Thank you for joining us – the webinar will start shortly

Longevity 102:
improvements / trends

March 31st, 2021

11am ET / 4pm GMT

linkedin.com/company/club-vita

@ClubVita

Longevity 102: *improvements / trends*

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Agenda

1. Introduction
2. Regression models
3. Structural stochastic models
4. Structural expert judgement models
5. What do we actually do?

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1 Introduction

Jargon buster

Longevity

How long you are expected to live

Mortality

When you are expected to die

Survival rates p_x - the probability a person aged x will survive the next year

Mortality rates q_x - the probability a person aged x will die within the next year

$$p_x = (1 - q_x)$$

Life Expectancy

The expectation of the number of years a person will live. Either,

- "years left" (20 years Life Expectancy for a 65 year old); or
- "total years" (Total Life Expectancy of 85 for a 65 year old)

Two steps to calculate life expectancy

Baseline

- Snapshot of current state of longevity
- Objective measure
- Based on past experience

Future trends

- How longevity will change in the future
- More subjective measure
- Recent experience a good starting point, but how and when will it change?

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Improvements

Annual mortality / longevity improvement

- The reduction in the mortality rate since the previous year.
- For someone aged x in year t, the annual improvement is given by

$$q_{x,t} = q_{x,t-1} \times (1 - \textit{improvement})$$

Age/Year	…	2020	2021	…
…	…	…	…	…
68	…	1.41%	1.40%	…
69	…	1.56%	1.55%	…
…	…	…	…	…

2021 improvement for a 68 year old:

1 – (**1.40%** / **1.41%**) = **0.7%**

Improvement projections: assumptions for how improvements will materialize in the future

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Mortality/longevity trends terminology

	Mortality / longevity **improvement**	Mortality / longevity **deterioration**
Mortality rates, $\mathbf{q}_x$	↓	↑
Survival rates, $\mathbf{p}_x$	↑	↓
Life expectancies	↑	↓

Calculating life expectancy

Mortality table with improvements

Age/Year	…	2021	2022	2023	2024	2025	2026	…
…	…	…	…	…	…	…	…	…
67	…	1.28%	1.28%	1.28%	1.28%	1.27%	1.27%	…
68	…	1.41%	1.41%	1.40%	1.40%	1.40%	1.40%	…
69	…	1.56%	1.55%	1.54%	1.54%	1.53%	1.53%	…
70	…	1.72%	1.71%	1.70%	1.69%	1.69%	1.68%	…
…	…	…	…	…	…	…	…	…

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Calculating life expectancy

Period life expectancy: no allowance for changes in mortality rates

Age/Year	…	2021	2022	2023	2024	2025	2026	…
…	…	…	…	…	…	…	…	…
67	…	1.28%	1.28%	1.28%	1.28%	1.27%	1.27%	…
68	…	1.41%	1.41%	1.40%	1.40%	1.40%	1.40%	…
69	…	1.56%	1.55%	1.54%	1.54%	1.53%	1.53%	…
70	…	1.72%	1.71%	1.70%	1.69%	1.69%	1.68%	…
…	…	…	…	…	…	…	…	…

Calculating life expectancy

Cohort life expectancy: uses future improvements to mortality rates for a person of a specified age in a specified year

Age/Year	…	2021	2022	2023	2024	2025	2026	…
…	…	…	…	…	…	…	…	…
67	…	1.28%	1.28%	1.28%	1.28%	1.27%	1.27%	…
68	…	1.41%	1.41%	1.40%	1.40%	1.40%	1.40%	…
69	…	1.56%	1.55%	1.54%	1.54%	1.53%	1.53%	…
70	…	1.72%	1.71%	1.70%	1.69%	1.69%	1.68%	…
…	…	…	…	…	…	…	…	…

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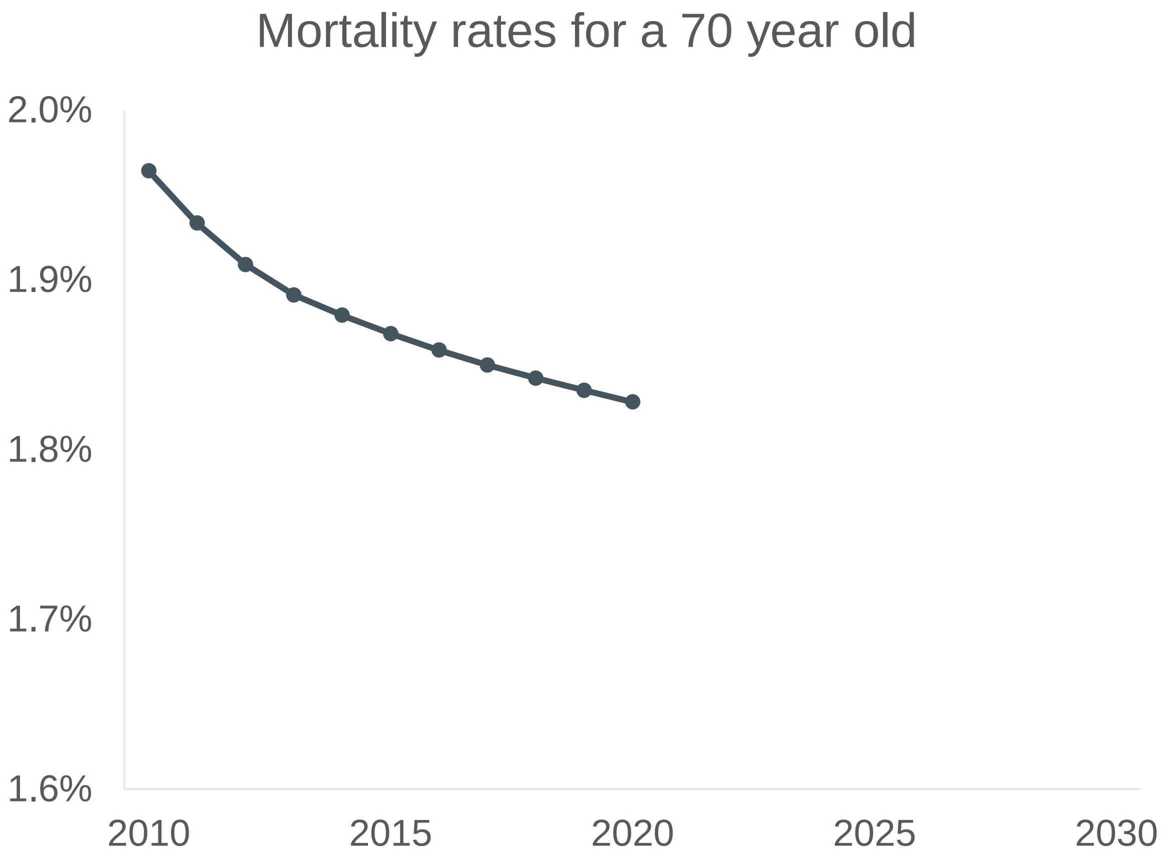
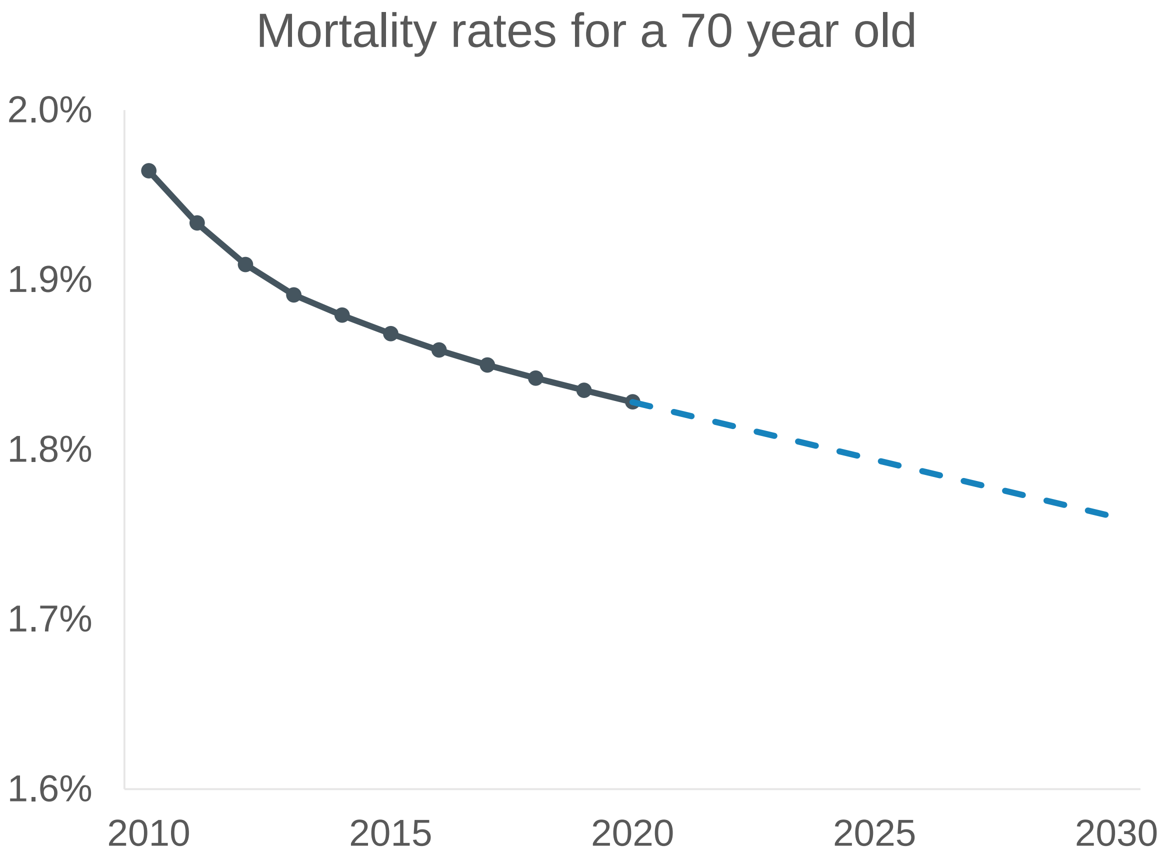
Projection models



