Continuous Mortality Investigation
Institute and Faculty of Actuaries

High Age Mortality

Steve Bale
Mark Cooper

19 November 2015

Agenda

- Why does high age mortality (90+) matter?
- Summary of observed experience and graduated tables
- Theories around mortality patterns at high ages
- What modelling and data issues should be considered?
- Issues with mortality of closed cohorts
- Summary of findings
- Future research

- Further information can be found in CMI Working Paper 85

Background

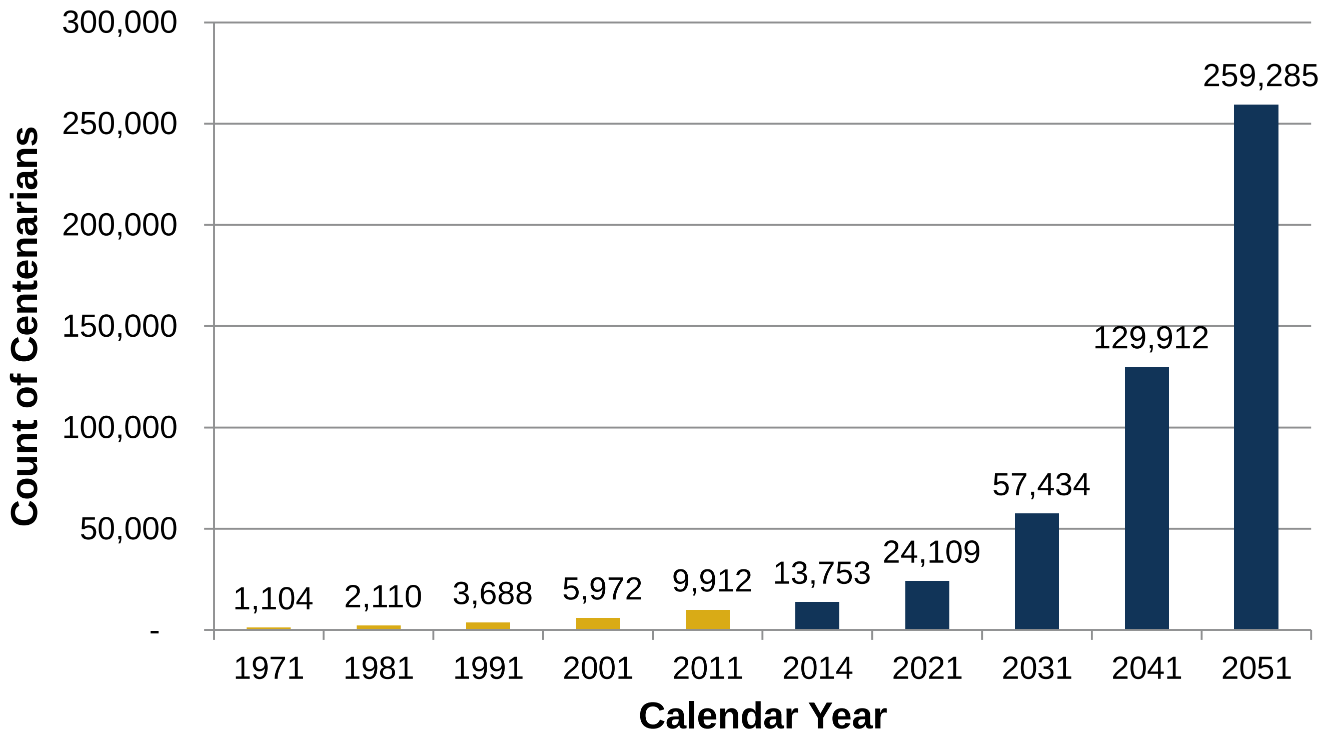
High Age Mortality Working Party

- Established Summer 2014
- Members predominantly drawn from CMI investigation committees

HAMWP terms of reference

- Investigate and summarise published research on high age mortality
- Investigate absolute mortality rates in respect of closing published tables
- Analyse data issues with available data sets (population / portfolio data)

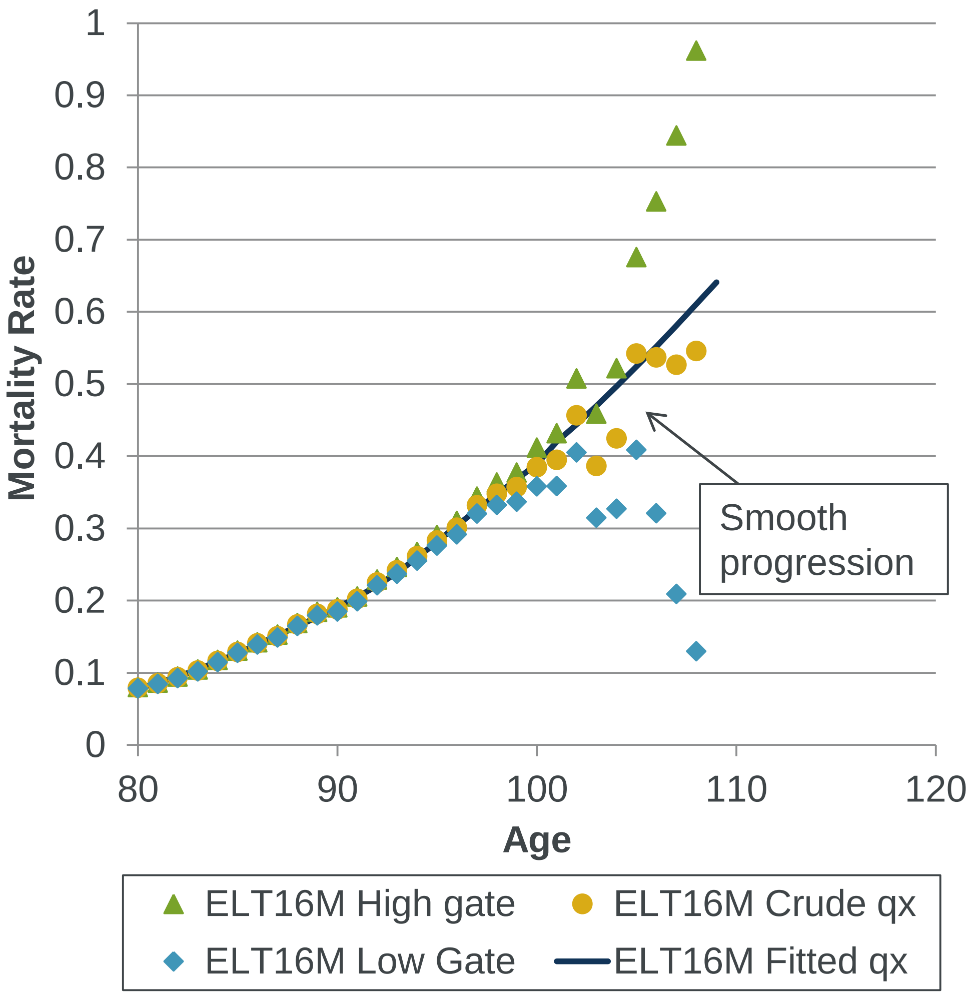
Why does high age mortality matter?

