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TWO-DIMENSIONAL MORTALITY DATA: PATTERNS AND PROJECTIONS

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ABSTRACT OF THE DISCUSSION HELD BY THE INSTITUTE OF ACTUARIES

Mr S. J. Makin, F.F.A. (introducing the paper)**:** It is a privilege to present the paper on behalf of the Faculty's Mortality Research Group.

The paper has its roots in the various papers on longevity which have been presented in recent years, including Willets *et al.* (2004), CMIB (2004, 2005c, 2005a, 2005b), and Richards *et al.* (2006) [all of these references are either given in the paper or in the discussion of it held by the Faculty of Actuaries]. Willets *et al*. considered longevity with particular focus on 20th century trends in the United Kingdom, including: the cohort effect; international comparisons of mortality; medical advances and changes in the causes of death; and the possible impact of a continuation of trends, all of which topics have a very strong link with our paper. The CMIB working papers explored the use of stochastic models for mortality projections, introduced the Profession to penalised spline (or *P*-spline) methods, and made available projection software for these new methodologies. Again, the link with our paper is clear. Finally, Richards *et al.* explained the use of *P*-spline regression in fitting models to historic mortality data. Yet again, the link with our paper is clear.

Turning now to the paper, our research objectives, which we outlined in Section 1, were as follows: to compare the trends in mortality rates for a number of countries, both at an aggregate level and by cause of death; to understand the key drivers of historic trends in the different countries; to carry out projections for the various countries using the techniques and software most recently developed by the CMIB; to look for evidence of cohort effects in countries other than the U.K.; to assess the projections in terms of possible changes in mortality rates by cause of death; to carry out a high level critique of the *P*-spline projection methodology; and to look at models which can be applied to experience data to separate time trends from cohort-based patterns.

The data used in our paper were taken from the Human Mortality Database, which is available on line at the web address given in our paper. This database is a very useful source of mortality data and statistics from many countries. It is maintained collaboratively by the University of California and the Max Planck Institute for Demographic Research.

Section 2 sets out the countries at which we chose to look and the rationale for choosing them, which was as much to do with the differences as it was to do with any similarities either between, or among, the countries.

Sections 3 to 9 give a brief summary of the 20th century social, political and demographic history of the countries considered. This history sets the background to the observed mortality experience over that period.

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Section 2 also sets out the format of the data as we used them. For all countries the data which we used started in 1961, although the data do go back significantly further in many cases; for example, 1841 for England and Wales, and even as far back as 1751 for Sweden. The final year of the data was the most recent year available at the time of our analysis, which ranged from 2002 in the case of Germany, to 2005 in the case of Sweden. The details are set out in Table 1.

Our modelling focused on the age range 40 to 100. The rationale for chopping the data below age 40 was to ensure that we focused on mature adult mortality, where the drivers of mortality are quite different from those for younger lives. The rationale for chopping the data above age 100 was mainly to avoid some of the effects of potential data peculiarities at the most advanced ages, where the data tend to be less reliable and where the exposed to risk data are often modelled, rather than being observed.

Table 2, giving the life expectancy at age 65 for males and females in each country, shows some wide disparities in life expectancy at retirement and of the league table implied by our table. Life expectancy for England and Wales is second bottom for males and bottom for females.

Many of us are managers of U.K. longevity risk in one shape or form, and, given that there seems to be plenty of room for further increases in U.K. longevity, and that is despite very strong improvements in recent times, we ought to be worried by, or very mindful of, the scope for further improvement.

It is notable that the differences in mortality between the sexes remains pronounced, despite faster improvements for males, recently, in the countries considered. The differences between the sexes are as large as the differences between the various countries considered. This, of course, is currently very topical, because of a European Union antidiscrimination directive, which, in principle at least, if perhaps not in practice in the U.K., prohibits the use of sex as a rating factor in the calculation of premiums and benefits for the purposes of insurance contracts concluded after 21 December 2007.

One point of note in relation to Japan is the high smoking prevalence for males, as shown in Table 3. Despite this, the expectations of life have risen more quickly than in other countries. To put this into context, Japanese males were at the bottom of our implied league table in 1960, but, quite remarkably, had risen to its top by 1980, where they have stayed since. While the large difference between male and female life expectancies in Table 2 is likely to be explained, at least in part, by the large smoking differential, it is possible that the impact of this smoking differential has yet fully to feed through to the expectations of life at age 65, particularly for Japanese males.

Section 10 explains the use of *P*-spline methodology. Further detailed information is also available from the CMIB working papers (CMIB, 2004, 2005c, 2005a, 2006a). The most recent CMIB working paper on mortality projections, Working Paper No. 27, which has come to be called 'The Library of Projections', usefully summarises certain aspects of the CMIB's work. However, the detail remains in its earlier working papers.

Section 11 sets out the results of applying *P*-spline regression to the various national data. We fitted both age-period and age-cohort models to the historic data for the seven countries, and compared the relative model fits using the Bayesian Information Criterion (BIC). All else being equal, a better fitting model is to be preferred to one which fits less well. Equally, a simple model is to be preferred to a complex one. The BIC is a statistical criterion, which quantifies simultaneously both the goodness of fit of the fitted model and its complexity, and a model with a smaller BIC is to be preferred to one with a larger BIC.

Table 5 shows BIC values for the age-cohort (AC) and the age-period (AP) *P*-spline models. A positive number in the BIC: AC-AP column on the right side of Table 5 indicates that the period effects dominate cohort effects, while a negative number indicates the dominance of cohort effects over period effects. These are marked in bold type in the paper.

The results of fitting the models are shown in the paper as heat maps, with the year of birth along the bottom and the year of observation up the side: the lighter the shade, the larger the rates of improvement; the darker the shade, the smaller the rates of improvement, with worsening mortality shown in black.

Figure 4 shows evidence of the very strong cohort effects for both males and females in

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England and Wales — these are the vertical patterns — and this is despite the graphs showing rates of improvement derived from an age-period model. This figure also shows evidence of strong cohort effects in the German population appearing to be slightly stronger for females.

