Continuous Mortality Investigation

Working Paper 38

A Prototype Mortality Projections Model:

Part One – An Outline of the Proposed Approach

It remains the responsibility of any actuary or other person using a projection of future mortality to ensure that it is appropriate for the particular purpose to which it is put, regardless of the source of the projection.

June 2009

Executive Summary

The Continuous Mortality Investigation (CMI) has become concerned about the continuing widespread use of the 'interim cohort' mortality projections. These projections do not take account of experience data published after 1999 and – as a result – have become increasingly out-of-date.

A Working Party was therefore established to develop a projection Model which:

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

A prototype Model has been published for consultation to coincide with the release of this paper. The structure proposed for the Model is based on the projection of annual rates of **mortality improvement** (i.e. the pace of change in mortality rates). Specifically, the Model assumes that 'current' (i.e. recently observed) rates of change will blend over time into a 'long-term' rate of change specified by the user. Effectively this approach assumes that in the very short-term, the best guide as to the likely pace of change in mortality rates is the most recently observed experience. In the long-term, the forces driving mortality change may be very different from those currently influencing patterns of improvement. Therefore, the long-term rate is better informed by 'expert opinion' and analysis of long-term patterns of change and the causes driving them. Over time, the relative weight placed on the recently observed past, versus the more subjective long-term view, can shift appropriately.

The Model produces a single, deterministic, mortality projection for each set of user inputs.

Two levels of parameters are proposed so that the Model may be operated at different levels of complexity, reflecting the needs and resources of different users and uses.

The 'Advanced' level contains a large set of parameters, and by selecting it users obtain unrestricted access with considerable flexibility to modify the projections generated.

However, users may choose to operate the Model at a much simpler level. When the 'Core' level is selected default values are applied to many of the parameters, leaving the user to concentrate on just two simplified parameters representing the most critical inputs:

- The Long-Term Rate of Mortality Improvement
- A Constant Addition to Rates of Mortality Improvement.

Detailed analysis explaining the selection of default values for all parameters will be given in a subsequent Working Paper to be published shortly. Most significantly, default Initial Rates of Mortality Improvement have been derived by fitting a P-Spline model to mortality experience for the population of England & Wales.

It is proposed that projections produced using only the Core level of parameters should be referred to as 'Core Projections' and be subject to a formal naming convention (set out in the paper). The paper compares sample Core Projections with selected projections included in the CMI's Library of Mortality Projections.

Feedback is sought from all interested parties on the Model, with the consultation period ending **31 August 2009**. The specific questions on which feedback is sought are listed in Section 5 of this paper.

Consultation meetings are planned for **7 July 2009** (Edinburgh) and **14 July 2009** (London). It is envisaged that the further, more detailed, Working Paper will be published in advance of these meetings.

Following the period of consultation it is expected that the final version of the Model will be published in **October 2009**.

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1. Introduction

1.1. Background

Over the past decade interest in assumptions made concerning future mortality improvements has grown materially. This interest has stemmed from the fact that mortality is a significant assumption in valuing the liabilities of final salary pension schemes and annuities written by insurance companies. The focus on increasing longevity has intensified as the pace of change has accelerated and the extent to which past projections have understated actual improvements has become apparent.

In 1999 the Continuous Mortality Investigation (CMI) published in CMIR 17 a projection basis to accompany the '92 Series' mortality tables, i.e. a table of reduction factors specifying an assumed pace of improvement in mortality rates by age and calendar year.

In 2002 a set of Interim Cohort Projections was published in CMI Working Paper 1 which provided possible modifications to the previously published projection basis. The Interim Cohort Projections (denoted the Short Cohort, Medium Cohort and Long Cohort bases) recognised the fact that the pace of improvement had been consistently more rapid for those individuals born in a particular generation than for those born before or after. Specifically, it assumed that improvements were most rapid for the generation born in 1910 to 1942, centred on 1926.

The Interim Cohort Projections were based on CMI experience data up to 1999 and assumed that the impact of the 'cohort effect' would begin to fade away from 2000, lasting until 2010 (Short Cohort), 2020 (Medium Cohort) or 2040 (Long Cohort).

Following the publication of the Interim Cohort Projections the CMI's Mortality Projections Working Party produced a series of working papers exploring the use of statistical models for mortality projection.

CMI Working Paper 3 (2004) set out some preliminary thoughts on the uncertainty surrounding mortality projections. It gave a summary of the different types of projection methodologies and their key features and summarised the discussion at the CMI/GAD seminar of 6 October 2003 on "Projecting Future Mortality".

CMI Working Paper 11 (2005) provided the CMI's response to feedback received on Working Paper 3, both at a seminar hosted by the CMI on 4 June 2004 and subsequently in writing. Feedback was unanimous on the need for a measure of the uncertainty associated with the projections and there was general agreement on the need for quantitative measures of this uncertainty. However, the feedback indicated that most respondents had no preference for any particular projection methodology.

CMI Working Paper 15 (2005) provided a summary of two stochastic methodologies – P-Spline and Lee-Carter models - and their key features, set out the types of uncertainty covered by the methodologies and provided a comparison highlighting the key considerations in making a choice between them.

CMI Working Paper 20 (2006) provided a further update on the work of the CMI's Mortality Projections Working Party. The paper included feedback received to Working Paper 15 and the Working Party's responses to this feedback. More detail was given on the P-Spline methodology, including a description of the models and datasets used; a guide to using the output from the P-Spline modelling software made available by the CMI; a discussion of various features of the P-Spline models; and guidance on parameterisation of the P-Spline model.

CMI Working Paper 25 (2007) completed the work of the Mortality Projections Working Party. The paper included detail on the Lee-Carter methodology and was analogous to Working Paper 20 which addressed similar areas for the P-Spline methodology. This paper included a description of the models and datasets used; a guide to using the output from the Lee-Carter modelling software made available by the CMI; a discussion of various features of the Lee-Carter model; results of some initial investigations into the features of the extension by Renshaw & Haberman of the age-period Lee-Carter model to an age-period-cohort model; an assessment of the P-Spline, Lee-Carter and the Lee-Carter age-period-cohort models against some high-level objectives desirable of projections models; and a summary of the Working Party's views on the three models.

The published work of the CMI Mortality Projections Working Party does not, and did not seek to, provide a comprehensive review of all the research in this field.

CMI Working Paper 27 (2007) and CMI Working Paper 30 (2007) described the construction of a ‘library’ of mortality projections. The Library was intended to bring together previously-published tables of projections, and adjustments to those in common use, together with sample projections using the P-Spline and Lee-Carter methodologies. CMI Working Paper 37 (2009) described Version 1.1 of the Library, which contained a range of additional projections.

However, in recent years there have been notable advances in statistical modeling. Following the publication of Lee & Carter’s statistical model in 1992 a large number of variants and alternative approaches have been developed. Cairns, Blake & Dowd (2006) have published a series of different models and have sought to determine quantitative criteria for judging the suitability of different models (e.g. Cairns *et al*, 2007). As mentioned above, Renshaw & Haberman (2006) have produced variants of the Lee-Carter model which allow for cohort effects. Furthermore, Richards *et al* (2007), Kirkby & Currie (2009) and Richards & Currie (2009) - have further explored empirical use and applications of the P-Spline model.

Others - as advocated by Willets (1999) & Willets *et al* (2004) - have focussed less on statistical modelling and more on understanding the drivers of mortality change. Love & Ryan (2007) described the construction of a disease-based mortality model; Humble & Wilson (2008) explored the impact of smoking on mortality trends and a Cause of Death Research Group has begun modelling trends by cause of death.

Despite advances in statistical modelling and the development of models which decompose improvements into constituent causes (of death or disease), the increasingly outdated Interim Cohort Projections are still in near universal use for many actuarial applications, for example:

- A PwC Actuarial Assumption Benchmarking Survey (2009) found that all but two of 14 insurance companies were planning to use Medium Cohort, Long Cohort or variants of these projections (e.g. with floors) for regulatory reporting of annuity liabilities.
- The Pensions Regulator (2008) showed that 82% of trustees were using a variant of the Medium cohort or Long Cohort projections.

Perceived advantages that Interim Cohort Projections have over more sophisticated models include:-

- they offer an easy basis for comparison - a ‘common currency’ - so it can be relatively straightforward for those familiar with these projections to judge the relative prudence of assumptions;
- they can easily be modified (e.g. by adding floors); and
- they can be applied to any base mortality table or assumption set.

The Interim Cohort Projections are fixed deterministic scenarios, so, unlike a stochastic model, cannot provide the user with multiple scenarios required for sophisticated portfolio modelling. However, in most cases (e.g. pension scheme valuation or regulatory reporting of insurance liabilities), deterministic projections rather than multiple simulations are used in practice.

The CMI has become concerned about the continuing widespread use of the Interim Cohort Projections. These projections do not take account of experience data published after 1999 and – as a result – have become increasingly out-of-date.

1.2. The Working Party & the Mortality Projections Model

In 2008 the CMI established a Working Party with the aim of developing a new mortality projection model.

The members of the Working Party are as follows:

- Richard Willets (chair)
- Adrian Gallop
- Joseph Lu
- Brian Wilson
- Neil Robjohns (secretariat)

The Working Party has sought to produce a projection model which shares the desirable features of the Interim Cohort Projections, but also:

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

A prototype Mortality Projections Model (referred to throughout this paper as the “Model”) has been released alongside this paper. A User Guide to the Model has also been published.

The Model is not as sophisticated as some alternatives and it is not proposed as superior to statistical or cause-based models. However, it is designed to be of widespread value and have practical application to actuaries in their day-to-day work.