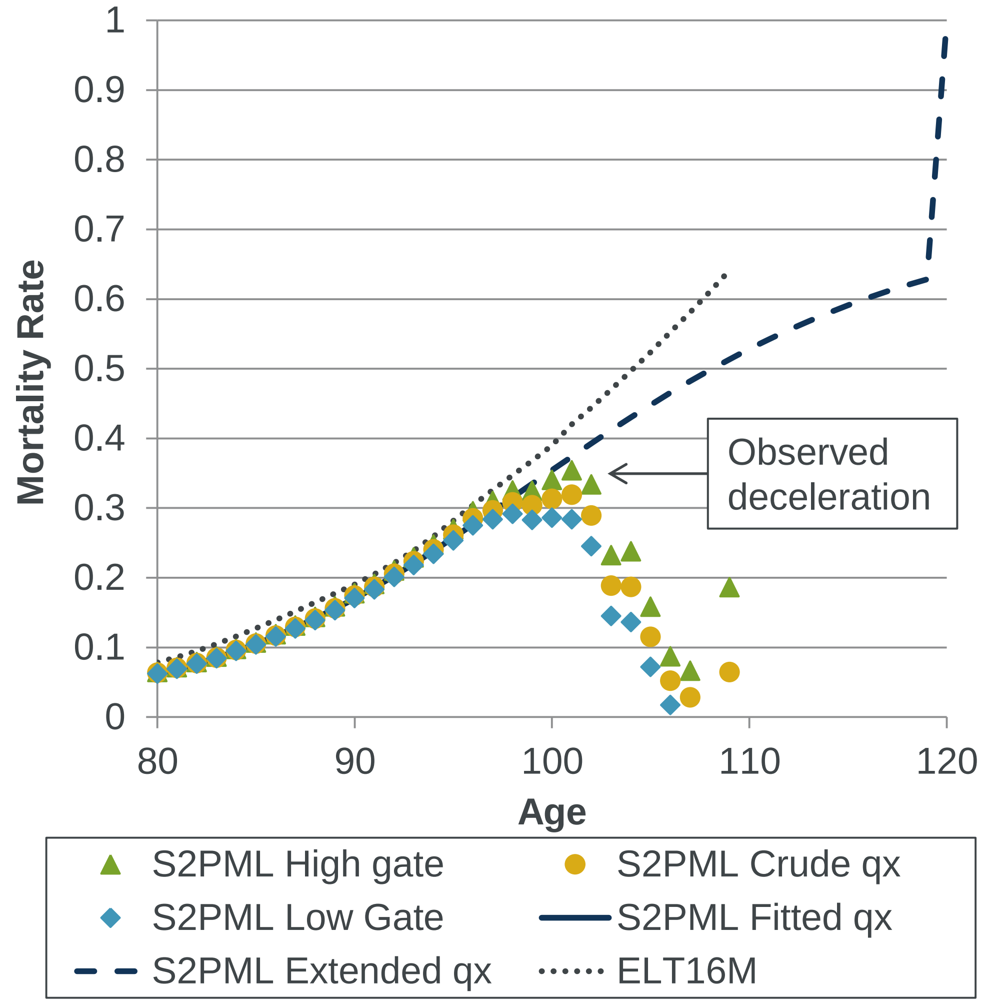


ONS 2012-based population-projection forecasted deaths at ages 90+:

- 20% of all deaths in 2013
- 36% of all deaths in 2040

Fitting mortality rates at high ages

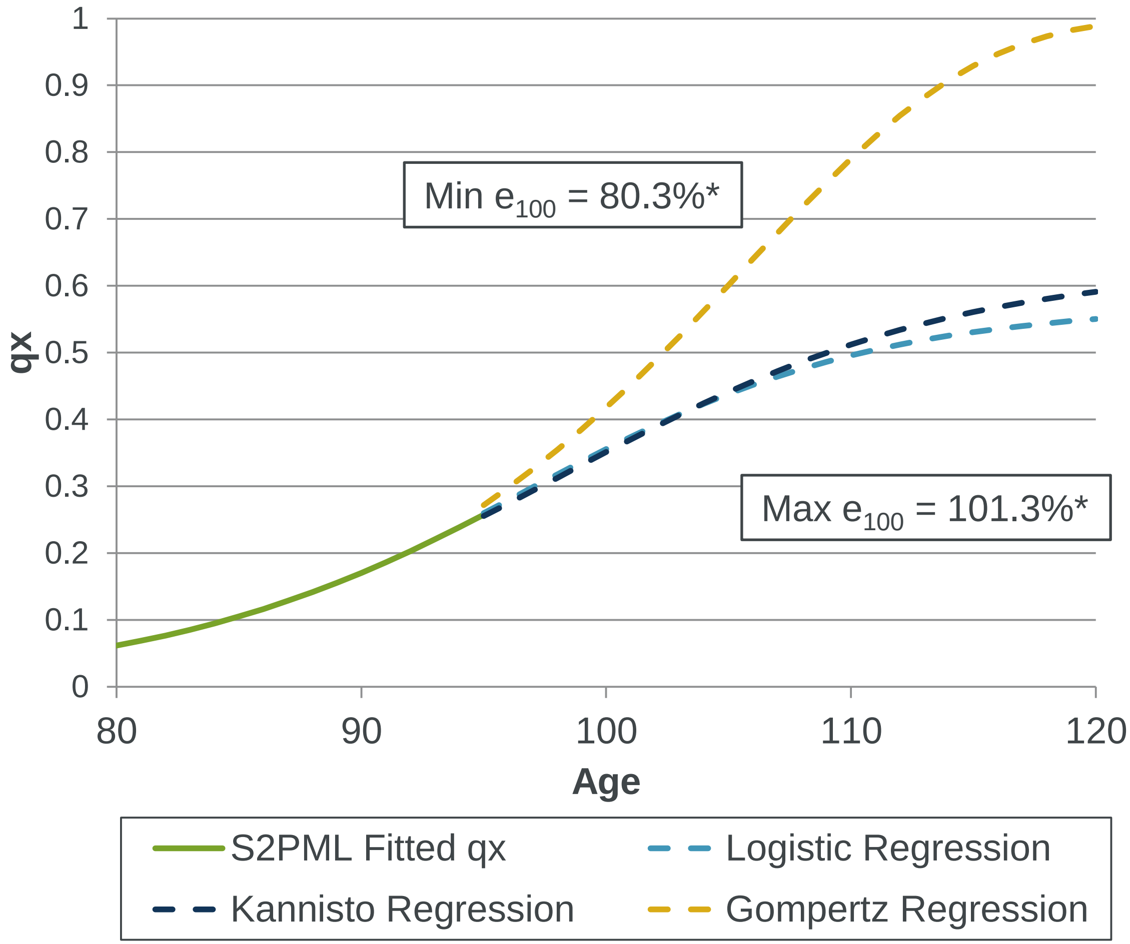




Academic Contributions

- A range of functional forms have been proposed for shape of mortality curve at older ages
- Graph shows impact on S2PML curve of **regressing** common functional forms

- Gompertz: $\mu_x = ae^{bx}$
- Kannisto: $\mu_x = ae^{bx}/(1+ ae^{bx})$
- Logistic: $\mu_x = c + ae^{bx}/(1+ \alpha e^{bx})$



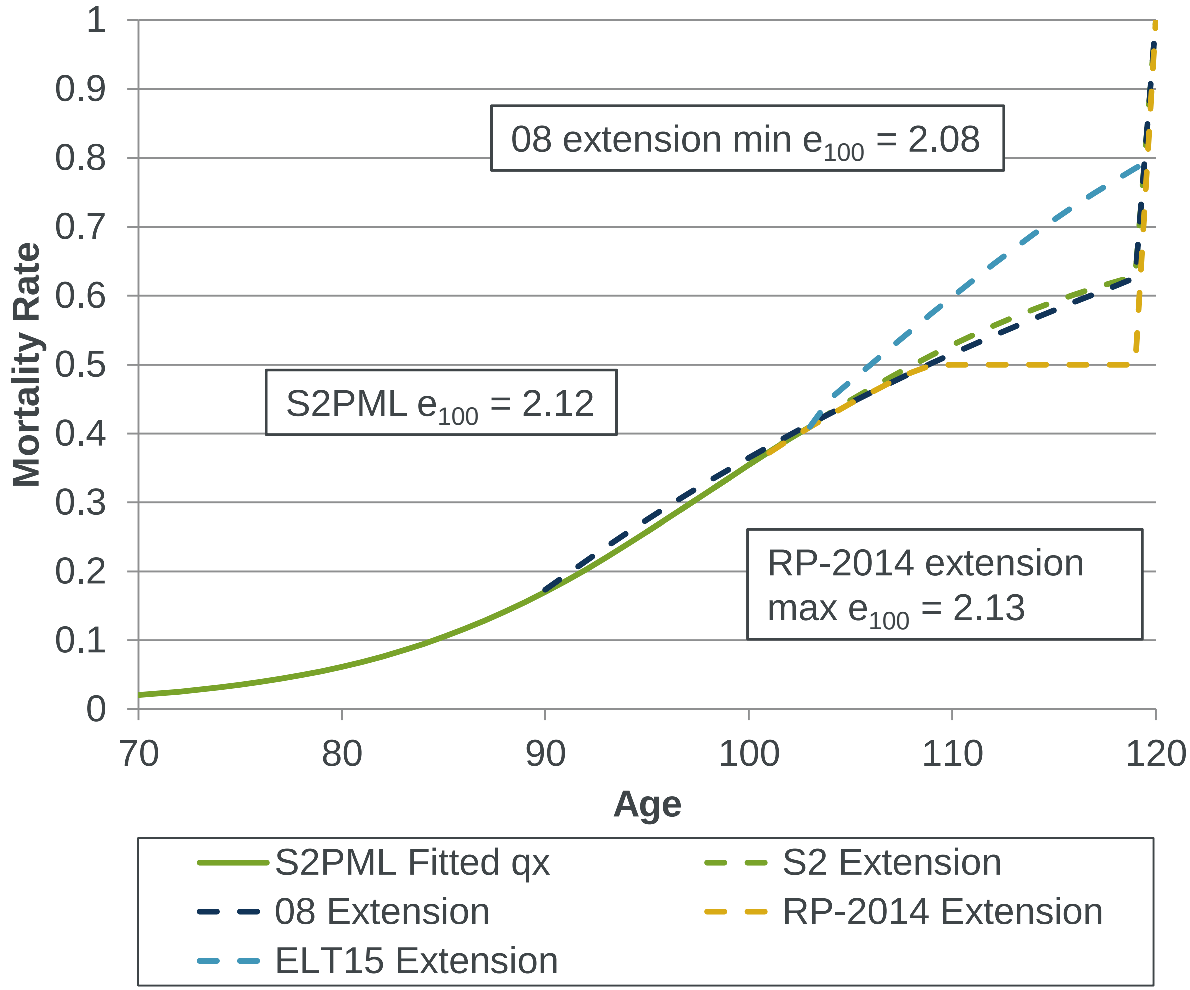
*relative to S2PML extension (baseline e_{100} = 2.12)