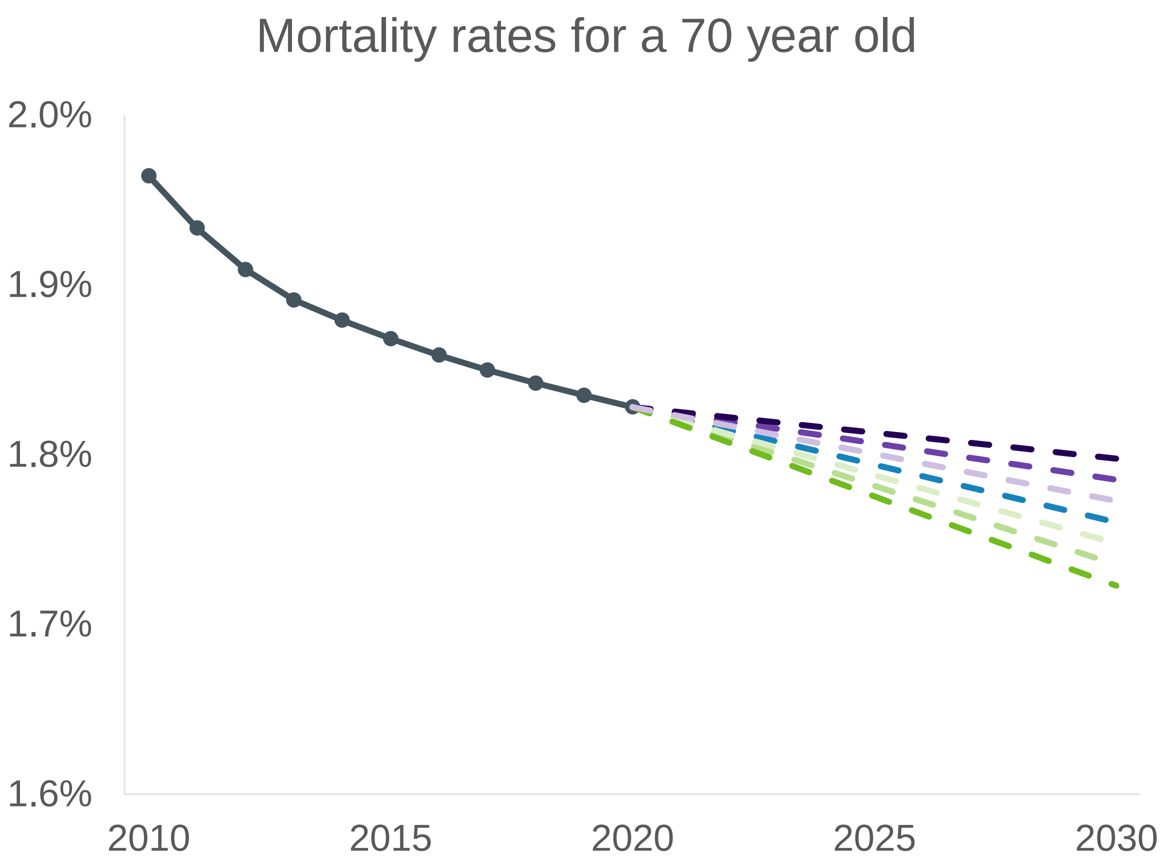
- Historical mortality rates and improvements are known
- Projection models estimate what mortality rates and improvements will be in the future

Deterministic projection



- Deterministic models project one set of mortality rates into the future
- Projected rates often represent a “best estimate” or “prudent estimate” for changes in future mortality
- Often used when a fixed value is needed for a set of cashflows which depend on future mortality. Eg,
  - Regulatory funding valuation
  - Valuation for accounting disclosures

Stochastic projection



- Stochastic models project many sets of mortality rates into the future, assigning probabilities to the resulting distribution
- Often used to understand the risk associated with a set of uncertain cashflows which depend on future mortality. Eg,
  - Understanding the range of outcomes in a given confidence interval
  - Assessing risk mitigation strategies

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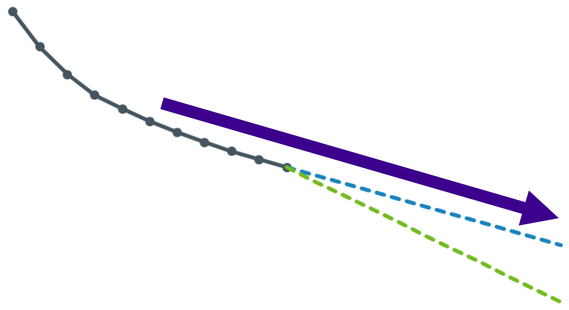
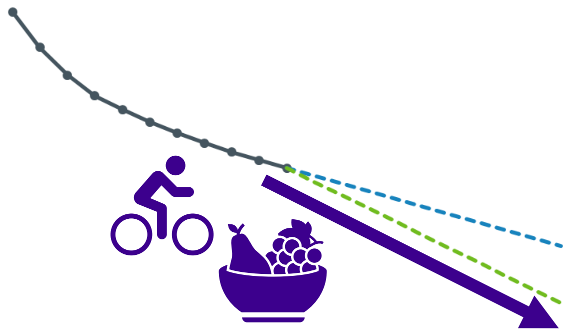
Stochastic and deterministic models often complimentary

Extrapolative vs explanatory



Extrapolative approach

- Projects historical data experience into the future
- Assumes historical trends will continue

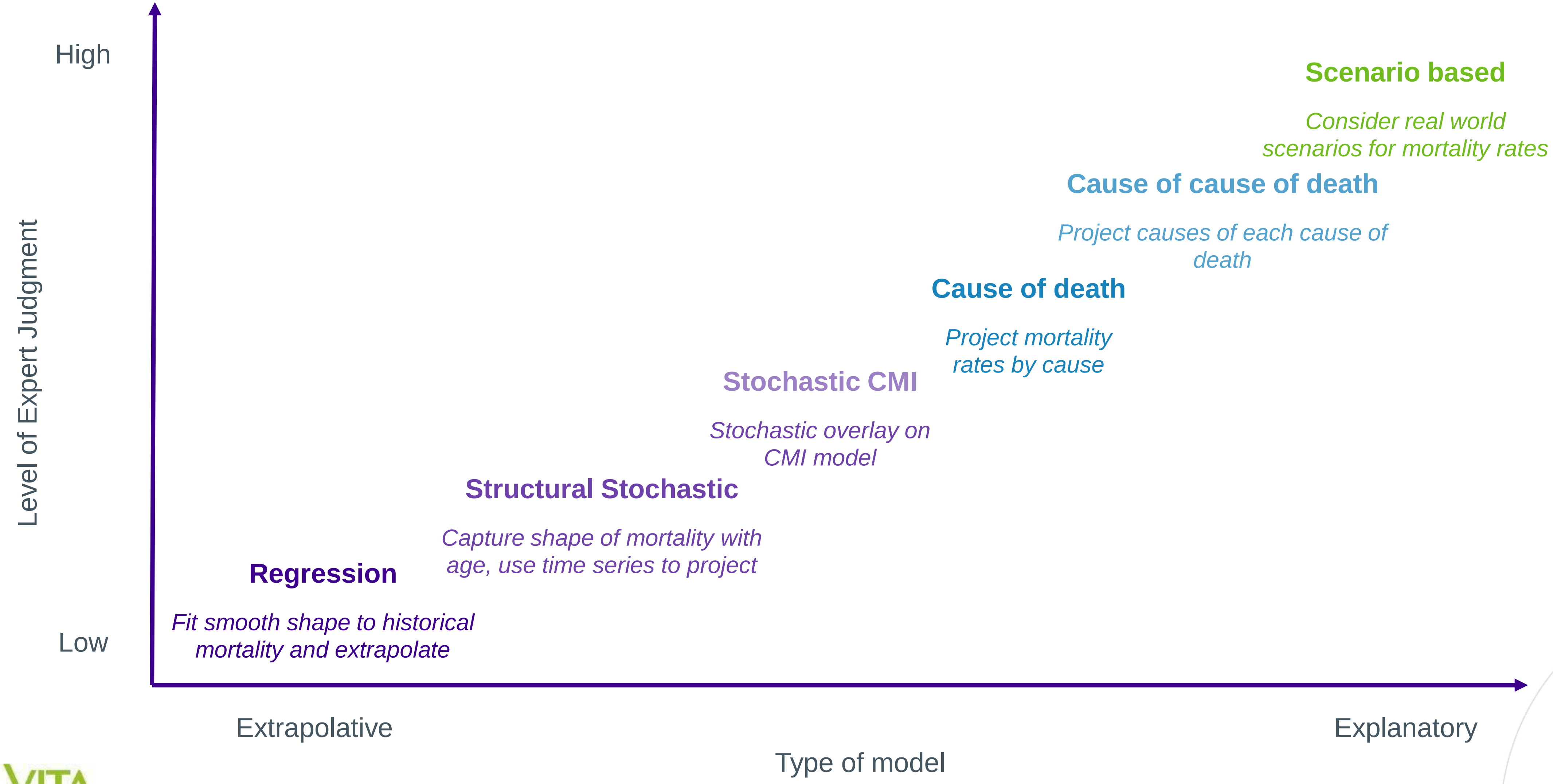


Explanatory approach

- Seeks to understand drivers of mortality changes
- … and uses changes in these drivers to project mortality

Models can use a combination of approaches

Different types of model



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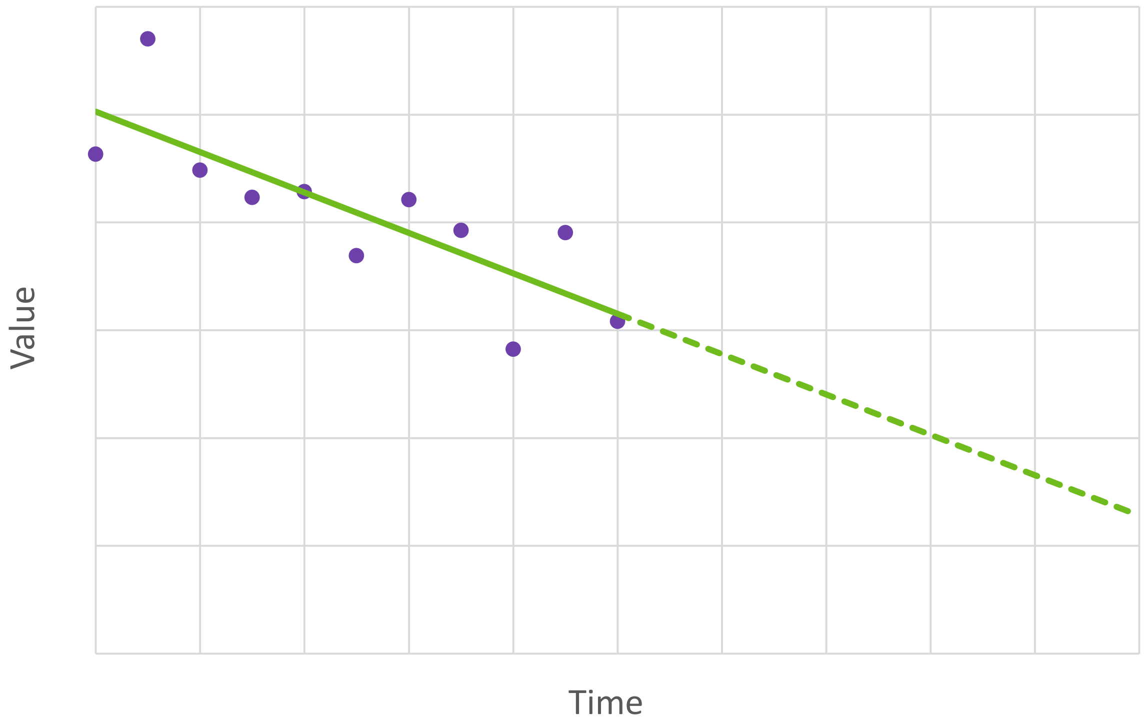
2 Regression models

Regression models

- Assume all information needed is contained in historical data
- Fit smooth shape to data
- Extrapolate into the future
- Limited (but non zero) expert judgement
  - Choice of model and parameterisation
- Fit of model balance between goodness of fit and avoidance of over-fitting
- Can have issues around sensitivity to ‘leading edge’ of data
- Lack of transparency in fitting process

Introduction to regression modelling

- Start from observed data
- Find best fitting line
  - Various statistical techniques used to define 'best fit'
- Use this line to project into the future
- Can extend this principle to e.g. multiple dimensions