The Model allows the user to produce alternative projections based on parameter values that can be specified by the user. Therefore the Model generates an infinite set of possible projections.

The Working Party feels it would be inappropriate for it to assign any specific meaning (e.g. a standard or benchmark) to any projection produced using the proposed Model.

1.3. Timescale for the Consultation Process

This Working Paper has been published to coincide with the release of the Model. A further Working Paper, with more detail on the construction of the Model and choice of parameters, will follow shortly. It is envisaged that the full title of this paper will be 'A Prototype Mortality Projections Model: Part Two – Detailed Analysis.' Throughout the remainder of this paper, this forthcoming paper is referred to simply as Part Two.

Feedback is sought from all interested parties on the Model, with the consultation period ending **31 August 2009**. The questions on which feedback is sought are listed in Section 5.3 of this paper. Please send comments:

- via e-mail to: projections@cmib.org.uk,
- or in writing to: Neil Robjohns, CMI, Cheapside House, 138 Cheapside, London, EC2V 6BW.

Consultation meetings are planned for **7 July 2009** (Edinburgh) and **14 July 2009** (London). It is envisaged that Part Two will be published in advance of these meetings.

Following the period of consultation it is expected that a final version of the Model will be published in **October 2009**.

1.4. Acknowlegements

The CMI would like to thank the Actuarial Profession for a research grant which has been used to fund the development of the Model.

The Working Party is also grateful to:

- The ONS for providing the Working Party with mortality experience data;
- James Kirkby for fitting P-Spline models to cause-of-death data;
- Paternoster for use of their offices for meetings of the Working Party;
- Adrian Pinington of the Mortality Projections by Cause of Death Research Group for a presentation of preliminary findings; and
- Club Vita for supplying the Working Party with results from their analysis of pensioner experience.

2. Model Structure, Parameters and Outputs

2.1. Model structure

The structure of the Model is based on the projection of annual rates of **mortality improvement** (i.e. the pace of change in mortality rates). Specifically, the Model assumes that 'current' (i.e. recently observed) rates of change blend over time into a 'long-term' rate of change specified by the user. This approach has been adopted by practitioners in a number of countries. In the UK the mortality projections that have formed part of the population projections - now produced by the Office for National Statistics (ONS) and formerly by the Government Actuary's Department (GAD) – have utilised this methodology for a number of years.

In contrast to mathematical models of mortality, fitted directly to relevant data and extrapolated to form a projection, the Model requires the user to set parameter values which directly control the projection. The Model produces a single, deterministic, mortality projection for each set of user inputs.

The structure of the Model allows user input of:

- Base mortality rates, reflecting the estimated current or recent past position
- Initial rates of mortality improvement, reflecting the current estimate of rates of change
- Assumed ultimate / long-term rate(s) of mortality improvement
- Assumed speed and pattern of convergence from 'initial' to 'long-term'.

'Initial' and 'long-term' rates of mortality improvement are each subdivided into two components: 'by age' and 'by cohort'. These components are projected separately, by age and by year-of-birth cohort respectively, and then recombined.

Convergence from 'initial' to 'long-term' rates of mortality improvement is defined (separately for 'by age' and 'by cohort' components) by user inputs for the convergence time-period and the proportion of the total change in rate remaining by the mid-point of that period.

Effectively this approach assumes that in the very short-term, the best guide as to the likely pace of change in mortality rates is the most recently observed experience. In the long-term, the forces driving mortality change are likely to be very different from those currently influencing patterns of improvement. Therefore, the long-term rate is better informed by 'expert opinion' and analysis of long-term patterns of change and the causes driving them. Over time, the relative weight placed on the recently observed past, versus the more subjective longer term view, can shift appropriately.

The Appendix to this paper provides an analysis of past trends by cause of death and describes future scenarios consistent with different projections.

The structure of the proposed Model could be achieved through a suitably parameterised statistical model. However, at the heart of this proposal is the desire to produce a model which is easy to understand, intuitive in structure and capable of widespread application by users with varying degrees of expertise in this field of actuarial work.

2.2. Core and Advanced Parameter layers

The Model may be operated at different levels of complexity, reflecting the needs and resources of different users and uses.

By selecting the Advanced parameter level for a group of inputs, users obtain unrestricted access with considerable flexibility to modify the projections generated.

However, when the Core parameter level is selected for a group of inputs, either a set of default parameter values is applied, or users are required to set the value for a single, simplified parameter (from which a full set of parameter values for the group is derived via a default mapping). In this way, users may choose to operate the Model at a much simpler level.

2.3. Core Projections

'Core Projections' are produced when the Core parameter level is selected for all inputs. In this case, the user is required to focus only on a core set of two simplified parameters, representing the most critical inputs:

- The Long-Term Rate of Mortality Improvement
- A Constant Addition to Rates of Mortality Improvement

The operation of these inputs at the Core parameter level is described below:

2.3.1. The Long-Term Rate of Mortality Improvement

This is the annual pace of change in (initial) mortality rates assumed in the long-term.

The single input value chosen at the Core level sets the Long-Term Rate of Mortality Improvement for all ages up to and including age 90.

For higher ages, the Long-Term Rate of Mortality Improvement for each calendar year is assumed to reduce (linearly) from age 90, reaching zero at age 120, and to be zero for ages above 120.

2.3.2. A Constant Addition to Rates of Mortality Improvement

This parameter allows the user to incorporate a degree of prudence (or an appropriate adjustment) to a projection. The Constant Addition to Rates of Mortality Improvement is applied to all ages and calendar years of the projection.

2.3.3. A naming convention for Core Projections

It is proposed that Core Projections, produced using only the Core parameter level - that is the two simplified inputs described above, with default values for the remaining parameters - should be capable of being described using a prescribed naming convention.

It is further proposed that such Core Projections should be given names of the following form:

CPMv*x.y* [a%] +c% {gender}

where:
- **CPM** is an acronym for CMI Mortality Projections Model
- ***vx.y*** is the version number of the Model
- **a%** is the Long-Term Rate of Mortality Improvement
- **c%** is the Constant Addition to Rates of Improvement for all ages and calendar years (omitted if zero)
- **{gender}** is either male or female

This prototype has been denoted version 0.0. It is envisaged that the final version of the Model, to be published after the consultation process, will be version 1.0.

So, for example:

CPMv*0.0* [1.5%] {male}

would be the Core Projection for males produced using this version of the Model in which:
- Initial Rates of Mortality Improvement converge towards the Long-Term Rate of Improvement; where
- the Long-Term Rate of Improvement is 1.5% p.a. reducing linearly from age 90 to reach zero at age 120; and
- there is no Constant Addition to Rates of Mortality Improvement.

Alternatively:

CPMv*0.0* [2.5%] + 0.5% {female}

would be the Core Projection for females produced using this version of the Model in which:
- Initial Rates of Mortality Improvement converge towards the Long-Term Rate of Improvement; where
- the Long-Term Rate of Improvement is 2.5% p.a. reducing linearly from age 90 to reach zero at age 120; and
- there is a Constant Addition to Rates of Mortality Improvement at each age and calendar year of 0.5% p.a.

2.4. The Full Parameter Set

As Section 2.2 outlines, users can select their own values for any parameters by selecting the Advanced option for the relevant group of inputs.

The full list of parameters is as follows:-

2.4.1. Initial Rates of Mortality Improvement

Users of the Advanced option are able to specify any rates of ‘current’ improvement they feel appropriate for any specific dataset under consideration.

If the Core option is chosen for this input, the Model uses default values for past rates of mortality improvement for individual ages, separately for males and females, for calendar years 1991 to 2005. These rates of improvement were derived using a P-Spline model fitted to ONS data for the population of England & Wales, for ages from 18 to 102 for the period 1961 to 2007. The methodology adopted to produce these past rates of change will be described in detail in Part Two.

The ‘current’ rates of mortality improvement are taken as those for calendar year 2005. The first year of the projection is therefore assumed to be 2006. The reason for ‘stepping back’ two years from the final year for which experience is available (i.e. 2007) is to avoid the distortion of ‘edge-effects’ which can be a feature of the P-Spline model. Again, the full rationale for a two-year ‘step back’ will be outlined in Part Two.

The Initial Rates of Mortality Improvement used as default values for Core Projections are shown in Figure 1.