Summary of published tables

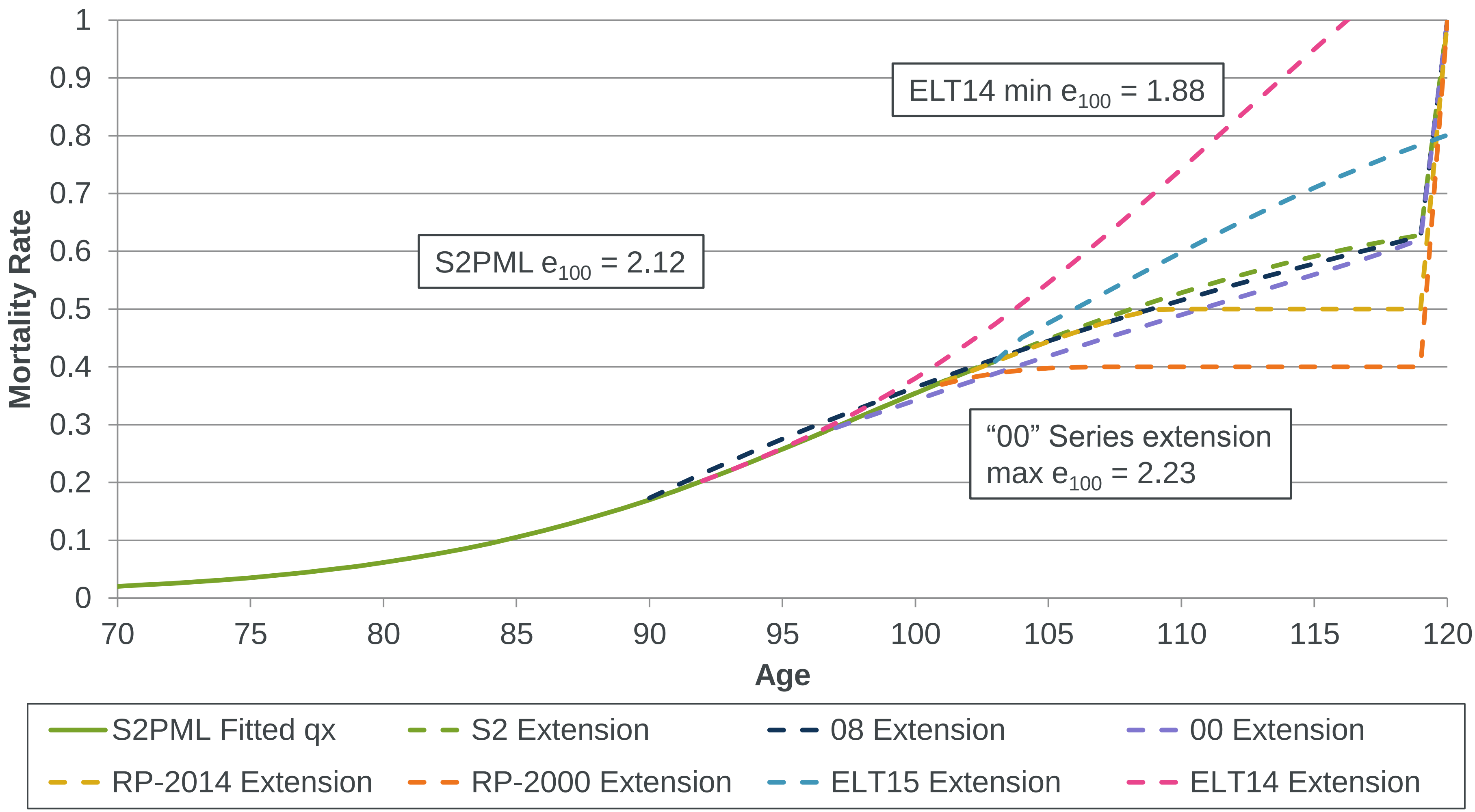
Table	Run in Age	Extension Approach	Limit mortality rate
ELT16	n/a	Variable-knot spline regression fitted to 108, used for high age extensions	$m_{120} = 2 / q_{120} \sim 1$
"S2" Series	95	Cubic spline with constraints	$\mu_{120} = 1 / q_{120} \sim 0.64$
"08" Series	90	Non-linear interpolation	$\mu_{120} = 1 / q_{120} \sim 0.64$
Canadian CPM2014	94	Quartic polynomial to bridge graduated rate to population rates at age 103	q_{114}=0.66
US RP-2014	Between 75 and 100	Kannisto regression for high ages 75-104 / interpolation between main regression and high age	Cap on q_x of 0.5