Age-Period-Cohort models

- Historical mortality experience recorded by age and calendar year
- Possible to build model using:
  - Age
  - Period (i.e. calendar year)
  - Cohort (i.e. birth year)
- Fit across each dimension and project into the future

Age/ Year	…	2012	2013	2014	2015	…
…	…	…	…	…	…	…
67	…	[illegible]	1.28%	1.27%	1.26%	…
68	…	1.41%	[illegible]	1.39%	1.38%	…
69	…	1.56%	1.54%	[illegible]	1.51%	…
70	…	1.72%	1.71%	1.70%	[illegible]	…
…	…	…	…	…	…	…

Cohort

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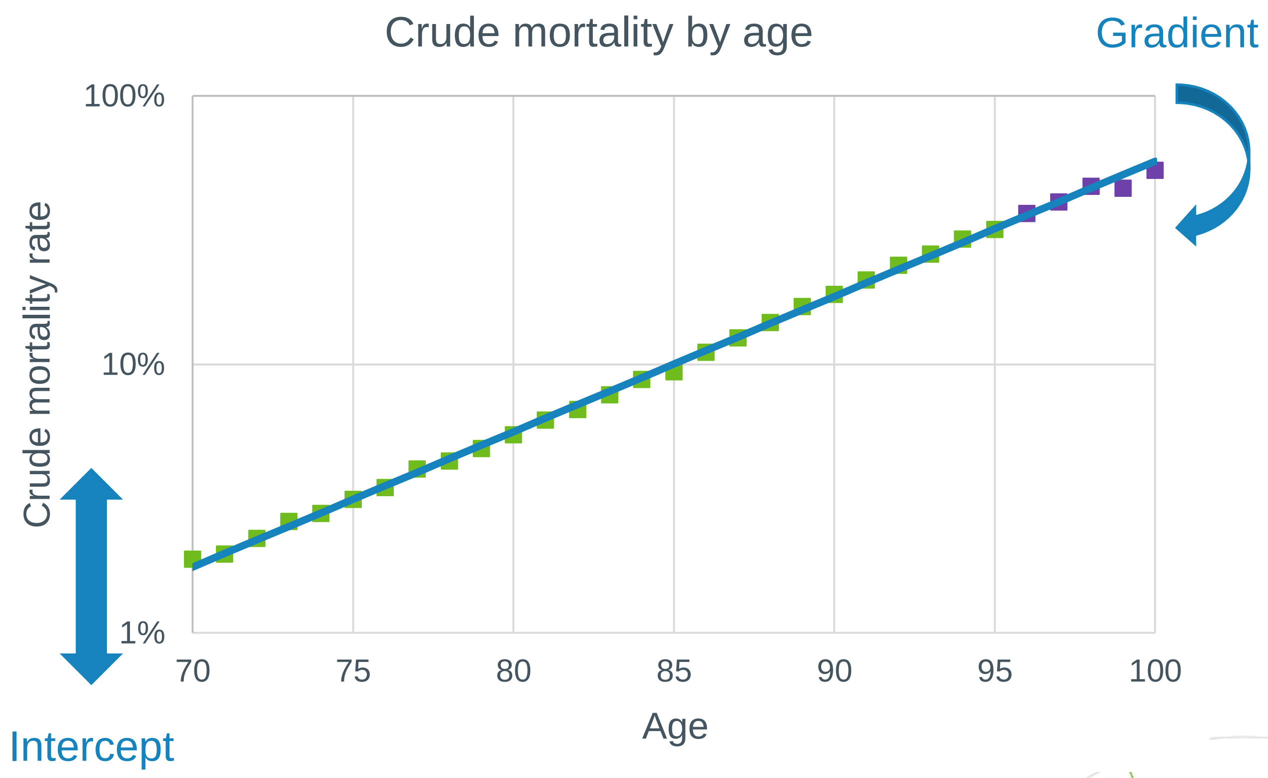
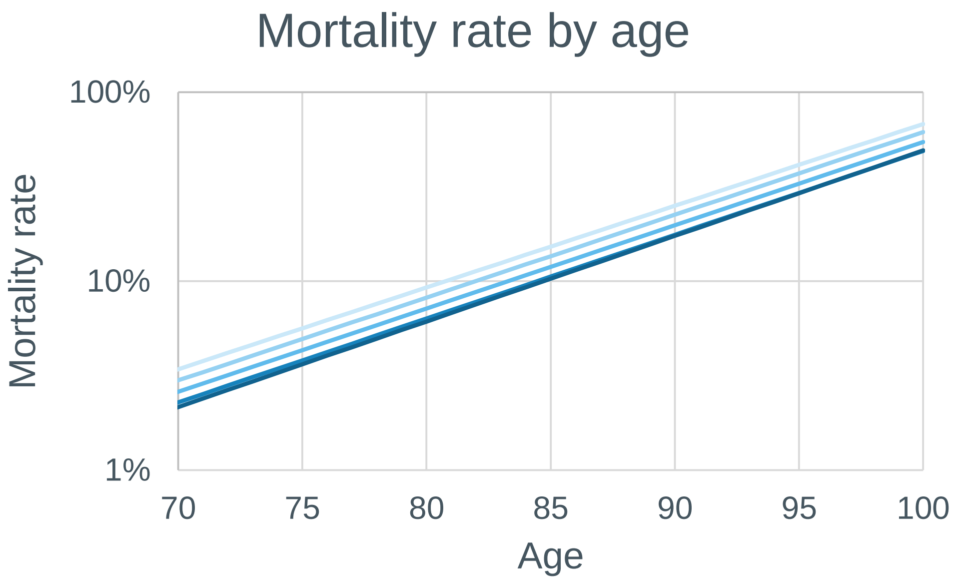
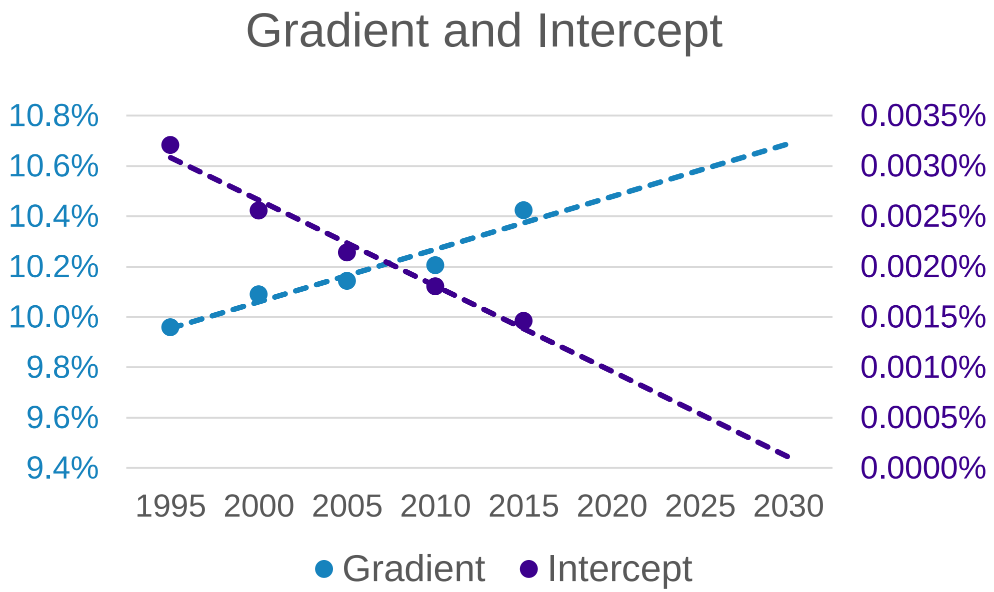
Basic regression model for mortality

- Mortality rates are (broadly) linear with age on log scale
- Fit straight line to (log) mortality
- Extrapolate to younger/older ages
- Fitted rates defined by:
  - gradient
  - intercept
- These both can vary over time



Evolution over time





- Repeat to obtain series of fitted lines for observed mortality rates
- Project gradients and intercepts to predict evolution of curve over time
- So obtain (deterministic) path for mortality rates at each age

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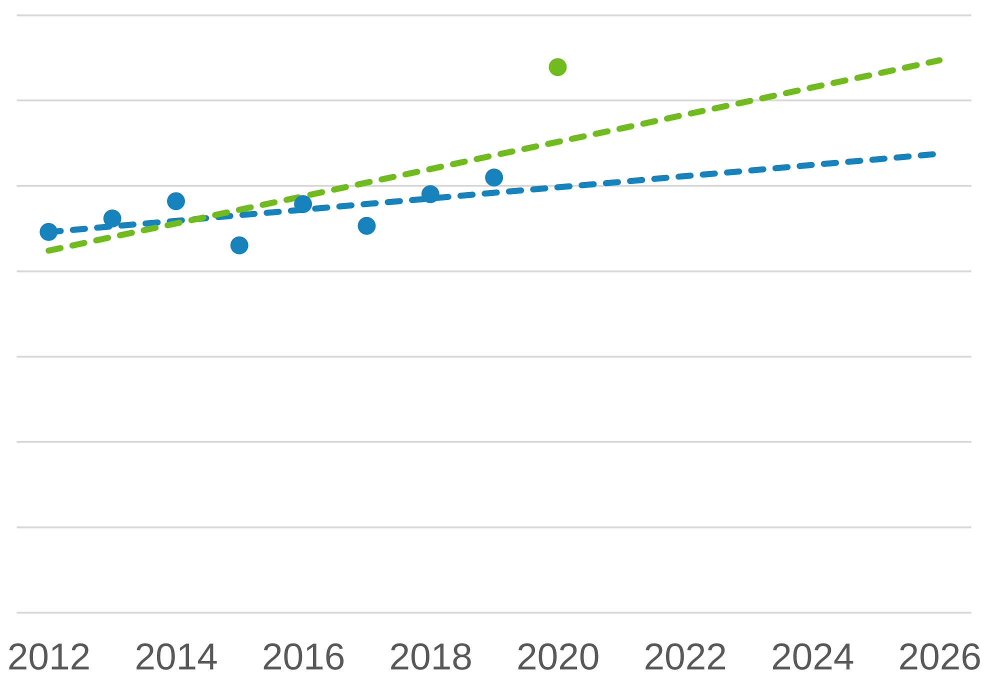
Edge effects

- Regression models sensitive to ‘leading edge’ of data
- Recent short term trends are extrapolated into the future
- So projection can be materially altered by one extra year of data
- Such volatility can be unhelpful
- 2020 is a topical example