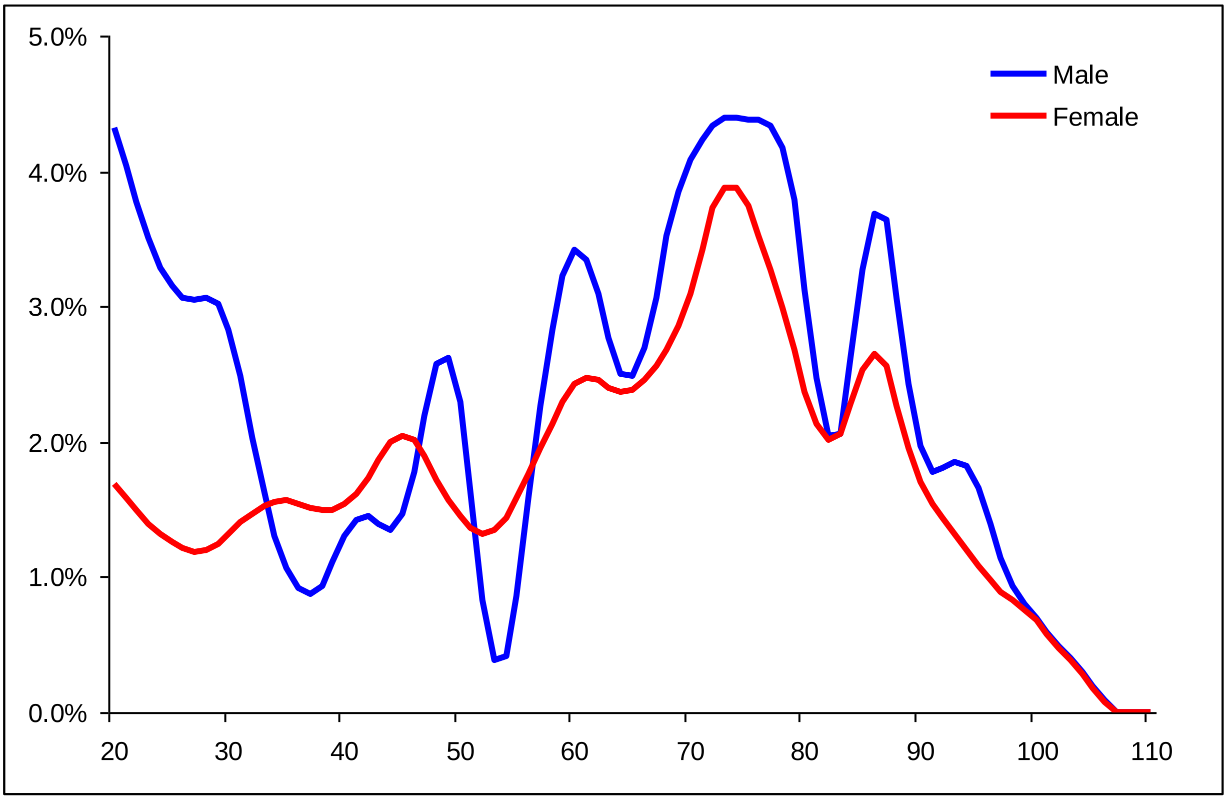

Figure 1: Default Initial Rates of Mortality Improvement, by age and gender

The Working Party explored:

- the use of alternative datasets to determine current rates of improvement for Core Projections, and also
- the idea of allowing the user to specify suitable adjustments or transformations to current rates of change derived using population data, to reflect the characteristics of different sub-groups.

Part Two will provide further detail on both of these areas of research. It will describe the Working Party’s analysis of improvements for different sub-populations and the rationale for selecting improvements based on ONS data for the default values used at Core level.

2.4.2. Cohort and Age/Period Components of Initial Rates of Mortality Improvement

The Initial Rates of Improvement in the Model are split into two components: a component influenced by age and period (but not birth cohort) and a component which is solely influenced by birth cohort.

Users of the Advanced option can specify for each age the Initial Rate of Improvement and also the separate Age/Period and Cohort Components. Each component can be either positive or negative, and a check is performed to ensure that the two components sum to give the overall improvement rate.

At the Core level, default values for the Cohort Component of Initial Rates of Improvement are given separately for males and females for each year of birth. The Age/Period Component for each age is defined such that the two components sum to give the overall improvement rate at each age.

Part Two will describe the derivation of default Cohort Component values using an age-period-cohort model developed explicitly for this purpose. The default values are shown in Figure 2.

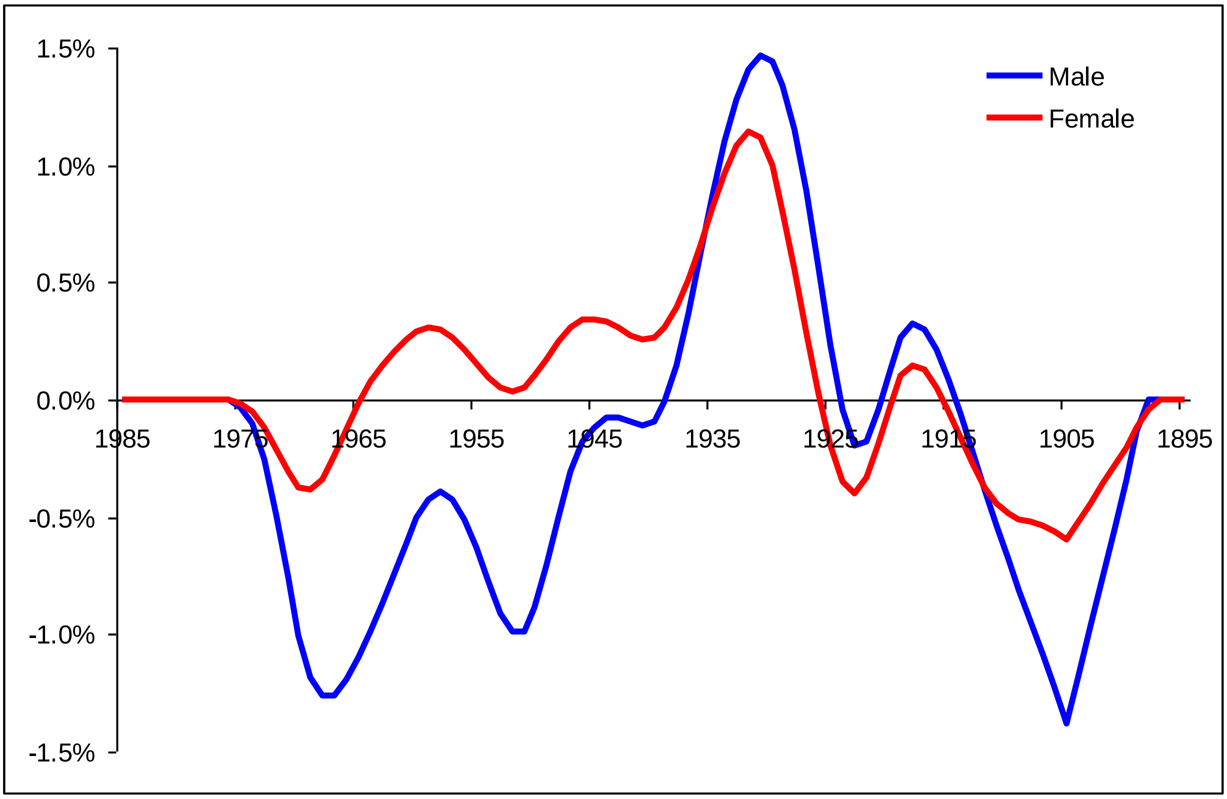

Figure 2: Default Cohort Component of Initial Rates of Improvement, by birth year and gender

2.4.3. Long-Term Rate of Mortality Improvement

Users of the Advanced option can specify, for each individual age, the Long-Term Rate of Improvement as separate Age/Period and Cohort Components.

There is no default option for this parameter. As described in Section 2.3.1, the user must select a value at the Core parameter level which defines a uniform Long-Term Rate of Mortality Improvement up to age 90.

2.4.4. Age/Period Component of Long-Term Rate of Mortality Improvement

As described above, users of the Advanced parameter level can specify the Age/Period Component of the Long-Term Rate to be used at each individual age.

At the Core level, the user has no flexibility to split the selected value into Age/Period and Cohort Components. The Model assigns the whole of the Long-Term Rate of Improvement to the Age/Period Component.

2.4.5. Cohort Component of Long-Term Rate of Mortality Improvement

Users of the Advanced option can specify the Cohort Component of the Long-Term Rate to be used for each individual year of birth.

At the Core level it is assumed that the Cohort Component of the Long-Term Rate is zero, i.e. the influence of current year-of-birth features on patterns of improvement is assumed to dissipate completely over the convergence period.

2.4.6. Period of Convergence

The Model assumes that Initial Rates of Improvement converge towards Long-Term Rates of Improvement, with the convergence based on a series of cubic polynomials. Details of the convergence approach will be given in Part Two.

2.4.7. Period of Convergence by Age/Period Component

The Age/Period Components of Initial Improvements are assumed to converge to the Age/Period Component of the Long-Term Rate over a period which can vary by individual age.

Users of the Advanced option can alter the Period of Convergence by Age/Period Component for each individual age to reflect a more or less rapid convergence from current to long-term rates of change.

At the Core level, default values are used for the Period of Convergence for the Age/Period Component of mortality improvement rates. The default period is 10 years for ages up to 50, increasing by one year for each year of age up to 60, then 20 years for all ages to 80, decreasing by one year for each year of age to 95 and then 5 years for ages 95 and above.

2.4.8. Period of Convergence by Cohort Component

The Cohort Components of Initial Improvements are assumed to converge to the Cohort Component of the Long-Term Rate over a period which can vary by individual year of birth.

Users of the Advanced option can alter the Period of Convergence by Cohort Component for each individual birth cohort to reflect a more or less rapid convergence from initial to long-term rates of change.

For the Core parameter level, default values are used for the Period of Convergence for the Cohort Component of mortality improvement rates. The default period is 5 years for year-of-birth cohorts 1910 and earlier, increasing by one year for each year-of-birth cohort up to 1945, and then 40 years for all year-of-birth cohorts 1945 or later.

2.4.9. Proportion of Convergence Remaining by Mid-Point for the Age/Period Component

The pattern of convergence for each age can be altered to influence the initial trajectory of the improvements over time. This is achieved by specifying the proportion of the change between the initial and long-term rate that is remaining at the mid-point of the period of convergence.

Users of the Advanced option can alter the Proportion of Convergence for each individual age. Selecting a relatively high proportion can generate projected improvements that initially increase before falling towards a long-term average rate. Users therefore have the flexibility to generate scenarios in which the rate of change continues to accelerate in the short-term, before decelerating in the longer term.

