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Continuous Mortality Investigation

Working Paper 63

The CMI Mortality Projections Model, CMI_2012

February 2013

Executive Summary

In November 2009 the CMI published a new mortality projections model, denoted 'CMI_2009'. The Model has been updated annually since then and the latest update, 'CMI_2012', has been published alongside this paper together with its User Guide.

The structure of the CMI_2012 Model is identical to that of the previous versions; however, the default parameters contained in the Model have been updated to reflect the latest England and Wales population mortality dataset. On this occasion there are two elements to updating the dataset:

- The first element is to incorporate a set of revised population estimates for England and Wales for mid-2002 to mid-2010. The revised estimates were released by the ONS following the 2011 Census and provide a consistent time-series of population estimates to mid-2011.
- The second element is to extend the dataset to include population mortality rates for 2011.

This Working Paper illustrates the impact of both these elements. The change in the smoothed P-spline estimates of the annual rates of mortality improvement, resulting from the updated dataset, is discussed. The overall results of projections, expressed in terms of expectations of life, from CMI_2012 are compared with those from CMI_2011.

At an aggregate level, mortality rates fell more rapidly from 2010 to 2011 than in the previous year. All-age standardised mortality falls of 3.9% for males and 3.7% for females followed the smaller drop (2.5% and 0.9%) from 2009 to 2010. It remains difficult to draw conclusions regarding the current trajectory of rates of mortality improvement (noting that provisional estimates for 2012 are for little change in male mortality, and rises in female mortality).

The default Initial Rates of Mortality Improvement are significantly lower than those published in CMI_2011 at the oldest ages, particularly for males. In contrast, at the youngest ages the default Rates are higher than those published in CMI_2011, for both males and females. The comparison is more complex between ages 40 and 85 with estimates higher at some ages and lower at others. The revised estimates show some quite significant shape changes by age, particularly for males where we have seen the near-removal of the peak and trough previously apparent in the dataset around ages 85 to 90.

Core Projections generated by the CMI_2012 Model produce expectations of life which are generally lower than those produced by CMI_2011 (with other parameters held constant). At most ages the reductions are small (less than 1%). However, there are more significant reductions for males at ages 80+, driven by the revisions to population estimates,

Sample projected annuity values and expectations of life are included in the paper to illustrate the sensitivity of CMI_2012 to the key parameter, the Long-Term Rate of Mortality Improvement. The relative significance of the sensitivity of CMI_2012 to this and other parameters is essentially unchanged from that of earlier versions of the Model.

Overall, the CMI believes that the CMI_2012 Model has shown a reasonably smooth evolution from the CMI_2011 Model, even though the one-off change in population estimates for 2002-10 has resulted in a slightly higher degree of change than has been seen in previous updates to the Model. Other than at the highest ages, the degree of change between the two versions is small compared to the sensitivity of their results to the assumed Long-Term Rate of Mortality Improvement.

Contents

1. Introduction

1.1. Background

In November 2009 the CMI published a new mortality projections model, denoted 'CMI_2009'. The Model was released in response to the continuation of significant year-on-year increases in life expectancy, and to concerns over the continued widespread use, albeit with modifications, of the Interim Cohort Projections which inevitably became increasingly out-of-date.

In producing the Mortality Projections Model, the CMI sought to develop a model which:

- reflects the latest experience on trends in mortality;
- is relatively straightforward to understand and describe;
- allows users the flexibility to modify projections tailored to their own views and purpose; and
- can be regularly updated over time to reflect emerging experience.

Since the publication of 'CMI_2009', the Model has been updated annually and a summary of all previous versions and their associated Working Papers is set out in Appendix A. The structure of the Model has not changed, but default parameter values have been updated each year to incorporate newly published data. The Model has now been updated again and CMI_2012 has been published alongside this paper together with its User Guide.

1.2. Changes from CMI_2011

The structure of the CMI_2012 Model is identical to that of the three previous versions.

The principal purpose of this annual release of the Model is to incorporate updates to the England and Wales population mortality dataset into the default Core parameters for the Initial Rates of Mortality Improvement. On this occasion there are two elements to updating the dataset:

- The first element is to incorporate a set of revised population estimates. In December 2012, the ONS published revised population estimates for England and Wales for mid-2002 to mid-2010. The revised estimates were released following the 2011 Census and provide a consistent time-series of population estimates to mid-2011.
- The second element is the usual annual update to extend the dataset, this time to include population mortality rates for 2011.

The impact of both these elements on the default Initial Rates of Mortality Improvement is discussed in section 3 of this paper.

Other changes have been kept to a minimum:

- The naming convention has been updated to refer to CMI_2012
- The default Calculation Date on the [Sample EoL & Annuities] worksheet has been changed to 31/12/2012.
- References to the CMI Library of Mortality Projections have been updated to the latest version, v1.3, along with the parameters for calculation of expectation of life and annuity values on a consistent basis with those shown in the Library User Guide.

These changes are described in more detail in section 6 of the CMI_2012 User Guide.

1.3. The Scope of this Working Paper

Sections 2 to 4 of this paper follow a similar layout to CMI Working Paper 55. This enables ready comparison of the 2012 update to the Model with the 2011 update.

Section 2 describes the shape of the Initial Rates of Mortality Improvement in 2009 for the Core parameter layer of CMI_2012. This provides an update to the research and data underpinning the previous versions of the model. Previous research and data are detailed in:

- CMI_2009: Appendix A to the CMI_2009 User Guide
- CMI_2010: Section 2 of CMI Working Paper 49
- CMI_2011: Section 2 of CMI Working paper 55.

Section 3 discusses the impact of the two elements to updating the dataset; the effect of adding data for calendar year 2011 and the effect of incorporating the revised population estimates for mid-2002 to mid-2010, following the 2011 Census. The combined impact of these elements on sample expectation of life values is shown in Appendix B.

Section 4 illustrates the sensitivity of CMI_2012 to the key parameter, the Long-Term Rate of Mortality Improvement.

1.4. Feedback on this paper

As the changes made in the latest version of the Model are limited, the CMI is not undertaking a consultation exercise on these revisions. The Committee intends to consult on the structure and parameterisation of the Model soon after the release of CMI_2012. The consultation will also encompass the future structure and use of the Library of Mortality Projections and will aim to ensure that these tools remain relevant to our users.

Feedback on the CMI Mortality Projections Model is always welcome, though, and can be sent via e-mail to projections@cmib.org.uk or in writing to: CMI, Cheapside House, 138 Cheapside, London, EC2V 6BW.

2. Derivation of Default Values for the Core Parameter Layer

The approach used to derive the default values for CMI_2012 is essentially unchanged from that used for the previous versions of the Model. This section comprises updated figures and charts for the new, extended dataset, with a brief accompanying commentary.

2.1. Initial Rates of Mortality Improvement

2.1.1. Initial Aggregate Rates of Mortality Improvement

The default tables for Initial Rates of Mortality Improvement cover calendar years 1991 to 2009 and contain values for individual ages, separately for males and females. These rates represent the total rate of improvement by age, year and gender before any split into Age/Period and Cohort Components and are referred to as 'aggregate' rates in papers relating to the Model.

These rates of improvement were derived by fitting a P-spline age-cohort model, separately for males and females, to crude mortality rate data for the population of England & Wales, for ages from 18 to 102, for the period 1961 to 2011. The underlying dataset was constructed by combining:

- A consolidated dataset of death registrations and mid-year population estimates, by single year of age (0 to 104 and grouped for ages 105+), calendar year (1961 to 2010) and gender
- 2011 death registrations data by single year of age (0 to 104, 105+) and gender
- Mid-2011 population estimates by single year of age (0 to 89, 90+) and gender
- Revised mid-year population estimates for 2002 to 2010 by single year of age (0 to 89, 90+), calendar year and gender; and
- CMI calculations mirroring the calculation algorithm used by the ONS to produce mid-year population estimates by single year of age within the 90+ age group. This enables CMI_2012 to be released without waiting for the ONS to publish that part of the required data. Details of the methodology are set out in CMI Working Paper 54.

Note: The dataset listed in the first bullet point above was provided by the ONS specifically for the CMI. The remaining datasets were published by the ONS between September and December 2012.

As well as providing the smoothed data from which to estimate 'current' (initial) rates, this modelling approach automatically also provides rates for earlier years on a consistent basis.

The initial rates of mortality improvement are taken as those for calendar year 2009, that is: $r_{x,2009} = 1 - \{ q_{x,2009} \div q_{x,2008} \}$. The first year of the projection is therefore assumed to be 2010. This reflects the previously confirmed view that 2 years inside the edge of the available data is the latest year for which sufficiently robust estimates of rates of mortality improvement may be made at present.

The derived estimates of aggregate Initial Rates of Mortality Improvement for calendar year 2009 are shown in Figure 1.

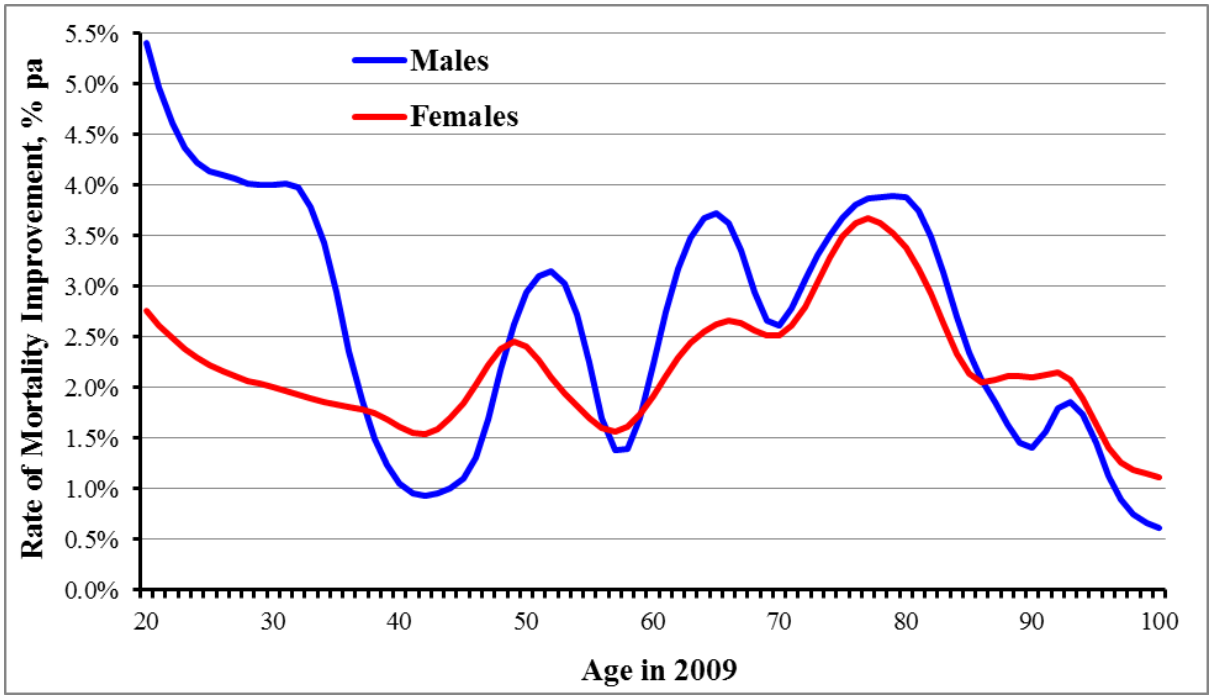

Figure 1: Estimated aggregate Initial Rates of Mortality Improvement; 2009

2.1.2. Split of Initial Rates into Age/Period Component and Cohort Component

The Model design incorporates splitting Initial Rates of Mortality Improvement into two components: Age/Period and Cohort Components. This approach has been retained for CMI_2012. This section illustrates the split of aggregate Initial Rates of Mortality Improvement into the two components for CMI_2012.

