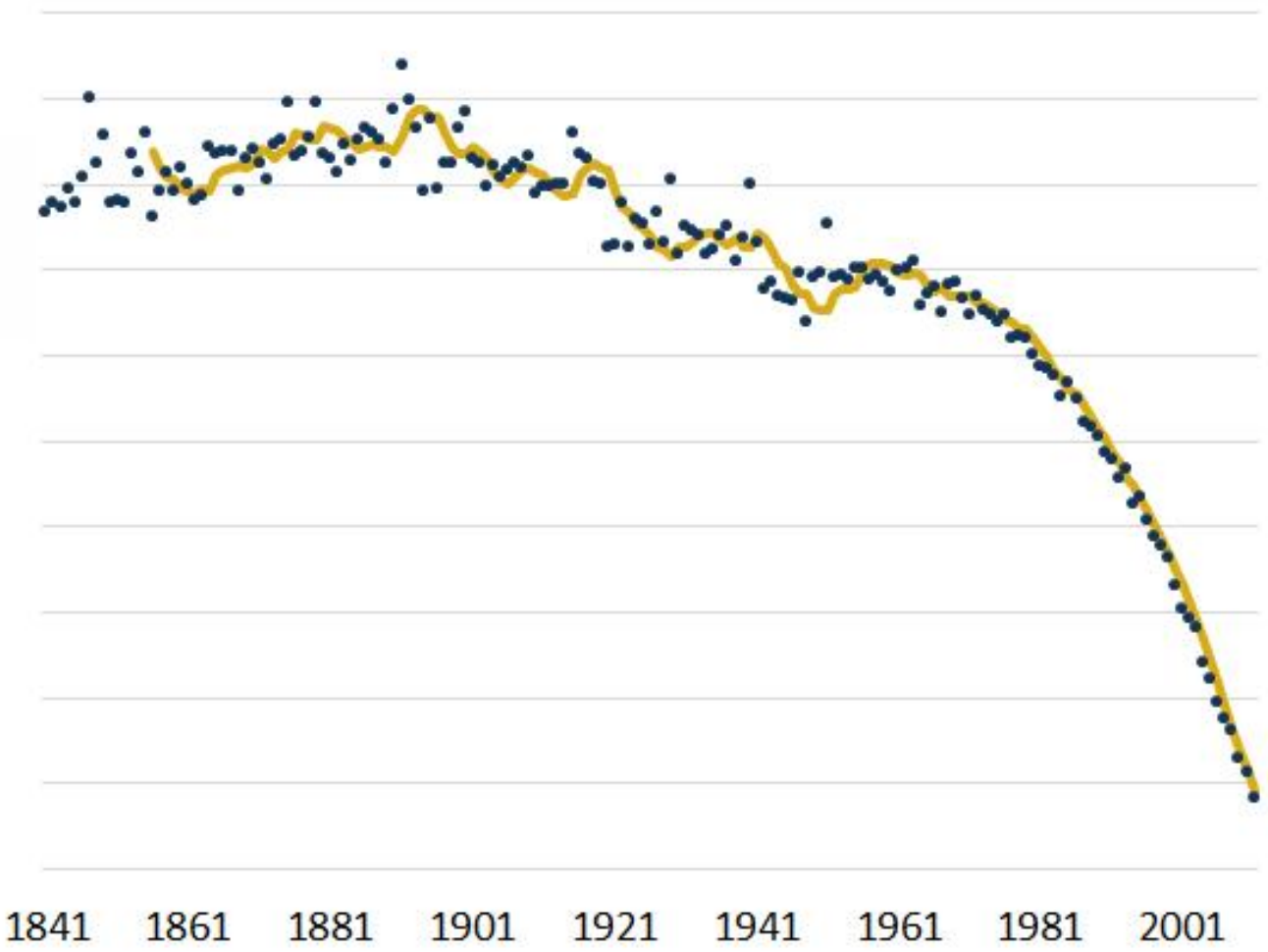
- Add rough trend line based on linear extrapolation of previous 15 years **(gold line)**