Figure 3 illustrates how the shape of the convergence can be altered in practice (with a 2.0% p.a. current rate converging towards 1.0% p.a. in 40 years' time).

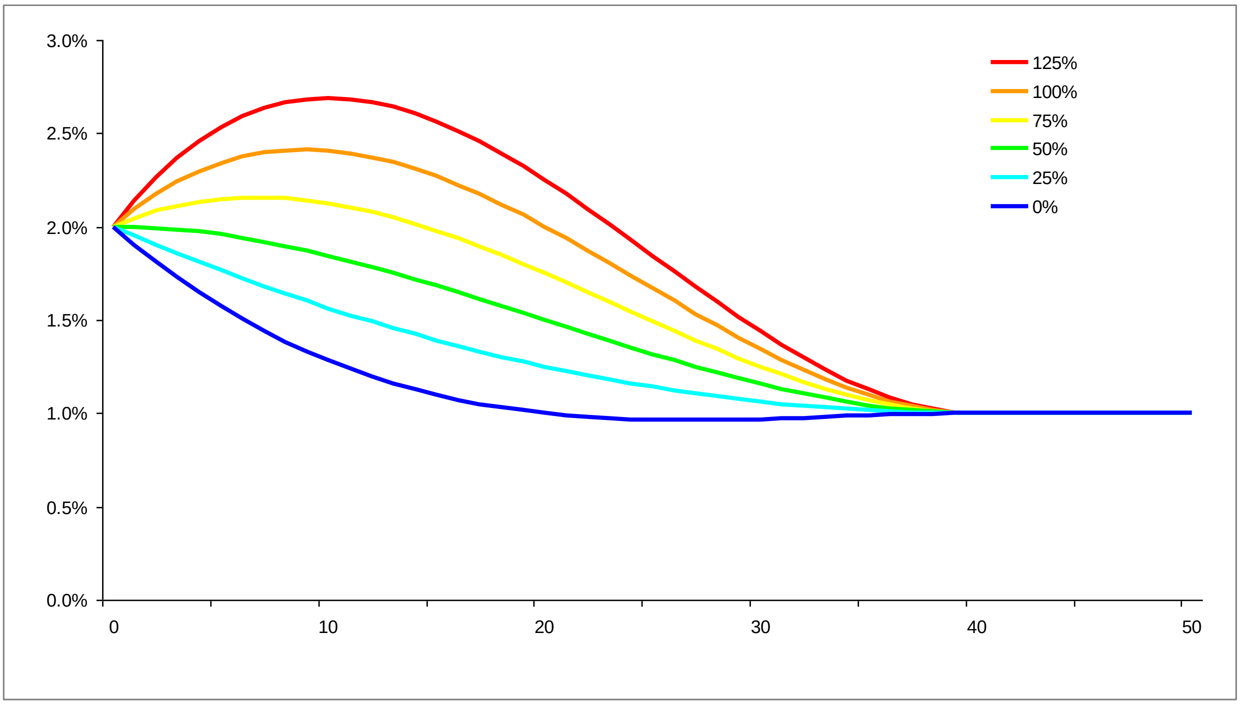

Figure 3: Illustration of the operation of the convergence formula over a 40-year period, with various proportions of the convergence remaining by the mid-point

For the Core parameter level the Proportion of Convergence Remaining by the Mid-Point of the Convergence Period is defaulted to 50% for all ages. Therefore, the projected rate of (age-period) improvement half-way through the period of convergence will be the average of the relevant Initial and Long-Term Rates.

2.4.10. Proportion of Convergence Remaining by Mid-Point for the Cohort Component

The pattern of convergence for each birth cohort can be altered to influence the initial trajectory of the Cohort Components over time. This is achieved by specifying the proportion of the change between the initial and long-term rate that is remaining after the mid-point of the period of convergence.

Users of the Advanced option can alter the Proportion of Convergence for each individual birth cohort.

For the Core parameter level the Proportion of Convergence Remaining by the Mid-Point of the Convergence Period is defaulted to 50% for all year-of-birth cohorts. Therefore, the projected rate of (cohort) improvement half-way through the period of convergence will be the average of the relevant Initial and Long-Term Rates. As noted in Section 2.4.5, the Long-Term Rates are defaulted to zero at Core level for the Cohort Component.

2.4.11. Base Rates of Mortality

A table of Base Rates of Mortality (q_x), by age and gender, can be entered so that the Model can calculate projected mortality rates and life expectancies. The Base Rates of Mortality do not influence the projected rates of mortality improvement generated by the Model, so their function is purely to aid the illustration of the projection.

Any Base Rate values (in the range [0,1]) may be input by users of the Advanced option.

For the Core parameter level, the user can select Base Rates of Mortality from the PCxA00, S1PxA or AxC00 Ult tables or from the Interim Life Tables for England & Wales (informally denoted in the Model as ILT05-07x[E&W]).

2.4.12. Constraints

No constraints have been put on parameter values other than basic input validation on the range of possible values. Users should therefore be aware that the Model may generate projections with unusual properties, or even errors, if extreme parameter values are entered.

2.5. Model outputs

The main outputs provided by the Model for each projection are:

- A table of projected annual rates of mortality improvement by age and calendar year
- A table of projected cumulative mortality reduction factors by age and calendar year

The Model also produces a variety of charts and tables to illustrate the projection. As well as providing information to facilitate comparison of projections, these outputs are also designed to support the user in reviewing the reasonableness of the projection.

Specifically, the following outputs are generated:

- Heat map of annual rates of mortality improvement, by age attained and calendar year
- Heat map of cumulative mortality reduction factors, by age attained and calendar year
- Sample expectation-of-life and annuity values.

- Charts showing projected rates of mortality improvement
  - by age attained and calendar year
  - by year-of-birth cohort and calendar year
- Charts showing projected mortality rates
  - $q_{x,t}$ by age (x) and calendar year (t)
  - logit[$m_{x,t}$] by age (x) and calendar year (t)
- Charts showing projected life expectancies, on both 'period' and 'cohort' bases
  - life expectancy at selected ages, by calendar year
  - annual increase in life expectancies at selected ages, by calendar year
- Charts showing projected survival probabilities, on both 'period' and 'cohort' bases
  - between selected ages, by calendar year

3. Analysis to Inform Setting of Parameter Values

Each user's judgement in setting parameter values for the Model is expected to be informed by analysis of a variety of data sources and by expert opinion.

New research and analysis, developed and used by the Working Party in designing the structure of the Model and in setting the initial default parameters, will be described in Part Two.

In broad terms, the major conclusions of this research and analysis (some of which have already been alluded to in Section 2) are as follows:-

- Although mortality data is available to 2007, the Working Party considers 2005 to be the latest year for which mortality improvement rates may be reliably estimated.
- Estimation errors inherent in deriving mortality improvement rates, by age, in insured/ pensioner datasets can be significant; as a result, the Working Party concluded that the default rates of current mortality improvement for Core Projections were best parameterised using population data.
- England & Wales population data shows clear evidence of persistent year-of-birth cohort features - with the strongest feature peaking at the 1931 cohort - together with a more general increase in mortality improvement rates across a wide range of ages over the last 25 years; this drives the proposal to separate 'by age' and 'by cohort' components of mortality change in the Model.
- The Working Party found patterns of improvement by year-of-birth appeared somewhat different for different datasets. However, the evidence to support different peak year-of-birth cohorts by socio-economic group or for insured/pensioner/population groups did not show a clear-cut, easy to interpret, pattern. The Working Party's analysis shows that sub-population datasets generally have insufficient volume to separate clearly the two features noted above for population data.
- For the CMI datasets for Life Office Pensioners and Permanent Assurances, the '1926 cohort' feature noted in CMI Working Paper 1 (based on data to 1999) appears less clear now with the addition of more recent data, and the peak rate of mortality improvement has drifted slowly across year-of-birth cohorts over the last 10 years. This pattern is consistent with an amalgamation of cohort and age/period effects similar to those seen in population data, but it is not possible to separate out the component parts given the limited data volumes available.
- Mortality improvement rates have historically run down to zero at high ages, typically between 90 and 100, although the point of reaching zero has been increasing, particularly over the last two decades.
- Whilst there is longer-term evidence of widening mortality differentials by socio-economic group, the more recent picture is unclear.
- There is widespread qualitative evidence that year-of-birth cohort features tend to persist for 25+ years (above age 40), whilst age and period features tend to be shorter-lived.
- Whilst mortality improvement rates averaged over very long periods tend to even out across ages and gender, the patterns of mortality change do shift materially even when comparing quarter-century intervals; mortality improvement rates for the last 25 years have been dramatically different to previous periods, particularly for males, with a marked shift to higher improvement rates at older ages.

4. Sample Projections and Parameter Sensitivities

4.1. Sample projections

The Model can be used to generate (an infinite number of) projections by adjusting the value of parameters. Therefore, no single projection can be taken to be *the* 'standard projection.'

In order to emphasise this position the prototype Model has been presented without a value entered for the parameter representing the Long-Term Rate of Mortality Improvement. Users are therefore required to enter a value for this parameter for the Model to generate a projection.

In the next section of this paper, Core Projections are compared with alternative projections. To do this, it was necessary to select a subset of Core Projections to evaluate. The subset selected was as follows:-

- CPMv*0.0* [0.0%]
- CPMv*0.0* [1.0%]
- CPMv*0.0* [2.0%]
- CPMv*0.0* [3.0%]

4.2. Comparison with other projections

Tables 1 and 2 how the subset of Core Projections listed in Section 4.1 compare with some selected alternative projections (using the terminology outlined in the User Guide to the CMI Library of Mortality Projections).