Comparison of published graduations (I)

- S2PML extended using methodologies underlying various industry tables
- Run in age used for each table applied to S2PML data
- Very little variation in e_{100} for the extensions shown due to closeness of q_x values near 100



Comparison of published graduations (II)



Comparison of life expectancies

Period life expectancy	“S2” Series	“08” Series	RP-2014	ELT15
e_{80}	8.03	(99.3%)	(100.0%)	(100.0%)
e_{90}	4.04	(95.8%)	(100.0%)	(100.0%)
e_{100}	2.12	(98.1%)	(100.7%)	(99.3%)

- Table percentages show LE relative to S2PML graduated rates
- “08” Series: outlier as extension applies from a young age (90)
- “08” Series extension: uses relative differences between annuitant and population mortality so applying to SAPS data may give misleading results
- RP-2014 extension: low impact as extension commences at age 100
- ELT15 extension: differences only seen at very high ages

Theories on mortality patterns at high ages

- Debate around mortality deceleration vs Gompertz progression at high ages
- A number of authors support deceleration with heterogeneous populations (frail die young) seen as main cause
- Gavrilov and Gavrilova (2011, 2014) propose no underlying deceleration, primarily due to:
  - Age misreporting
  - Aggregation of single year birth cohorts (heterogeneity)
  - Studying age-specific probabilities of death rather than force of mortality
  - Data recording in older studies was less accurate

What data issues should be considered?

Issue	Population Data	Portfolio Data
Exposure estimation	Mid year population estimates used as proxy for exposed to risk	Exposed to risk calculated from data
Death reporting	Death registrations required within 5 days of death	Late reported / unreported deaths common
Phantoms	“Phantom” cohorts possible due to rolling forward of census data	“Phantom” exposures possible if deaths not removed from data set
Migration	Assumption required for impact on exposures	Tracing overseas deaths difficult, likely delays in reporting

Model of late reporting and age misstatement

- Constructed stationary population by fitting Gompertz curve to data underlying "08" Series tables
- Rolled forward population with assumed mortality rates and allowance for late reporting

Exposure for age_x in $year_{t-1}$ → Remove deaths with probability of death $q_{x,t}$ plus allowance for late reporting → Exposure for age_x in $year_t$

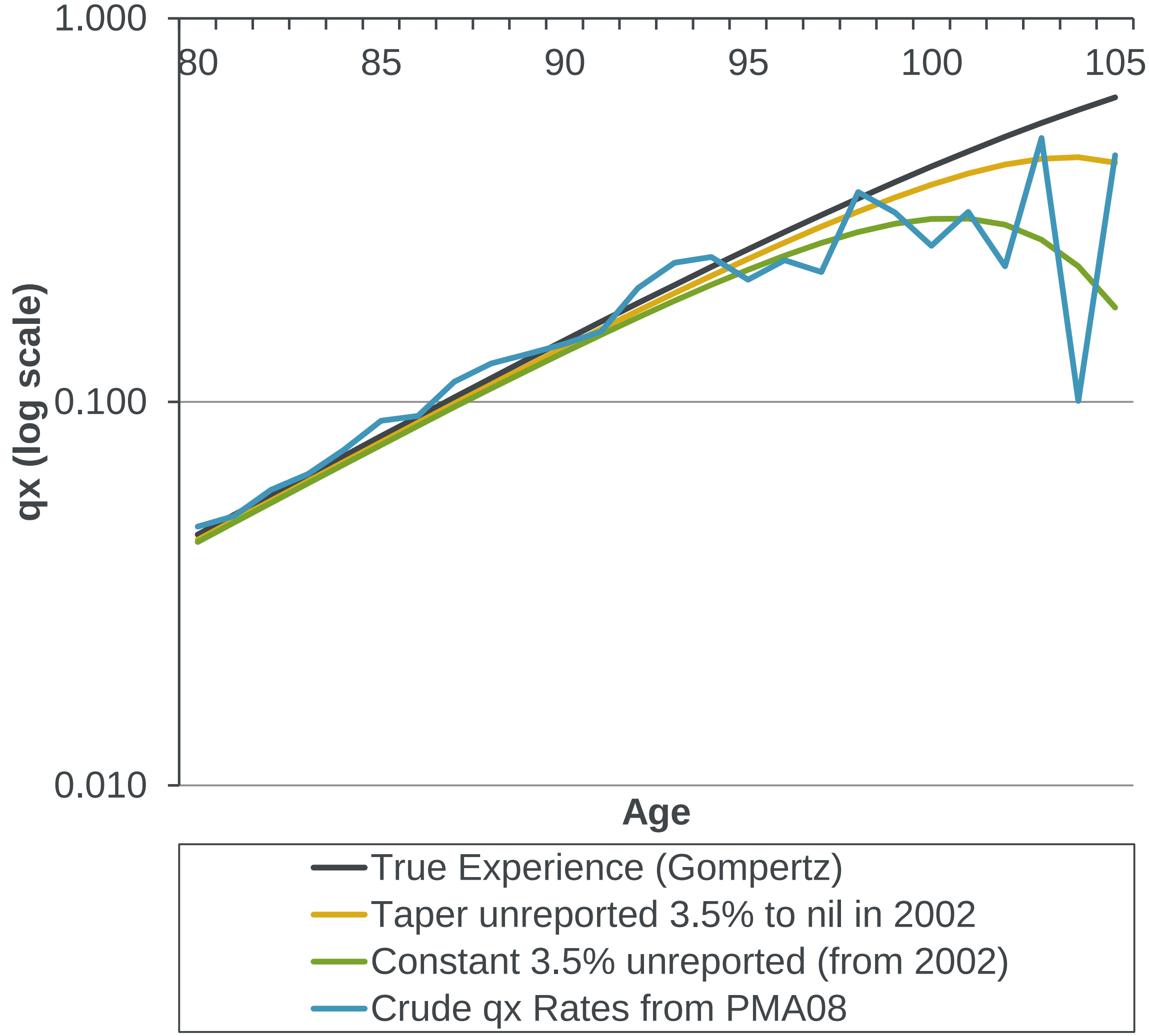
- Looked at impact on mortality curve based on consistent observation timing with "08" Series tables
- Analysed impact of age misstatement by redistributing exposures and deaths across ages