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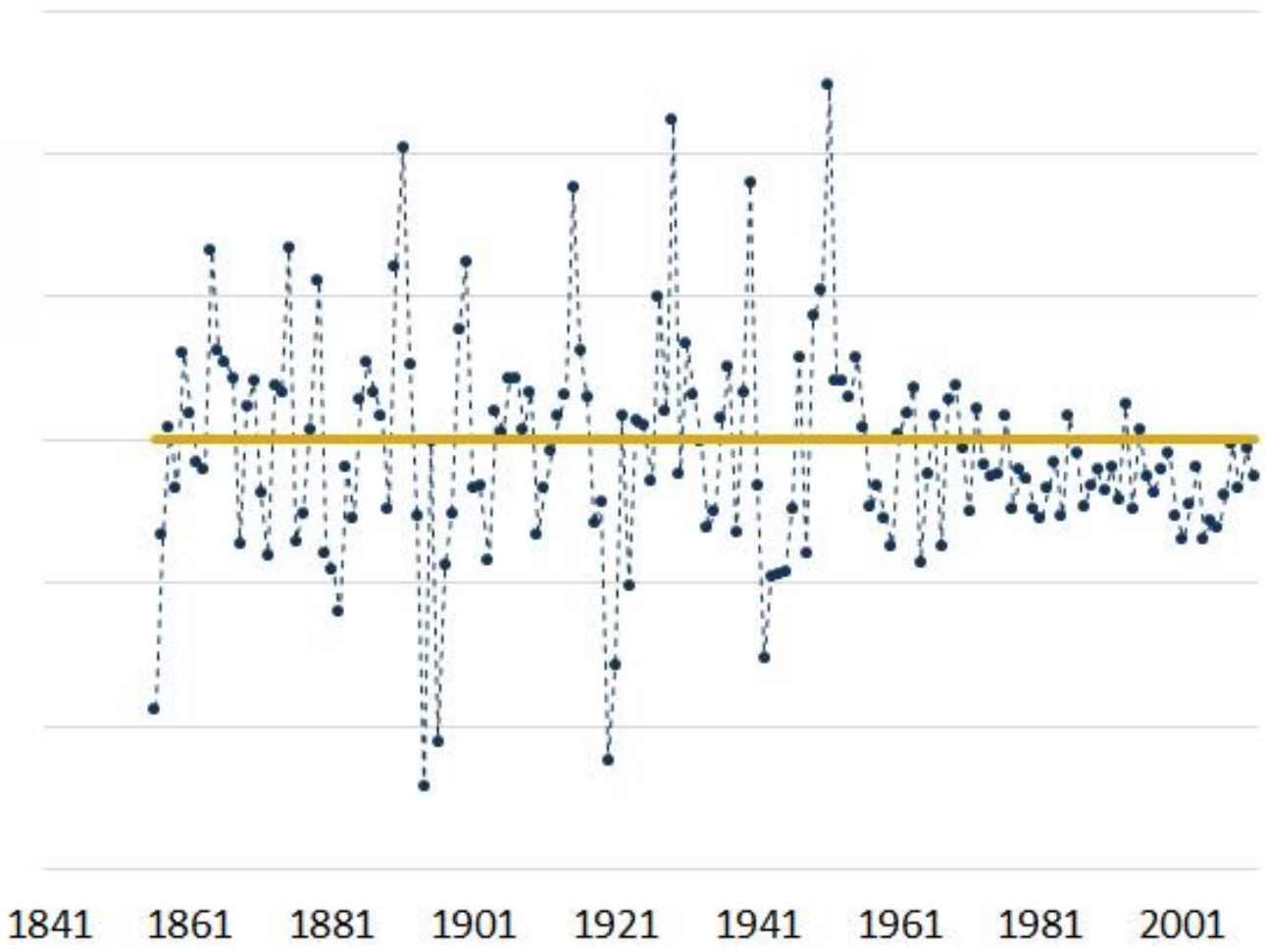
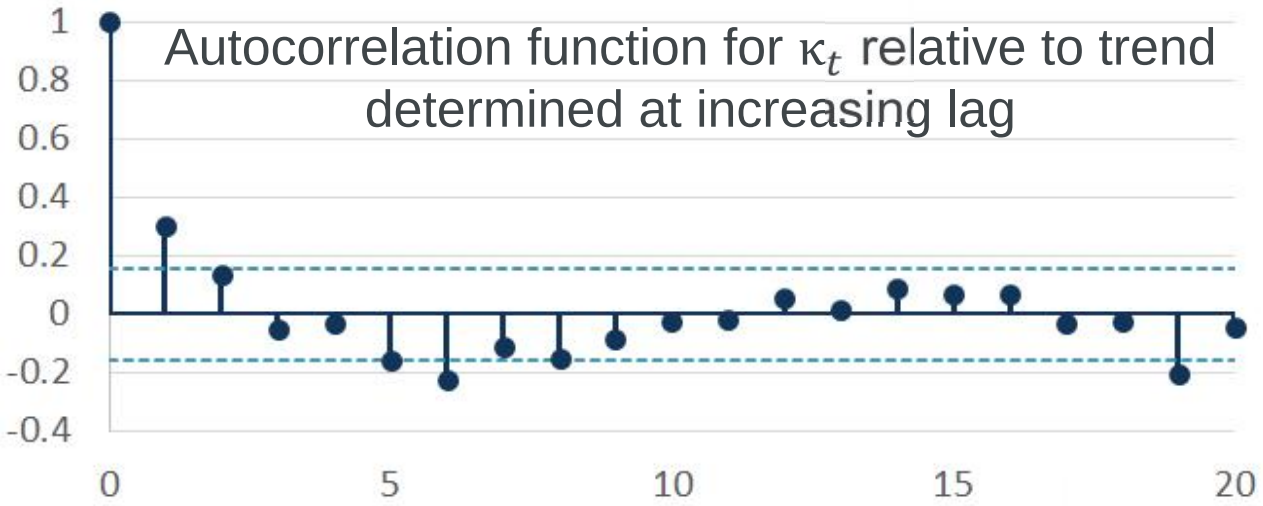
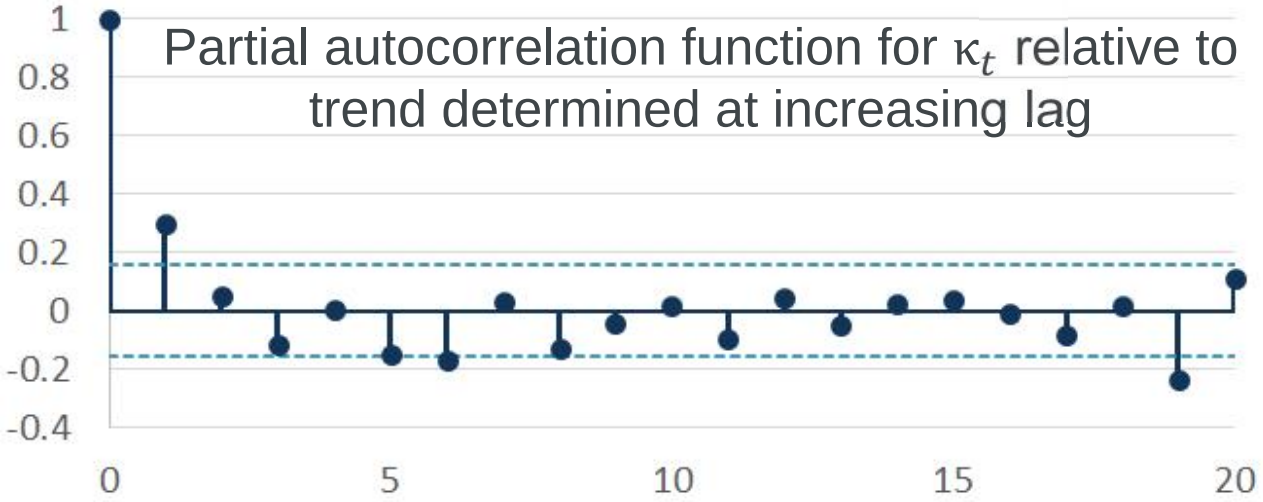
- Extract the period element, κ_t **(blue dots)**
- Add rough trend line based on linear extrapolation of previous 15 years **(gold line)**
- Take difference to give rough stationarity



How to interpret a new year of data?

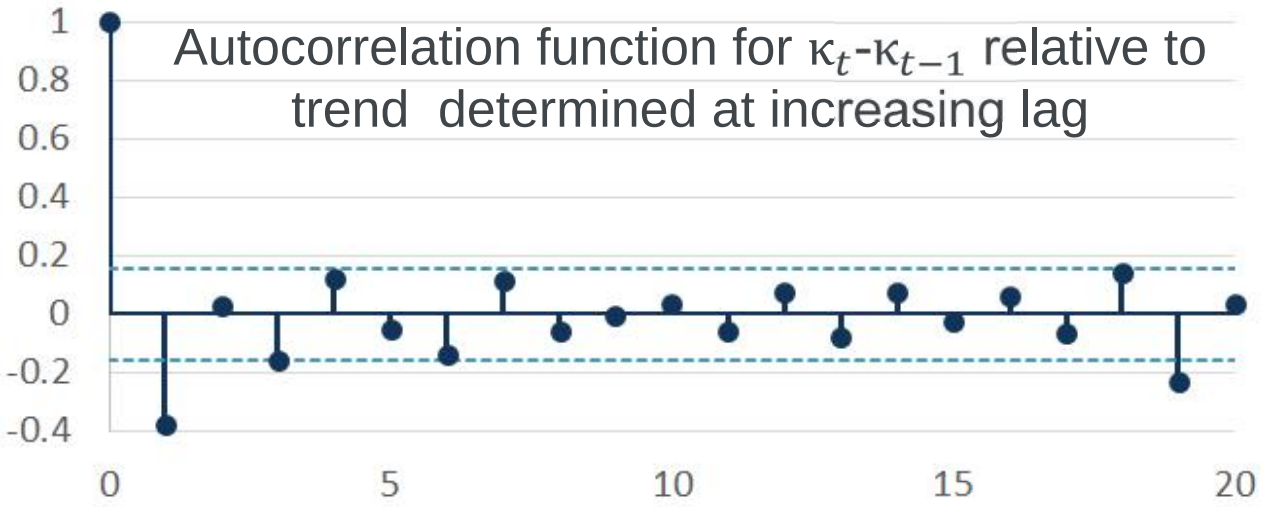
- At lag of one year there is a degree of positive correlation.
- After a year with above trend mortality rates, the following year is likely again to have mortality rates above trend, but moving closer to trend
- The correlograms do not suggest that the observed κ_t relative to recent trend represent a memoryless, white noise process.