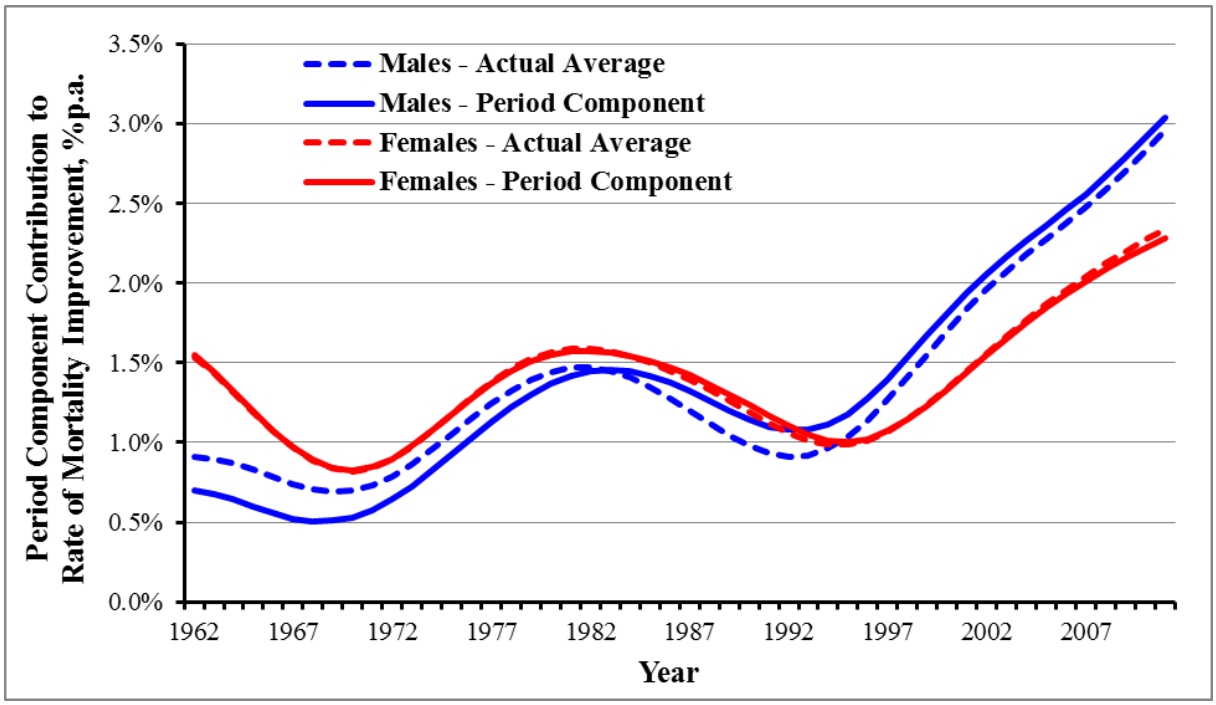

Figure 2: Comparison of the Period Components derived in APC Model with the All-Age Average Rates of Mortality Improvement

Figure 2 shows the period components derived from the Age-Period-Cohort (APC) model and compares them with the actual average (across ages 18 to 102) rate of improvement by calendar year. The close match between the APC model period component and the actual averages reflects the constraints applied (which are unchanged from previous version of the model; see section A1.2 of the CMI_2009 User Guide).

Figures 3 and 4 show the age, period and cohort components from the fitted APC models, for males and females respectively. Also shown are the residual errors.

Reasonableness checks were performed on the age, period and cohort components, for example by comparison with analysis of the underlying population data and with those in the previous versions of the Model. The residual errors were allocated in an identical manner to previous Model versions – the errors below age 30 were allocated to the Age/Period Component and those above age 60 to the Cohort Component, with a linear transition in between. In addition, the fitted Cohort Component was constrained to be zero near the edges of the data and in particular up to age 30 (as there are too few years' data, and too much 'noise' in the data at young ages, to form a safe conclusion on cohort components).

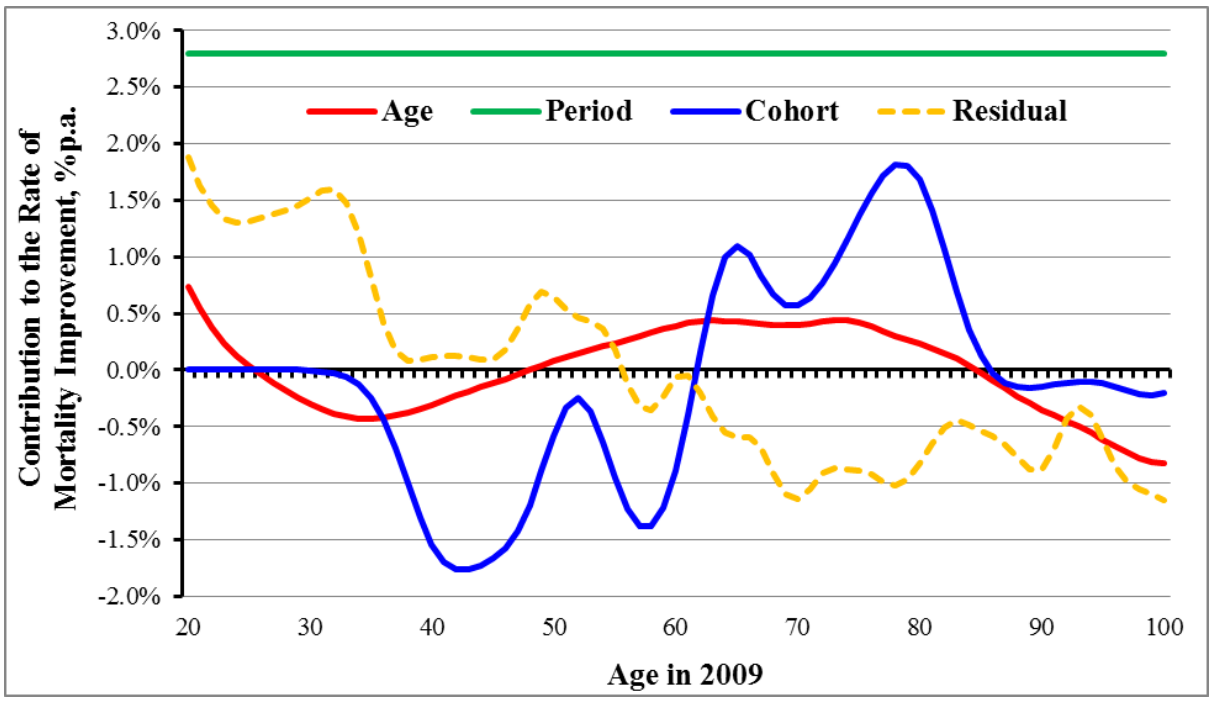

Figure 3: Results Derived from Fitted APC Model, Males; 2009 Age, Period and Cohort Components, plus Residual Errors

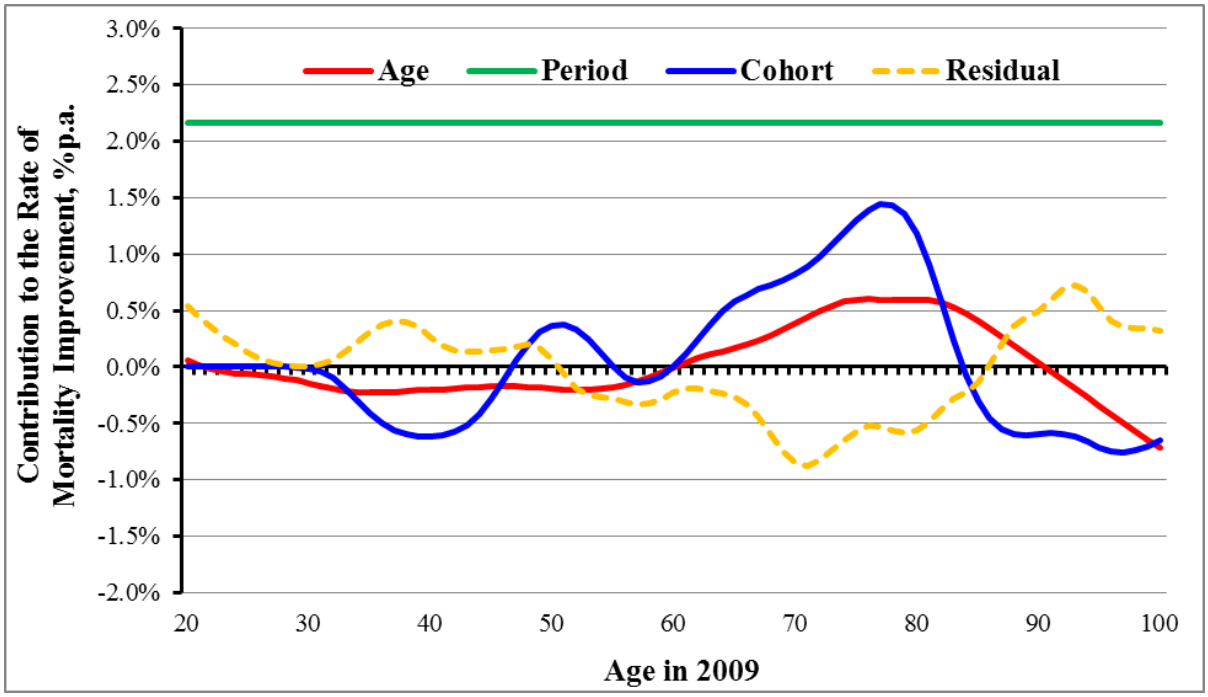

Figure 4: Results Derived from Fitted APC Model, Females; 2009
Age, Period and Cohort Components, plus Residual Errors

Figures 5 and 6 show the final derived Age/Period and Cohort Components of the Initial Rates of Mortality Improvement.