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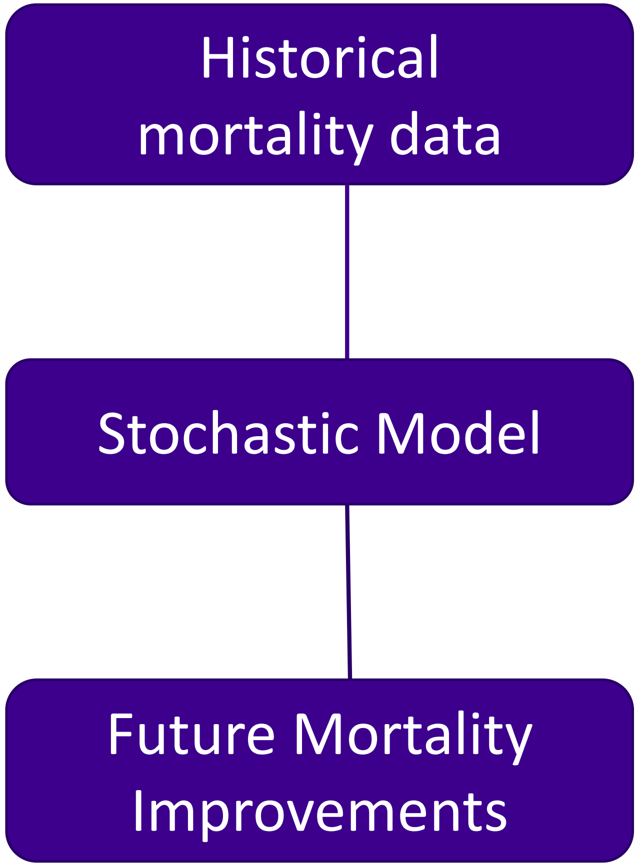
3 Structural stochastic models

Structural stochastic models

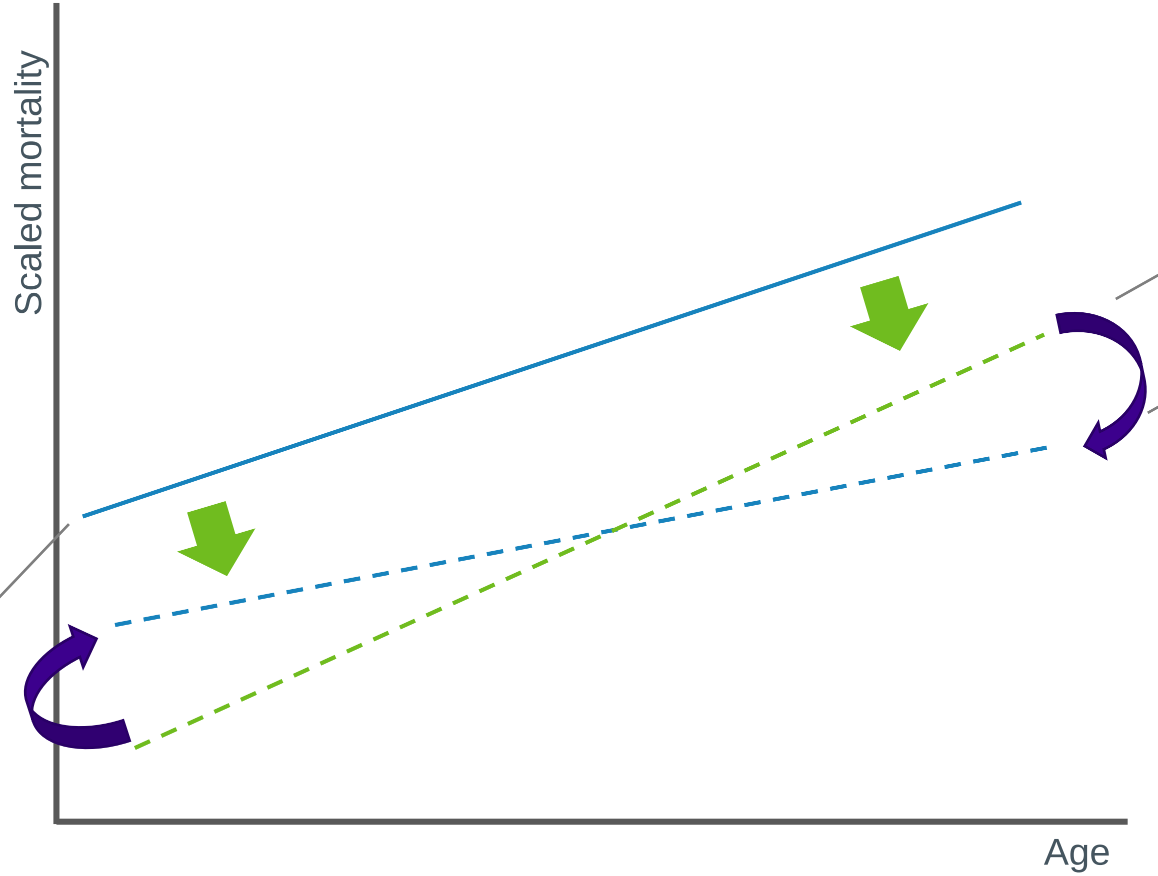
- Class of extrapolative models
  - fitted to historical data
- Combine a mathematical structure which captures the shape of mortality with age and the changes in mortality over time
- One or more time-varying parameters are identified
- Overlay views of the likely evolution of mortality improvements over time by choice of the model
- Stochastic models project many sets of mortality rates into the future, assigning probabilities to the resulting distribution



Fundamental process of structural stochastic models

1 Select measure and scale for mortality

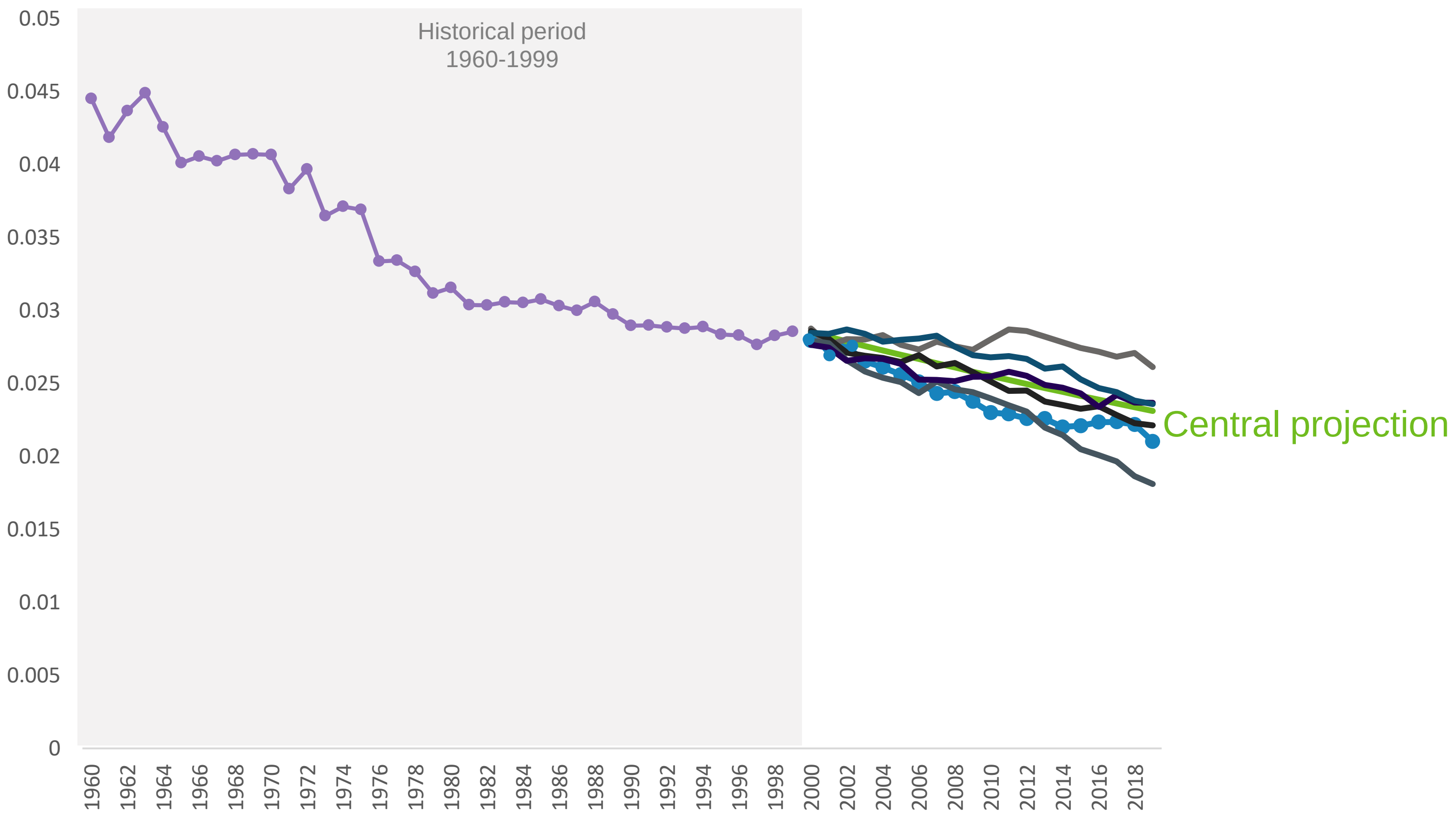
2 Determine the "shape" of the curve with age



3 Time series governs “shifts” and “rotations” of mortality curve over time.

Fundamental process of structural stochastic models

Illustration of Stochastic Mortality Projection using USA Mortality Rates for Females,
aged 75, 1960 – 2019



Own calculations based on data from the Human Mortality Database

Structural stochastic models project a best-estimate trend outcome and many sets of mortality rates into the future.

Common approaches in stochastic modelling

Lee and Carter (1992)

Developed in the United States

Single factor model

Modelling and forecasting U.S. mortality

Developed in the United Kingdom

Two-factor model

A Two-Factor Model for Stochastic Mortality with Parameter Uncertainty: Theory and Calibration

Cairns, Blake and Dowd (2006)

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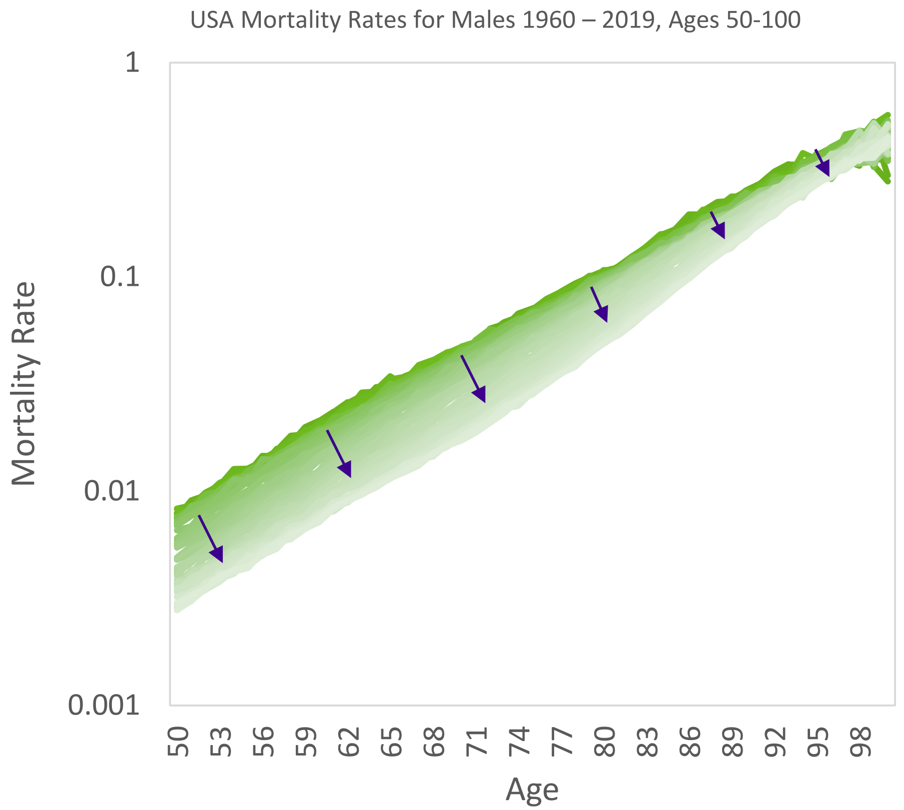
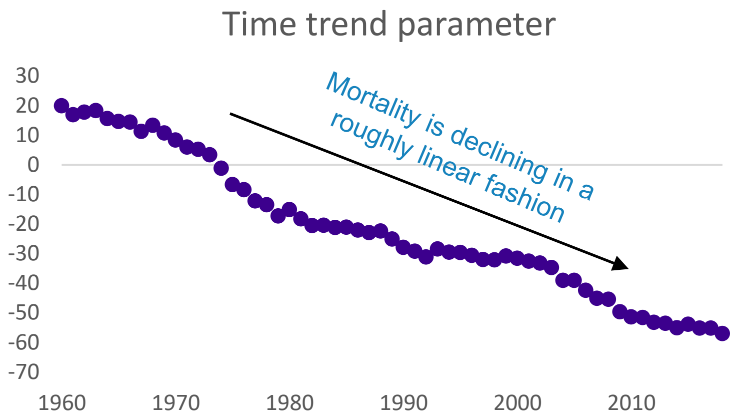
Lee and Carter (1992) model



1 ***Age parameter*** - captures average level of mortality across ages

2 ***Time trend parameter*** - captures the "average" year-on-year improvement that tracks the changes in mortality



3 ***Time sensitivity parameter*** – captures the sensitivity by age to the general year-on-year improvements

Own calculations based on data from the Human Mortality Database.