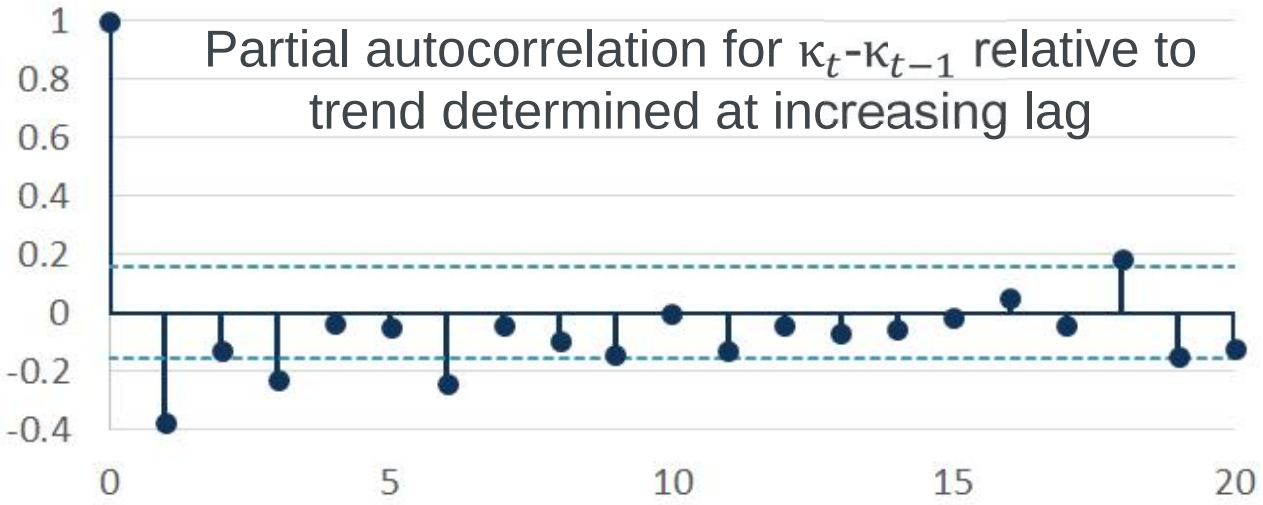




How to interpret a new year of data?

- Can consider the first difference process (which is akin to the mortality improvement process)
- At lag of one year there is negative correlation.
- After a year with mortality improvement above the determined trend, the following year is likely to have mortality improvements below the determined improvement trend