Modelling late reporting of deaths

- Constant 3.5% unreported deaths distorts Gompertz curve to crude rate levels at old ages

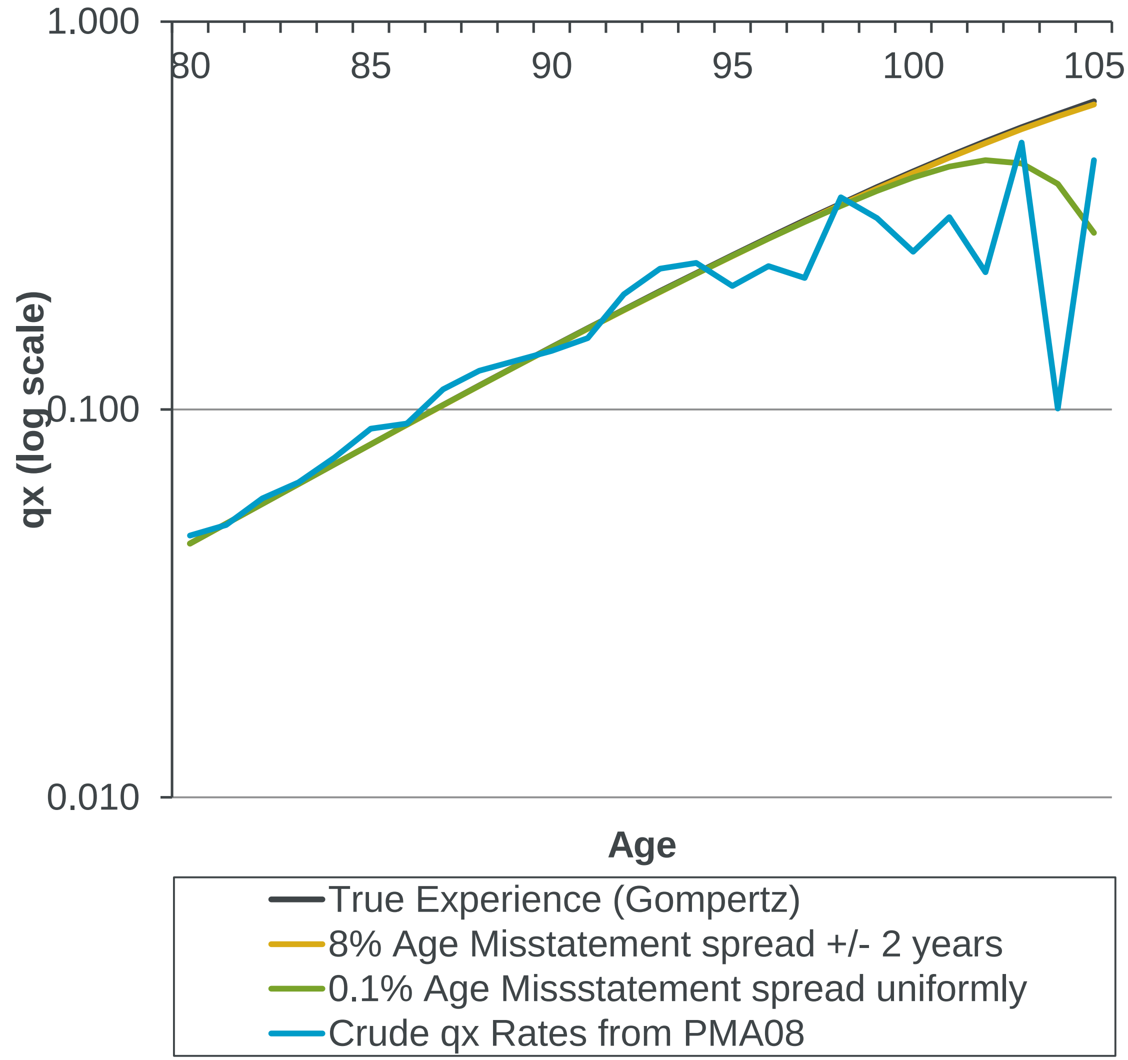
Percentage difference LE vs Gompertz

	Constant 3.5% unreported (from 2002)	Taper unreported 3.5% to nil in 2002
65	102.1%	101.3%
80	104.3%	102.4%
90	110.1%	104.4%