For each projection the cohort life expectancy at age 65 has been produced using the PCxA00 base mortality table projected to mid-2005 using the past rates of improvement contained in the Model. Projected mortality rates in years after 2005 are derived using the various projections listed. The life expectancies given are values as at 01/07/2009 and are complete rather than curtate.

Annuity values have been derived using the same mortality assumptions and a discount rate of 5.0%. The annuities are assumed to be payable yearly in advance.

Table 1: Comparison of alternative projections – males

Projection	**Cohort Life Expectancy at age 65**	**Annuity Value at Age 65**	**Annuity Value relative to Medium Cohort**
Original "92" Series	20.9	12.9	**98.4%**
Short Cohort	21.0	12.9	**98.6%**
Medium Cohort	21.5	13.1	**100.0%**
Long Cohort	23.1	13.5	**103.2%**
Medium Cohort_1.0% minimum	22.0	13.2	**100.7%**
Medium Cohort_1.5% minimum	22.6	13.3	**101.9%**
Medium Cohort_2.0% minimum	23.5	13.6	**103.4%**
PSAC_Male_ONS_EW_2005_50	30.2	14.8	**113.1%**
LC_Male_ONS_EW_2005_Central	21.3	13.0	**99.2%**
ONS_2006_Male_EWNI_Principal	22.6	13.4	**102.4%**
CPMv0.0 [0.0%] {male}	21.5	13.1	**100.2%**
CPMv0.0 [1.0%] {male}	22.5	13.4	**102.4%**
CPMv0.0 [2.0%] {male}	23.8	13.7	**104.8%**
CPMv0.0 [3.0%] {male}	25.2	14.1	**107.3%**

Table 1 shows that the cohort life expectancy for a male at age 65 using the Model with a Long-Term Rate of Improvement of **zero** is the same as the equivalent life expectancy using the Medium Cohort projection. The life expectancies using Long-Term Rates of 1.0%, 2.0% and 3.0% are higher by 1.0 years, 2.3 years and 3.7 years respectively.

Table 2: Comparison of alternative projections - females

Projection	**Cohort Life Expectancy at age 65**	**Annuity Value at Age 65**	**Annuity Value relative to Medium Cohort**
Original "92" Series	23.2	13.7	**98.6%**
Short Cohort	23.3	13.8	**98.8%**
Medium Cohort	23.9	13.9	**100.0%**
Long Cohort	25.5	14.4	**103.0%**
Medium Cohort_1.0% minimum	24.5	14.1	**100.8%**
Medium Cohort_1.5% minimum	25.2	14.2	**102.0%**
Medium Cohort_2.0% minimum	26.2	14.4	**103.5%**
PSAC_Female_ONS_EW_2005_50	30.5	15.2	**109.1%**
LC_Female_ONS_EW_2005_Central	24.0	13.9	**99.8%**
ONS_2006_Female_EWNI_Principal	24.9	14.2	**101.9%**
CPMv0.0 [0.0%] {female}	23.2	13.8	**98.9%**
CPMv0.0 [1.0%] {female}	24.4	14.1	**101.0%**
CPMv0.0 [2.0%] {female}	25.7	14.4	**103.3%**
CPMv0.0 [3.0%] {female}	27.2	14.7	**105.6%**

Table 2 shows that the cohort life expectancy for a female at age 65 using the Model with a Long-Term Rate of Improvement of **zero** is the same as the equivalent life expectancy using the Original "92" Series projection. Life expectancies using Long-Term Rates of 1.0%, 2.0% and 3.0% are higher by 1.2 years, 2.5 years and 4.0 years respectively.

4.3. Sensitivity of Core Parameters

Figures 4 and 5 show the sensitivity of selected expectation-of-life and annuity values for males to the value set for the Long-Term Rate of Improvement, using the same timing, mortality and discount rate assumptions as set out in Section 4.2.

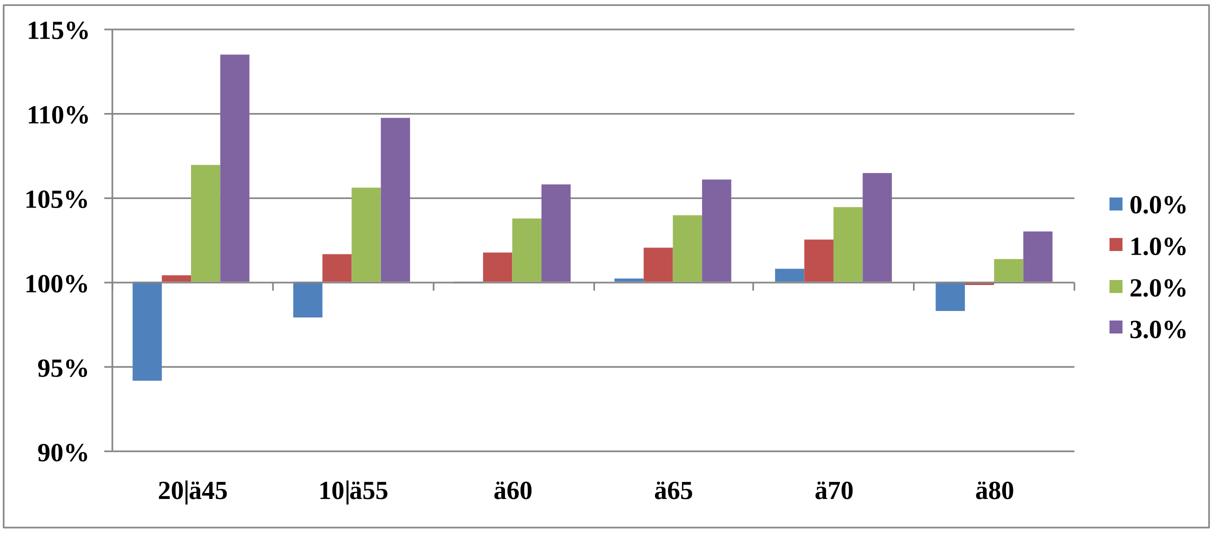

Figure 4: Variation in selected annuity values for males, as % of the values resulting from the Medium Cohort projection, for changes in assumed Long-Term Rate of Mortality Improvement

Figure 4 shows that immediate annuity values, calculated using a discount rate of 5%, for males aged 60 to 80, increase by approximately 2% for each 1.0% added to the Long-Term Rate of Improvement. The equivalent increase is substantially greater for deferred annuities.

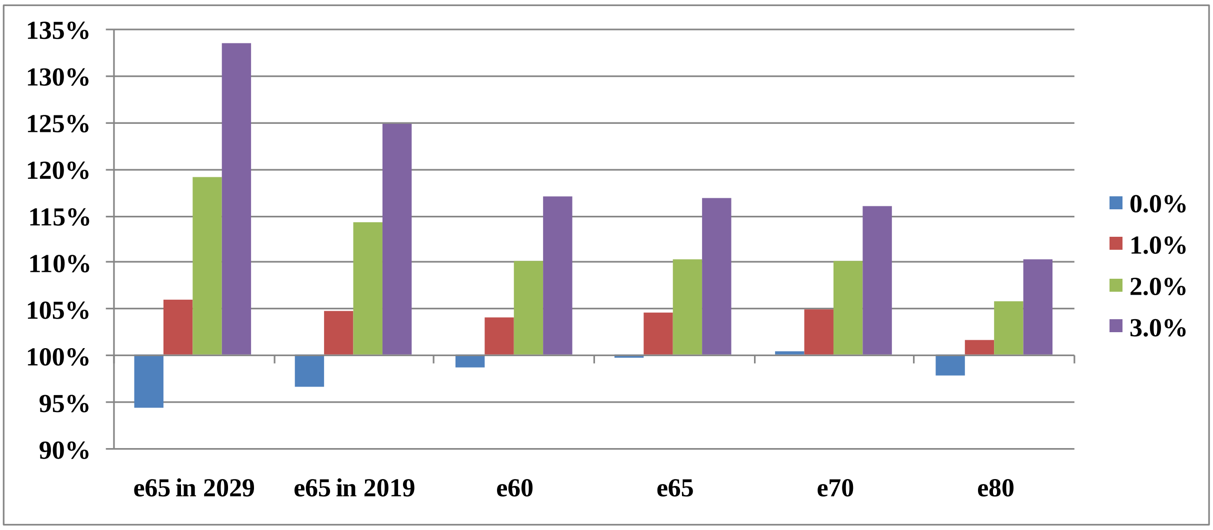

Figure 5: Variation in selected cohort expectation-of-life values for males, as % of the values resulting from the Medium Cohort projection, for changes in assumed Long-Term Rate of Mortality Improvement

Figure 5 shows the cohort expectation-of-life for males aged 60 to 80, increases by approximately 5% for each 1.0% added to the Long-Term Rate of Improvement. Again the impact is considerably more marked for expectations-of-life applying in future years.

The other parameter adjustable at Core level is the Constant Addition to Rates of Mortality Improvement. Sensitivity to this parameter is illustrated in Figure 6 by reference to $ä_{65}$ for males, again calculated using the same timing, mortality and discount rate assumptions as set out in Section 4.2.