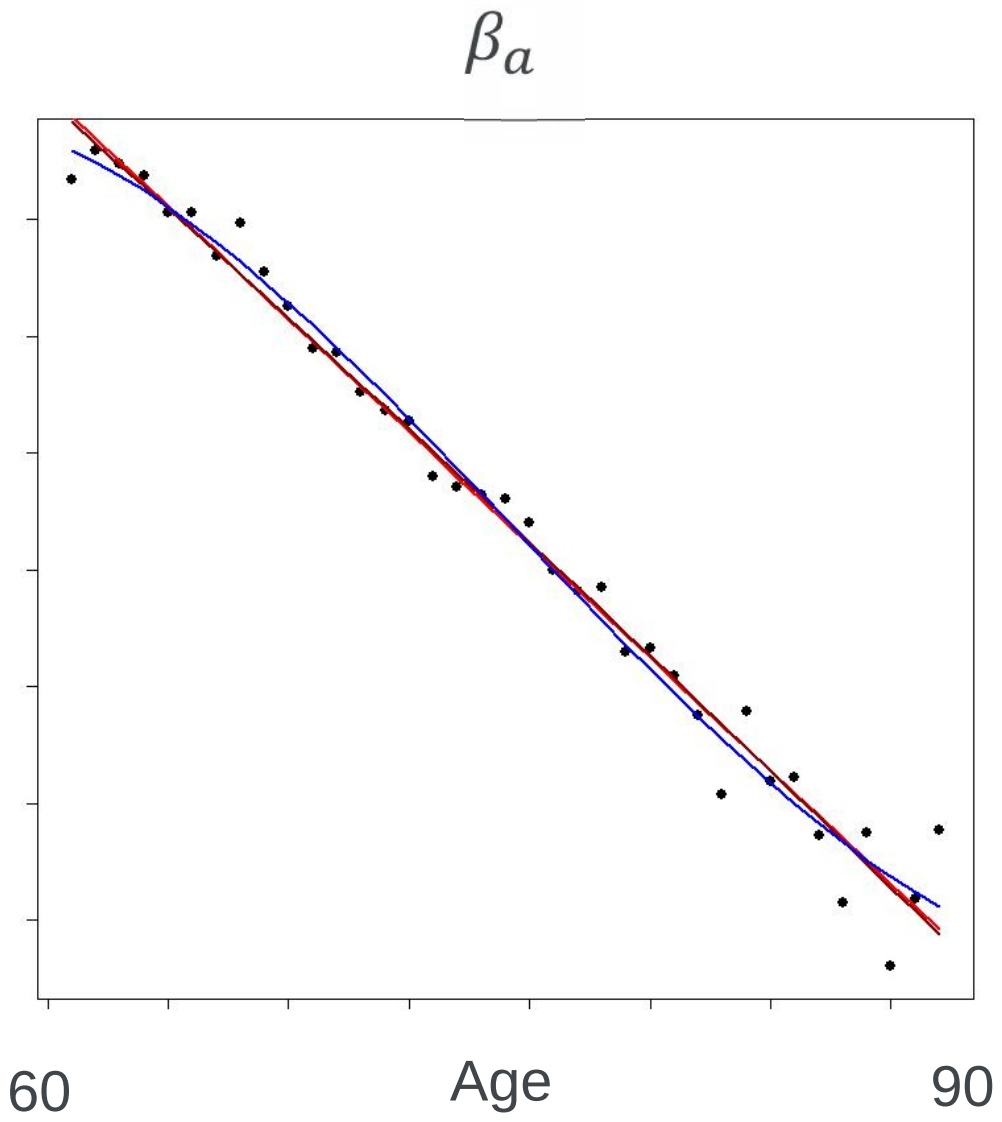


Ability to predict

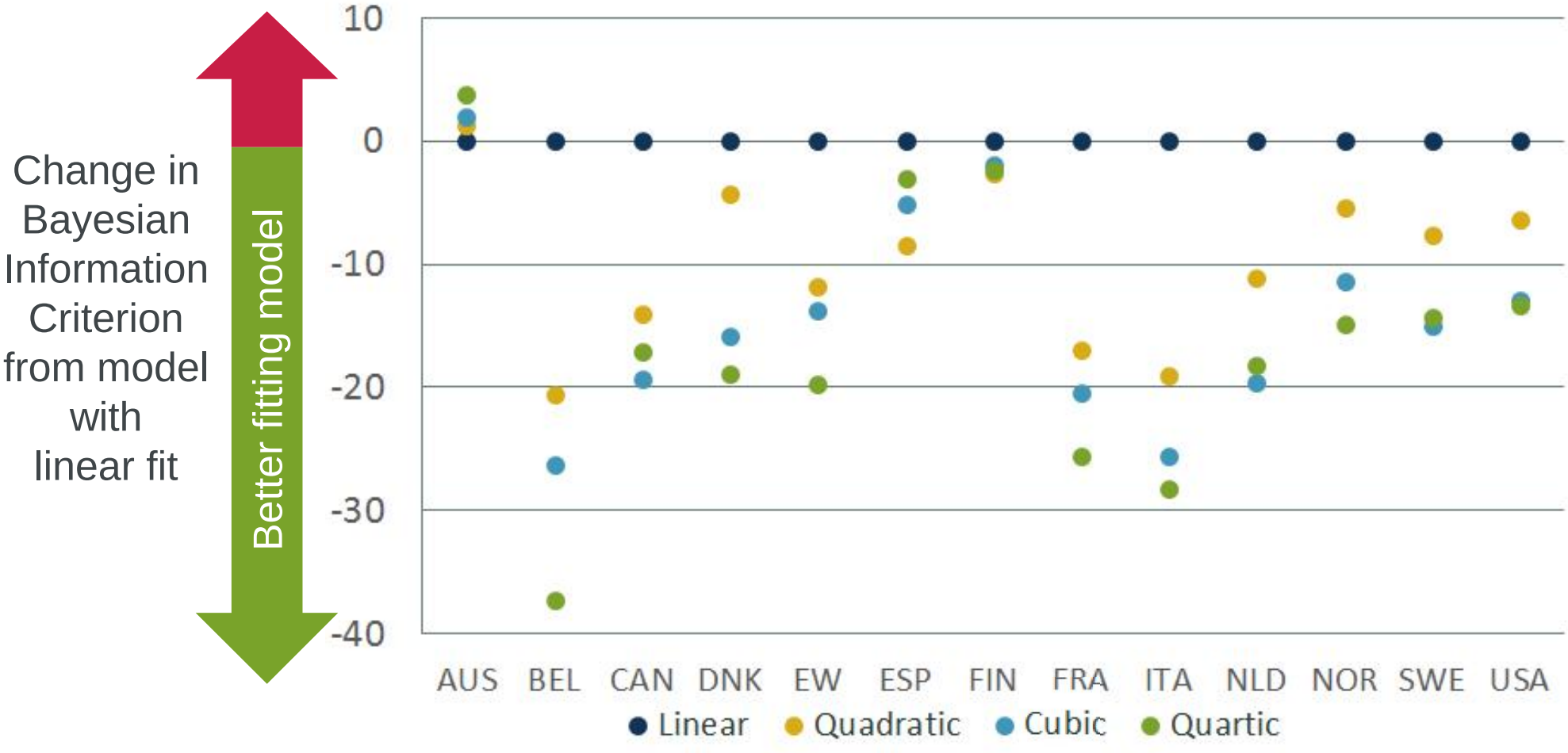
- Fit a Lee-Carter model based on a forty year window of data:

$$\ln m_{at} = \alpha_a + \beta_a \kappa_t + \varepsilon_{at}$$

- Project mortality rates forward for a further 10 years
  - Using the raw result for β_a
  - Using a polynomial fit for β_a
- Compare predicted (period) life expectancy with actual life expectancy
- Repeat for a sequence of rolling periods
- Repeat for a range of countries



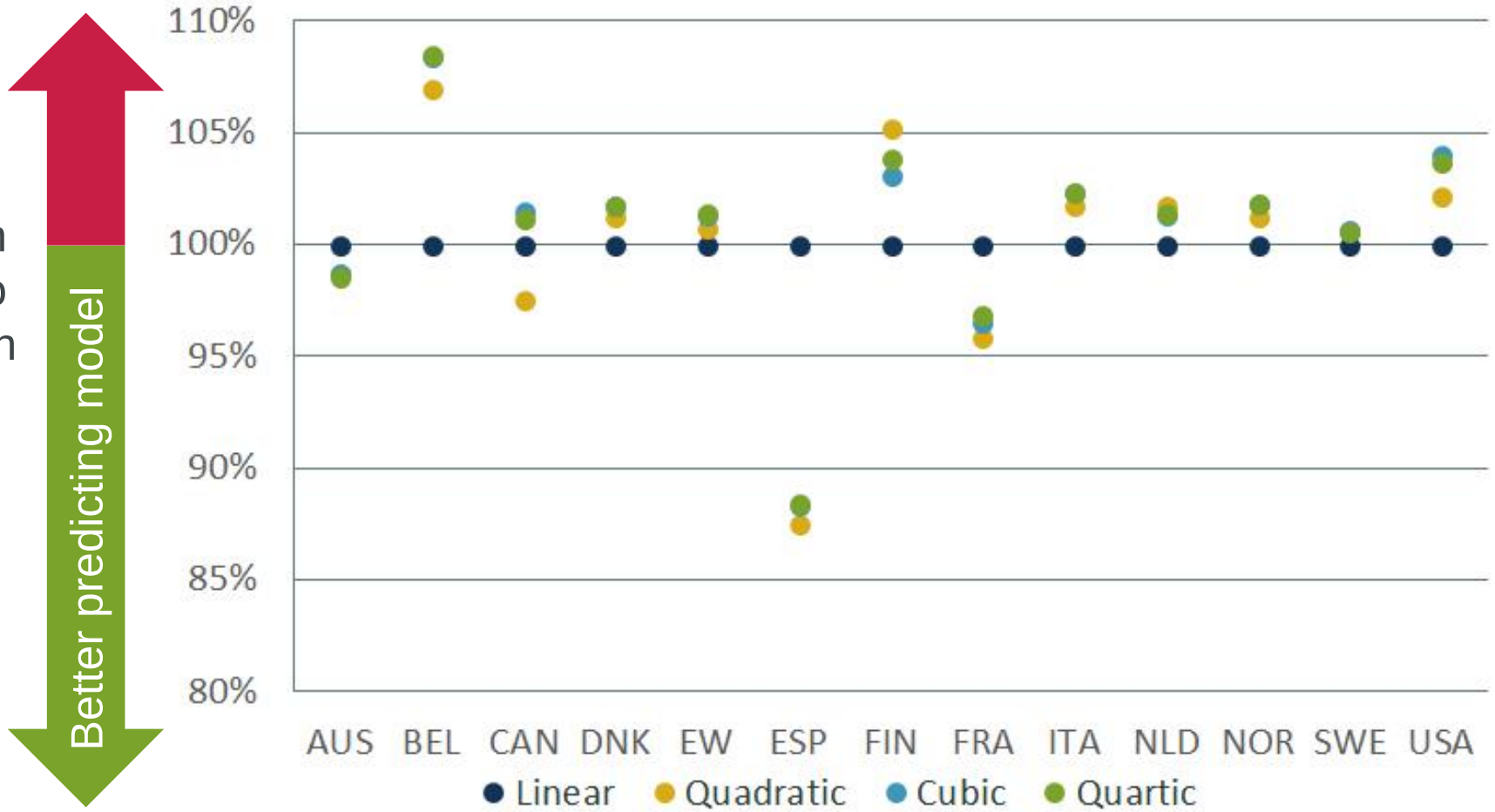
Which polynomial provides the best fit?



The information criterion suggest that a higher order polynomial is warranted to describe the shape of β_a in all but one case

Which polynomial best predicts?

Error in prediction relative to model with linear fit



In nine of 13 cases, the simplest model performed best in out-of-sample prediction. No material increase in predictive power in any case beyond quadratic fit.

Discussion questions

- **Does mortality show a pattern over time?**
  - Aim should be to use a model which does not show auto-correlation in its predictions. If there is auto-correlation in the raw data, how can a model be constructed which allows for this?
  - The current CMI model smooths the observed mortality rates then 'steps-back' to remove these edge effects. Is the current level of smoothing sufficient to negate any auto-correlation?