Modelling age misstatement

- Age misstatement scenarios considered less impact on mortality curve than late reporting



Percentage difference LE vs Gompertz

	8% Age Mis-statement spread +/- 2 years	0.1% Age Mis-statement spread uniformly
65	100.0%	100.0%
80	100.1%	100.1%
90	100.3%	100.5%

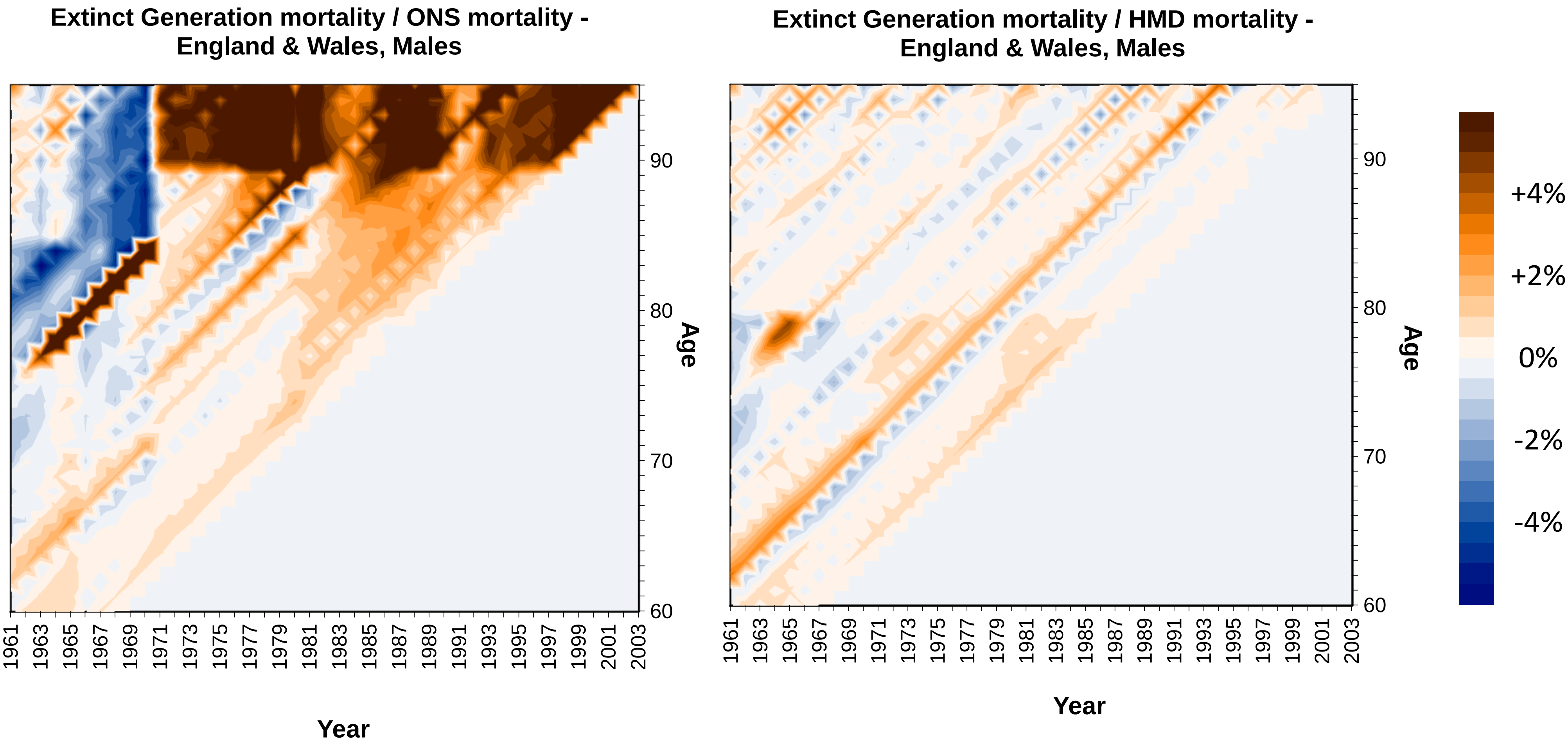
Closed cohort mortality

- Considered deaths for cohorts which are essentially extinct (reached their 110th birthday)