The results for England and Wales were not quite as we had expected when we set out. Despite the undeniable existence of a strong and extremely well-documented cohort effect, our research shows that period effects dominate over cohort effects. This is in contradiction to Richards *et al.* (2006), where cohort effects were found to dominate period effects. The reasons for this are described in the paper. However, the dominance of period effects does not imply the non-existence of cohort effects, and we can see that quite clearly if we look at the example of England and Wales.

Figure 5, with the United States of America shown at the top and Canada at the bottom, is interesting, because of the striking difference in patterns for two neighbouring countries with similar levels of wealth. Canada seems to have enjoyed better rates of mortality improvement for most generations for most of the time. The results for the U.S.A. were also slightly surprising. The U.S.A. was reputed not to have a cohort effect, or, at least, to have only a very weak one, whereas our research shows the existence of strong cohort effects, which, again, are clear enough as the vertical patterns in Figure 5.

Despite the use of age-period penalties in the model fitting, cohort effects are clearly visible in Figure 6, as vertical patterns for males in both Japan and France. The heat map for Japanese females immediately stands out in the whole paper as being the lightest in shade, indicating, consistently, the largest rates of improvement among the countries surveyed.

Figure 7 shows both model fits for Sweden. Period effects dominate for male lives while cohort effects dominate for female lives, and these cohort effects are highly visible in the top right panel of Figure 7, where age-cohort penalties have been used in the model fit.

Sections 12 and 13 look at international trends in mortality rates by cause of death. Deaths are categorised as: deaths from diseases of the circulatory system; deaths from diseases of the respiratory system; malignant neoplasms or cancers; and other deaths. The rationale for this categorisation has a sound basis from both a biological and a practical perspective.

In the two decades up to the year 2000, the key trends in the causes of death for the countries investigated may be summarised as follows. First, the proportion of deaths, and also the independent rates of death relating to circulatory disease, fell significantly across all countries, ages and sexes. When viewed from 2000, they seemed set to fall further, and that has been backed up, certainly in England and Wales. Secondly, while the independent rates of death relating to cancers were broadly stable across the period, the proportion of deaths from cancers generally increased. The most significant increases tended to be observed for populations where death rates from circulatory diseases fell most. This is a feature of the dynamic nature of competing mortality risks. Thirdly, proportions of deaths and independent death rates, relating to respiratory and other diseases, with one or two exceptions, remained largely unchanged for the period.

Turning now to circulatory disease, this is the major killer of old people. Changes in this were the largest contributor to the improvement in mortality between 1980 and 2000. Table 15 shows that these improvements came from two main sources: a reduction in the risk factors causing the disease contributed in total something of the order of 60% of the improvement, and over half of that was related to a reduction in smoking prevalence; and a reduction in fatality following the onset of the disease contributed to something of the order of 40% of the improvement, thereby proving the adage that prevention is, indeed, better than cure.

Section 14 considers communicating mortality trends using cause of death interpretation, this being a commonly used currency of communication in other fields, notably also in the media. As actuaries, if we are to enhance our image as communicators, we must try more often to use the language and the terminology which others use.

Table 16 shows the projected number of years required to observe various scenarios of the reduction in mortality equivalent to certain stated reductions in the causes of death in England and Wales. For example, for a male aged 70, a reduction equivalent to the complete elimination of circulatory and cancer-related deaths was projected to occur after 37 years.

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Although the time periods look very short for some of the scenarios, it is incorrect to think that the *P*-spline projection, or any other projection for that matter, actually requires the elimination of a major cause of death. In the extreme, if everyone's ultimate cause of death remains the same, but the age at death is increased merely by a few months each year, this would have the same effect as some of the *P*-spline mortality projections, while keeping the relative roles of the various causes of death entirely unchanged.

Projection of the various causes of death could be used to complement current methods of projecting aggregate mortality. However, cause of death assessments should be interpreted with great care for a number of reasons, not least because of a significant risk of misclassification of death, as is described in the paper.

In Sections 15 and 16 a high level critique of the *P*-spline projection methodology is carried out, with a deliberate focus on the practical points as opposed to the underlying mathematics. Back-testing of projections, as was done by the CMI Mortality Projections Working Party, shows that the methodology is capable of producing very credible results indeed. Figure 9 shows this for French males. The central line represents the median projection, while the upper and lower lines together show the 95% confidence interval around that median. The forecasting starts in 1982, which is where we see the fanning out of the confidence intervals. Not only do virtually all observations, which are represented by the dots, lie within the confidence interval in the area of the projection, they are extremely well forecast by the model. However, *P*-splines are not perfect, and I now share with you a number of their features, so that you may be aware of them in your own work.

One possible criticism of *P*-spline projections is what they can do to the age structure of mortality. Figures 11 and D.1 show age structure cross-sections of the fitted and subsequently forecast forces of mortality for males in England and Wales. Although evident, to some extent, in the early years of the projection, the longer-term projections do show something of an over-dampening of senescence. To put it another way, the familiar exponentiation of mortality after middle age does not seem as pronounced as would seem reasonable. In short, the projected mortality curves are too flat.

Another observation is that the models do not always converge. Try as we might, and we

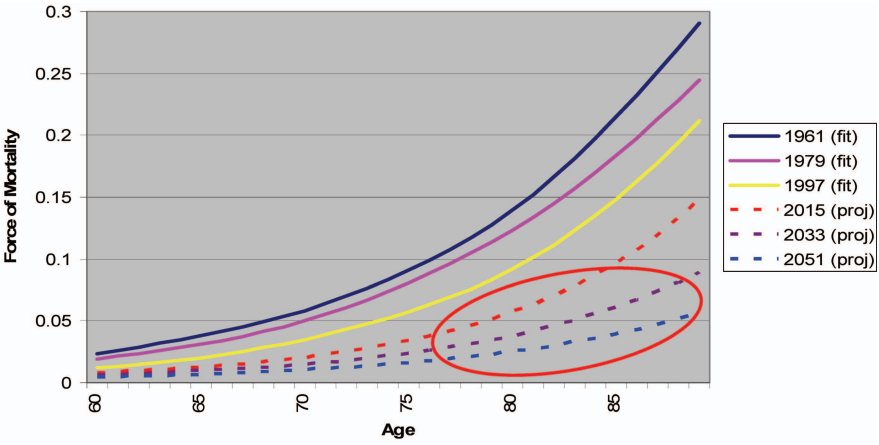


Figure D.1. Two-dimensional mortality data: patterns and projections; critique of *P*-splines

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tried, we could not fit a model with five-year knot spacings to the data for French females. This can often be overcome by fitting models with different parameter values, and, although not shown in the paper, we were able, readily, to fit models to data for French females using three-year knot spacings. I have a word of warning in changing parameters like this, however. One cannot directly compare BICs of age-period and age-cohort models with different parameter values. The BICs become incomparable because the model's complexity, as measured by the number of parameters in the model, differs, and this directly affects the BIC.