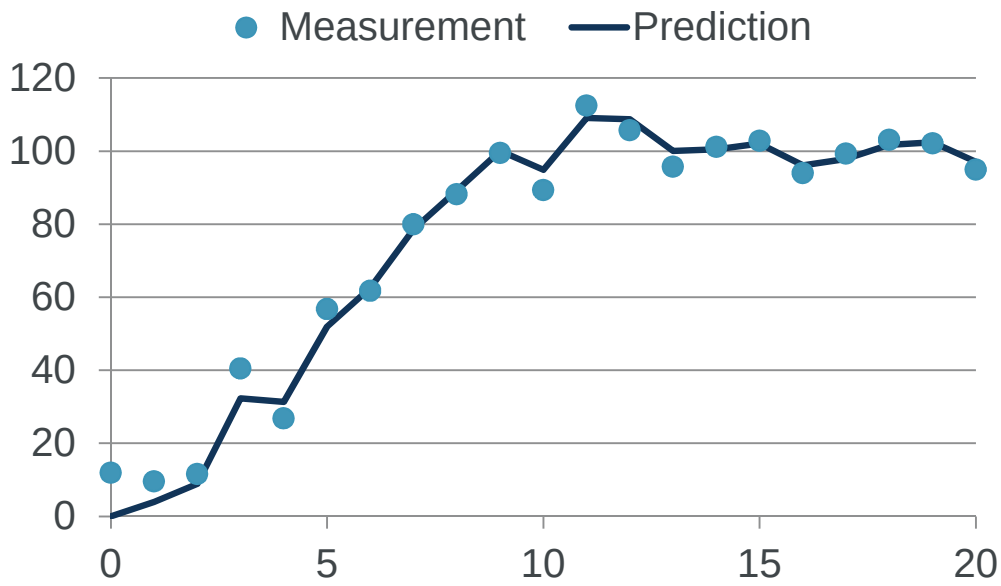
- **How much smoothing should be applied in building a predictive model?**
  - Would a smoother fit give a better prediction of life expectancy?
  - Would a smoother fit respond too slowly to an underlying change in trend?
  - The current CMI model uses QBIC, which allows for over-dispersion and leads to a smoother fit than unadjusted BIC. Are there other metrics to guide the level of smoothing to apply, which target predictive ability?

Updating for new information

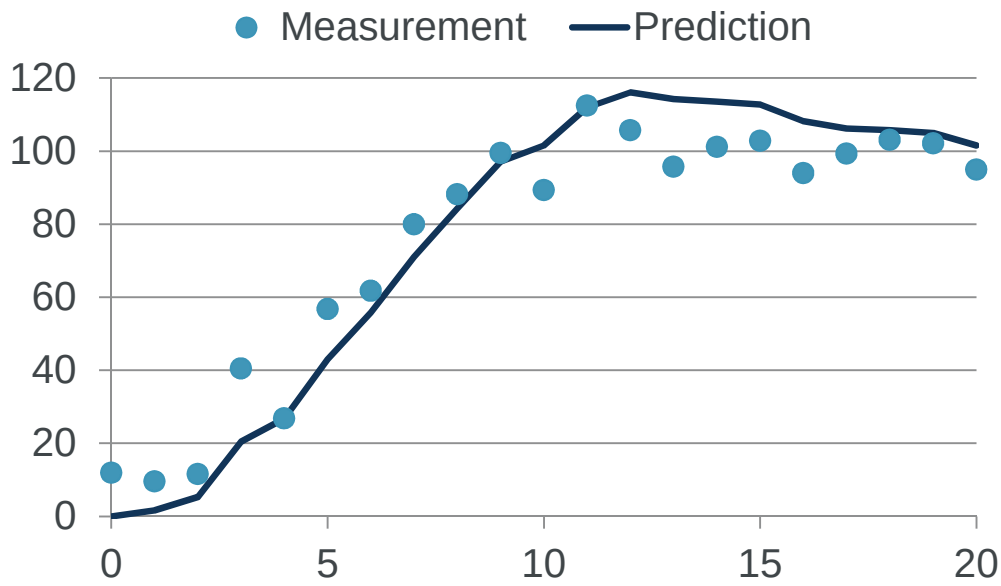
Steve Bale

What weight do we put on new information?

- Example – a moving object stopping after 100m



More emphasis placed on the measurement



More emphasis placed on the prediction

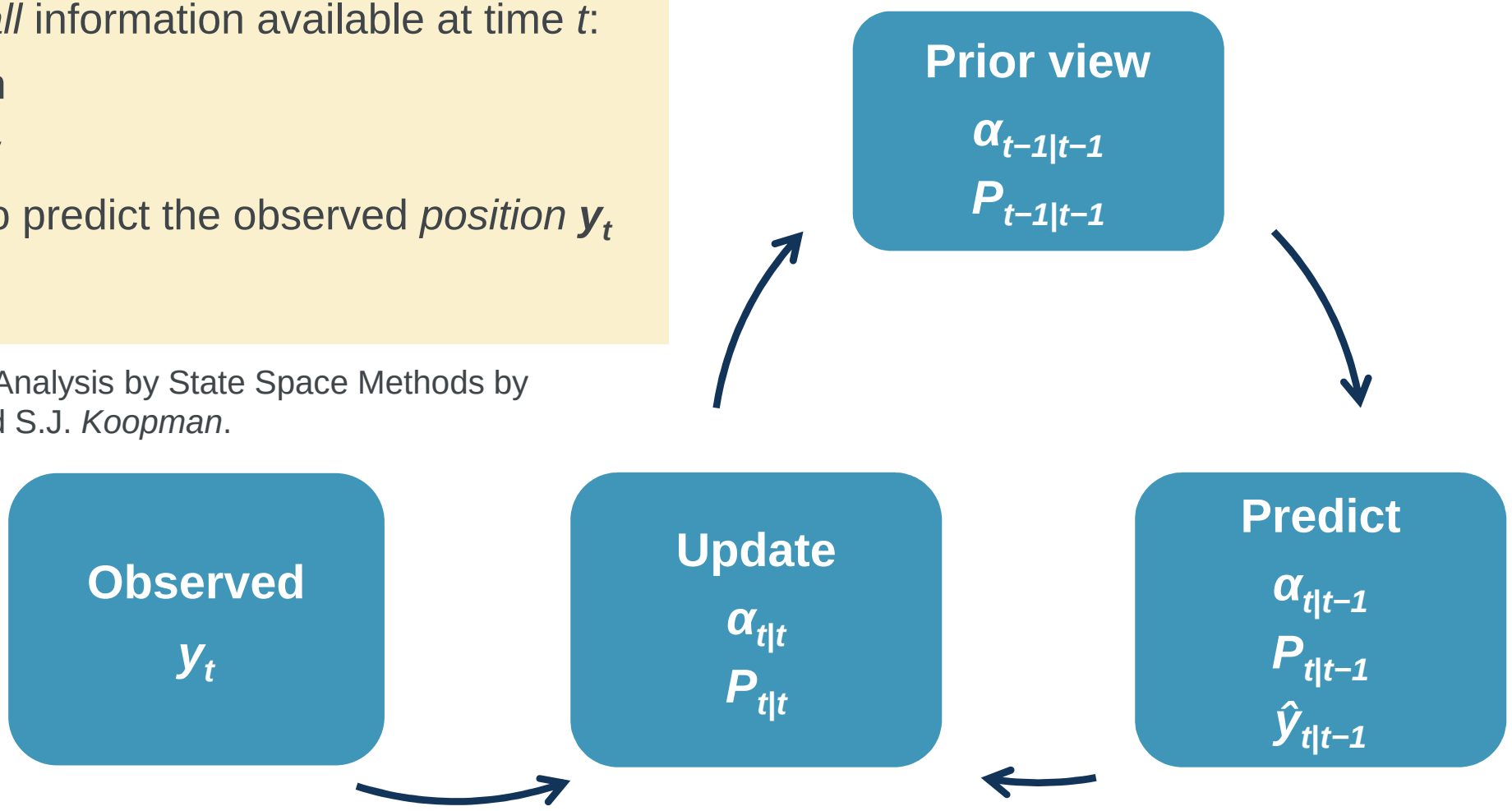
Kalman Filter Smoothing – Moving Object

The state vector $\boldsymbol{\alpha}_t$ and its uncertainty $\boldsymbol{P}_t$ contains *all* information available at time *t*:

- position
- velocity

Use this to predict the observed *position* $\boldsymbol{y}_t$

Time Series Analysis by State Space Methods by J. *Durbin* and S.J. *Koopman*.