Reference: Lee & Carter (1992) "Modelling and forecasting U.S. mortality" journal of the American Statistical Association 87 (419) pp659-671

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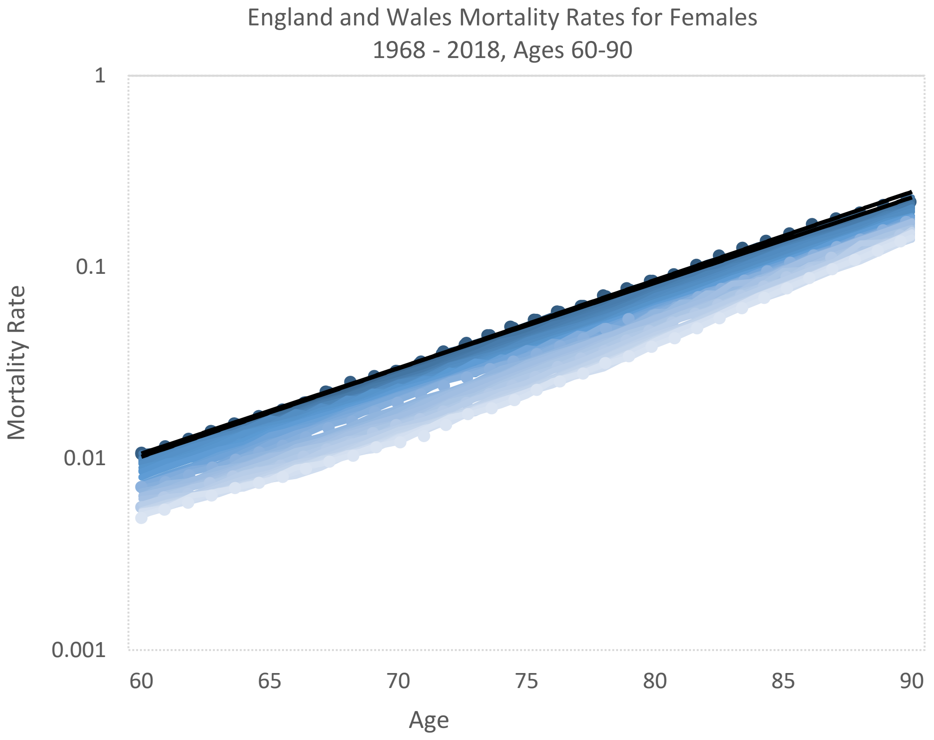
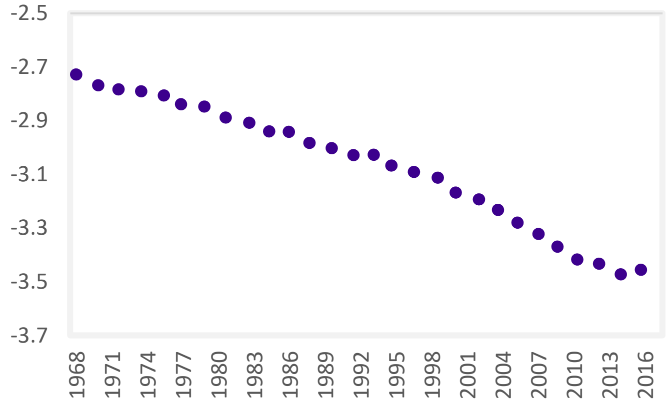
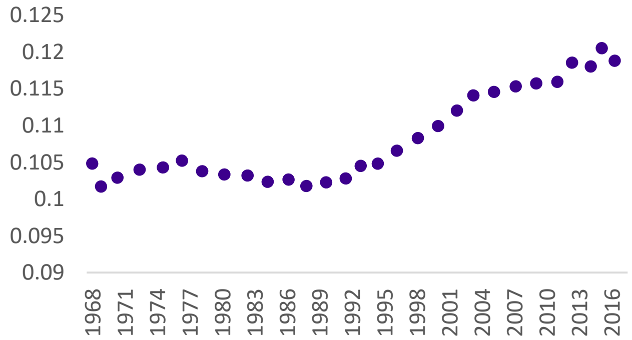
Cairns, Blake and Dowd (2006) model



1 ***Time trend parameter 1 "Intercept"*** - captures the changes in mortality over time



2 ***Time trend parameter 2 "Gradient"*** - Captures the steepness in mortality in each year



Own calculations based on data from the Human Mortality Database.

Reference: Cairns, Blake and Dowd (2006) "A Two-Factor Model for Stochastic Mortality with Parameter Uncertainty: Theory and Calibration" The Journal of Risk and Insurance, 73 (4) pp687-718

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Comparison of LC and CBD models

Lee-Carter (LC)

- Single random period effect - cannot cope with different improvements at different ages at different times
- Provides a good fit over a wide age ranges

Cairns-Blake-Dowd Model (CBD)

- Two random period effects - allows different improvements at different ages at different times
- Simple structure at higher ages – focuses on pension plan longevity risk

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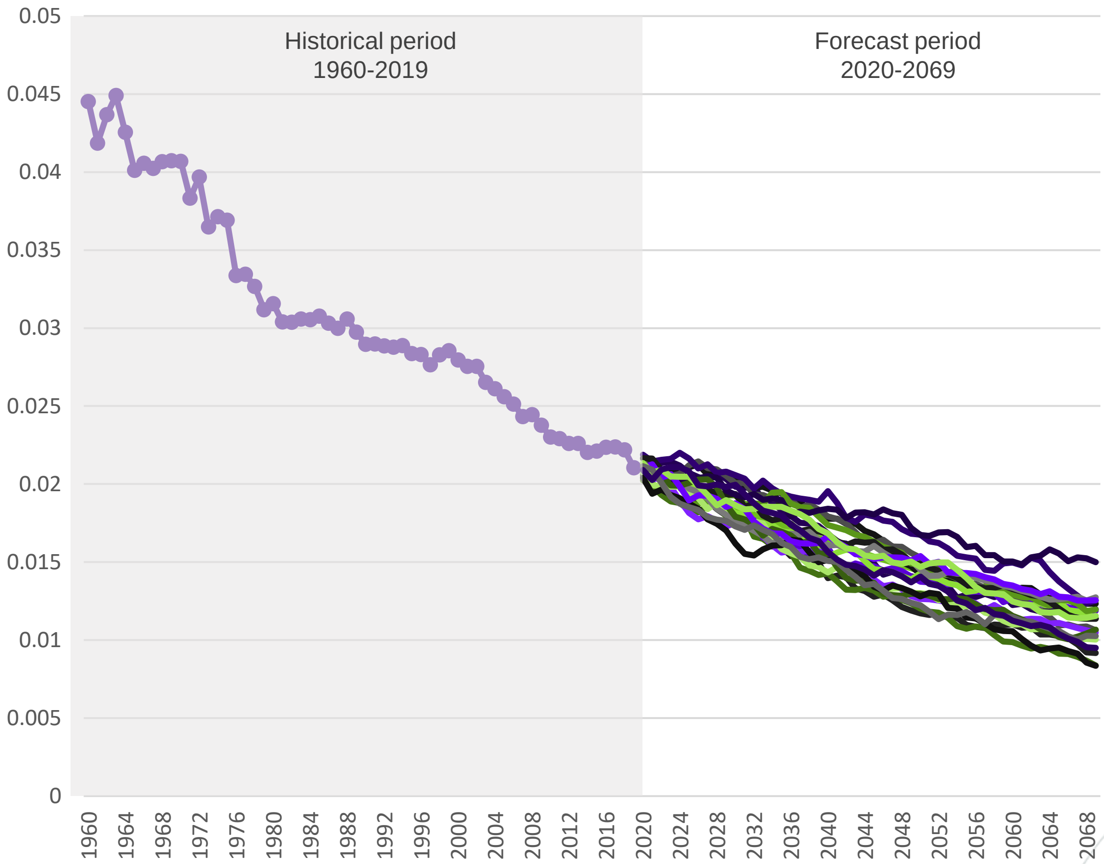
Forecasting with stochastic models

- Choose model to extract historical trends in mortality e.g., Lee-Carter and Cairns-Blake-Dowd model
- Based on historical data and judgements about the future trend of mortality rates, stochastic models can simulate future mortality rates around a central, expected path
- The mortality forecast is driven by extrapolation of time trend parameters in the stochastic model

Illustration of Forecasting with Lee-Carter model using USA Mortality Rates for Females, aged 75, 1960 – 2069



Own calculations based on data from the Human Mortality Database

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Judgements needed for stochastic models

- Choice of past data
  - inherent beliefs about the period of historical data that is relevant to future trends in mortality
- Choice of model
  - depends on the nature of the data and biological beliefs about the trends underpinning it
- Set assumptions/constraints on model parameters

4 Structural expert judgement

We all die from something…

MED A 28 000000

BIRTHS AND DEATHS REGISTRATION ACT 1953

(Form prescribed by the Registration of Births and Deaths Regulations 1987)

Registrar to enter No. of Death Entry

MEDICAL CERTIFICATE OF CAUSE OF DEATH

For use only by a Registered Medical Practitioner WHO HAS BEEN IN ATTENDANCE during the deceased's last illness, and to be delivered by him forthwith to the Registrar of Births and Deaths.

Name of deceased .... Fred Forrest

Date of death as stated to me .... day of .... Age as stated to me ....

Place of death ....

Last seen alive by me .... day of ....

1 The certified cause of death takes account of information obtained from post-mortem.
2 Information from post-mortem may be available later.
3 Post-mortem not being held.
4 I have reported this death to the Coroner for further action. *[See overleaf]*

Please ring appropriate digit(s) and letter

a Seen after death by me.
b Seen after death by another medical practitioner but not by me.
c Not seen after death by a medical practitioner.