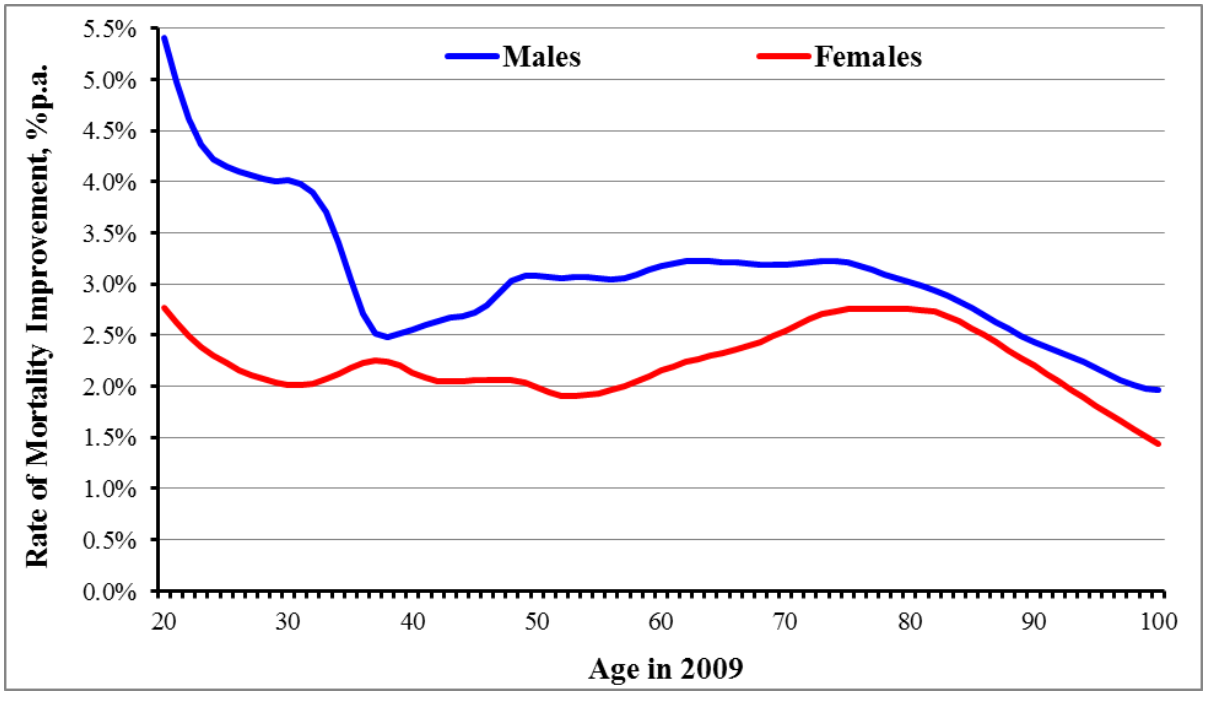

Figure 5: Estimated Age/Period Component of Initial Rates of Improvement; 2009

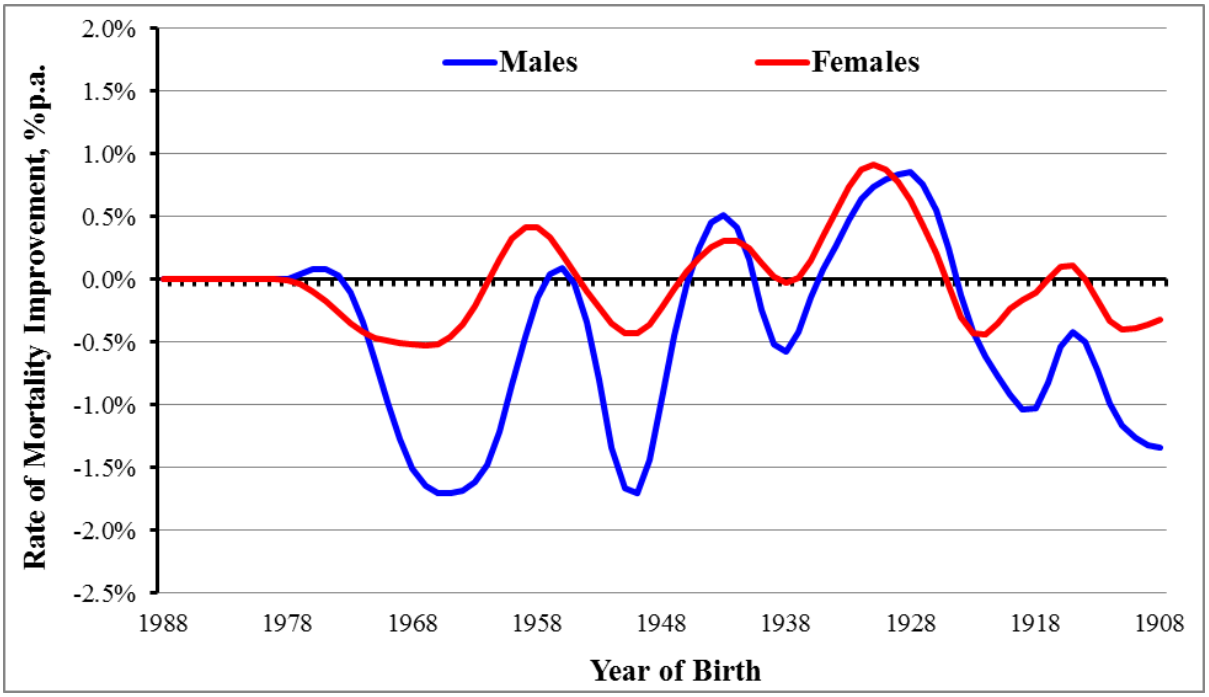

Figure 6: Estimated Cohort Component of Initial Rates of Improvement; 2009

2.2. Convergence

The Model assumes that Initial Rates of Mortality Improvement converge towards Long-Term Rates of Improvement. The convergence path is controlled by two sets of parameters:

- The Period of Convergence, and
- The Proportion of Convergence Remaining at the Mid-Point of the Convergence Period.

The convergence process is operated separately for Age/Period and Cohort components, and both sets of parameters may be varied by age and by year-of-birth cohort respectively for the two components.

The default value of 50% for the Proportion of Convergence Remaining at the Mid-Point of the Convergence Period has been retained in CMI_2012.

For the Convergence Period, the Committee again decided to maintain:

- The default parameter values for the periods of convergence for Age/Period Components in the CMI_2012 Model, and
- The approach taken to setting the default values for the periods of convergence for Cohort Components in the CMI_2012 Model. This approach assumes that the periods run to age 100, subject to a minimum of 5 years and a maximum of 40 years; as a result, the default periods of convergence for the Cohort Components have reduced by one year compared with CMI_2011 for year-of-birth cohorts from 1914 to 1948.

The default values are therefore unchanged from the pattern shown in Figure A.7 of the CMI_2009 User Guide, which illustrated the convergence periods by current age. (The question of whether to maintain the length of the convergence periods, moving the end-point

on by one year, or to fix the end-point from which the Long-Term Rates of Improvement apply was discussed in the context of CMI_2009 – see section 2.11 of CMI Working Paper 41.)

As with all the default Core parameter values, users can change these periods using the Advanced parameters within the Model if they wish.

3. The Effect of Revising and Extending the Data to Calendar Year 2011

3.1. Changes to the Population Dataset for England & Wales

Default values for Initial Rates of Mortality Improvement in the Core parameter layer of the CMI_2012 Model, issued alongside this paper, were derived from ONS data for the population of England & Wales, covering calendar years from 1961 to 2011. The base year for the projection in CMI_2012 is 2009. The corresponding dataset to 2010 was used in the CMI_2011 Model, with a base year of 2008.

The new data incorporated into the updated dataset to 2011 are:

- Estimated mortality rates for 2011 – using ONS data for death registrations and mid-year population estimates for 2011.
- Revised estimates of mortality rates for 2002-10. These arise from the revision of ONS mid-year population estimates for 2002-10 to take account of the 2011 Census and provide a consistent time-series of population estimates to mid-2011. Note that the death registrations data for 2002-10 have not been revised and remain unchanged from those used for CMI_2011.

The percentage change in the ONS mid-year population estimates for 2010 by gender, for ages 50 to 85, is illustrated in Figure 7.

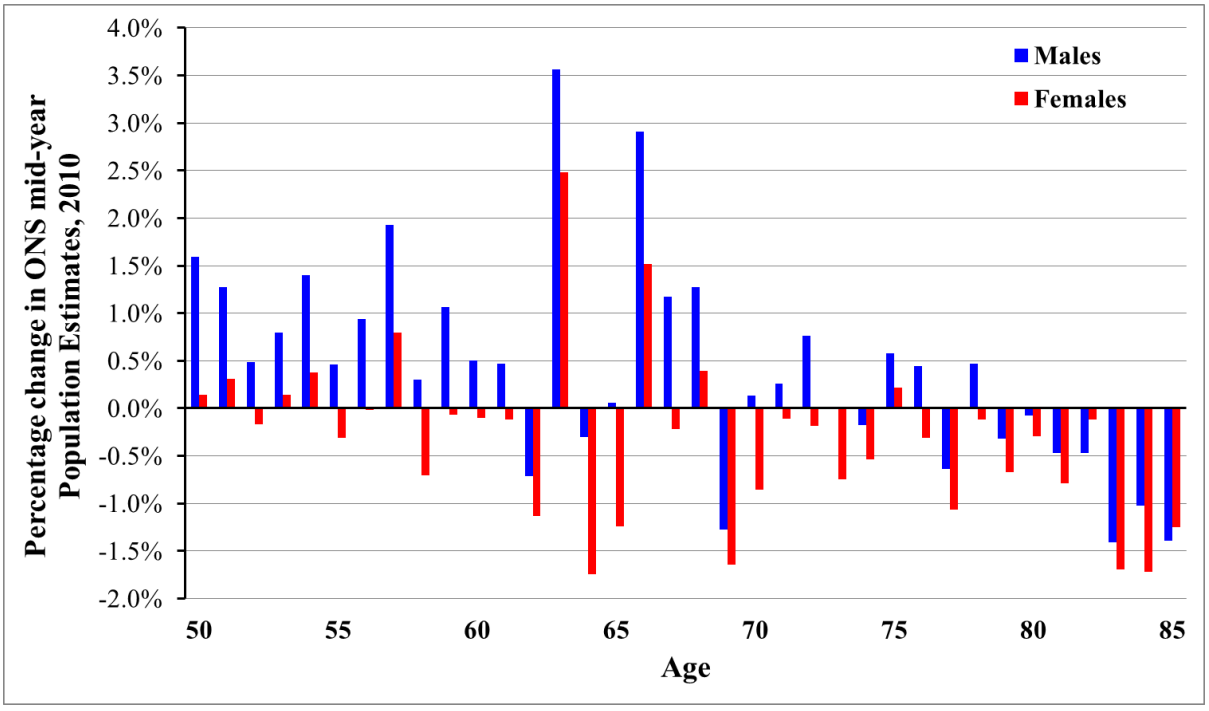

Figure 7: Percentage change in ONS mid-year Population Estimates for 2010, by sex and age; England & Wales Population

Overall the 2011 Census led to increases in the official population estimates for 2011 of 0.5% for males and 1.2% for females. The changes vary significantly by age and were typically greatest for ages 10 to 39. For the highest ages (90+), the 2011 Census led to reductions of around 15% for males, and 5% for females, in the 2011 population estimates. To provide a consistent time-series of population estimates, the revisions described were fed back through

prior year estimates to 2002 (the estimate for 2001 is unchanged), typically working back along birth-cohort lines, and with the magnitude of the revisions decreasing for each earlier year.

This section discusses the impact of the revised population estimates and the 2011 data extension on the Model, with many of the changes split out into the two components. The impact on selected cohort expectation of life values is illustrated in Appendix B to this paper. A similar discussion on the impact of adding 2010 data is contained in section 3 of CMI Working Paper 55.

3.2. Observed Rates of Mortality Improvement to 2011

At an aggregate level, mortality rates fell more rapidly from 2010 to 2011 than in the previous year. This is illustrated in Table 1, which shows crude annual mortality improvement rates for all-age mortality (ages 18-102, age-standardised using 2001 population estimates) for recent years.

Table 1: Observed Crude Annual Mortality Improvement Rates
England & Wales Population, ages 18-102

Year	Males	Females
2001	+3.0%	+1.8%
2002	+1.4%	+0.0%
2003	+1.7%	-0.6%
2004	+5.3%	+6.1%
2005	+2.5%	+0.8%
2006	+3.4%	+3.9%
2007	+2.3%	+0.8%
2008	+1.4%	+0.1%
2009	+4.3%	+6.1%
2010	+2.5%	+0.9%
2011	+3.9%	+3.7%

Table 1 shows there is considerable variation in mortality from year to year, even at the all-age level for the population of England and Wales. It is therefore necessary to apply some form of smoothing mechanism over time in order to try to detect time trends. For the avoidance of doubt, a positive value in Table 1 (and for the mean difference in Table 2) means that mortality rates have fallen.

The figures in Table 1 are based on mortality rates which take account of the revised population estimates for 2002-10. These revisions have reduced the calculated annual mortality improvement rates by up to 0.2% compared with the equivalent rates presented in Table 1 of CMI Working Paper 55.

For interest, it is possible now to estimate how Table 1 may be extended for 2012 experience. In January 2013, the ONS released provisional data on the total number of deaths in England and Wales in 2012. Based on those figures, the CMI has calculated initial estimates for 2012 crude annual mortality improvement rates. The analysis suggests the all-age mortality rates improved by only around 0.2% from 2011 to 2012 for males and deteriorated (increased) by around 2.0% for females. These results are initial estimates and are subject to revision once

the ONS publishes population estimates for 2012. For reference, a similar early estimate was produced for 2011 and the initial estimate of a 4.0% improvement for both males and females is reasonably close to the final figures (3.9% and 3.7% respectively), despite the revision of population estimates in these final figures shown in Table 1.

3.3. Changes in Estimates of Current Aggregate Rates of Mortality Improvement

In order to calculate default values for initial rates of mortality improvement, P-spline age-cohort models were again fitted to the population dataset. As expected, the revision of the population estimates, following the 2011 Census, and the addition of 2011 data both affect the fitted surface for earlier years. Table 2 shows two measures of the difference in estimated mortality improvement rates for recent years – the all-age mean difference, and the all-age mean absolute difference (calculated over the age range 18-102).

Table 2: Mean Difference and Mean Absolute Difference in fitted P-spline model Estimates of Annual Rates of Mortality Improvement (%) for the 1961-2011 dataset minus the 1961-2010 dataset
England & Wales Population, ages 18-102

Year	Mean Diff		Mean Absolute Diff	
	Males	Females	Males	Females
2001	−0.03	+0.02	0.18	0.07
2002	−0.05	+0.01	0.21	0.08
2003	−0.07	+0.01	0.24	0.09
2004	−0.08	+0.01	0.27	0.10
2005	−0.09	+0.02	0.32	0.12
2006	−0.08	+0.02	0.38	0.13
2007	−0.07	+0.03	0.45	0.15
2008	−0.04	+0.05	0.52	0.16
2009	+0.00	+0.07	0.59	0.17
2010	+0.05	+0.09	0.64	0.18

For the avoidance of doubt, the value of +0.05 for the Mean Difference in Table 2 for males in 2010, for example, corresponds to an increase in the mean mortality improvement rate for that year from 2.78% p.a. using the 1961-2010 dataset to 2.83% p.a. using the 1961-2011 dataset.