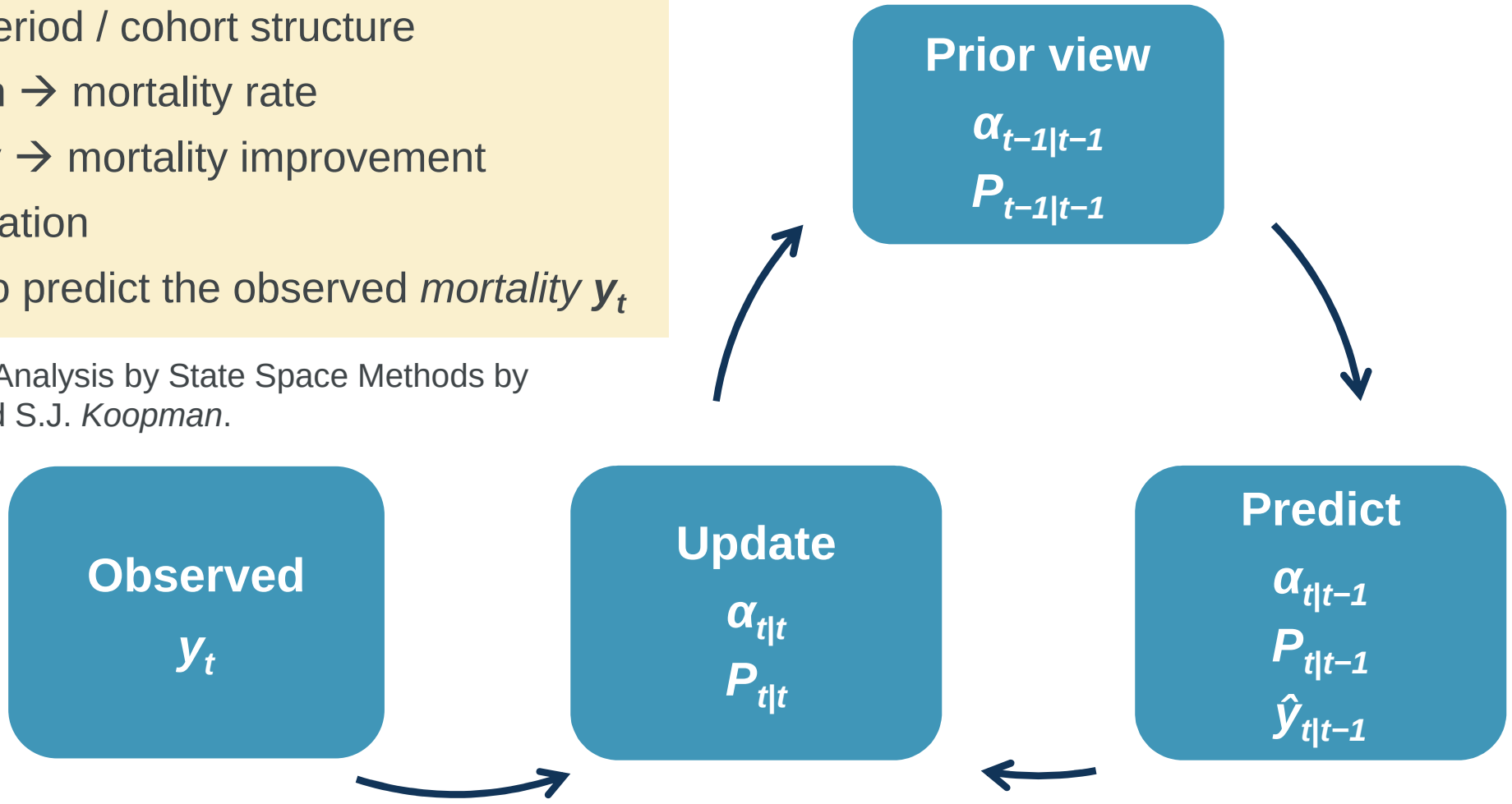
Kalman Filter Smoothing – Mortality

The state vector $\boldsymbol{\alpha}_t$ and its uncertainty $\boldsymbol{P}_t$:

- age / period / cohort structure
- position → mortality rate
- velocity → mortality improvement
- acceleration

Use this to predict the observed *mortality* $\boldsymbol{y}_t$

Time Series Analysis by State Space Methods by J. *Durbin* and S.J. *Koopman*.

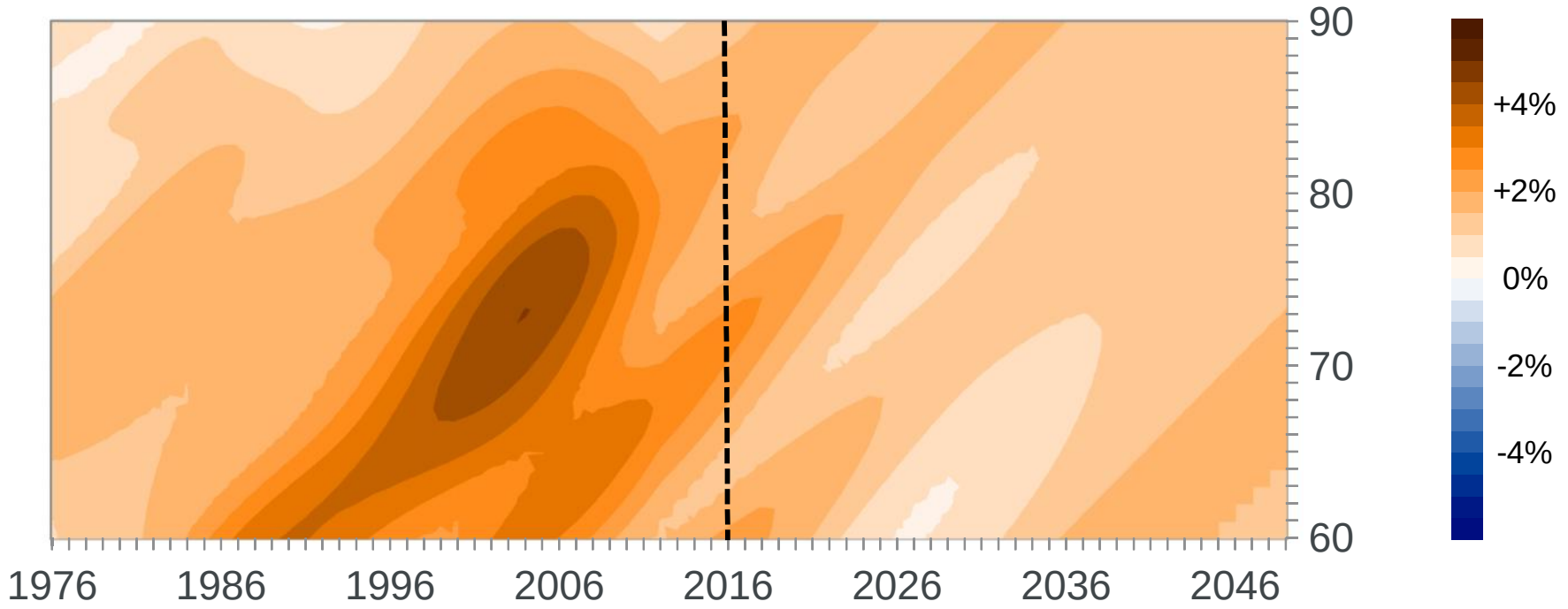


Results

- We have built a proof-of-concept prototype model, and have focused on fitting historical data, rather than long-term future projections.
- All results shown are for males, calibrated to the data used in CMI_2015.
- Results are shown as heatmaps of mortality improvements by age and calendar year.