CAUSE OF DEATH

The condition thought to be the 'Underlying Cause of Death' should appear in the lowest completed line of Part I.

These particulars not to be entered in death register

Approximate interval between onset and death

I (a) Disease or condition directly leading to death† .... Heart Attack

(b) Other disease or condition, if any, leading to I(a) .... Diabetes

(c) Other disease or condition, if any, leading to I(b) ....

II Other significant conditions CONTRIBUTING TO THE DEATH but not related to the disease or condition causing it. ....

The death might have been due to or contributed to by the employment followed at some time by the deceased. ☐ Please tick where applicable

†This does not mean the mode of dying, such as heart failure, asphyxia, asthenia, etc: it means the disease, injury, or complication which caused death.

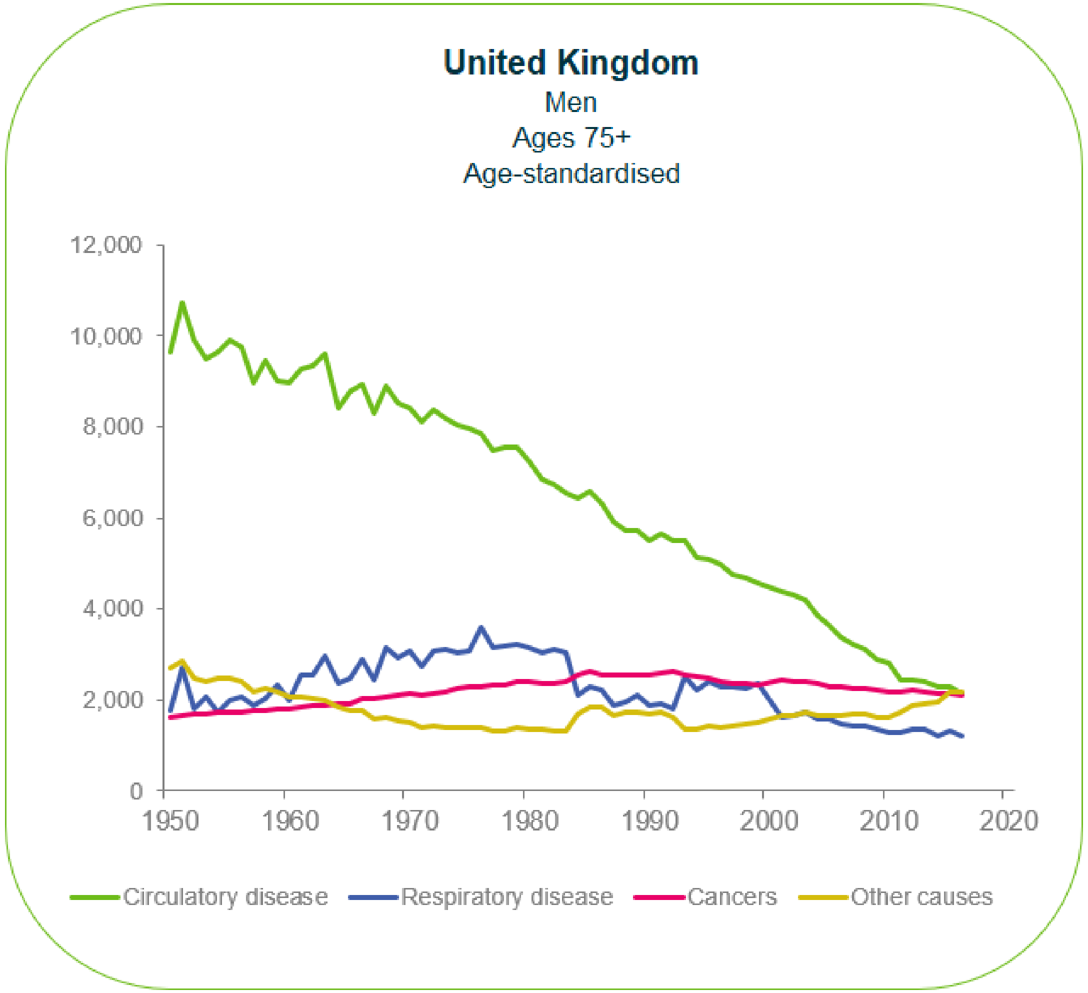
I hereby certify that I was in medical attendance during the above named deceased's last illness, and that the particulars and cause of death above written are true to the best of my knowledge and belief.

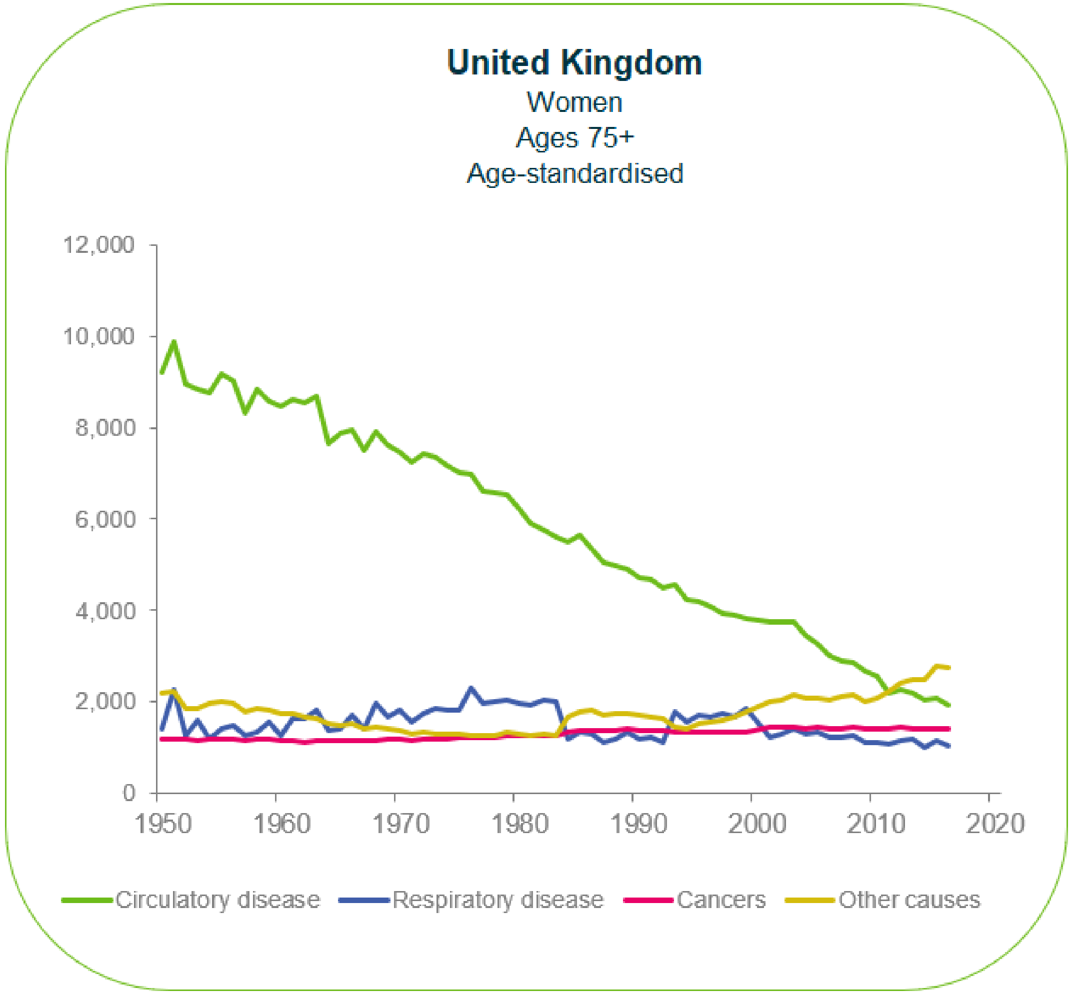
Signature .... Qualifications as registered by General Medical Council ....

Residence .... Date ....

For deaths in hospital: Please give the name of the consultant responsible for the above-named as a patient ....

Cause of death patterns (Aged 75+, 1950-2016)





Own calculations based upon data from World Health Organisation (WHO) and United Nations (UN). Figures are shown as deaths per 100,000 lives.

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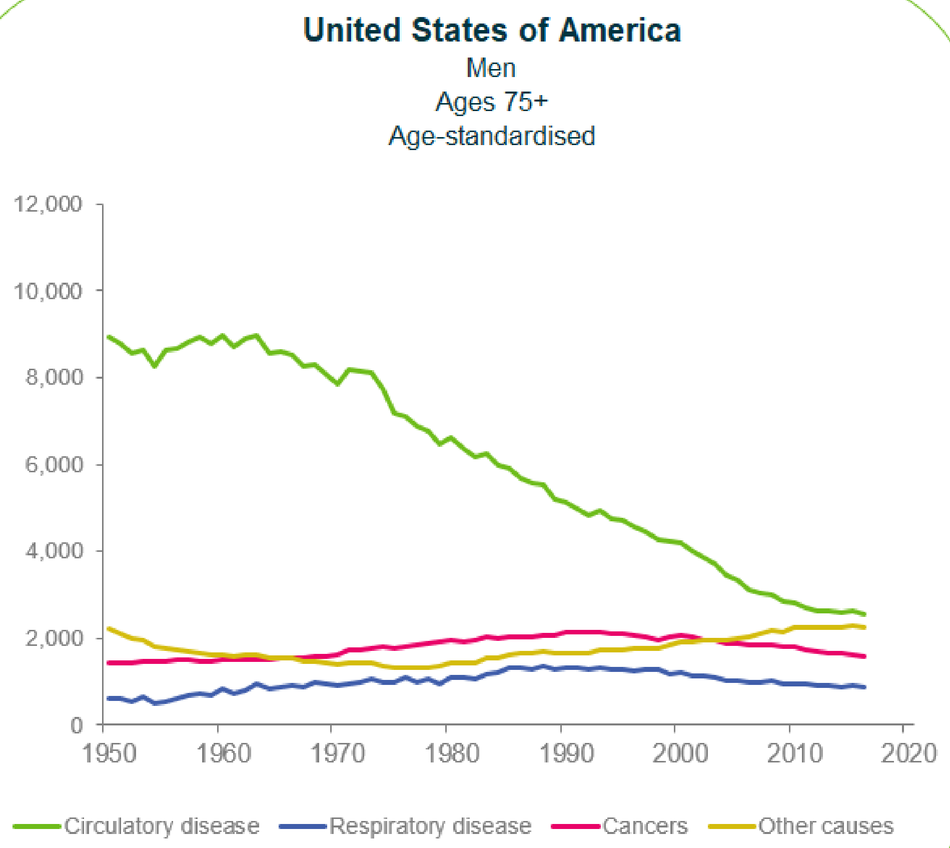
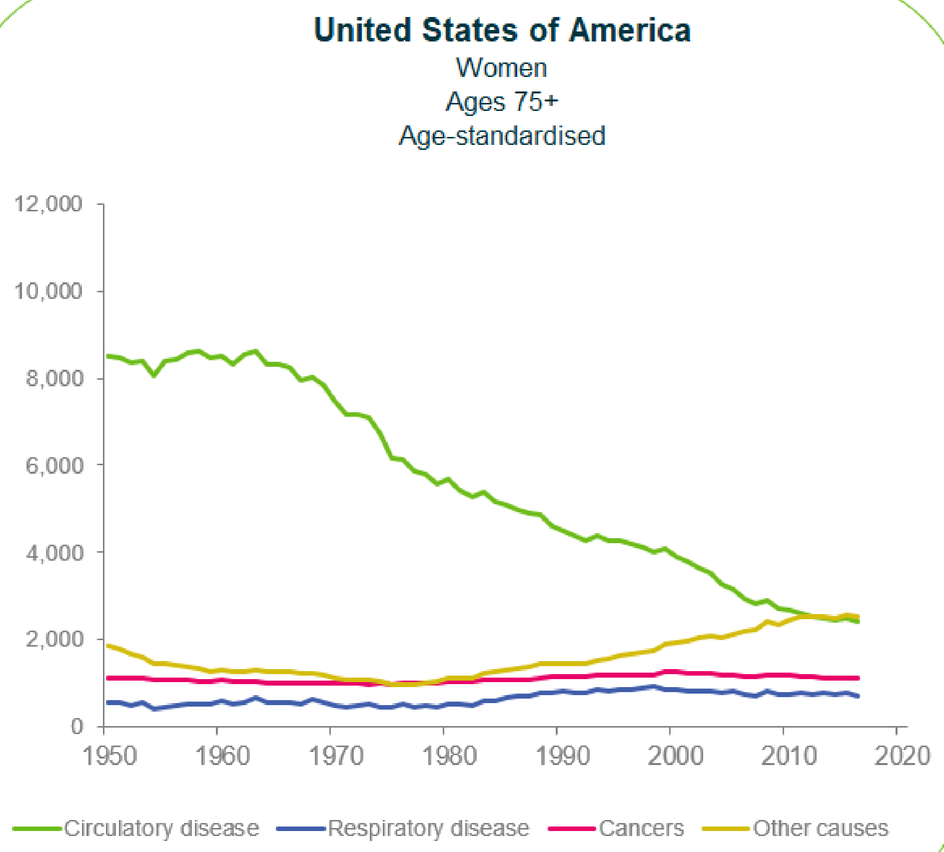
Cause of death patterns (Aged 75+, 1950-2016)