Fitted results can also be sensitive to the final year of the data and/or the model parameterisation. Table 17 shows an example of this in the context of Canadian females.

There is also a counterintuitive relationship between data size and the confidence intervals surrounding *P*-spline projections. Specifically, confidence intervals tend to become larger as data sets become larger, all else being equal. Although logical, once understood, this does go against the grain.

Note that the results from applying *P*-spline models can be very erratic, which is shown in the left panel of Figure 15. The black lines represent the results from the fitted model in the area of the data. The model provides a good, smooth fit to these data, although not shown in the paper. The grey lines show the projections in years 2015, 2033 and 2051. These are at best described as erratic, and at worst they could cause one to disregard the *P*-spline as a useful means of projection.

All things considered, however, our view is that *P*-splines remain a very useful means of informing one's view on projection bases. More than this, they give a means of exploring uncertainty within a formal statistical framework, deriving from the parametric nature of the fitted models. We view exploration of the uncertainty, and its subsequent communication, as absolutely fundamental in furthering the appreciation and the understanding of the underlying risks among those whom we advise on a daily basis.

Other models allow the separation of time trends from cohort-based patterns. In Section 17 a Poisson model is fitted to grouped male population data, and in Section 18 a survival model is applied to the individual life level data in a life office portfolio of male lives. In both sections, statistical tests showed that models including a period parameter provided a better fit than models without one. Next, models including cohort-based parameters also provided better fits than models without them. Then, models which included both cohort-based and period-based parameters fitted best of all.

The corollary of this is that, even in the presence of clear cohort effects, a significant residual component of the observed rates of improvement is time based, which would seem to back up the current life office practice of using a floor percentage, or underpin, for mortality improvements in annuity pricing and annuity reserving.

By extension, it would seem, also, to back up the use of a 1% p.a. underpin in the FRS 17 basis for the Faculty and Institute's defined benefit pension scheme.

A premium or valuation basis has to be concerned with future improvements for which past experience, and, therefore, models fitted to that past experience, may not be relevant, and we would advise caution in reading the results of such modelling directly into future improvement assumptions.

So, some key conclusions are:

(1) The differences in mortality between the sexes remains pronounced, despite faster improvements for males recently, and the differences between the sexes are as significant as the differences between the various countries considered.
(2) Although mortality improvements in England and Wales have been particularly strong of late, there seem few grounds, if any, for assuming that they will slow down materially at any point soon, let alone stop. The poor international ranking suggests that continued strong improvements are perfectly possible, with the example of Japanese females showing that already-low mortality is no barrier to further improvement.
(3) The cohort effect exists for both males and females in the U.K., and similar effects are evident in many other countries around the world.

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(4) The *P*-spline model, despite certain limitations in certain areas, can produce very credible results. However, actuaries using the results of *P*-spline models must do so with care, with caution, and with due regard to the underlying uncertainty.

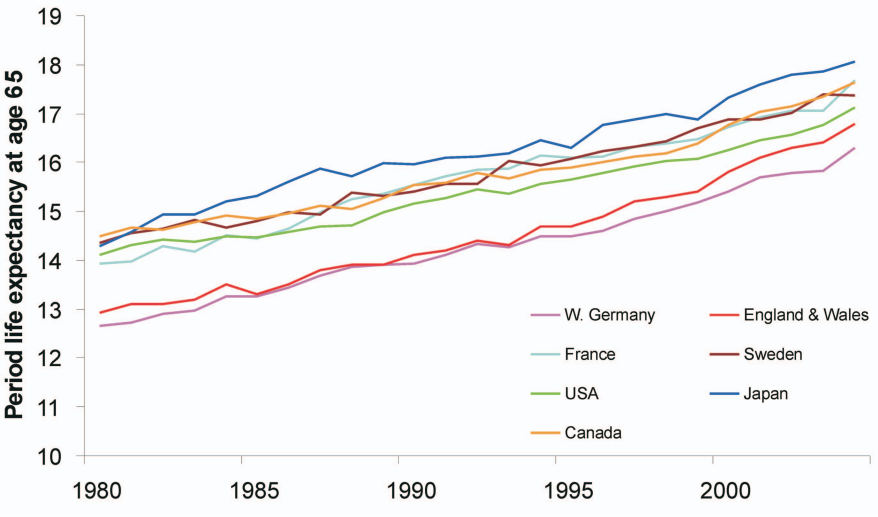
Mortality is again a key focus area for the Profession, and one where we can, and indeed must, add significant value. As a research group, we did not, and still do not, see our paper as anything like the final word. Part of the intention behind the paper was to stimulate debate, and, as a consequence, further research. As a group, we shall be delighted to develop suggestions and comments made.

Mr G. L. Jones, **F.I.A.**(opening the discussion)**:** This paper is an interesting and coherent addition to the debate on mortality improvements, which is now rightfully, not only a central topic of the Actuarial Profession, but far beyond.

Figure D.2 shows the results from the seven countries which the authors studied, of male life expectancy at age 65 over the last quarter of a century. The graph shows consistent increases of around two months a year over that period. Prior to the 1970s, we had seen very little change in post-retirement life expectancy over a period of, perhaps, 100 years. This has led to a wide range of projection bases in use, some of which, including those prescribed by regulation, may not be appropriate for purpose.

In the U.K., mortality improvements have been particularly identified with a cohort effect, especially due to the work of Mr Willets. The paper addresses the explanatory power and persistence of such a model, but it does not resolve fully how we might expect a cohort effect to develop.