The magnitude of the differences for females is well within the range expected and suggests there is nothing especially unusual about the development of the time-series data.

However, the magnitude of the absolute differences for males is significantly greater than the typical differences derived in the back-testing of the prototype model (see section 3.1.2 of CMI Working Paper 39), and is much greater than those seen in previous updates of the Model. The differences also extend further back in time than is usually the case. These features are caused primarily by significant reductions in the estimated mortality improvement rates at high ages following the 2011 Census-based revisions to population estimates. Once these one-off revisions are taken into account, the addition of the extra year's data leads to changes more similar in magnitude to those seen in previous updates of the Model.

Although the mean absolute differences for males are relatively large, the mean differences are close to zero. This simple all-age average conceals more significant variations within the age range as illustrated in the following paragraphs.

Figures 8 and 9 compare the estimates for mortality improvement rates in 2008 (in CMI_2011, based on ONS data to 2010) with the estimates for 2009 (in CMI_2012, based on ONS data to 2011), for males and females respectively. Two intermediate steps are also shown as updates to the estimates for 2008:

- The first (and more significant) intermediate step reflects the revised ONS population estimates to 2010,
- The second also takes account of the extension of the data to include 2011.

The revised estimates show some modest shape changes by age.

The estimated improvement rates at the oldest ages for males are significantly lower than in the previous dataset, resulting from the revision of population estimates for 2002-1010. The revised population estimates have also led to the near-removal of the peak and trough previously apparent in the male dataset around ages 85 to 90 (probably linked to the 1919 cohort and possible distortions in the crude population mortality rates). The estimated mortality rates for males below age 40 are significantly increased when the dataset is extended to include data for 2011.

The differences between the estimated improvement rates for females are less marked than for males. Although there was also some reduction in the estimated improvement rates at the oldest ages for females as a result of the revised population estimates, it was of much lesser magnitude than that for males and has been offset by an increase in estimated improvement rates at high ages resulting from the addition of the data for 2011. As for males, we see the near-removal of the peak and trough previously apparent around ages 85 to 90. There has also been an increase in improvement rates below age 40 but, in contrast to males, more of the difference for females relates to revisions to 2002-10 data rather than the addition of data for 2011.

Although the absolute values will be different, the Committee has made no changes to the run-off patterns used at the oldest ages in CMI_2012 (the mortality improvement rates are assumed to linearly reduce (or increase) to zero in steps of 0.1% p.a. from age 100). The lower mortality improvement rates at age 100 (for males, in comparison to CMI_2011) will mean that these improvement rates now reach zero at a lower age than in CMI_2011.

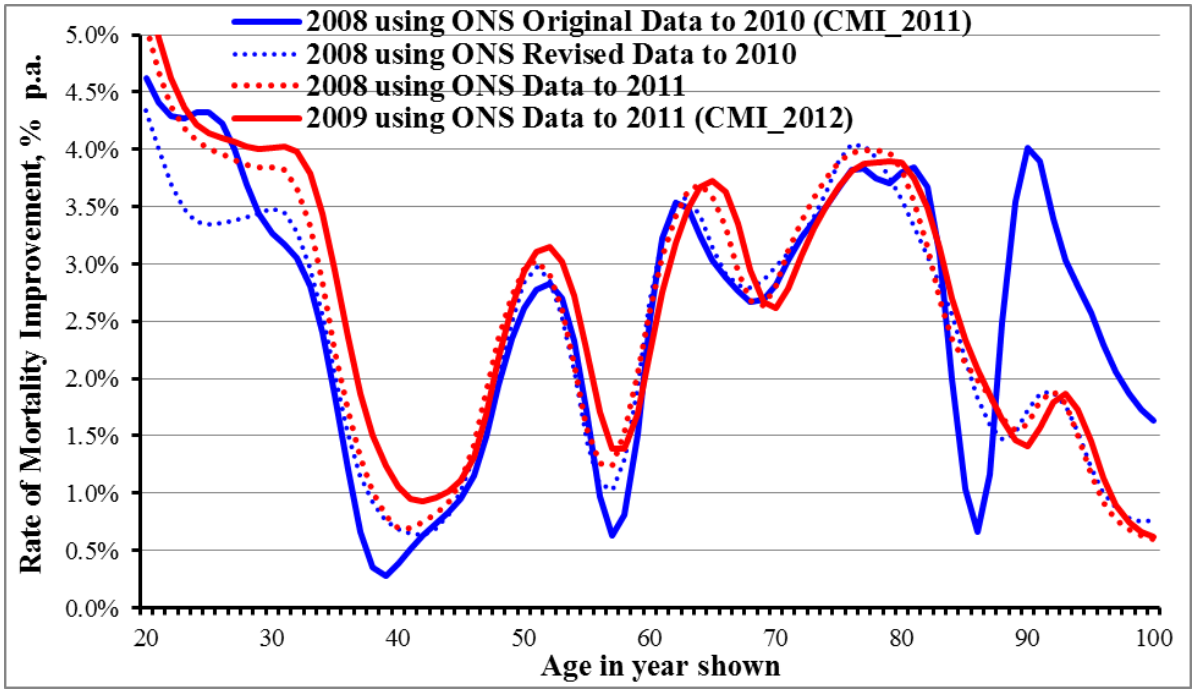

Figure 8: Estimated Aggregate Rates of Mortality Improvement, by age and dataset
Males, England & Wales Population
Estimates derived by fitting P-spline age-cohort models

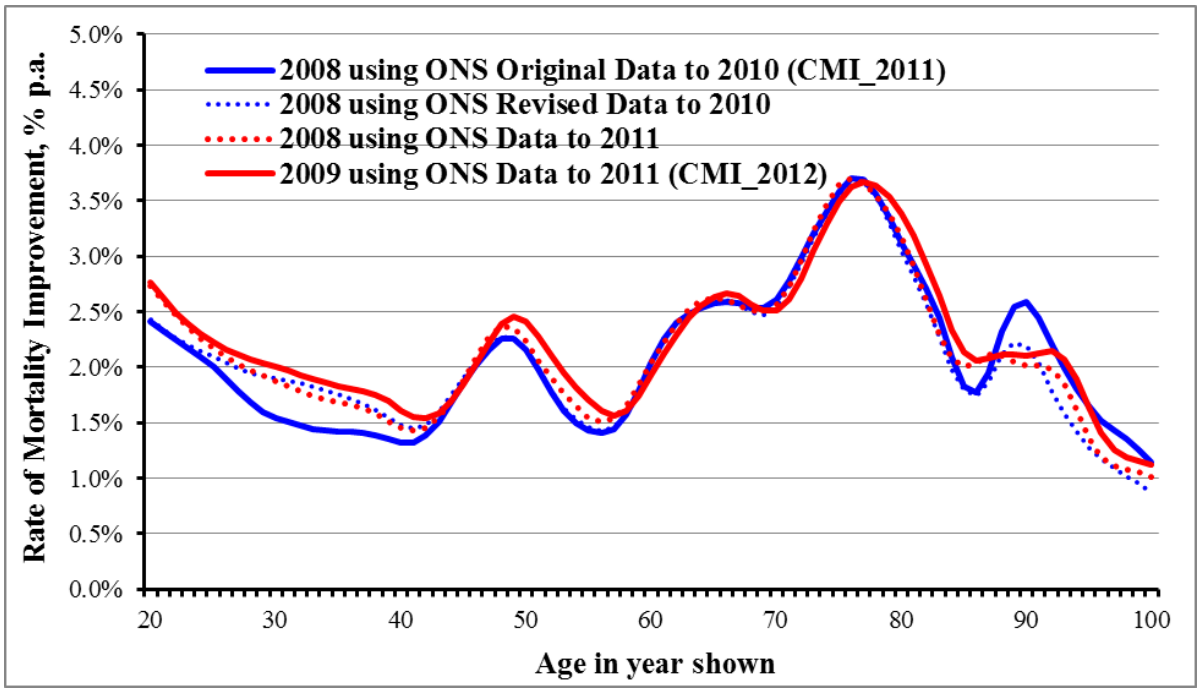

Figure 9: Estimated Aggregate Rates of Mortality Improvement, by age and dataset
Females, England & Wales Population
Estimates derived by fitting P-spline age-cohort models

Note that the x-axis for both Figure 8 and Figure 9 shows the age in the year the estimate relates to: 2008 or 2009. Many of the peaks and troughs move one year to the right, when comparing the 2008 and 2009 estimates, which suggests these features are related to birth-cohort rather than to absolute age. (This also naturally applies to the Cohort Components shown in Figures 10 and 11, below.)

3.4. Changes in Estimates of Components of Current Rates of Mortality Improvement

The Age/Period and Cohort Components for the 2009 Initial Rates of Mortality Improvement were again determined by fitting the Age-Period-Cohort (APC) model. The results are shown in Figures 9 and 10, together with the 2008 components used in CMI_2011. An intermediate step reflecting the 2008 components resulting from the revised population estimates for 2002-10 is also shown.

For males, the prior-year population estimate revisions led to some reduction in the Age/Period component of estimated improvement rates for 2008 at both extremes of the age range. The addition of data for 2011 then led to a significant increase in rates at ages under 40, plus a modest increase above that age. The shape of the Cohort Component has changed little for ages up to 80, but the Census-based revisions led to a marked reduction in this component at the older ages, combined with a flattening out of the peak and trough in rates previously estimated.

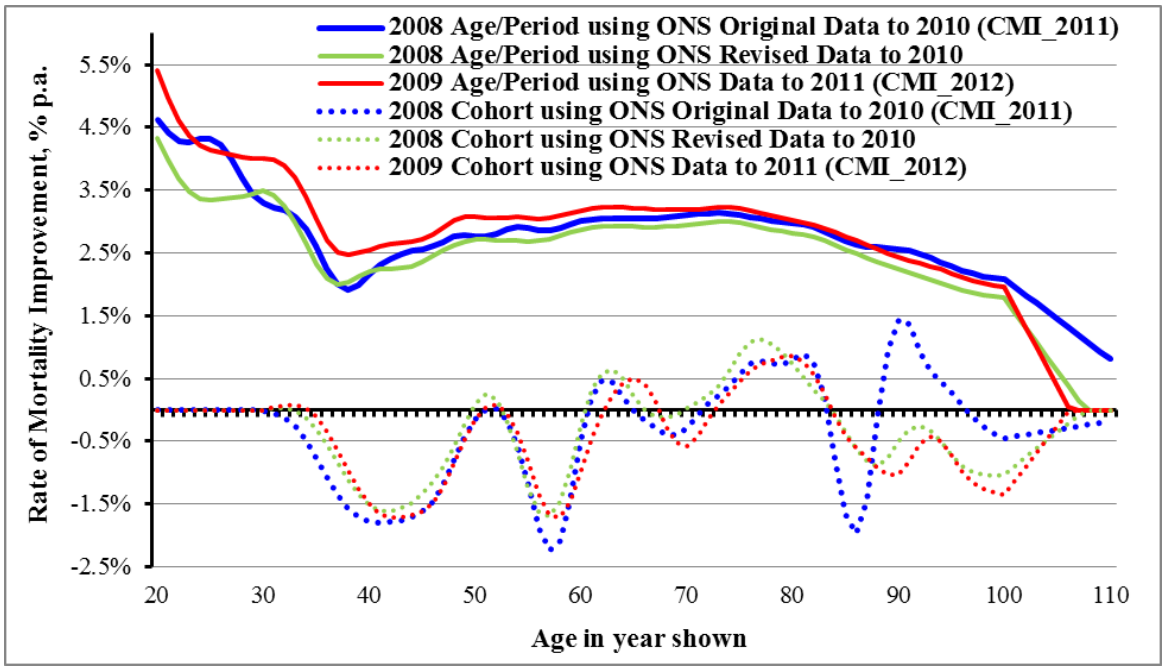

Figure 10: Estimated Age/Period and Cohort Components of Mortality Improvement, by age and dataset; Males, England & Wales Population
Estimates derived by fitting APC models to smoothed mortality improvement rates