Own calculations based upon data from World Health Organisation (WHO) and United Nations (UN). Figures are shown as deaths per 100,000 lives.

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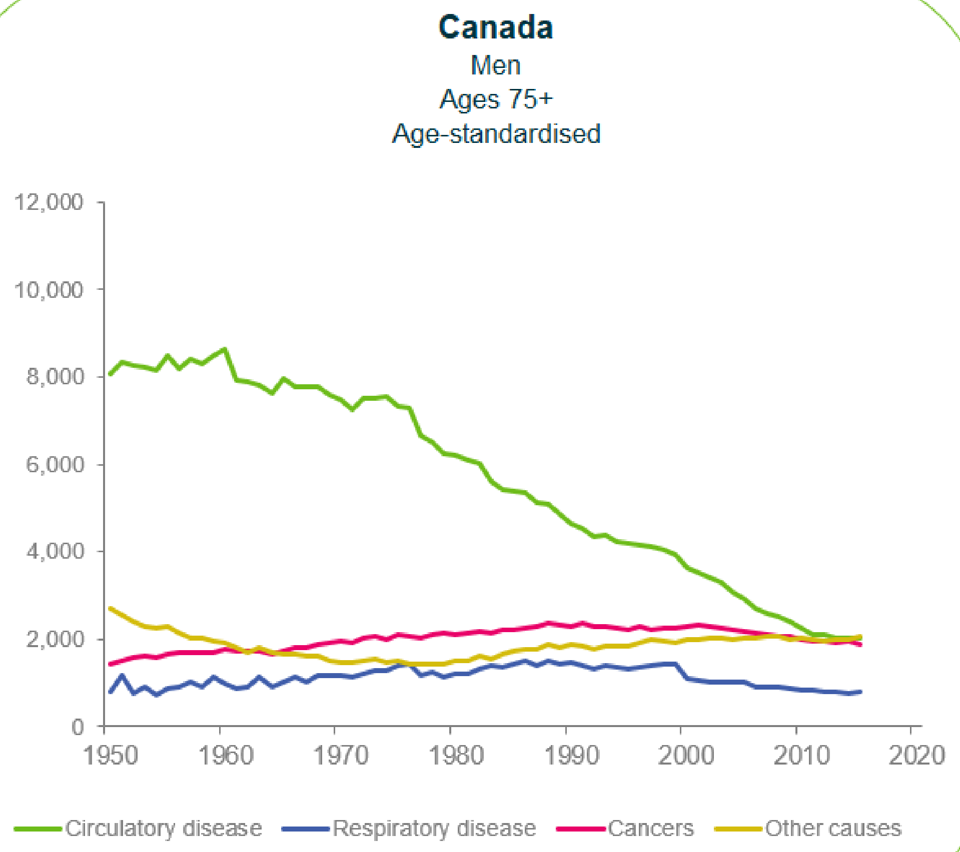
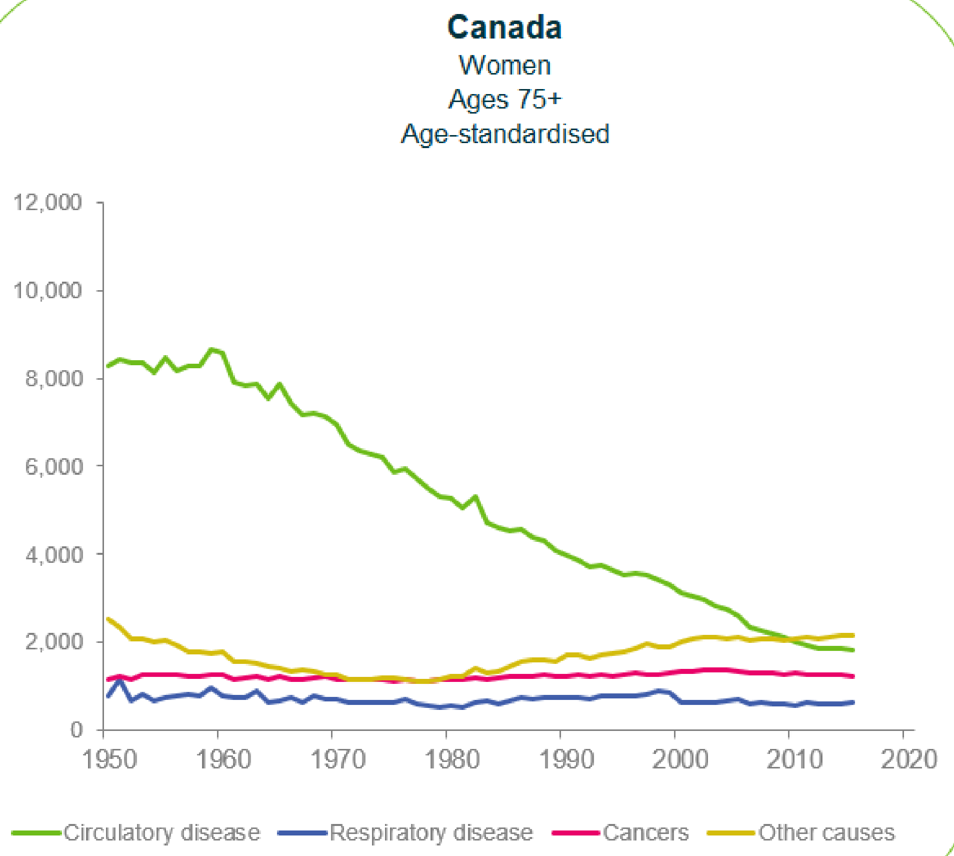
Cause of death patterns (Aged 75+, 1950-2015)





Own calculations based upon data from World Health Organisation (WHO) and United Nations (UN). Figures are shown as deaths per 100,000 lives.

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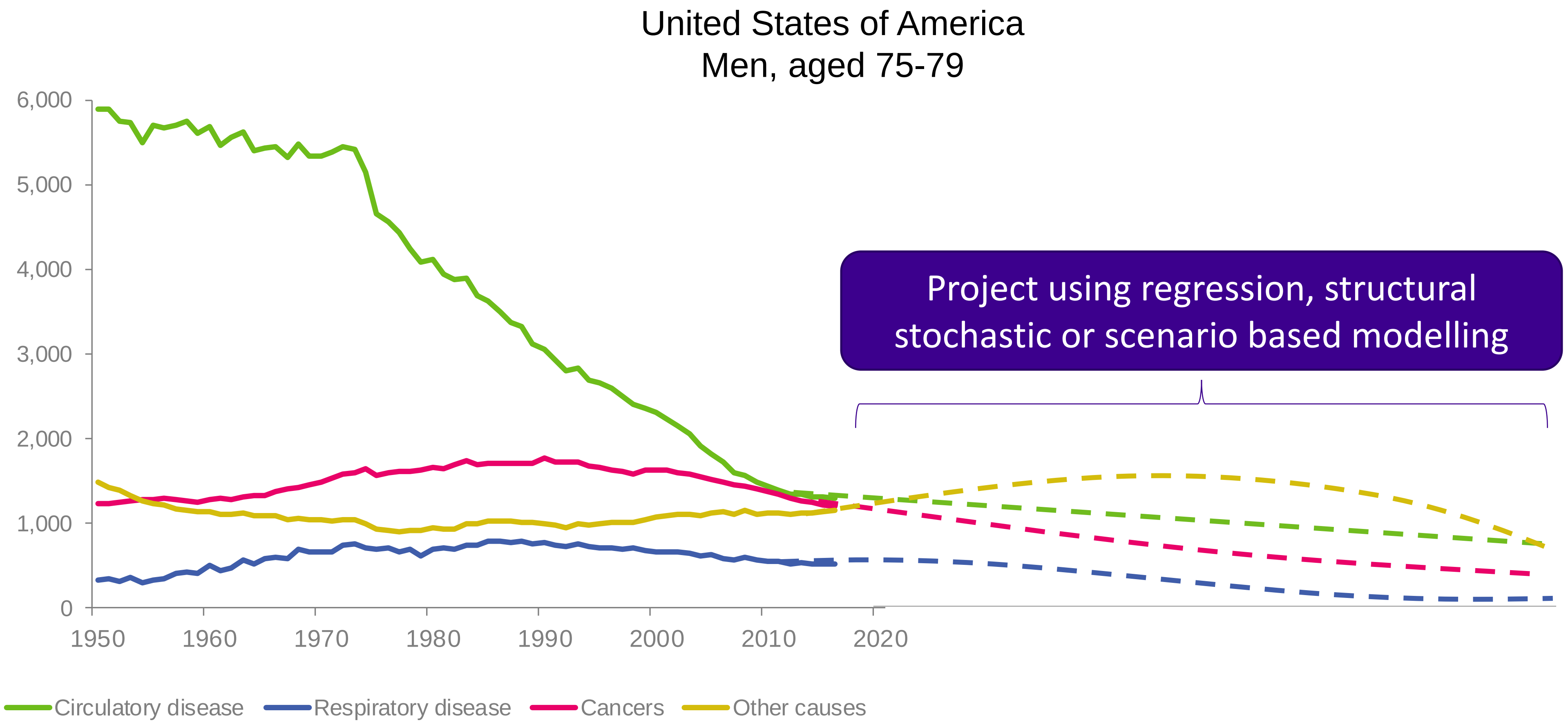
Projecting mortality by cause of death