At the same time as we have looked at that, the uncertainty around the mortality projections has become increasingly emphasised, for example with the publication of Working Paper 27 from the CMI, which has provided the Profession with a library of 42 projections. In the words of



Source: www.mortality.org

Figure D.2. Male life expectancy at age 65

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that Working Paper: "It is the responsibility of the actuary or other person using a mortality projection to ensure that it is appropriate for the particular purpose to which it is put." This paper exhibits a variety of techniques which may assist our judgement, but which do not provide an explicit recommendation.

The authors start from a sweep of the evolution of social, economic and political developments over the course of the 20th century, and then go on to provide detailed statistical approaches to modelling mortality and also a cause-based account of mortality improvements. We still lack a clean tie up between those cause-based accounts of mortality improvements, or microscopic modelling approaches, and transparent projections of future improvements. That is well known through the difficulty of developing credible cause of death models of aggregate mortality improvements.

From the other side, the versatility of the *P*-spline technique is highlighted in fitting historical data, but that does not necessarily lend itself, unmodified, as a credible projection technique at all ages and at all durations. However, the comparison of that technique, the *P*-spline projection, and the medium cohort, in Figure 10, should concern anyone who is carrying annuity type liabilities on an unadjusted medium cohort basis.

We take very well the caution against the naïve linkage of statistical projections with movements in causes of death. The description advanced in the paper of an evolution of causes of death by delaying onset, reduction in incidence and genuine elimination does seem to provide a helpful framework within which to understand the evolution of mortality.

One feature of the paper is the impact of reducing circulatory disease on post-retirement life expectancy across all of the countries studied. Heart disease has been the main driver in the U.K., but for Japan it has been stroke, which has moved substantially, and the authors draw out the medical insights that the initial advances were driven by lifestyle changes, which are now being succeeded by material improvements driven by medical intervention. These, as Mr Willets has noted, show accelerating mortality improvements in cardiovascular causes of death of 7% to 8% p.a. in both males and females at post-retirement ages. It is now plausible, at least to the medical world, that premature death from ischaemic heart disease could be eliminated. Certainly, that could present an impact greater than that allowed for in some current bases, and particularly for deferred benefits to which pension schemes are particularly exposed.

However, there is much more to do, as the authors acknowledge. The conclusion which I might draw indirectly from the paper is that an optimal fit to England and Wales mortality improvements, on a historical basis, might be best fitted by a cohort-based projection and a longer-term floor or underpin. Another example is the ONS/GAD projections, which now look very much like that.

The paper provides an evidence-based approach to mortality improvement assumptions. That is something which I commend to the Board of Actuarial Standards, in the report which we await early in 2008. However, beyond the narrow focus of our profession, there has been a surge of interest in longevity risk transfer from new entrants to that market. To develop and to continue both the commercial opportunities and the social benefit of mitigating individual longevity risk requires some level of comfort in quantifying the liabilities for the people providing the capital for that risk. Transparency in the process of pricing this risk rationally, therefore, is likely to be, not only desirable, but necessary, for the long-term development of a sustainable and liquid market, and if we have that, we would expect a secondary market to evolve.

Mr J. L. C. Lu, **F.I.A.:** My remarks cover:

— an introduction on international causes of deaths;
— two key international observations;
— projections of causes of deaths;
— causes of improvements; and
— a conclusion.

In this paper we have investigated trends of causes of death in the U.K., the U.S.A., Japan, France, Canada, Sweden and Germany. We categorised the various causes of death into:

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— diseases of the circulatory system;
— diseases of the respiratory system;
— cancers; and
— other.

The advantages of this grouping method are: that it reflects the underlying functions of the body (e.g. the circulatory system brings nutrients and waste around the body); it reflects characteristics of the cause of death (e.g. cancers are the results of the uncontrolled growth of tissues); and it reduces the probability of errors of diagnostics, in that it is less likely to confuse between cancers and heart attacks, and that a more detailed grouping would introduce errors, such as confusion between diseases of the coronary artery and a pulmonary embolism.

There are two key observations:

(1) There has been a dramatic decline in deaths relating to circulatory diseases from 1980 to 2000 in:
   — the U.K., the U.S.A., Japan, France, Canada, Sweden and Germany; and
   — a large part of the mortality improvement (75%) of U.K. males (ages 65 to 74) between 1990 and 2000 is attributable to the decline in deaths relating to circulatory diseases; and

(2) There has been a relatively modest decline in deaths relating to cancers, respiratory diseases and 'other' diseases (with increases in some causes).

These observations transcend gender, age and nations.

Given these relatively consistent trends, it would be tempting to project them into the future. The projection of the cause of death could contribute to the methods currently available to us in understanding future mortality. The projection of individual causes of death uses more information than projecting total deaths. However, we need to incorporate key observations, such as cohort effects, which are notable in a population.

The following example shows that the projection of the cause of death could serve as a tool to understand and to communicate other projection methods, such as medium-cohort (MC) or *P*-spline. It could also complement currently available methods. The example is for illustrative purposes only. It is not a recommendation.

In this example we need to make two forecasts. The first is a ten-year forecast, as shown in Table D.1. The second is the maximum reduction in death rates achievable at 'infinity', say 200 years from now, as shown in Table D.2. This assumption will stop us from predicting that people will live for ever. There is a limit to the number of lives which we can save or postpone. This is not a new concept. The CMIR17 projection, on which the cohort projections are built, has this assumption. We need to justify various assumptions and data. We would also need to account for cohort effects in the U.K.