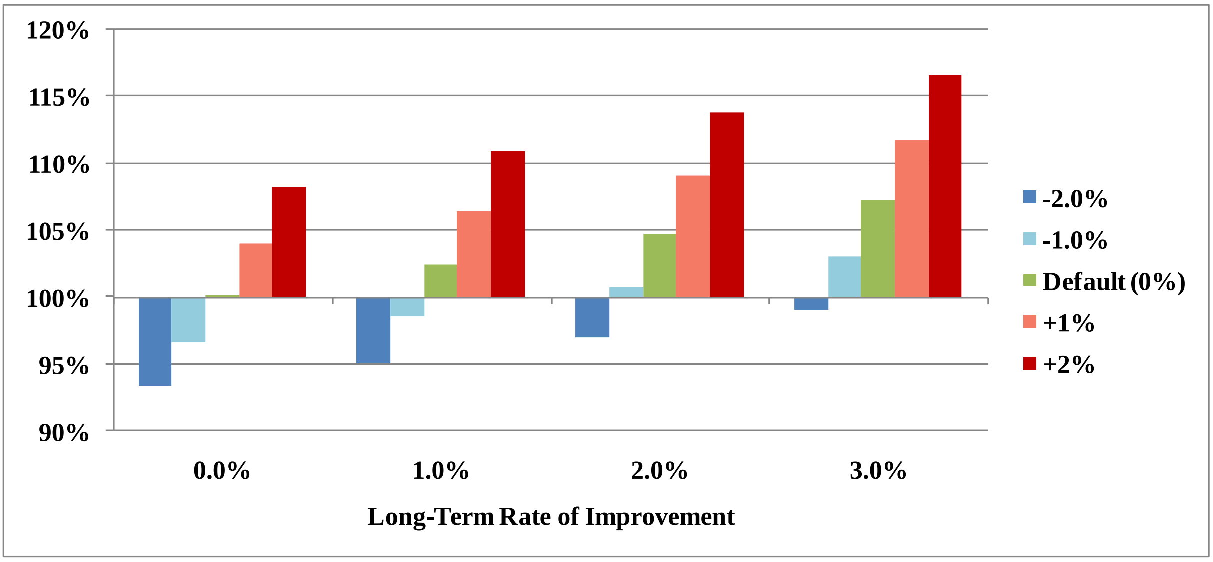

Figure 6: Variation in $\ddot{a}_{65}$ for males, as % of the value resulting from the Medium Cohort projection, for changes in the Constant Addition to Rates of Improvement and the assumed Long-Term Rate of Improvement

Figure 6 shows that values of $\ddot{a}_{65}$, calculated using a discount rate of 5%, for males, increase by approximately 4% to 5% for each 1.0% increase in the Constant Addition to Rates of Improvement.

Though not shown here, similar results for the sensitivities of these two parameters can be seen for females.

4.4. Sensitivity of advanced parameters

The sensitivity of adopting different values for selected advanced parameters will be described in Part Two.

The impact of adopting different values for the remaining parameters is generally less material than is the case for the two Core level parameters. This was one of the criteria for selecting which parameters should form the Core level and which should only be accessible within the Advanced layer. The Core level parameters were also chosen to be assumptions that the Working Party thinks users could more readily form a view on.

5. Next Steps and Consultation Process

5.1. Next steps

As outlined in Section 1.3, it is envisaged that Part Two will be published in advance of the planned Consultation Meetings. These will take place on **7 July 2009** (Edinburgh) and **14 July 2009** (London).

Feedback is sought on the both parts of the paper, with a deadline of **31 August 2009**.

It is then planned that, subject to the feedback received, version 1.0 of the Model will be published in **October 2009**.

5.2. Working Paper Part Two

The contents of this paper is expected to include sections covering:-

- The approach selected to determine historic and current rates of mortality improvement.
- A comparison of recent improvements in different sub-populations and by socio-economic class.
- The rationale and method adopted for disaggregating improvements into age-period and cohort components.
- An analysis of the pattern of historic improvements at high ages.
- The methodology selected for convergence (from current to long-term improvements).
- The rationale for the default periods of convergence for age-period and cohort components.
- An analysis of long-term rates of improvement in England & Wales and similar countries.
- Discussion of long-term improvement assumptions used in published projections in different countries.
- The sensitivity of results to the choice of Advanced parameter values.

5.3. Consultation

Feedback should be submitted:

- via e-mail to: projections@cmib.org.uk,
- or in writing to: Neil Robjohns, CMI, Cheapside House, 138 Cheapside, London, EC2V 6BW.

Feedback is sought on the following specific questions:

a) Do you agree that the CMI should be producing such a mortality projections model for use by practising actuaries? Please give reasons.

b) Do you agree with the broad structure of the proposed Model, i.e. a relatively simple, deterministic model with ‘core’ and ‘advanced’ level parameters, offering a common currency against which alternative methodologies could be benchmarked? Please give reasons.

c) Do you have any comments or suggestions on the proposed structure of the Model?

d) Do you agree with the proposed number (two) of parameters at Core level and the choice of these Core parameters?

e) Do you feel it would be useful to allow users to vary the long-term rate over time? So, for example, in the very long term the rate of change could be allowed to approach zero?

f) Do you have any comments or suggestions on the default values given to parameters?

g) Do you have any comments or suggestions on the proposed naming convention?

h) Do you anticipate you would use the Model in practice? If so, for what purpose would you use it?

i) Do you have any thoughts on how the proposed Model should be developed in the future?

j) Should the CMI maintain the proposed Model as new data becomes available? If so, should this be each year, or at some lesser frequency?

k) Do you have any other comments?

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CMI Working Paper 25: Stochastic projection methodologies: Lee-Carter model features, example results and implications (Revised version, 2007)

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Appendix

Mortality projections by cause of death

The idea of making future mortality projections by cause of death is not a new one. Pollard (1949) was one of the first to suggest making mortality projections by cause. In the UK the Government Actuary's Department (GAD) used a cause-of-death methodology for their '1976-based' National Population Projections, but have subsequently reverted to a methodology based on aggregate mortality rates.

More recently a research group within the Actuarial Profession has been established - the 'Mortality Projections by Cause' Research Group - and has presented some preliminary findings (e.g. Understanding the interactions between causes of death, Actuarial Profession Mortality & Longevity Seminar, March 2009).

Others have gone further and built models that have factored in trends in disease incidence and the mortality of people suffering from different diseases (e.g. Love & Ryan, 2007). Epidemiologists have also developed models that include potential explanatory factors for mortality including economics, risk factors and treatment of diseases. The Global Burden of Disease project, supported by the World Health Organisation, projects mortality relating to various diseases by taking account of indicators of wealth, education, technology and tobacco consumption in various countries (Mathers and Loncar, 2006). Capewell and colleagues have studied and projected mortality relating to cardiovascular diseases in various countries by taking account of risk factors and treatments of cardiovascular diseases (for references see Capewell and O'Flaherty, 2008).

However, there are a number of well-documented issues with projecting mortality by cause. CMI Working Paper 3 (2004) listed the following issues:-

1. Deaths from specific causes are not always independent and the complex inter-relationships are not always well understood.

2. There is limited understanding of how various risk factors (e.g. smoking) affect different causes of death.

3. It is not possible to identify a unique solution for the relationship between 'competing risks' by analysis of past data.

4. Medical resources will shift between causes over time as their relative importance changes.

5. There can be specific problems with the accuracy of cause of death as recorded on death certificates, e.g. changing methods of diagnosis and classification over time and the difficulty of establishing a single cause, particularly at very advanced ages.

6. There may be causes of mortality at extreme old ages that have not yet been identified as other, known, causes have resulted in deaths at earlier ages.

Despite these recognised limitations, those who favour the use of cause of death data argue that analysis by cause can help the user to understand the drivers of mortality change and form a view on whether the pace of change is likely to increase or decrease in the future as a result. It could be argued that this feature is of particular relevance at present because such a large proportion of improvements at higher ages in recent years have been driven by reduced deaths from circulatory disease.

The Working Party felt that producing a cause-of-death, or disease-based, model would not have been appropriate given the underlying aim of its work; in particular the objective of producing a relatively simple, straightforward model with widespread application.

However, the Working Party did consider it appropriate to provide some analysis of past trends by cause of death. Furthermore, some cause-of-death scenarios consistent with Core Projections generated using the proposed Model have also been derived and are outlined below.

Past trends by cause of death

Reviews of long-term trends in mortality in the UK - e.g. Health of Adult Britain, ONS (1996); Twentieth Century Mortality Trends in England & Wales, ONS (2003); Longevity in the 21st Century, Willets *et al* (2004) – describe how the pattern of improvements by cause shifted significantly over the course of the last century.

In the first half of the 20th Century there were substantial reductions in deaths from infectious diseases and, partly for this reason, mortality rates for children and younger adults reduced significantly. The latter half of the century was characterised by increasingly rapid improvements in mortality rates for older adults, largely driven by falling numbers of deaths from circulatory diseases such as heart disease and stroke.

Overlaying this 'ageing of mortality improvement' was the effect of the rise and (partial) fall of the cigarette smoking 'epidemic.' Deaths from smoking-related causes, such as lung cancer, rose during the first half of the 20th Century and then fell as the prevalence of cigarette smoking reduced. Trends in cigarette smoking are believed to be a significant driver of the birth cohort patterns which have characterised trends in UK mortality in recent decades. Indeed, the ONS (1996) described the pattern of lung cancer mortality in the UK as being a 'perfect example of a cohort effect.'

In order to decompose recent improvements in aggregate mortality into constituent causes, the Working Party fitted P-Spline models to deaths and exposures for individual ages in England & Wales from five specific cause-of-death groups; namely:

- Heart disease
- All circulatory causes (excluding heart disease)
- Lung cancer
- All cancers (excluding lung cancer)
- All causes other than circulatory and cancer

The data used for this exercise spanned the period from 1968 to 2006. The Working Party checked the data received against other published sources (e.g. deaths by 5-year age band published elsewhere by the ONS) to ensure consistency.