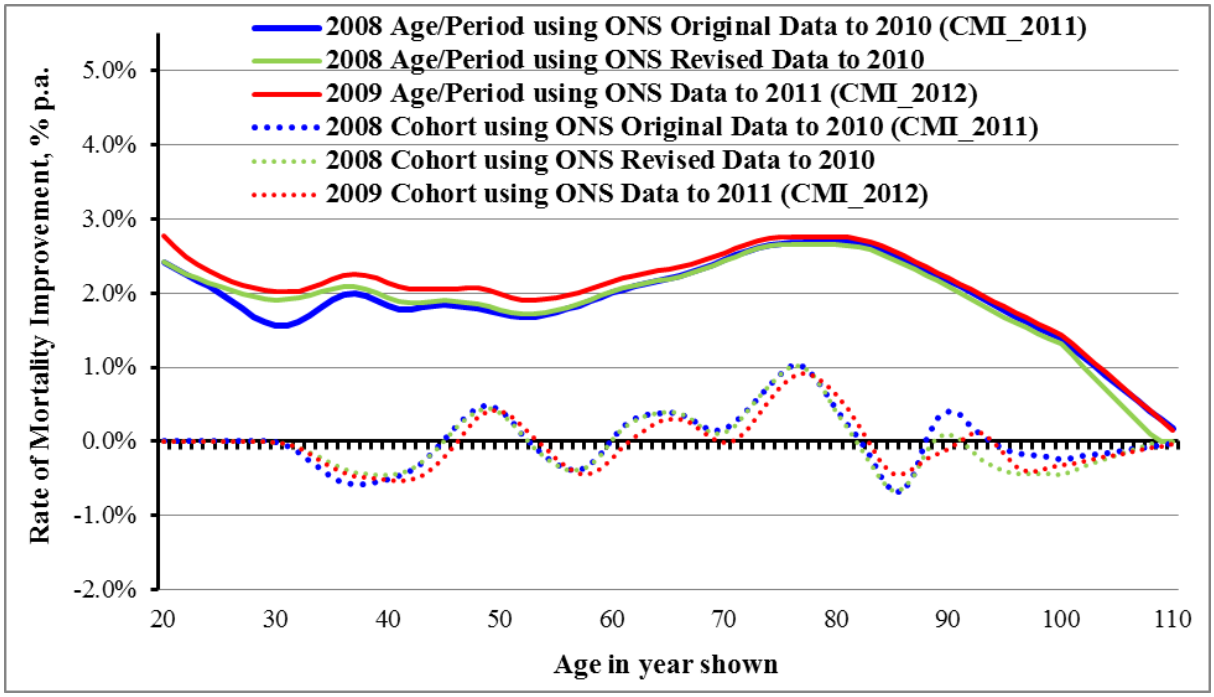

Figure 11: Estimated Age/Period and Cohort Components of Mortality Improvement, by age and dataset; Females, England & Wales Population
Estimates derived by fitting APC models to smoothed mortality improvement rates

Figure 12 illustrates how the Period Components have changed between CMI_2011 and CMI_2012. The change has been illustrated in two steps. The first step shows the change resulting from the revised population estimates, whilst the second step shows the further change resulting from the addition of 2011 data. The degree of change emphasises the difficulty in drawing sound conclusions regarding the current trajectory of rates of mortality improvement. Based on the initial estimates for 2012 mortality improvement rates (detailed in section 3.2 above) the curves in Figure 12 are expected to be pulled a little lower again on the right hand side when the chart is extended in the next update of the Model.

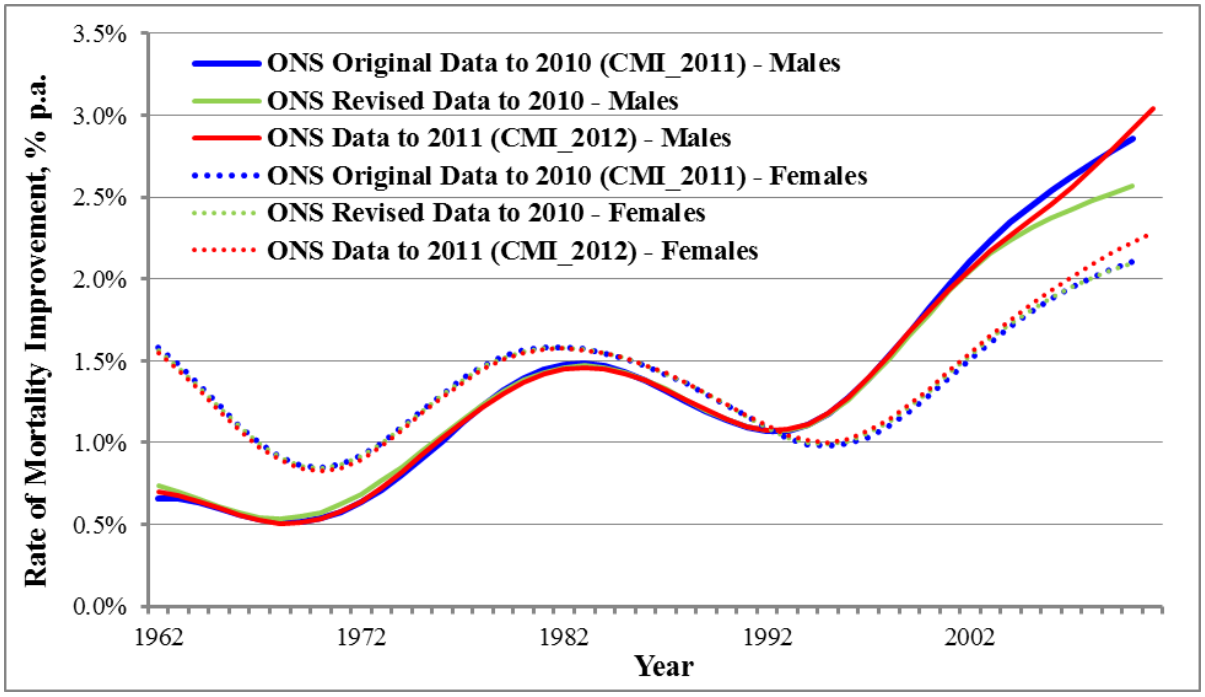

Figure 12: Period Component of the Rate of Mortality Improvement, by year, dataset, and gender; England & Wales Population Estimates derived by fitting APC models to smoothed mortality improvement rates

3.5. Quantification of the Effect of Reflecting Revised Data to 2011 in the Model

The CMI_2012 version of the Model, published alongside this paper, includes Core parameter default values for Initial Rates of Mortality Improvement as at 2009, derived using population data up to 2011 – that is, taking account of revised population estimates for mid-2002 to mid-2010, following the 2011 Census, and an extra year's observations in the underlying dataset compared with that used for the CMI_2011 Model.

The overall effect of these changes is illustrated in Appendix B by comparing cohort expectation of life values at a range of ages, for males and females, using a Long-Term Rate of Mortality Improvement of 1.5% p.a. In summary, depending on the type of business under consideration, cohort life expectancies have:

- changed relatively little (in the range 0.1% to -0.3%) for **male** lives below age **60** but **decreased** progressively for **male** lives as age rises above 60 – for example, **decreases** of around 0.3% at age 65, 2% at age 80 and 7% at age 95; and
- shown a similar pattern of changes with age for **female** but with much lower magnitude of variation – for example, almost no change below age 60, and **decreases** of around 0.1% at age 65, 0.2% at age 80 and 0.9% at age 95.

To put this in context, increasing the Long-term Rate of Mortality Improvement by 1% p.a. adds around 5% to cohort life expectancies at age 65.

The overall change in the cohort expectation of life values can be broken down into two steps; the change resulting from the revised population estimates for mid-2002 to mid-2010, following the 2011 Census, and the change resulting from the addition of an extra year's observations. Figures 13 and 14 illustrate the relative impact of the revised population estimates to the overall change. Note that the y-axis scales differ between the two Figures.

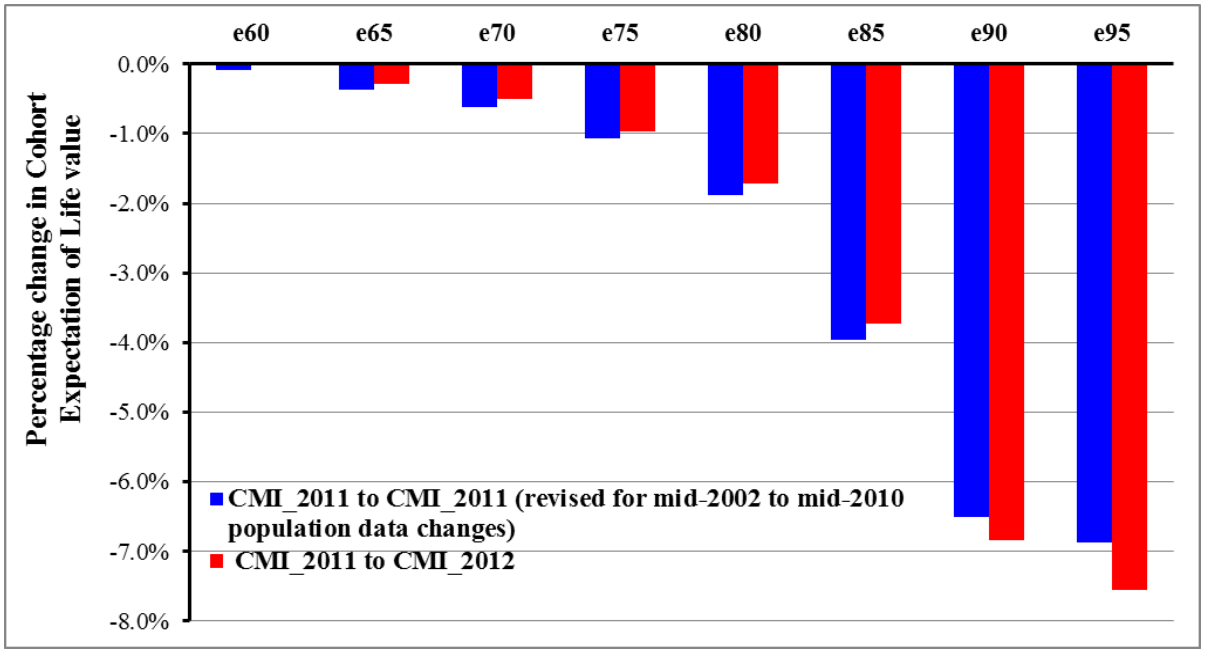

Figure 13: Percentage change in Cohort Expectation of Life Value compared with CMI_2011; Males

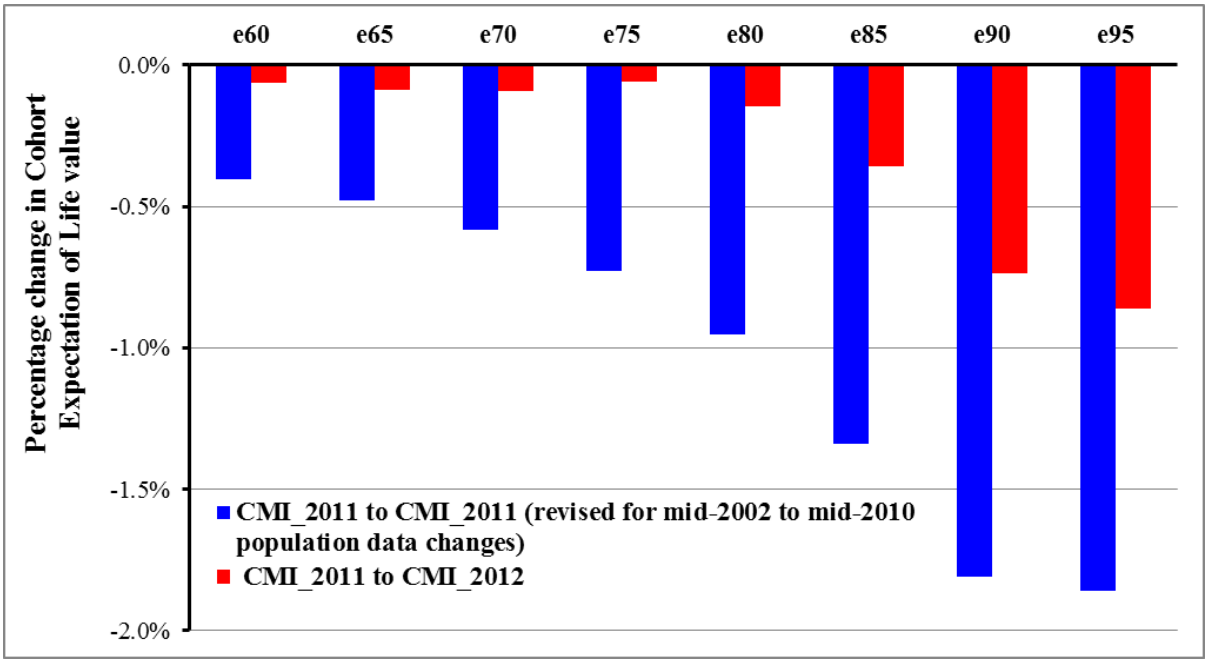

Figure 14: Percentage change in Cohort Expectation of Life Value compared with CMI_2011; Females

The revised population estimates for mid-2002 to mid-2010 have led to significant decreases in the cohort expectation of life values at older ages, particularly for males. Although the percentage decrease rises steeply with advancing age, the actual decrease in expectation of life varies less by age, at around 3 months for males and 1 month for females.