After setting these assumptions, we could generate future improvements in mortality with some formulae. The results of these projections could be compared with currently available

Table D.1. Ten-year forecast of the reduction of death rates from the level of 2005 (2005 to 2015) (for illustrative purposes only)

	Ages 50 to 74	Ages 75+	Note
Circulatory	40%	20%	Government target and historical
Cancers	20%	10%	Government target and historical
Respiratory	5%	5%	Assume
Other	5%	5%	Assume

Apply these to ONS 2005 cause of death data

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Table D.2. Maximum limit of the reduction of death rates; 200 years' forecast; 2005 to 2205 (for illustrative purposes only)

	Ages 50 to 74	Ages 75+	
Circulatory	90%	70%	Advancement in
Cancers	90%	70%	science, technology,
Respiratory	70%	50%	health care, etc.
Other	70%	50%	

Table D.3. Life expectancies of males in 2005 (base table PCMA00 unadjusted in 2005) (for illustrative purposes only)

	Age 50	Age 60
MC	33.9	24.5
CoD no cohort adjustment	34.4	24.8
MC_1% minimum	34.6	25.0
MC_1.5% minimum	35.6	25.6
CoD with cohort adjustment*	35.7	25.9
PSAC_Male_Ass_2005_50	38.7	27.0
PSAC_Male_ONS_2005_50	48.1	32.8

* equals blend of *P*-spline CMI data (first 20 years) and CoD (after 20 years)

methods, and Table D.3 shows life expectancies using various methods. The life expectancies for males aged 50 and 60, generated from the scenarios given, are equivalent to those from the MC with a floor of 1%. After adjusting for cohort effects in the U.K., the life expectancies are close to those generated by the MC with a floor of 1.5%.

In this example, the cause of death (CoD) with cohort adjustment is a blend of two methods. It uses the results of *P*-spline age-cohort-50% on CMI male assured lives data for the first 20 years. Then the reduction factors blend into the cause of death projection. This combined method takes advantage of the strength of the *P*-spline in detecting and projecting cohort trends, and uses the cause of death scenarios to set a limit on mortality improvement.

There are challenges for the projection of the causes of death, which are:

— *data reliability*, where some research suggests a 9% discrepancy between clinical diagnosis and autopsy, but the actual discrepancy should be lower, because many autopsy cases would have been more uncertain cases, and a broader grouping would reduce errors (e.g. four groups not ten);
— *the relevance of the data to the insured population*, in that there are differences between social classes; the interaction of risks, such as whether cancer deaths increase as heart attacks reduce; and
— *the underlying causes of mortality improvement*.

We have established that, in the past, mortality improvements have been driven by falls in deaths relating to circulatory diseases. Research has shown that two thirds of the fall in death rates relating to heart attack are due to reductions in the occurrence of heart attacks, and the remaining third is due to reductions in fatality rates after getting heart attacks. Publications in medical journals suggest that non-medical intervention, such as smoking cessation and improvement in risk factors, is responsible for 60% of the reduction in deaths relating to heart attacks. Medical intervention, such as drugs and surgery, is responsible for the remaining 40% reduction in deaths relating to heart attacks.

It appears that, historically, improvement in mortality has been a result of reductions in deaths relating to circulatory diseases, which, in turn, has been driven, primarily, by healthier

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life-styles. However, the improvement in life-style does not seem to have had as large an impact on other causes of death.

A sustained improvement in future mortality would have to come from a reduction in deaths relating to cancers and other diseases, after the diminishing proportion of deaths relating to circulatory diseases. I suspect that medical intervention would play an increasing role relative to the life style in future mortality improvement.

Some key potential drivers for future longevity are:

— *science:*
  — the understanding of diseases and longevity;
  — there are many journals dedicated to the findings from individual diseases; and
  — there are areas of science dedicated to keep life forms youthful, which could result in drugs which keep us youthful, and avoid age-related diseases, such as cancer — it is not good enough to live long, but weak; we want to live long and strong;

— *IT/engineering:*
  — Moore's laws; the speed of computers doubles, but the costs halve yearly;
  — these support the development of bio-medicine; and
  — computers and IT are needed in the sequencing of DNA, the mapping of DNA to proteins, and the understanding of the function and the structure of proteins;

— *biotech:*
  — unlocks the potential of knowledge on DNA and proteomics to detect, cure and care for diseases;
  — potentially leads to drugs which are more effective and specific, because cancer drugs today are not very specific, in that they kill the cancerous cells and the normal cells; and
  — enhances health;

— *nanotech:*
  — manipulates matters at an atomic and at a molecular scale, producing drugs; and
  — there has been a rapid increase in investment (from U.S.$10b to U.S.$30b between 2005 and 2008); and

— *the health care system*, and the delivery of health technology to people.

So, from 1980 to 2000 we have been relatively successful in reducing death rates of circulatory diseases compared with other diseases, because of medical and non-medical reasons. This improvement is likely to continue. The challenge for the future is: "How do we predict future mortality, given the observed trends and information?"

Mr P. Cocevar, F.I.A.: As an actuary of Italian nationality, I decided to investigate the mortality trends in my own country. Italy, being one of the G8 members and with an over age 40 population of about 29 million people, shares several similarities in history and in social reforms with some of the countries examined in the paper. Therefore, I fitted the data for Italy from the Human Mortality Database website, using the program developed by the CMI and following the methodology described in the paper. At this point, I commend the authors for making available data and source codes, which enables other actuaries to replicate the results from the paper, and which help to widen the comparison with other countries.

Figure D.3 shows the maps of the mortality improvements for Italy and for England and Wales which I have calculated. As for the England and Wales data, an age-period model is a better fit for the data for Italy than an age-cohort model.

The similarity between the graphs of the mortality improvements for the England and Wales male population and the Italian male population is striking. One can recognise most of the improvement patterns of the England and Wales male population in the Italian male population.