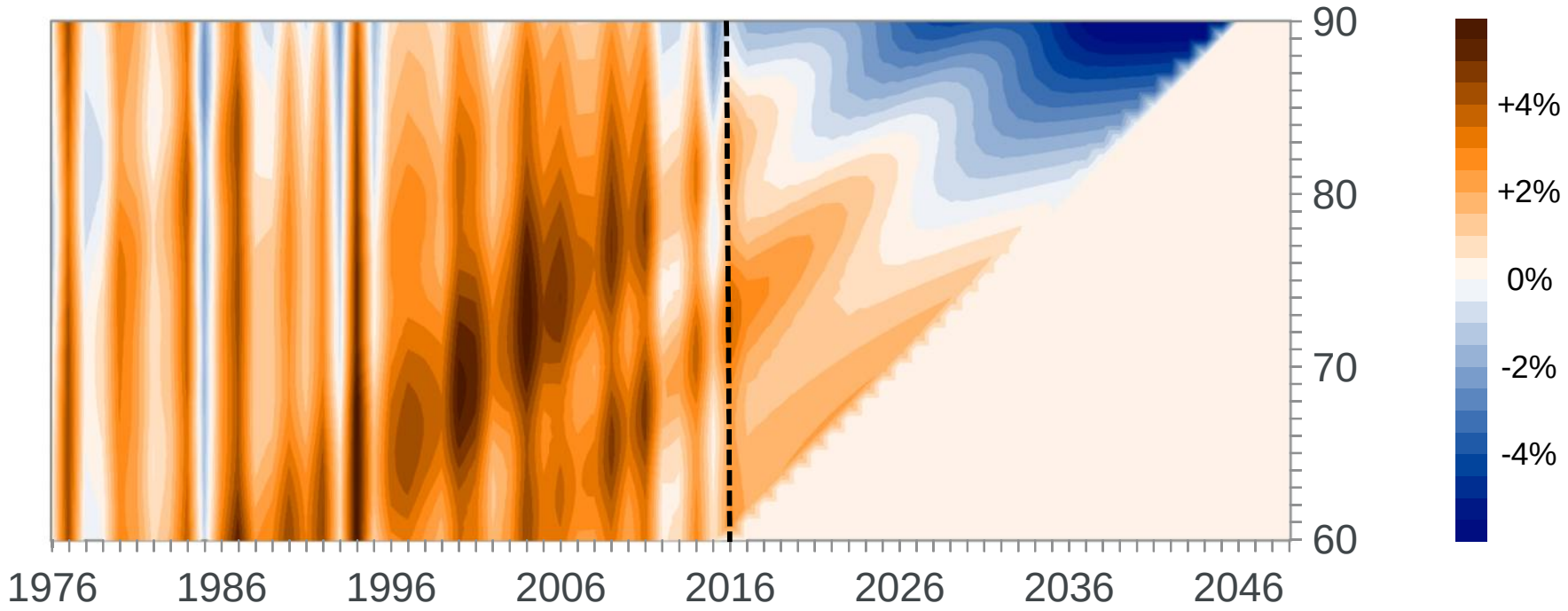
Results – 1

- Mortality improvements from CMI_2015_M [1.5%]



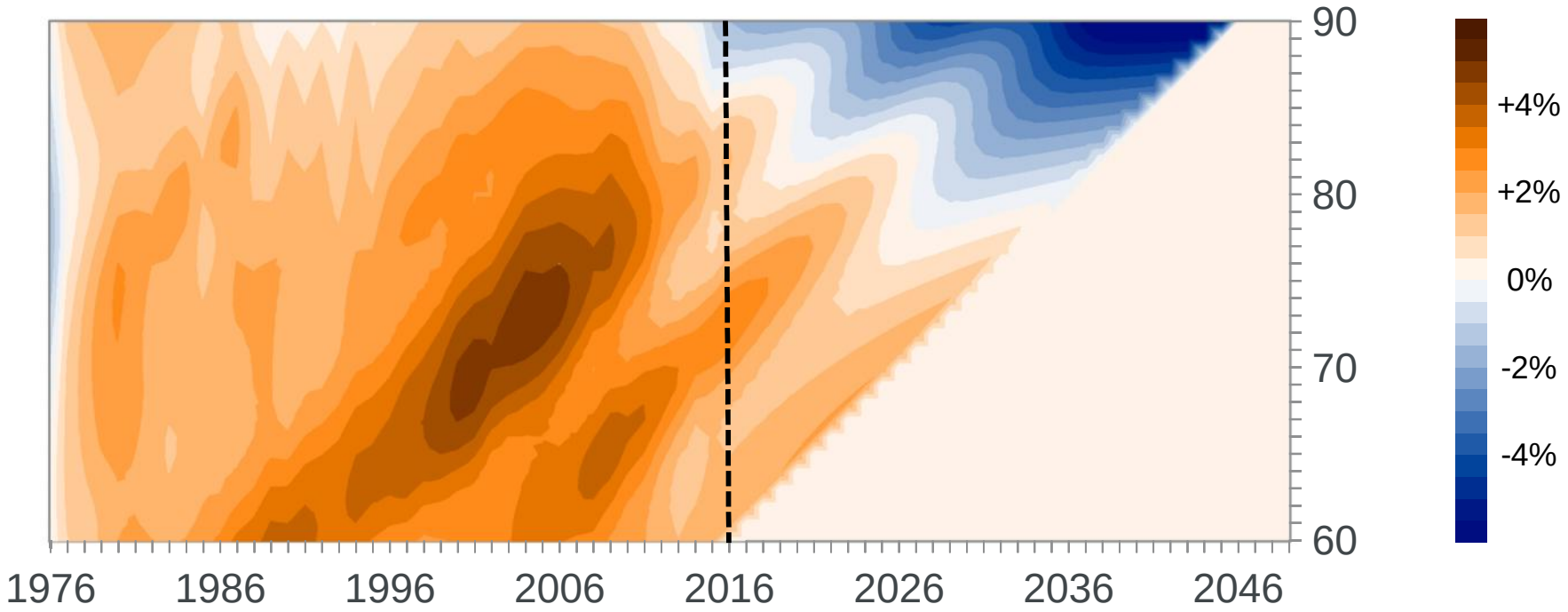
Results – 2

- Mortality improvements from the Kalman filter, including all four components (Age, Period, Cohort and Noise); excluding younger cohorts
- Projected improvements are the model's best estimate based on the available data without any convergence to long term rates of improvement.



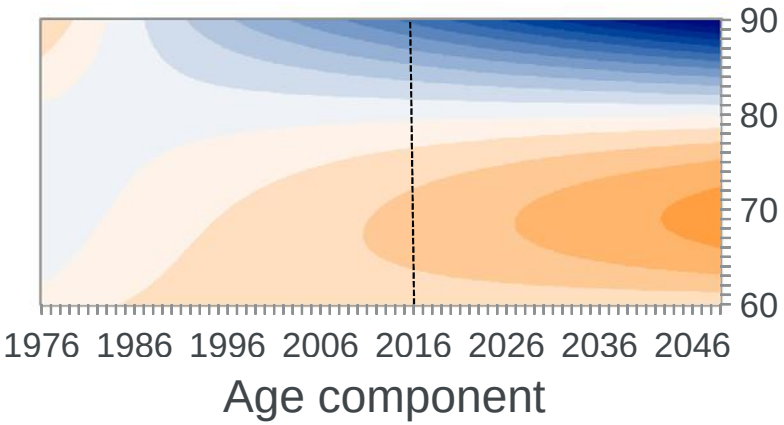
Results – 3

- Mortality improvements from the Kalman filter, excluding noise: we have isolated and removed the annual volatility
- The model has age, period and cohort features similar to the CMI Model, but period effects still appear more prominent than in the CMI Model.