The P-Spline models fitted to the data allowed for changes in cause-of-death classification by introducing 'step functions' at relevant points (i.e. in 1984 and 1993 when the method of classifying the primary cause of death changed and in 2001 when ICD10 was introduced).

The smoothed surfaces fitted to deaths from each cause group were adjusted so that, when aggregated, the combined total exactly matched the smoothed surface fitted to aggregate mortality rates.

For this purpose of this Working Paper, this analysis was only performed for males. However, it is hoped to extend this modelling to also include females in due course.

Figure A1 shows how age-standardised mortality rates for males age 60 to 89, smoothed using the P-Spline model, varied between 1968 and 1995. The age-standardisation was performed using the age distribution of the England & Wales population in 2005. Specifically, weighted average mortality rates were derived using weights based on the number of males in the population of England & Wales in 2005 at each age from 60 to 89.

The age range 60 to 89 has been used throughout this Appendix as these are the ages of most significance in the calculation of annuity values or the valuation of pension liabilities.

Over the period it can be seen that the aggregate age-standardised mortality rate fell from 6.7% to 3.6%. Therefore, rates almost halved over the period 1968-2005 with an average annual reduction of 1.7% p.a.

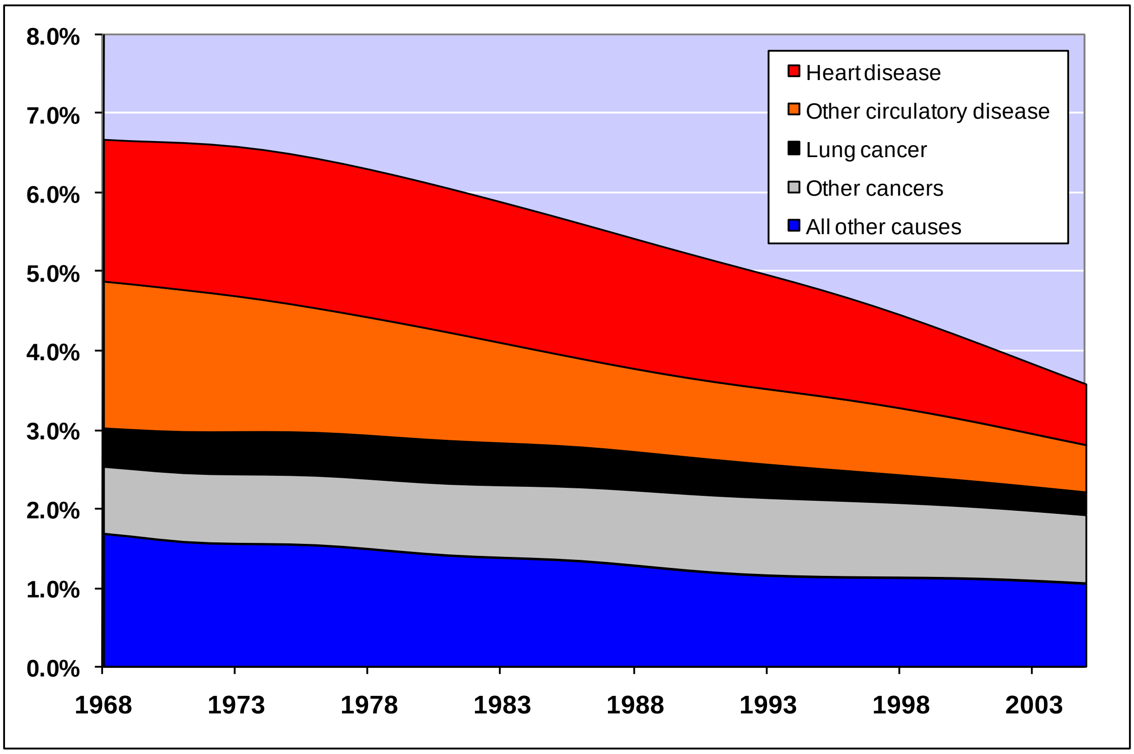

Figure A1: Age-standardised mortality rates for males in England & Wales aged 60-89, 1968-2005, by constituent cause

Table A1 shows the aggregate annual rate of improvement split into constituent causes.

Table A1: Components of the average annual improvement in age-standardised mortality rates for males in England & Wales aged 60-89, 1968-2005, by constituent cause

Cause of death	Contribution to average annual reduction in aggregate age-standardised mortality rates	Proportion of total improvement
Heart disease	0.6%	33%
Other circulatory disease	0.7%	41%
Lung cancer	0.1%	6%
Other cancers	0.0%	0%
All other causes	0.3%	20%
All causes	**1.7%**	**100%**

It can be seen that, over the whole 37-year period, the bulk of the improvement - around 75% - has stemmed from fewer deaths from circulatory disease. Most of the balance of the improvement has come from fewer deaths from causes other than cancer. Rates of cancer mortality (excluding lung cancer) are little different in 2005 than they were at the beginning of the period.

The breakdown in improvements by cause-of-death group, by decade, is given in table A2.

Table A2: Components of the average annual improvement in age-standardised mortality rates for males in England & Wales aged 60-89, by decade, 1975-2005, by constituent cause

Cause of death	1975-1985	1985-1995	1995-2005
Heart disease	0.3%	0.7%	1.4%
Other circulatory disease	0.7%	0.5%	0.8%
Lung cancer	0.0%	0.2%	0.2%
Other cancers	-0.1%	-0.1%	0.3%
All other causes	0.3%	0.4%	0.2%
All causes	**1.3%**	**1.8%**	**2.9%**

Table A2 indicates that the average annual rate of improvement has accelerated over the past three decades; and in particular the last ten years. At the same time the proportion of the improvement due to fewer deaths from circulatory disease has remained relatively steady (i.e. 78% in 1975-1985, 68% in 1985-1995 and 75% in 1995-2005).

The changing balance of contributions from different causes can be seen in Figure A2.

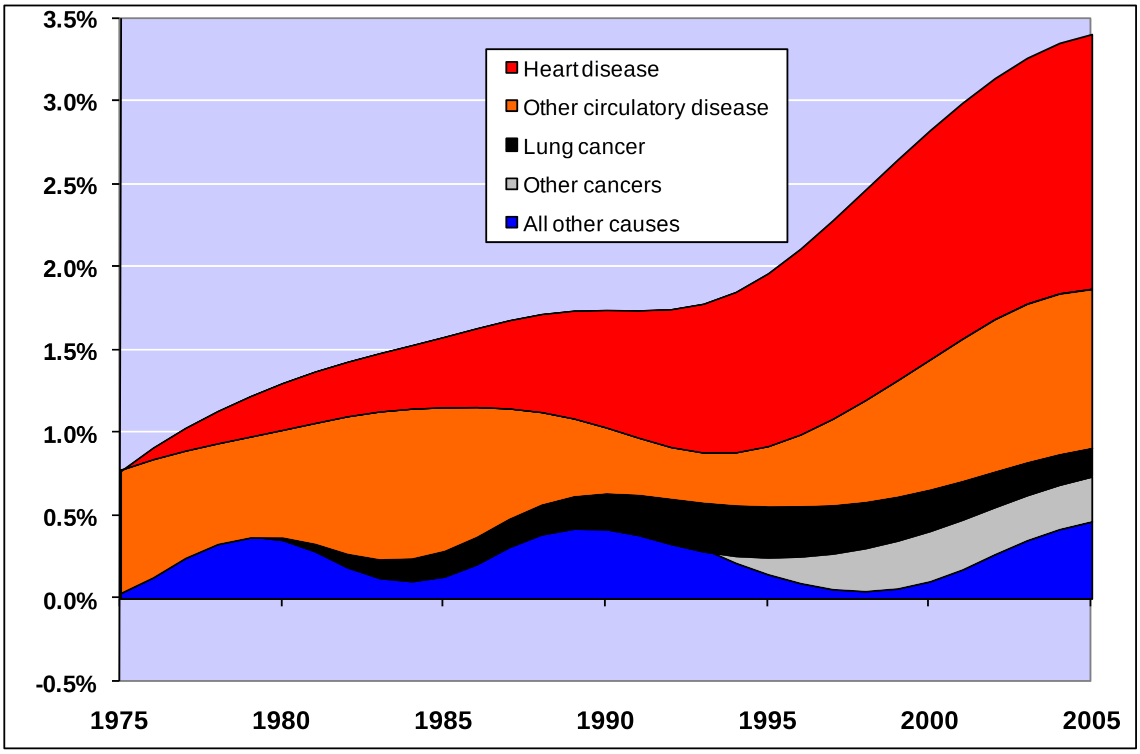

Figure A2: Average annual rate of improvement in age-standardised mortality rates for males in England & Wales aged 60-89, 1975-2005, by constituent cause

Figure A2 highlights that most of the acceleration in the aggregate pace of improvement has been due to fewer deaths from heart disease.

The age-standardised mortality rate for cancers other than lung was increasing until the early 1990s (and hence the rate of improvement from this cause group was negative). However, more recently, improvements from reduced deaths from other cancers have also begun to make a material contribution towards the aggregate rate of improvement.

Table A3 shows improvement in mortality rates in the different cause-of-death groups in successive ten-year periods.