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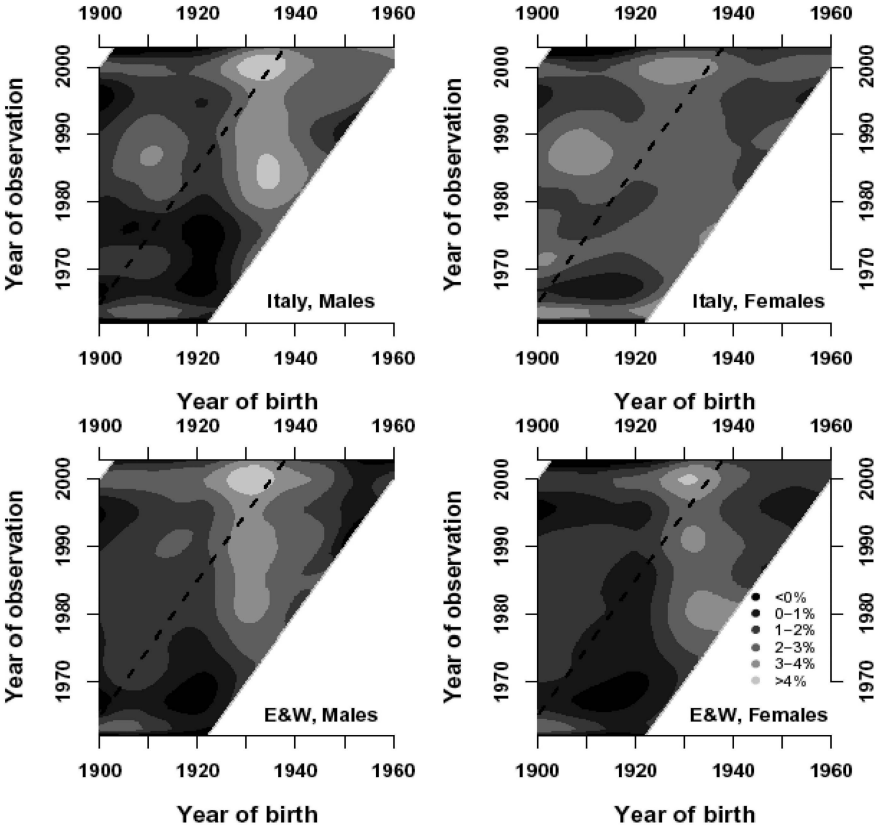


Figure D.3. Improvements in the smoothed force of mortality; *P*-spline regression with age-period penalties for Italy (top panels) and England and Wales (bottom panels); males in left panels, females in right panels; the dashed line shows age 65 for each cohort

The most prominent feature is certainly the 1925 to 1940 cohort effect, which is clearly visible as a vertical pattern for the males in both graphs.

The cohort effect in the model fit actually appears more pronounced for the Italian male population. Much has been written about the U.K. cohort effect and its causes. Although the data on mortality by cause, which I have examined so far, is not very detailed, it would appear that the male cohort effect in the Italian population, unsurprisingly, may be due to the same reasons identified for the U.K. population; a rapid reduction in deaths due to lung cancer and heart disease.

It looks as if, as for the U.K., a reduction in the prevalence of smoking has played an important role. As for most of the other countries in the international comparison, Italy has a very significant post-war proportion of smokers, which has fallen, for males, from 55% in 1980

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to under 29% in 2005. Interestingly, Italy also introduced a smoking ban in 2005, which has led to a fall of 8% in the sale of cigarettes, and to which some are already attributing a beneficial effect on the incidence of heart attacks.

Actuaries in the U.K., when advising on future improvements in mortality, may need to consider if similar consequences can be expected following the recent smoking ban in England and Wales. Unlike males, smoking prevalence in Italian females has not changed significantly in the last 25 years, and for them lung cancer death rates have been increasing. This may explain the more moderate mortality improvements observed for females.

To my knowledge, life companies in Italy still tend to rely on government agencies to produce mortality projections, and have not yet applied methodologies such as the ones studied by the CMI and the ones advocated in the paper. I believe that this is due partly to a limited interest in longevity studies, as the local annuity market is still relatively small. However, as the annuity market is set to grow (as a consequence of pension reforms approved in the mid 1990s), Italian life companies will find the use of these techniques beneficial.

Mr C. D. Daykin, C.B., F.I.A., Hon.F.F.A.: Cohort patterns are a well-established feature of the U.K. data, which were first reported by Mr John Field of the Government Actuary's Department (GAD) at the beginning of the 1990s, and have been reflected for many years in the GAD projections at a national level.

A number of countries have denied their existence, and I have had discussions with Government Actuaries in other jurisdictions in recent months, which have indicated that they do not see the cohort effect so clearly in their data. Therefore, it is useful to have the comparison in this paper, which identifies cohort effects in most of the relevant jurisdictions.

It seems that the cohort effects are weaker in countries where there is a considerable heterogeneity in the population, such as the U.S.A. and Canada, which have experienced very significant inward migrations. The changing nature of the population probably has overshadowed the underlying cohort effects which may be there.

For the U.K., the paper points to the fact that the cohort effect is only part of the story. It is an important part, but it is certainly not the whole story. It is essential to take into account both cohort effects and secular trends, in order to reflect properly what is happening to mortality. Tables 18 and 19 indicate the improved understanding of the trends, which result from looking at a combination of cohort and secular effects.

We see similar cohort effects in the CMI and in national data. If anything, the CMI data are showing stronger improvements; this is probably largely as a result of selection effects and changes in the underlying population, which is covered by the pensioner mortality investigations of the CMI. This is also referred to in the paper.

This suggests that, in making projections of the future, we ought to start by looking at the overall population data, and to see what underlying improvements are there. A second stage may be to superimpose some additional improvements, because of the changing population which may be exposed to risk within the insurance industry or within the pensions world, or in any particular application. We get a better idea of where we stand if we look first at the national population data, which are larger and more stable, and also do not include those changes of the population arising from selection effects.

The *P*-spline method is very attractive. The paper makes a lot of that, and explains very well how it works and why it works. However, it is a mechanical projection method. As actuaries, we need, sometimes, to be suspicious of applying projection methods mechanically. It is very good to have them as benchmarks, which enables us, then, to think about other factors. I recall our experience, as a profession, of mechanical projection methods, such as the extrapolation of returns on unit-linked policies based on the returns in a previous period. There was another classic example in the population world in the 1960s, where the GAD came under pressure for a number of years to extrapolate in the population projections the very strong, clear and direct upwards past trend in fertility. In the year when we introduced that into the projections fertility rates turned down and declined for the next 20 years, in line, more or less, with what we had projected previously.

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There have been some references to the kick down which is implied in the medium-cohort projection as compared to what has been happening up to now. The medium-cohort projection is a very crude mechanism for adjusting the existing data. The fact that it kicks down does not necessarily mean that it is wrong. There is no particular reason to assume that the cohort effect will go on for ever. A number of people have argued that, if you see the expectation of life going up in a nice linear way, you should obviously assume that it can continue going up in that way. If you look at the underlying changes in mortality rates, which are needed to generate expectations of life which continue to rise in a linear fashion, you find that they are difficult to believe. Of course, projecting mortality is not something which any of us is going to get right, and anything could happen.