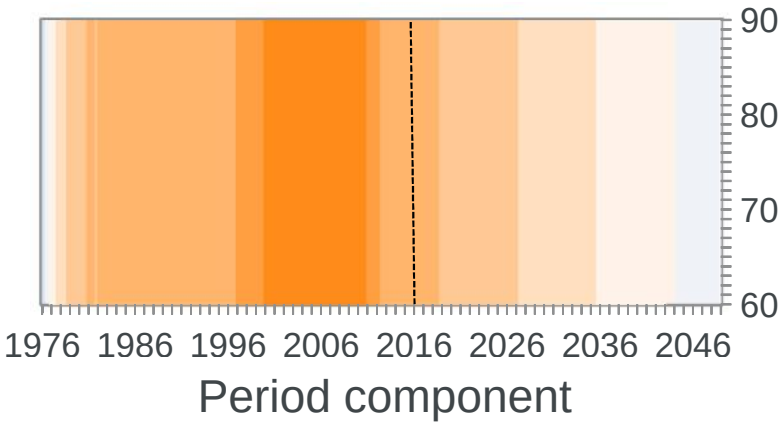


Results – 4

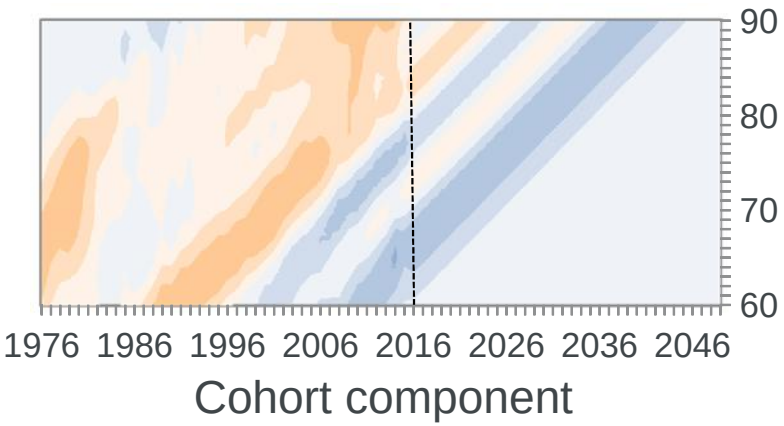
- Mortality improvements split into four components



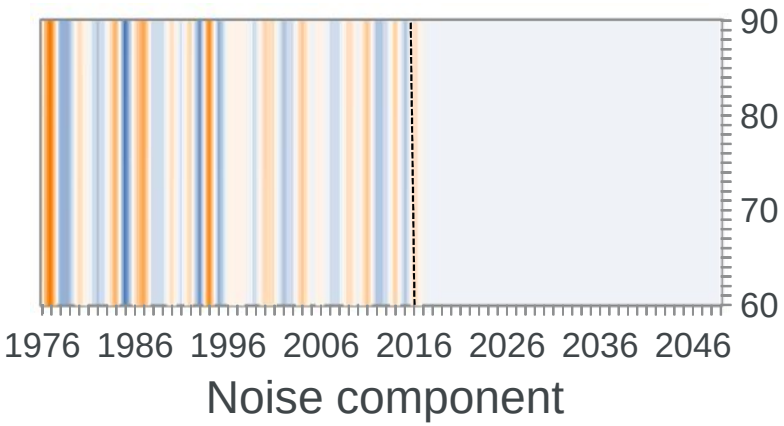
Age component



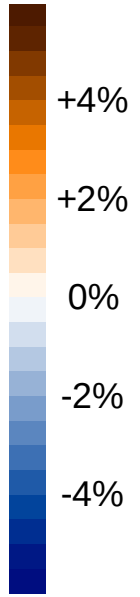
Period component



Cohort component

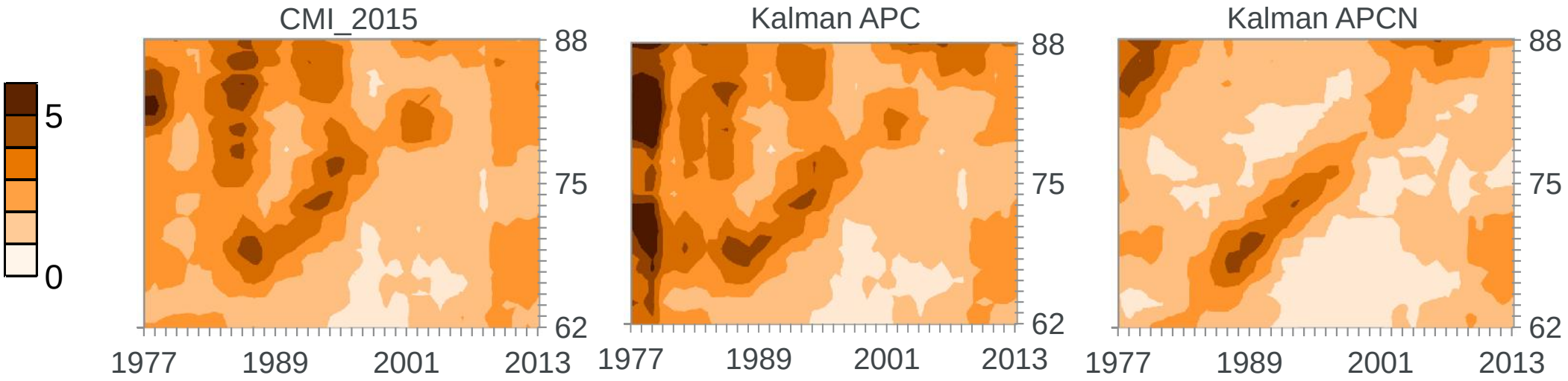


Noise component



Results – 5

- Smoothed deviance residuals



- Residuals are low for all periods and ages
- Similar results from both the CMI model and the Kalman APC
- If we include the annual noise terms we see smaller residuals across all periods and ages
- Main remaining residuals attributable to the 1919/1920 cohort

Assessment

- Provides validation of CMI model
- Differentiate variation in improvements between short and long term effects
- Framework could include CMI model features (cohort, projection to long term rate)
- Stability of historical improvements
- Single, consistent framework analysing historic, current and future improvements
- Quantifies the level of uncertainty within the projection
- Explicit allowance is made for annual noise
- Method unfamiliar to Subscribers
- Higher period volatility than under the P-Spline model

Discussion

- What are your initial views on this research?

Other issues

Tim Gordon

Other issues

- Coherent modelling, i.e. inter/intra population correlation and co-integration
  - M v F / UK v Western World / sub-populations
  - Important for longevity modelling but we may not address it
- We do plan to *test* the model in multiple locales
- We expect to retain the requirement for some user input
  - Different from actuarial professions in other locales – strong IFoA steer
  - LTR similar to implied volatility in options markets
- Cause of death modelling
  - informs LTR etc, but
  - we have no plans to create a cause of death model
- Transparency/openness

Open discussion

projections@cmilimited.co.uk

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

Continuous
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Institute and Faculty of Actuaries

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26 October 2015