In contrast to this, the addition of the extra year's data for 2011 to the observations has had relatively little impact on the projected cohort life expectancies for males, but has led to

increases for females, offsetting a large part of the reduction arising from the revision of population estimates.

To help place these changes in context, Table 3 shows the percentage change in projected annuity values for four steps in the annual updates of the Model:

- CMI_2009 to CMI_2010
- CMI_2010 to CMI_2011
- CMI_2011 to CMI_2011 revised for 2002-10 population data changes
- CMI_2011 revised for 2002-10 population data changes to CMI_2012.

The annuity values are calculated as at 31/12/12 in each case (using a discount rate of 5% p.a.), with all others parameters held constant, and therefore primarily reflect only the changes in default Initial Rates of Mortality Improvement in each version of the Model.

The main features shown by Table 3 are:

- Annual updates allowing for an extra year's data have generally led to minor changes in projected annuity values; the percentage changes tending to be greater at the highest ages.
- The one-off revision of population estimates for 2002-10 has led to additional changes of a similar magnitude, at most ages, to those seen in the usual annual updates; however, for males at ages 80+, the annuity value changes arising from this element of the update are greater in magnitude.

Table 3: Percentage changes in Cohort Annuity Values for Age x exact on 31/12/12
Base Rates of Mortality = 100% S1PMA as at 01/09/2002
Core Projection with 1.5% pa Long Term Rate of Improvement

	Males				Females			
	2009-2010	**2010-2011**	**2011-Revised**	**Revised-2012**	**2009-2010**	**2010-2011**	**2011-Revised**	**Revised-2012**
${}_{45}\ddot{a}_{20}$	0.2%	-0.3%	0.2%	0.2%	0.4%	0.0%	-0.1%	0.2%
${}_{40}\ddot{a}_{25}$	0.2%	-0.3%	0.3%	0.2%	0.4%	0.0%	-0.1%	0.2%
${}_{35}\ddot{a}_{30}$	0.2%	-0.3%	0.3%	0.2%	0.4%	0.0%	-0.1%	0.2%
${}_{30}\ddot{a}_{35}$	0.2%	-0.4%	0.4%	0.2%	0.4%	0.0%	-0.1%	0.2%
${}_{25}\ddot{a}_{40}$	0.2%	-0.4%	0.4%	0.2%	0.4%	0.1%	-0.1%	0.2%
${}_{20}\ddot{a}_{45}$	0.3%	-0.3%	0.3%	0.2%	0.5%	0.1%	-0.2%	0.3%
${}_{15}\ddot{a}_{50}$	0.4%	-0.3%	0.3%	0.2%	0.5%	0.1%	-0.2%	0.3%
${}_{10}\ddot{a}_{55}$	0.4%	-0.3%	0.2%	0.2%	0.5%	0.1%	-0.2%	0.2%
${}_{5}\ddot{a}_{60}$	0.3%	-0.3%	0.2%	0.2%	0.4%	0.1%	-0.2%	0.2%
$\ddot{a}_{65}$	0.4%	-0.2%	0.0%	0.1%	0.4%	0.1%	-0.2%	0.2%
$\ddot{a}_{70}$	0.3%	-0.2%	-0.2%	0.1%	0.6%	0.1%	-0.3%	0.3%
$\ddot{a}_{75}$	0.2%	-0.2%	-0.5%	0.1%	0.8%	0.1%	-0.4%	0.4%
$\ddot{a}_{80}$	0.4%	0.1%	-1.1%	0.2%	1.0%	0.1%	-0.6%	0.6%
$\ddot{a}_{85}$	0.7%	0.4%	-2.8%	0.3%	1.3%	0.2%	-1.0%	0.7%
$\ddot{a}_{90}$	1.5%	1.4%	-5.0%	-0.2%	1.5%	0.7%	-1.4%	0.8%
$\ddot{a}_{95}$	2.7%	1.7%	-5.3%	-0.5%	1.6%	0.9%	-1.4%	0.8%
$\ddot{a}_{100}$	2.6%	0.8%	-3.8%	-1.3%	1.0%	0.5%	-1.1%	0.7%

Selected results from Table 3 are also shown through a series of Figures in Appendix C.

4. Parameter Sensitivities

When CMI_2009 was issued, it was important that the sensitivity of the new Model to the various parameters was widely understood. In particular:

- Appendix B of the CMI_2009 User Guide contains a large range of sensitivities, illustrated relative to the Medium Interim Cohort Projection.
- A spreadsheet containing the results of a wider range of sensitivity tests was made available for download from the CMI pages of the Actuarial Profession's website.

These sources remain available to users who can, of course, also investigate sensitivities using the Model itself.

For the CMI_2010 to CMI_2012 updates to the Model, the relative significance of the sensitivity of results to the various parameters is essentially unchanged so that little value would be added by producing the full range of sensitivity tests updated for CMI_2012. However, some limited results are shown in this section to emphasise the sensitivity of results to the key parameter, the Long-Term Rate of Mortality Improvement. This analysis corresponds to section 4 of CMI Working Paper 49.

Figures 15 and 16 show sample projected single life annuity values and cohort expectations of life for males for various Long-Term Rates of Mortality Improvement in CMI_2012. All other parameter values are unchanged from their Core values in the Model. The annuity and expectation of life values are calculated on the following basis:

- The values are calculated as at 31/12/2012;
- Annuities, based on payments of 1 p.a, are assumed to be payable yearly in advance using a net discount rate of 3.0% p.a.;
- The expectation of life values are complete rather than curtate; and
- The values have been derived using S1PMA base mortality table at 01/09/2002 projected to 2009 using the past rates of mortality improvement contained in the Core parameter layer of the Model, and forward from 2009 using the rates of mortality improvement given by the various projections illustrated.

Note that the y-axes for Figures 15 and 16 do not start at zero.

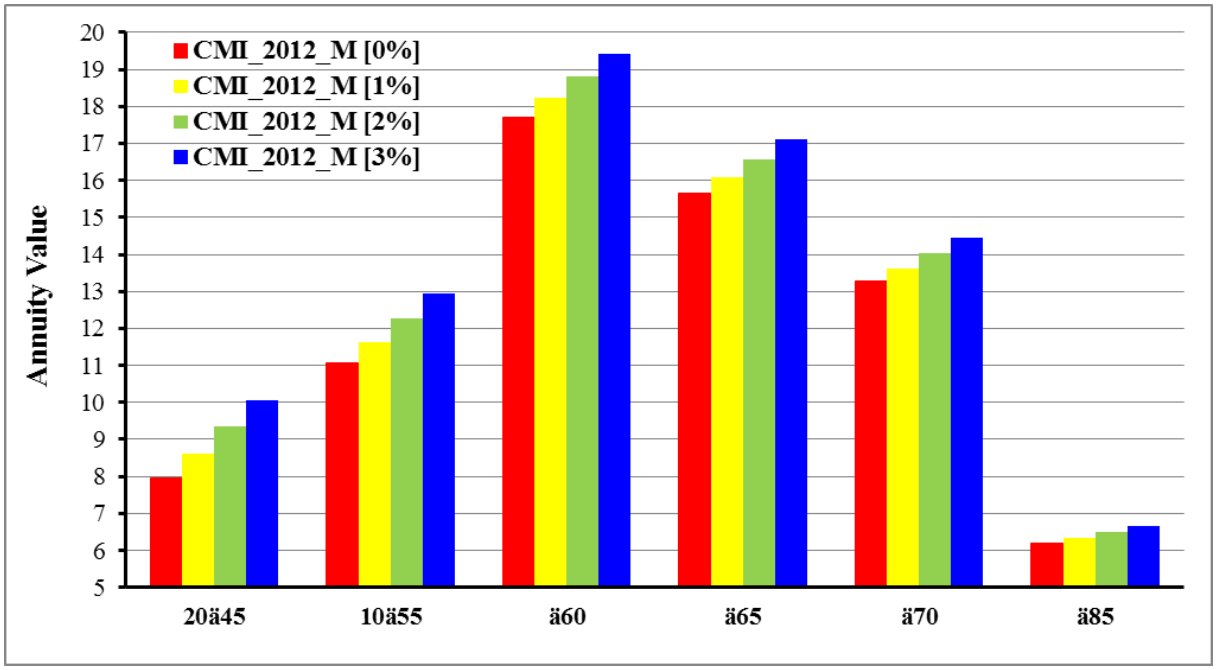

Figure 15: Variation in selected single life annuity values for males, for changes in assumed Long-Term Rate of Mortality Improvement.

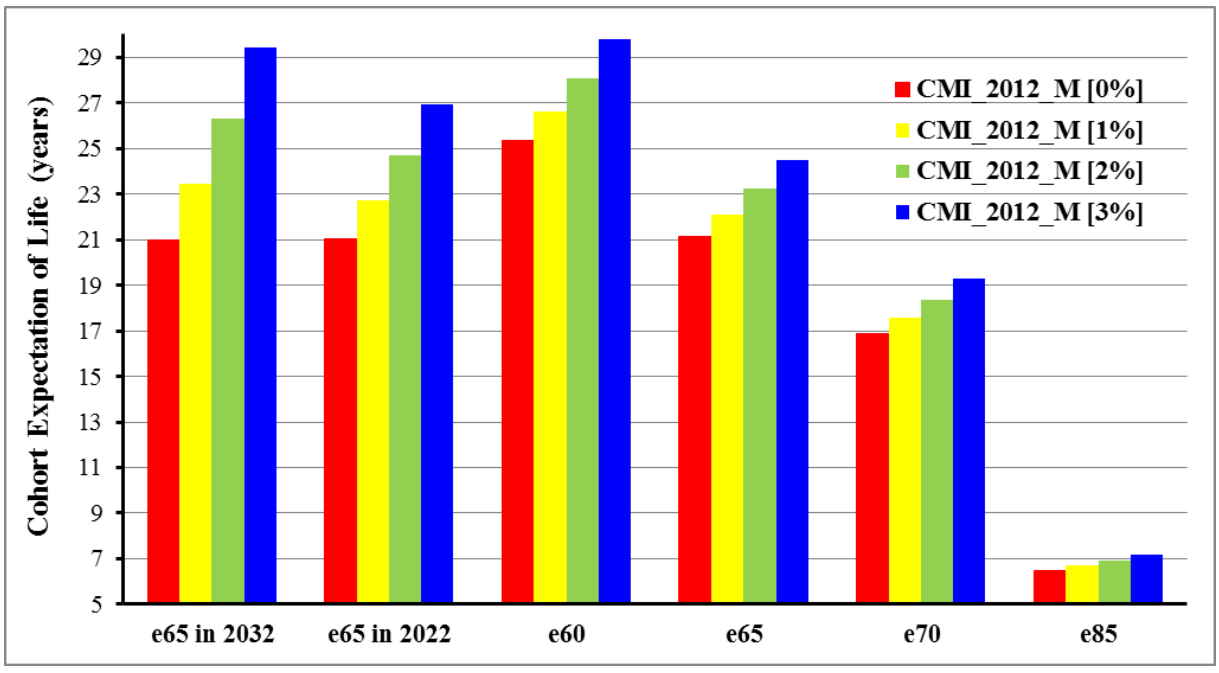

Figure 16: Variation in selected cohort expectation of life values for males, for changes in assumed Long-Term Rate of Mortality Improvement.