Table A3: Reductions in age-standardised mortality rates for males in England & Wales aged 60-89, over successive decades, 1975-2005, by cause

Cause of death	1975-1985	1985-1995	1995-2005
Heart disease	9%	22%	43%
Other circulatory disease	28%	21%	35%
Lung cancer	5%	24%	27%
Other cancers	-5%	-5%	11%
All other causes	13%	16%	7%
All causes	**12%**	**16%**	**25%**

Table A3 shows that - for example - age-standardised mortality rates from heart disease fell by 9% from 1975 to 1985, by 22% between 1985 and 1995 and by 43% over the ten-year period to 2005. Over the same three decades, aggregate age-standardised mortality rates fell by 12%, 16% and 25% respectively.

Future scenarios

Tables A4 and A5 show ten-yearly reductions in the different cause-of-death groups for two future scenarios consistent with Core Projections for males with the Long-Term Rate of Mortality Improvement set to 1.0% and 3.0% respectively.

In each case, any number of alternative outcomes could have been produced by shifting the emphasis towards or away from the different cause-of-death groups. However, the particular scenarios chosen were selected to be broadly plausible representations of the two Core Projections.

Table A4: Reductions in age-standardised mortality rates for males in England & Wales aged 60-89, over successive decades, 1975-2005 actual and 2005-2035 projected, by cause, future scenario consistent with CPMv*0.0* [1.0%]

Cause of death	1975-1985	1985-1995	1995-2005	2005-2015	2015-2025	2025-2035
Heart disease	9%	22%	43%	49%	36%	19%
Other circulatory disease	28%	21%	35%	41%	26%	10%
Lung cancer	5%	24%	27%	19%	8%	6%
Other cancers	-5%	-5%	11%	10%	6%	11%
All other causes	13%	16%	7%	12%	1%	3%
All causes	**12%**	**16%**	**25%**	**25%**	**11%**	**8%**

A graphical representation of the projected improvements is given in Figure A3.

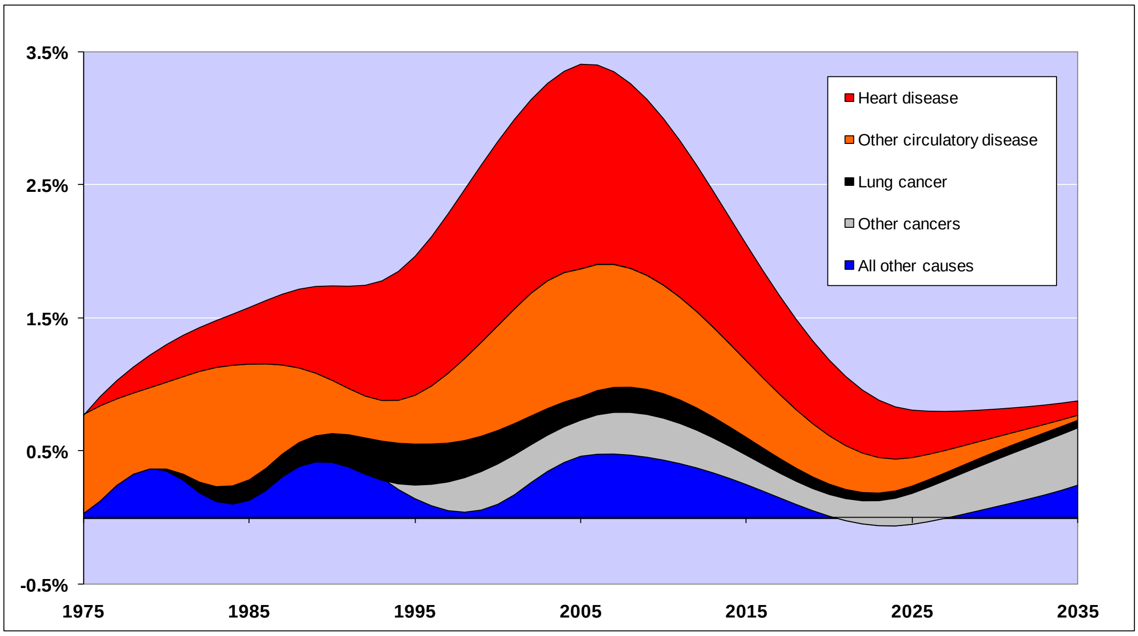

Figure A3: Average annual rate of improvement in age-standardised mortality rates for males in England & Wales aged 60-89, 1975-2035, by constituent cause, projected future rates consistent with CPMv*0.0* [1.0%]

The scenario shown in Table A4 and Figure A3 - consistent with the **CPMv*0.0* [1.0%]** Core Projection - is one in which:

- the rate of improvement in heart disease mortality is more rapid in 2005-2015 than 1995-2005, but then decelerates markedly in subsequent decades;
- likewise, the rate of improvement in other circulatory disease is also more rapid in 2005-2015 than 1995-2005, but decelerates markedly thereafter;
- the rate of improvement in lung cancer mortality declines over time;
- the rate of change in mortality from other cancers stays at broadly the same level as 1995-2005, but becomes a more significant component of aggregate mortality improvement as deaths from circulatory causes reduce; and
- the rate of improvement in mortality from all other causes reduces to a low level.

Values for a scenario consistent with the **CPMv*0.0* [3.0%]** Core Projection are given in Table A5 and Figure A4.

Table A5: Reductions in age-standardised mortality rates for males in England & Wales aged 60-89, over successive decades, 1975-2005 actual and 2005-2035 projected, by cause, future scenario consistent with CPMv*0.0* [3.0%]

Cause of death	1975-1985	1985-1995	1995-2005	2005-2015	2015-2025	2025-2035
Heart disease	9%	22%	43%	53%	51%	44%
Other circulatory disease	28%	21%	35%	46%	43%	36%
Lung cancer	5%	24%	27%	23%	25%	28%
Other cancers	-5%	-5%	11%	15%	22%	29%
All other causes	13%	16%	7%	15%	13%	15%
All causes	**12%**	**16%**	**25%**	**29%**	**26%**	**25%**

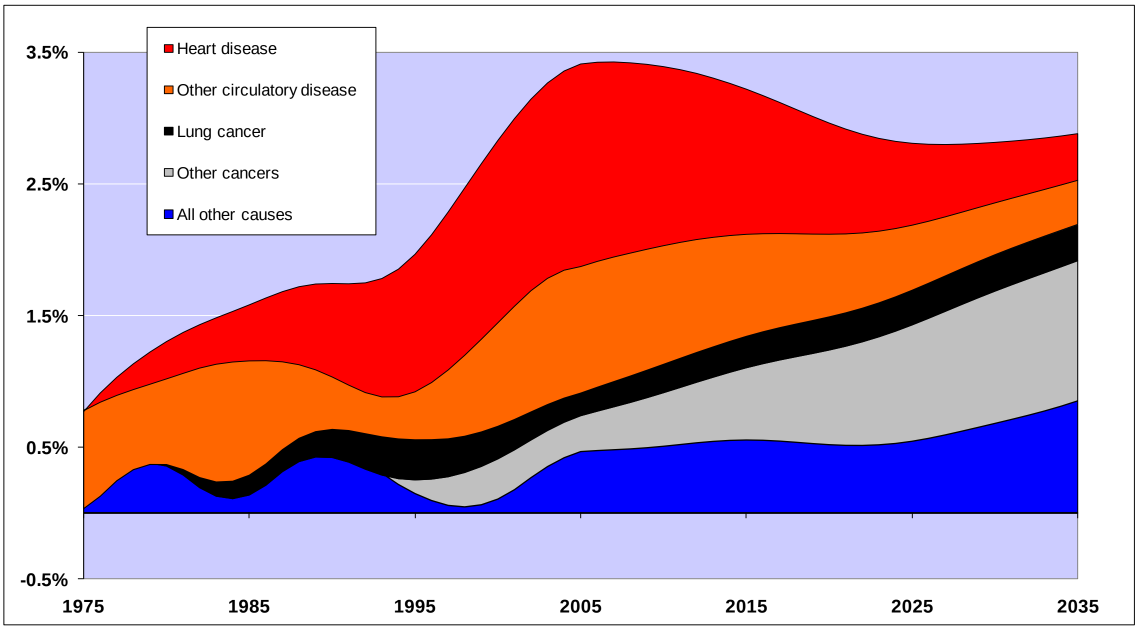

Figure A4: Average annual rate of improvement in age-standardised mortality rates for males in England & Wales aged 60-89, 1975-2035, by constituent cause, future scenario consistent with CPMv*0.0* [3.0%]

The scenario shown in Table A5 and Figure A4 - consistent with the **CPMv*0.0* [3.0%]** Core Projection - is one in which:

- the rate of improvement in heart disease mortality is more rapid in 2005-2015 than 1995-2005, and the rapid pace of improvement continues in subsequent decades;
- likewise, the rate of improvement in other circulatory disease is also more rapid in 2005-2015 than 1995-2005, and continues to be rapid thereafter;
- the rate of improvement in lung cancer mortality remains at broadly the same level over time;
- the rate of change in mortality from other cancers increases significantly over time, becoming an increasing significant driver of mortality change; and
- the rate of improvement in mortality from all other causes is significantly more rapid in 2005-2015 than 1995-2005, and this pace of change is maintained in subsequent decades.

It was noted earlier that approximately 75% of the improvement over 1968-2005 in the age-standardised mortality rate for males aged 60-89 has been the result of reduced deaths from circulatory disease, with the 25% balance due to reduced deaths from other causes. Under the scenario described above, consistent with **CPMv*0.0* [3.0%]**, the equivalent split has reversed by 2035, with only 25% of the improvements now due to reduced deaths from circulatory disease, and the 75% balance due to reduced deaths from other causes.