The Lee-Carter method has, in my opinion, little justification as it stands. For England and Wales data, it has performed extremely badly. Also, it really fails to represent what is going on, because it is just applying an autoregressive process to an underlying factor. It does not represent the variability in the underlying data in an adequate way. The work which has been done, more recently, on developing a Lee-Carter age-period cohort model, suggests that there may be ways of improving Lee-Carter so that it will perform better.

I welcome the library of projections which has been produced. I notice that, whenever it is mentioned, everybody emphasises that there are no recommended projections; it is just 40 different projections, which are all equally valid, and you choose which one you want. That is fair enough. Nobody wants to be committed to say which one is going to be right, when clearly they are all going to be wrong. Nevertheless, the availability of the library is very important, in terms of helping people to be able to use some of the more complex methodologies without, necessarily, having to become experts in all the different aspects.

However, what does concern me is that they are based on a 1992 start date, and what happens between 1992 and 2004 is entirely artificial in some cases, when we actually know what has happened between 1992 and 2004, and, indeed, a little beyond. If you are doing work on any particular portfolio of annuitants or pensioners, your starting point is what the current experience is of that group. You are not really interested in artificial changes which someone deems to have taken place over the previous 15 years, but in what the data actually show. So, you need to start by thinking about what the base line should be in your starting year, and then there is a separate decision as to what you do about mortality improvement after that. The library of projections seems to confuse those two issues and to give some differences between the long-term projections, which are caused, not by the projection after 2004, but by the period up to 2004, which is, in fact, already known.

There are also some confusions in the terminology. You cannot have LC meaning both Lee-Carter and long cohort, and you cannot have ONS 2004 meaning both ONS data between 1992 and 2004 and GAD projections for 2004 onwards. We need to have a clearer understanding of what means what and whether they are past data or that they incorporate future projections.

What is clear from all of this is that there is a very wide range of possible outcomes. There is no doubt about that. No actuary or demographer should be saying that we can predict what is going to happen. Mr Lu indicated a number of significant things which could happen, in the future, which would result in mortality improvement. In fact, the things which have happened in the past are not going to happen again, so this is a case where we definitely cannot extrapolate what has happened from the past to the future. You cannot have the eradication of infectious diseases again. You cannot have the reduction in the level of smoking which we have had again.

The things which will happen in the future will be quantitatively and qualitatively different from what has happened in the past. That is not to say that there will not be continued improvements, but they will be different ones, and we need to take these into account as we think about them, as well as the fact that there are influences which could go the other way. There are some demographers who are saying, very strongly, that there are adverse possibilities from obesity, from infectious diseases, which we cannot bring under control, and this sort of thing. So, we should not rule out the possibility that there may be some factors going in the opposite direction.

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I can see that debates on this will continue for a long time, and I welcome the contribution of the paper to the ongoing debate.

Mr D. I. W. Reynolds, F.I.A.: While I admire the work which has been done in this paper, I should like to raise a different point of view, and see whether we can actually expand some of our thinking.

It may be just as with fertility; when it was assumed to be improving, it worsened. So, I should be interested to know how people will analyse what has happened to life expectancy in Russia, and why the fall happened, and why a similar fall has happened in various parts of Africa.

Probably what we are seeing are the consequences of war, some breakdown of social cohesion and the destruction of economic wealth. Some of the improvements in mortality which we see, some of the reductions in cancer and in circulatory disease, can only happen if we have the wealth to spend on it.

A couple of years ago, I saw an article by an epidemiologist which has stayed with me. What she said was that you have to consider two diseases: SARS, which created panic for a while, because it was so easily transmitted; and Ebola fever, which creates a different panic, because it is completely untreatable. However, it is very hard to get. What the epidemiologist said was that we must expect, at some time, to get a transmittable disease, which is as deadly as Ebola fever and is as transmittable as SARS. So, there are things out there which can change all this assumption of a favourable trend in mortality.

I now turn to consider global warming. There are various proposals as to how we will reduce global warming. However, there is only one thing which will actually bring it about, and that is to reduce the population of humans on this planet. I do not know how you do that. I know that it is politically very difficult, despite what the Chinese have done on one-child families, which actually may be solving issues on two levels, because they are getting a much greater proportion of men, and therefore that will reduce fertility later. It is very difficult to say how a smaller world population will come about.

Something which could happen is that, as other diseases are cured or ameliorated in the Western economies, people start getting to the stage where life is intolerable, and, like the Dutch, euthanasia starts cutting off the population at the high ages.

So, we need to be thinking about how we reduce the world population. The phrase which I have is: "We had better plan it, because otherwise the planet will plan it'', whether it is through war, through lack of water or through a decline in civilisation.

At some stage within the period of these projections, the change in fertility referred to by Mr Daykin will probably happen to mortality. One way or another, these numbers will then be wrong on the upside.

Mr J. Goford, F.I.A.: We need to distinguish clearly between pricing and reserving. When it comes to pricing, it is down to shareholders to assess the price. However, for reserving we cannot afford to under provide in setting annuity reserves.

In the paper, I see worries about the considerable scope for increased longevity, despite recent significant improvements. Some projected mortality curves look too flat, and there are also some serious warnings that there is still the scope for further improvement in longevity. Then I look at the last paragraph, where I find a typical actuarial statement, which says: "Finally, where an actuary chooses to apply a cohort-based projection of future mortality rates, evidence from both the general population and an insured data set in England and Wales suggests that a floor value of improvements may be required.''

We need to strengthen this to say that a floor is essential. We have heard 1%, but, in my opinion, 2% is much nearer the mark. If the Profession does not give informed statements about where mortality improvement is going, then the Board for Actuarial Standards and the FSA will do it for us.

Mr D. J. Grenham, F.I.A.: Mr Reynolds' comments about the population should incorporate

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consumption. Consumption affects, not only the global warming impact, but also life expectancy.