References

CMI Working Paper 38 "A Prototype Mortality Projections Model: Part One – An Outline of the Proposed Approach". (2009)

CMI Working Paper 39 "A Prototype Mortality Projections Model: Part Two – Detailed Analysis". (2009)

CMI Working Paper 41 "CMI Mortality Projections Model: Feedback on Consultation and Issue of 'CMI_2009' ". (2009)

CMI Working Paper 49 "The CMI Mortality Projections Model: 'CMI_2010' ". (2010)

CMI Working Paper 54 "Advancing the release date of the CMI Mortality Projections Model". (2011)

CMI Working Paper 55 "The CMI Mortality Projections Model: 'CMI_2011' ". (2011)

User Guide for the CMI Mortality Projections Model - Model Name / Version: 'CMI_2009' (2009)

User Guide for the CMI Mortality Projections Model - Model Name / Version: 'CMI_2012' (2013)

All of the above may be accessed and downloaded from the CMI pages, under "Research and resources", on the UK Actuarial Profession's website; in particular:

- CMI_2012 and its User Guide are located alongside CMI Working Paper 63
- CMI_2011 and its User Guide are located alongside CMI Working Paper 55
- CMI_2010 and its User Guide are located alongside CMI Working Paper 49
- CMI_2009, its User Guide and the spreadsheet of parameter sensitivity tests are located alongside CMI Working Paper 41.

Population Estimates for England and Wales, Mid-2002 to Mid-2010 Revised (National) (ONS, 2012)

Appendix A. Previous versions of the Model and Working Papers

A consultation was carried out over the Summer of 2009 following the release of a prototype version of the Model supported by two Working Papers:

- CMI Working Paper 38, providing an overview of the Model and specific questions for the consultation; and
- CMI Working Paper 39, containing further analysis to help inform the setting of parameter values for the Model.

CMI_2009 was published in November 2009 alongside CMI Working Paper 41. The paper summarised the responses to the consultation and outlined the changes between the prototype Model and CMI_2009. In particular, the default parameter values in CMI_2009 were updated (from those in the prototype Model) to incorporate the England & Wales population mortality data for calendar year 2008.

CMI_2010 was published in November 2010 alongside CMI Working Paper 49 and reflects the incorporation of England & Wales population mortality data for calendar year 2009.

In August 2011, the CMI Mortality Projections Committee proposed changing its process of working with the high-age population data published by the ONS to allow earlier release of the updated Model. Further details of this change of process were set out in CMI Working Paper 54

CMI_2011 was published in September 2011 alongside CMI Working Paper 55 and reflects the incorporation of England & Wales population mortality data for calendar year 2010.

Appendix B. Sample Expectations of Life from the CMI_2012 Model

A small number of changes have been made between the CMI_2011 Model and the current version, CMI_2012. These are summarised in section 1.2 of this paper and detailed in section 6 of the accompanying User Guide.

The principal changes result from incorporating the revised mid-2002 to mid-2010 population estimates and the 2011 population mortality data into the default Core parameters for the Initial Rates of Mortality Improvement. The effect of these data changes is described in section 3 and illustrated further in this Appendix by showing the combined impact of these changes on selected cohort expectation of life values.

Cohort expectation of life values, for males and females, for a large grid of model points, are compared for CMI_2012 and CMI_2011 on the following basis:

- Like-for-like Core Projections using a Long-Term Rate of 1.5% p.a.
- Base Rates of Mortality are the published S1PxA tables (for lives aged x exact on 01/09/2002)
- Calculation Date(s) are 31/12/year.

Tables 4 and 6 show the sample expectation of life values produced by CMI_2012, for males and females respectively; Tables 5 and 7 show the percentage change measured against the equivalent values produced by CMI_2011, for males and females respectively. See section 3.5 for a brief commentary on these results.

Table 4: Cohort Expectation of Life for Age x exact on 31/12/Year
Males ; Base Rates of Mortality = 100% S1PMA as at 01/09/2002
Core Projection: CMI_ 2012_M [1.5%]

Age, x	Year						
	2012	2017	2022	2027	2032	2037	2042
20	70.35	71.08	71.79	72.49			
25	64.69	65.43	66.15	66.86	67.56		
30	59.05	59.79	60.52	61.24	61.94	62.63	
35	53.43	54.18	54.91	55.64	56.35	57.04	57.73
40	47.91	48.65	49.38	50.11	50.82	51.52	52.21
45	42.59	43.25	43.97	44.68	45.39	46.08	46.77
50	37.47	38.04	38.68	39.38	40.07	40.75	41.43
55	32.37	33.00	33.57	34.21	34.88	35.54	36.19
60	27.33	28.00	28.59	29.16	29.78	30.42	31.05
65	22.64	23.09	23.69	24.26	24.82	25.41	26.02
70	17.95	18.62	19.03	19.58	20.11	20.66	21.22
75	13.72	14.28	14.83	15.22	15.71	16.21	16.72
80	9.94	10.46	10.90	11.35	11.72	12.16	12.61
85	6.80	7.27	7.64	7.99	8.36	8.69	9.07
90	4.54	4.82	5.12	5.39	5.67	5.96	6.23
95	3.08	3.22	3.41	3.60	3.79	3.98	4.18
100	2.19	2.30	2.42	2.54	2.66	2.78	2.91

Table 5: % Change in Cohort Expectation of Life for Age x exact on 31/12/Year
Males ; Base Rates of Mortality = 100% S1PMA as at 01/09/2002
Core Projections: CMI_ 2012_M [1.5%] against CMI_2011_M [1.5%]

Age, x	Year						
	2012	2017	2022	2027	2032	2037	2042
20	0.0%	0.0%	-0.1%	-0.1%			
25	0.0%	0.0%	-0.1%	-0.1%	-0.1%		
30	0.1%	0.0%	0.0%	-0.1%	-0.1%	-0.1%	
35	0.1%	0.1%	0.0%	0.0%	-0.1%	-0.1%	-0.2%
40	0.1%	0.1%	0.0%	0.0%	-0.1%	-0.1%	-0.2%
45	0.1%	0.1%	0.1%	0.0%	-0.1%	-0.1%	-0.2%
50	0.1%	0.1%	0.0%	0.0%	-0.1%	-0.1%	-0.2%
55	0.0%	0.1%	0.0%	0.0%	-0.1%	-0.2%	-0.2%
60	0.0%	0.0%	0.0%	-0.1%	-0.2%	-0.2%	-0.3%
65	-0.3%	-0.1%	-0.2%	-0.2%	-0.3%	-0.4%	-0.4%
70	-0.5%	-0.5%	-0.4%	-0.5%	-0.5%	-0.6%	-0.7%
75	-1.0%	-0.8%	-0.9%	-0.8%	-0.9%	-1.0%	-1.1%
80	-1.7%	-1.7%	-1.6%	-1.7%	-1.7%	-1.8%	-1.8%
85	-3.7%	-3.4%	-3.4%	-3.4%	-3.4%	-3.4%	-3.4%
90	-6.8%	-6.8%	-6.5%	-6.3%	-6.2%	-6.0%	-5.9%
95	-7.5%	-7.7%	-7.5%	-7.3%	-7.1%	-6.9%	-6.8%
100	-6.9%	-6.8%	-6.7%	-6.5%	-6.4%	-6.3%	-6.2%

Table 6: Cohort Expectation of Life for Age x exact on 31/12/Year
Females ; Base Rates of Mortality = 100% S1PFA as at 01/09/2002
Core Projection: CMI_ 2012_F [1.5%]

Age, x	Year						
	2012	2017	2022	2027	2032	2037	2042
20	72.20	72.91	73.61	74.29			
25	66.54	67.27	67.98	68.67	69.35		
30	60.92	61.66	62.38	63.08	63.77	64.44	
35	55.38	56.13	56.85	57.56	58.25	58.93	59.59
40	50.01	50.73	51.45	52.16	52.85	53.52	54.18
45	44.86	45.53	46.23	46.92	47.59	48.26	48.91
50	39.84	40.50	41.15	41.81	42.46	43.11	43.74
55	34.85	35.54	36.17	36.79	37.41	38.04	38.65
60	29.88	30.53	31.17	31.76	32.36	32.96	33.55
65	24.99	25.56	26.16	26.76	27.33	27.90	28.46
70	20.17	20.79	21.32	21.87	22.43	22.97	23.51
75	15.65	16.23	16.77	17.25	17.76	18.27	18.77
80	11.55	12.10	12.58	13.04	13.47	13.92	14.38
85	8.10	8.59	8.99	9.37	9.76	10.13	10.51
90	5.51	5.79	6.11	6.41	6.71	7.00	7.30
95	3.64	3.82	4.02	4.22	4.42	4.63	4.84
100	2.48	2.60	2.73	2.85	2.98	3.11	3.25

Table 7: % Change in Cohort Expectation of Life for Age x exact on 31/12/Year
Females ; Base Rates of Mortality = 100% S1PFA as at 01/09/2002
Core Projections: CMI_ 2012_F [1.5%] against CMI_2011_F [1.5%]

Age, x	Year						
	2012	2017	2022	2027	2032	2037	2042
20	0.0%	0.0%	0.0%	0.0%			
25	0.0%	0.0%	0.0%	0.0%	0.0%		
30	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
35	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
40	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
45	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
50	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
55	0.0%	0.0%	0.0%	-0.1%	-0.1%	-0.1%	-0.1%
60	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%
65	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%
70	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%	-0.2%	-0.2%
75	-0.1%	-0.1%	-0.1%	-0.2%	-0.2%	-0.2%	-0.2%
80	-0.1%	-0.1%	-0.2%	-0.2%	-0.3%	-0.3%	-0.3%
85	-0.4%	-0.3%	-0.3%	-0.4%	-0.4%	-0.5%	-0.5%
90	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%
95	-0.9%	-0.9%	-0.9%	-0.8%	-0.8%	-0.8%	-0.8%
100	-0.6%	-0.5%	-0.5%	-0.5%	-0.5%	-0.5%	-0.5%

Appendix C. Illustration of changes in projected Annuity Values

Figures 17 to 22 show the percentage changes in projected annuity values (calculated at a discount rate of 5% p.a.), for sample ages 60, 70 and 80, for the series of four steps in the annual updates of the Model from CMI_2009 to CMI_2012, separating out the impact of the revisions to population estimates for 2002-10 in the latest update to the Model:

- CMI_2009 to CMI_2010
- CMI_2010 to CMI_2011
- CMI_2011 to CMI_2011 revised for 2002-10 population data changes
- CMI_2011 revised for 2002-10 population data changes to CMI_2012.

The projected cohort annuity values are calculated as at 31/12/12 in each case, with all others parameters held constant, and therefore primarily reflect only the changes in default Initial Rates of Mortality Improvement in each version of the Model. Base Rates of Mortality are 100% S1PxA as at 01/09/2002 using a Core Projection with a 1.5% pa Long Term Rate of Improvement.

The blue bars at the right-hand end of each Figure show the overall percentage change in annuity value between CMI_2009 and CMI_2012. The other bars show the magnitude of the change arising in each of the four steps (measured as a percentage of the CMI_2009 value), with red representing an increase in value, green representing a decrease in annuity value and the shaded bars representing the magnitude of change arising from the revised population estimates.