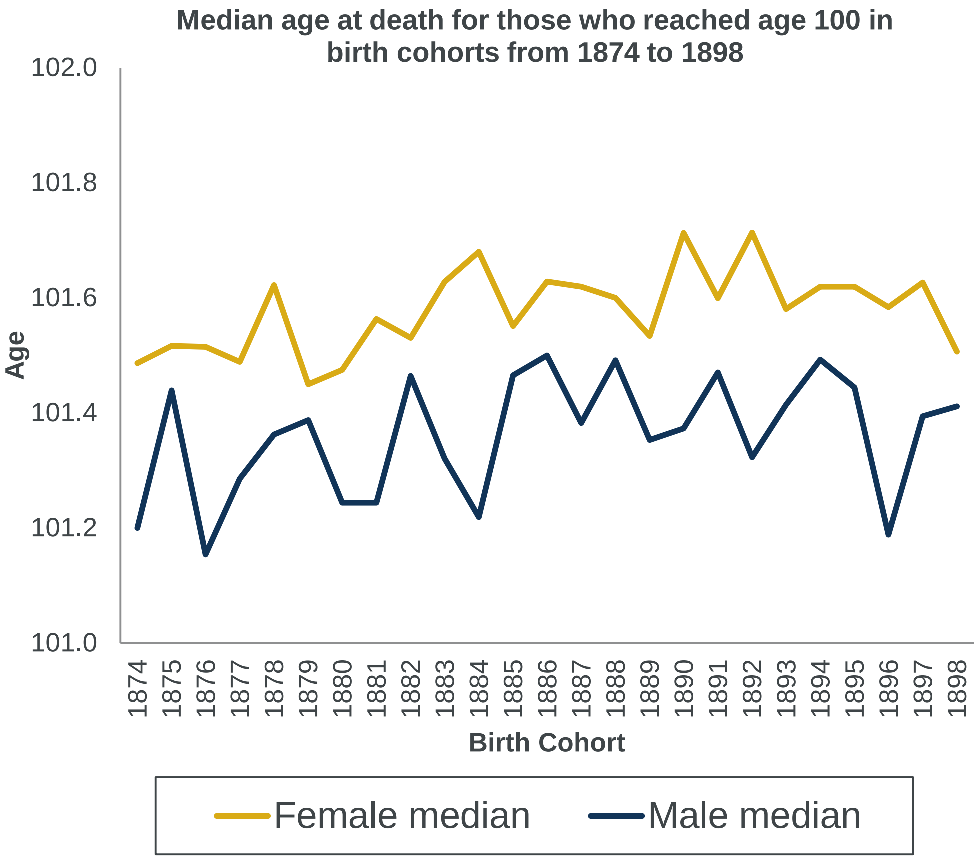
- Estimate historical populations (and mortality) from recorded deaths
  - Population for age x in calendar y year y = $P_{x,y}$
  - Deaths for age x in calendar y year y = $D_{x,y}$
  - $P_{max,y} = D_{110,y}$
  - $P_{x,y} = P_{x+1,\, y+1} + D_{x,y}$

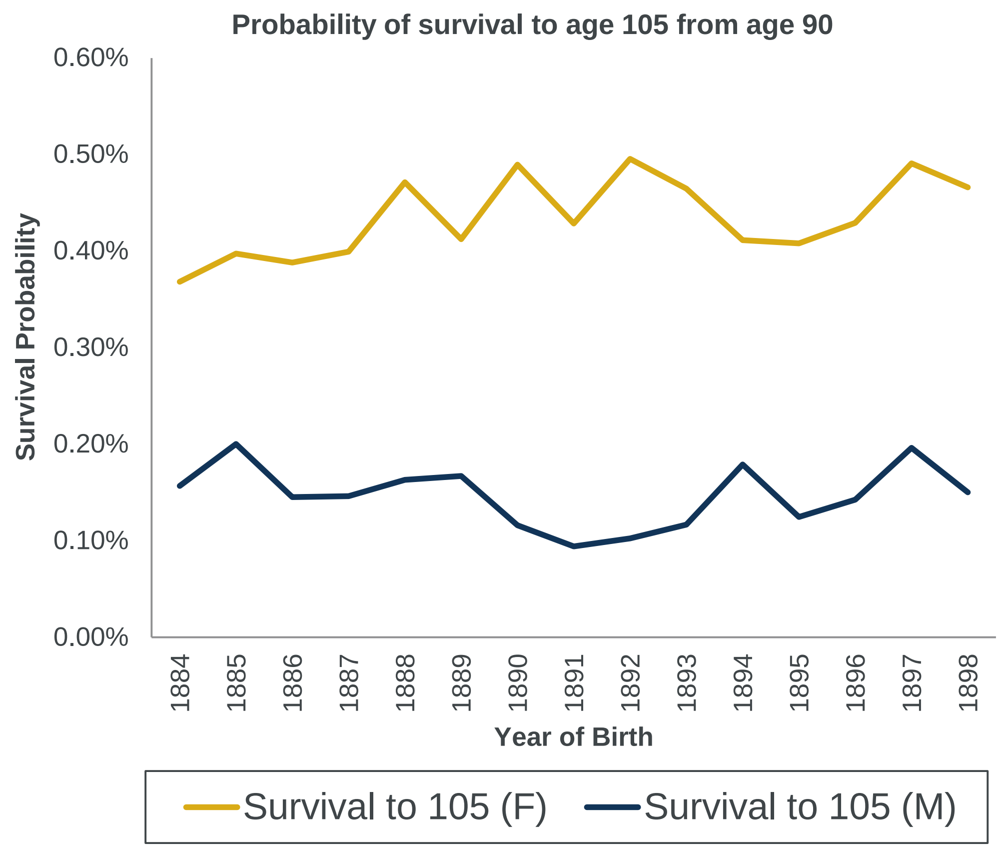
- Implied mortality compared against ONS and HMD published mortality

Closed cohort mortality



Areas of further investigation – time trends





- No clear evidence for a material change in mortality patterns for England & Wales centenarians born between 1884 and 1898.

Summary of findings

- Data and modelling issues at very high ages:
  - Inconclusive debate on mortality shape at high ages
  - Users should consider age misstatement and late reporting issues
  - Published closed cohorts mortality appears to be understated
- Impact of different mortality rates derived using different models generally not material except at very old ages
- Given this and data issues mentioned above, the Working Party feels that old age extrapolation choices in recent graduated CMI tables were reasonable

Areas for further exploration

- Population mortality at high ages
- Mortality trend insights
- International comparators
- Seasonal mortality
- CMI datasets

Questions

Comments

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

Please send any views or feedback to
Highagemortality@cmilimited.co.uk

Continuous Mortality Investigation Limited
Registered in England & Wales (Company number: 8373631)
Registered Office: Staple Inn Hall, High Holborn, London, WC1V 7QJ

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)

Continuous Mortality Investigation Limited (‘the CMI’) is wholly owned by the Institute and Faculty of Actuaries.

19 November 2015