Challenges projecting by cause of death

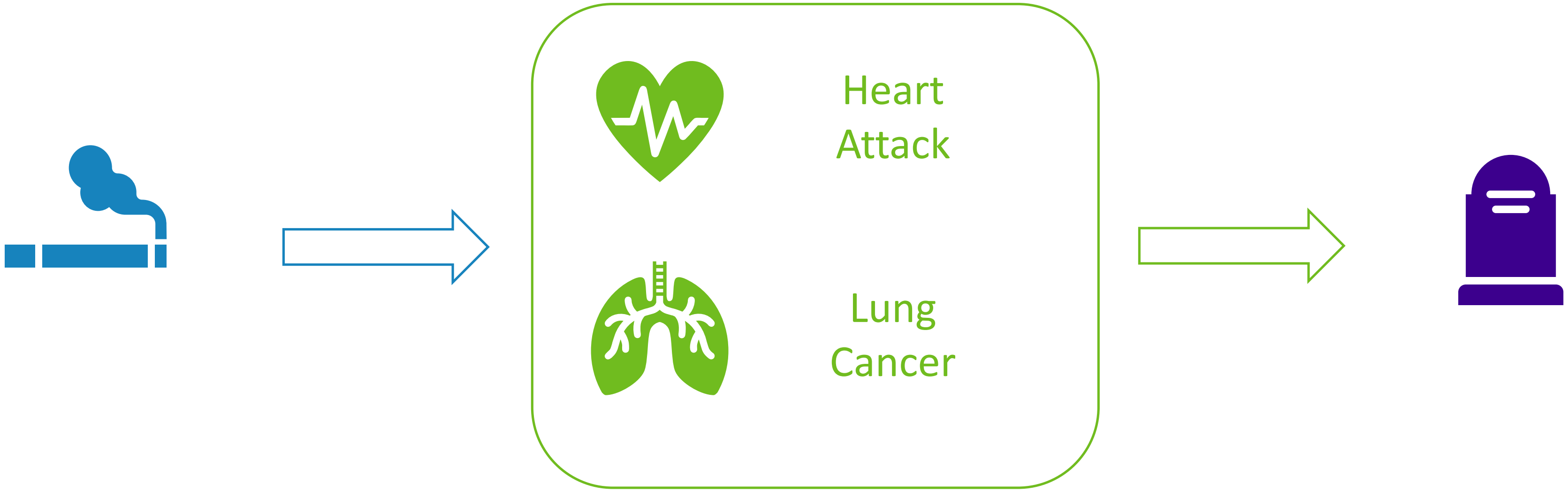
How to group causes?

Changes to classifications over time

Multi-morbidity and competing risks

Older ages

Cause of Cause of Death



How have smoking patterns changed by generation? What will these be in future years?

What will the impact be of these changes on different causes of death?

How will **overall** mortality rates change as a consequence?

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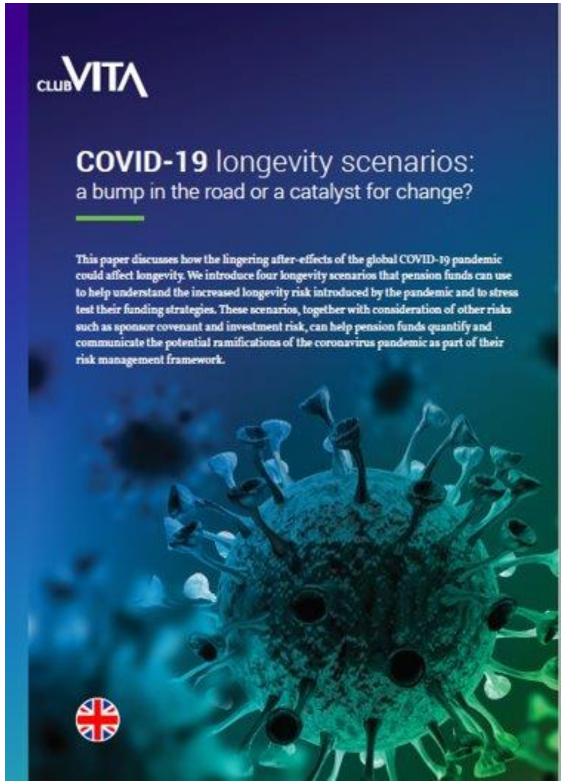
Scenario Analysis

COVID-19



Climate Change

Our library

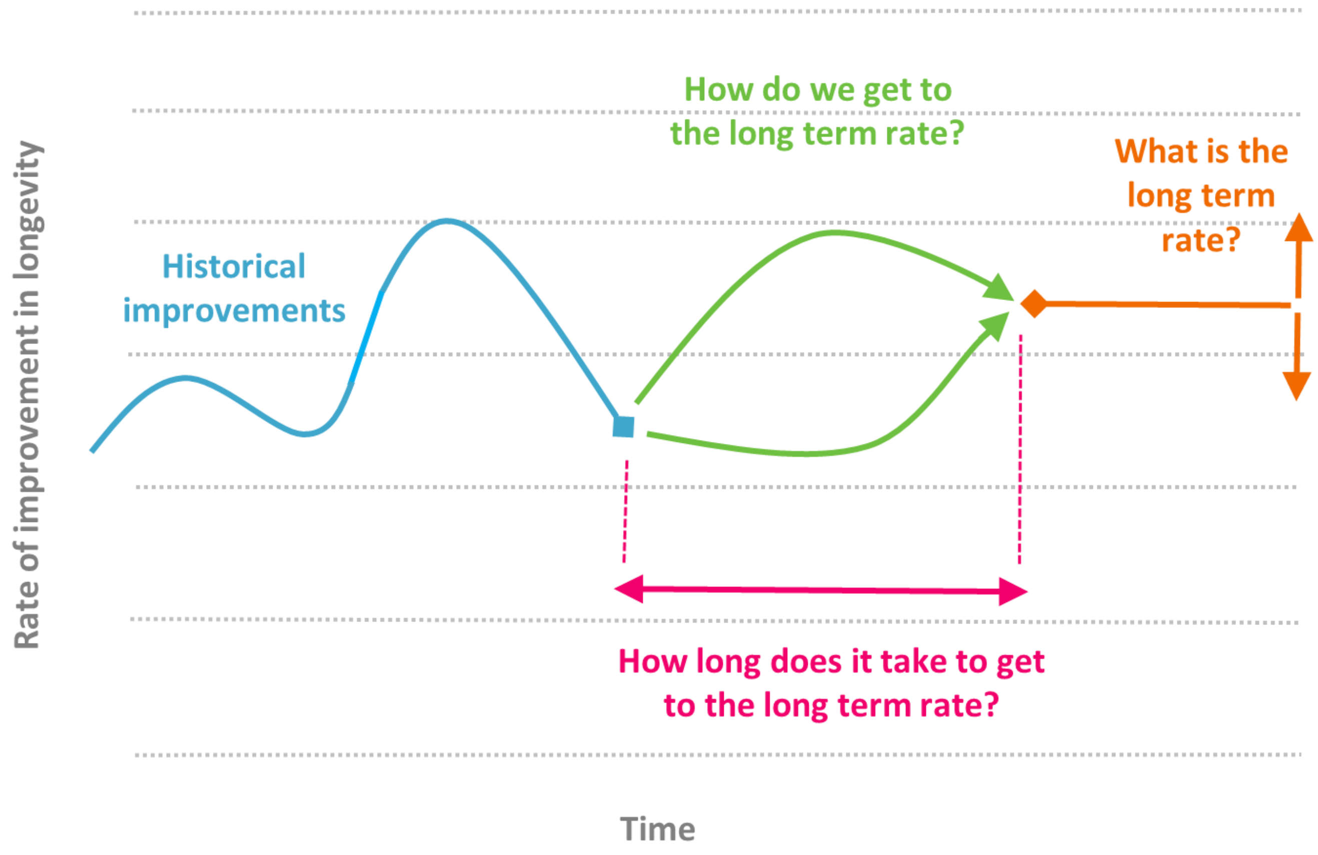
Heath Cascade

Extended Youth

“Cure” for Cancer

5 What do we actually do?

Using models in practice



- Each model has the same steps:
  - Fit to historical data to get ‘initial’ rates
  - Make assumptions about long term
  - Transition from initial to long term
- Variations in approaches taken for each step
- Advanced users have ability to adjust settings for more granular control

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3 countries, one model?

	UK	US	Canada
Latest version	CMI_2020	*MP-2020*	*MI-2017*
Initial rates (IR)	Fit APCI model to log of population mortality with user defined level of smoothing (S_κ)	Whittaker-Henderson smoothing of log of population mortality *2 year step-back*	Whittaker-Henderson smoothing of A/E ratios of log of population mortality *2 year step-back*
Cubics in..	Age-Period (AP) Cohort (C)	Age-Period (AP) Cohort (C)	Age-Period (AP)
Long term rate (LTR)	AP: User defined C: 0%	AP & C: 1.35% *(Default)*	AP & C: 1.0% *(Default)*
Tapering of LTR	Decline from age 85 to 0% at 110 AP only	Decline from age 62 to 1.1% at age 80, then 0.4% at age 95, and 0% at age 115	Decline from age 90 to 0.2% at age 100 and 0% at age 105
Convergence period (CP)	AP: Variable – max 20 years C: Variable - max 40 years	AP: 10 years C: 20 years	AP: 10 years for ≤40 20 years for 60+
Constraints	IRs; LTR and 0 slope at CP *plus* Direction of Travel *or* Proportion remaining at mid-point	IRs; LTR; slope 0 at start and at CP	IRs; LTR; 0 slope at CP Implied slope at start (subj to max)
Other		Improvements held constant (by age) beyond 20 years	Improvements held constant (by age) beyond 20 years

CMI framework common across countries; US & Canada based on pre CMI-2016 approach

Source: Club Vita summary of key features of core/default version of the model in each country. Note that UK includes richer advanced options including addition to initial improvements / constant addition to improvements.

Adding stochastic components

Mechanistic

- Simulate extra year of data
- Refit model including this extra year
- No (additional) judgements beyond simulation approach

Judgement based

- Apply statistical distributions to key parameters
  - Fit to historical data
  - Long term rates
  - Shape and time of transition
- Judgement required

- Run large number of simulations, each creating a grid of improvements
- Generate distribution of mortality rates, cashflows etc

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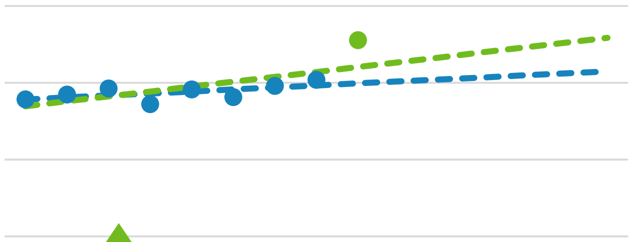
6 Other things to consider

Further considerations

- High ages – how to handle low levels of data?

- Different groups – should you model subgroups separately?



- Unusual year of data – assume new trend or blip?

- Is there hidden expert judgement in the model?

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Questions?

Erik Pickett PhD FIA CERA
Webinar chair

Chief Content Officer,
Club Vita

Conor O’Reilly FFA
Panelist

Head of Analytics,
Club Vita

Shantel Aris ASA
Panelist

Longevity Risk
Modeler, Club Vita
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Thank you