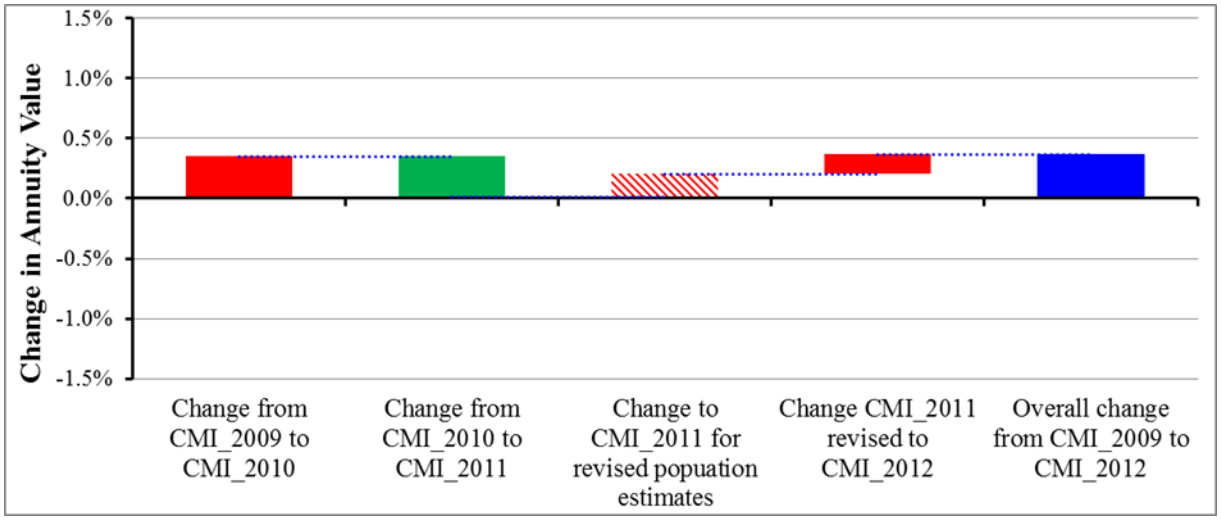

Figure 17: Percentage changes in annuity value; Male, aged 60 (5ä60)

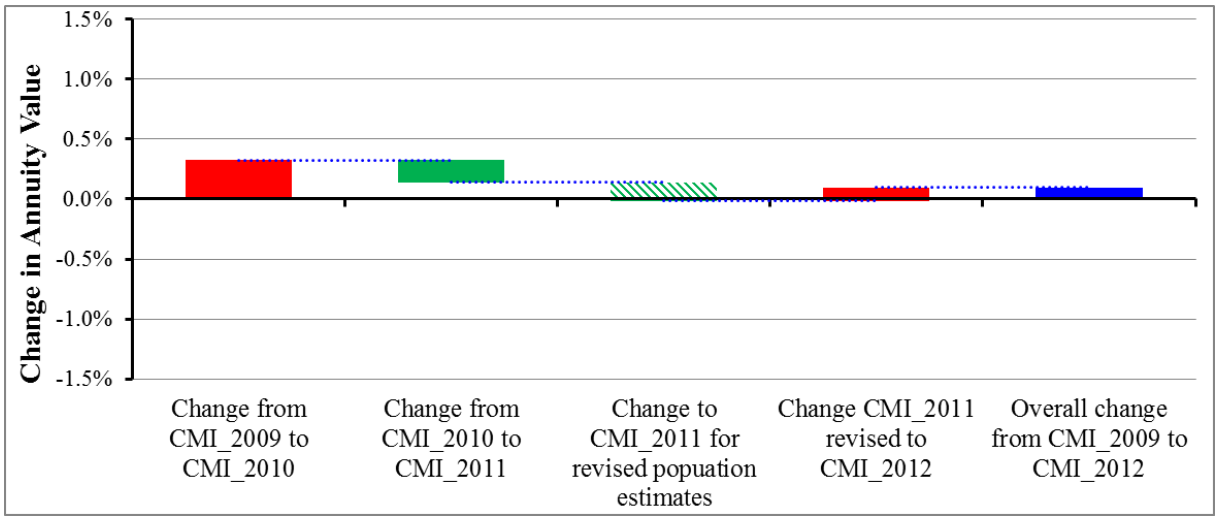

Figure 18: Percentage changes in annuity value; Male, aged 70 (ä70)

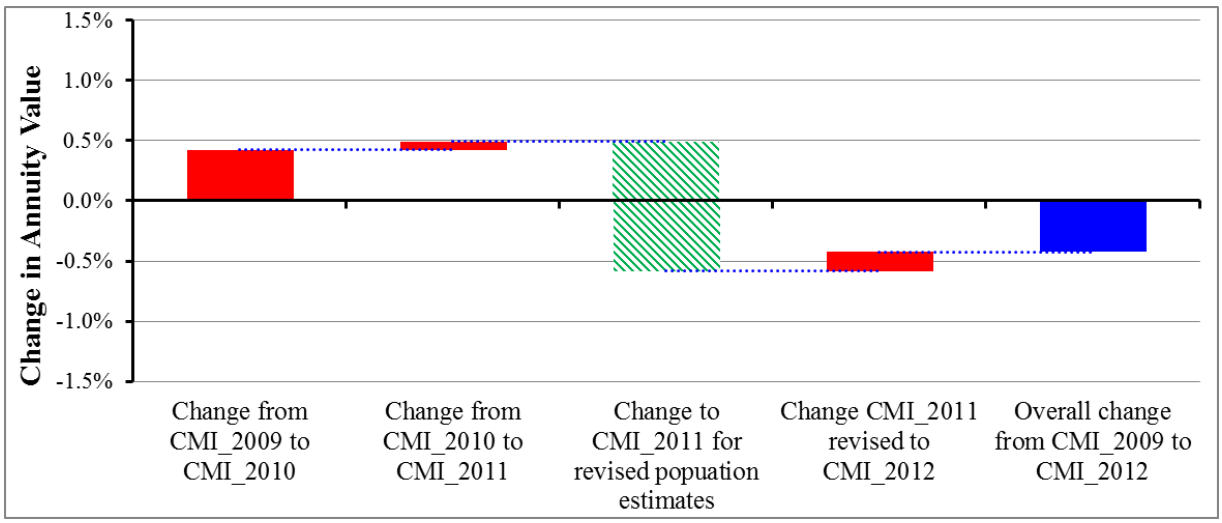

Figure 19: Percentage changes in annuity value; Male, age 80 (ä80)

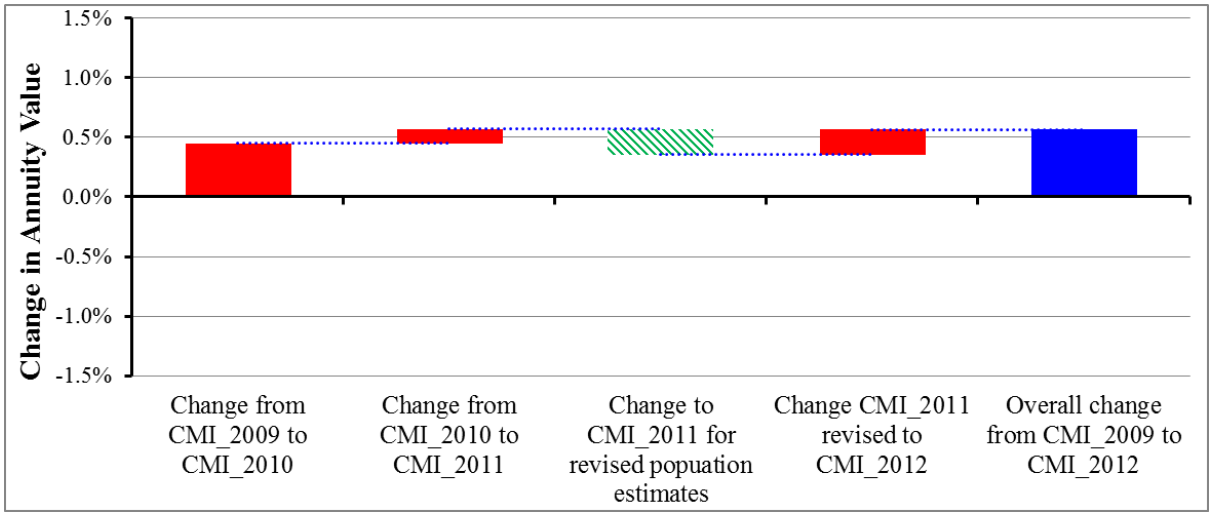

Figure 20: Percentage changes in annuity value; Female, aged 60 (5ä60)

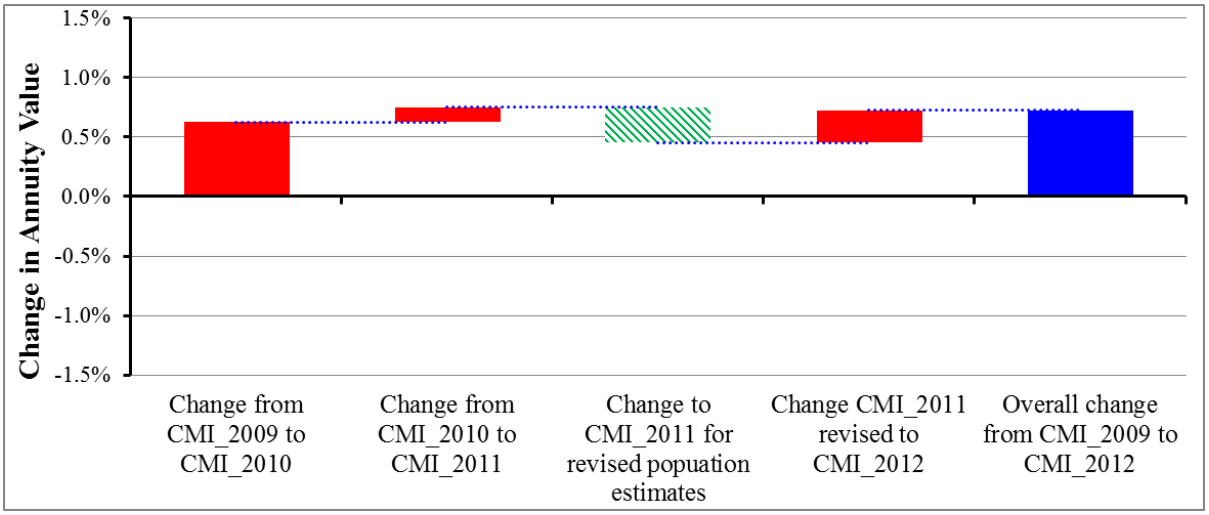

Figure 21: Percentage changes in annuity value; Female, aged 70 (ä70)

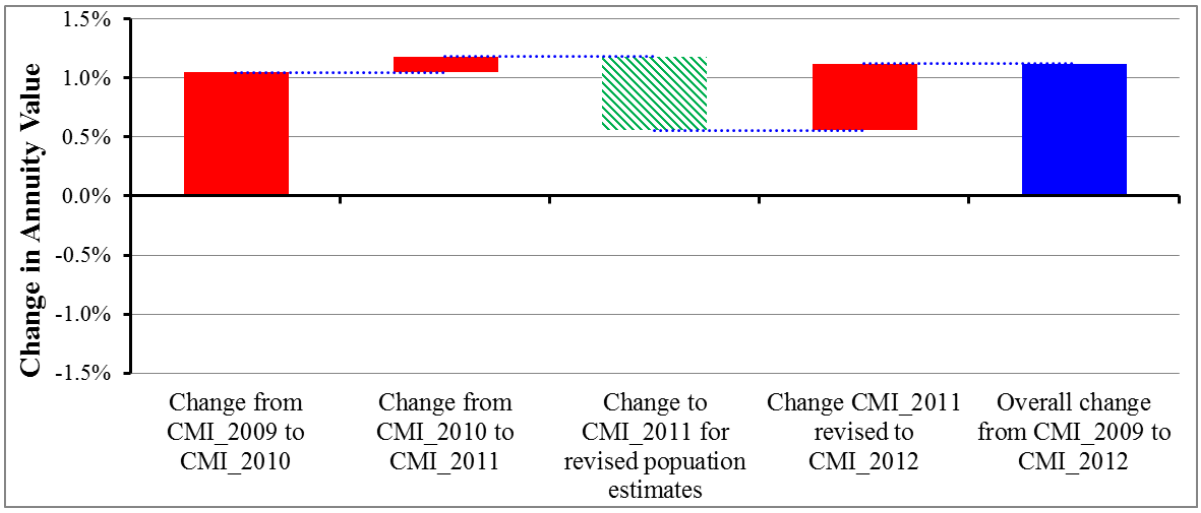

Figure 22: Percentage changes in annuity value; Female, aged 80 (ä80)