The Senior Vice-President (Mr N. B. Masters, F.I.A.): This paper is an important work. It is the cross-territory aspects which I found particularly useful. My own background is that I now have to look across a number of territories, and Mr Daykin made the point that there is a reluctance on the part of some territories to grasp the findings, which came out so clearly from the U.K. It is difficult to go into another actuary's territory: Germany, Switzerland, Italy, or whatever; and to say: "We know better than you do." We clearly do not. I was very grateful for the contributions on Germany and Italy. Certainly, I will take back to my own organisation the necessity to look again at the data in these territories, using these techniques and seeing whether there are cohort effects and what that really means for us.

It is important to draw conclusions, where conclusions should be drawn. Indeed, Mr Goford was very forthright on that, which I echo. It is important that we give the messages clearly. It is also important to recognise the shortcomings of the statistics. That is something which really resonated with me with this paper.

I recently had a discussion about how long this improvement can keep going. How old are we all going to be? What is the extent of life? I had an opportunity to ask that of an eminent professor from the Max Planck Institute. He was very clear that the furthest extent of life is not moving out anything like as fast as the averages which we are seeing. So, maybe we are living longer, but, perhaps, as we all get into our nineties, we are not necessarily making it through to our 100th birthdays and beyond quite so readily. A Swiss actuary called this 'orthogonalisation'.

The other point is the issue about the pace of funding, and whether or not there is a timing issue to some of these things. Clearly, there are issues over the next five years. For example, the authors' shape of the projections on the *P*-splines compared to the medium cohort, in particular, is telling, and to see the medium cohort dropping off sharply, despite the wise words of Mr Daykin about fertility. I will certainly challenge my own actuaries when they hang on in there with the medium cohort for a few more years.

However, further out, do we really have to commit to any one of those uncertainties now, or is it better to commit and reassess, in, maybe, three or five-year cycles? The covenant of the employer and the ability to flex premiums is as important to the design of our contracts as anything.

To summarise, this is an excellent paper. It is sparking me to sponsor some more research, including the working party, to keep going, because there are some real issues there.

Mr P. J. Sweeting, F.I.A.: One of the comments made by Mr Goford was that he might want to have a floor on a projection basis used. That is right if you are doing reserving for annuities. However, is the converse that you want to have a cap on any improvement basis if you are doing reserving for life assurance business? You are not too worried about life assurance business if people start living a lot longer. If they start dying more quickly, then it becomes an issue. Suggestions of caps and floors indicate that you are trying to build some level of prudence into the mortality basis which you are using. That is not necessarily the best way to go about incorporating mortality into the mathematics which we use. It is better to use a best estimate, and then look at how wrong you could be.

The most interesting graph in this paper was Figure 9, which shows the projections using data up to 1980 and to 2000, and then looks at the fifth and 95th percentiles. The force of mortality on the 95th percentile is about three times the force of mortality on the fifth percentile. That is a very large difference indeed. As an earlier speaker said, one thing which you know about the projections is that they are all going to be wrong. You need to allow for the fact that they could be very wrong indeed. One should look at that level of variability rather than try to build a level of safety into a central projection.

Ms D. R. Cooper, F.I.A. (closing the discussion)**:** The discussion has confirmed my original view that this paper is a useful and an interesting addition to the knowledge which the Profession

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is accumulating steadily on mortality trends at the beginning of the 21st century. I particularly liked the way in which it draws on several disciplines to analyse the mortality experienced in different countries, including how those differences might have arisen. Something on which we have not touched is that the paper mentions Japan as an interesting object lesson. It has bucked several trends observed in other countries, and the increases in longevity among Japanese women, in particular, should make any of the naysayers left among us, who think that the increases which the U.K. has experienced the over the past 20 years cannot be continued, to think again.

Also interesting are the beneficial effects of a change in diet as the Japanese economy became more affluent. Anecdotally, I understand that there is concern that, ultimately, increased affluence is beginning to have detrimental health effects in Japan, with increased levels of obesity among younger generations. The influence of smoking, for example, among Japanese males was mentioned. I was also intrigued by the example of Okinawa, where the poorest part of the country has the longest life expectancy, in marked contrast to the experience in the U.K.

The cultural links in China begged the question as to how that country will deal with its own demographic changes, as it balances economic growth with the consequences of its one-child policy at the end of the last century.

Being, at best, a part-time statistician in my current role, I found the modelling sections also very useful. They helped to consolidate my understanding of the *P*-spline model, and to appreciate better the techniques, strengths and weaknesses. I have had to struggle to reconcile some of the *P*-spline models' outputs first with my own vision of reality, but also with the range of possibilities which the model itself can envisage. I found the descriptions here, particularly the critical analysis of the models' outputs, quite reassuring.

This aspect of the paper, together with its synthesis of modelling techniques and qualitative analysis, brings together what, for me, is one of the attractions of the Actuarial Profession; its ability to combine quantitative data analysis with more general sources of information, to create the tools which we need to give a credible analysis of mortality.

For Mr Reynolds, the Holy Grail, I guess, for longevity forecasting would be, presumably, some sort of targeted hell. I was hoping that, perhaps, analysis by cause of death might solve some of the dilemmas which I was having, but I understand that there are possibly insuperable structural difficulties to create such a model.

However, one of the difficulties with the *P*-spline model, and, to a lesser extent, with some of the other statistical models, is understanding how they relate to reality. Several aspects of the paper helped me to reconcile the absence of a cause of death model, in particular ¶14.6 and Table 16, which provide a handy way of putting sometimes apparently outrageous results which the *P*-spline model produces into a context which a lay person can grasp more easily. I also found the additional analysis given by Mr Lu, which shows how the *P*-spline model might behave if some sort of limiting factor were imposed, very helpful, although, of course, that introduces another subjective influence into the model.

Mr Jones mentioned that the paper lacked a concluding recommendation. Although some people have found this apparently unhelpful, and taking Mr Goford's contribution on board, I actually welcome this. As well as similarities, there are strong differences between the different countries' experiences, and this will also be the case between insurance books of business, although that is not my field, but certainly among different pension schemes.

I support Mr Sweeting's comment that the work which I should like to see developed is how the techniques which it uses can be applied to small to medium-sized schemes, and also how the uncertainty in future projections can best be illustrated and be explained to clients.

The paper illustrates that modelling, particularly when used to project results over a long period of time, is, at best, an abstraction if it is isolated from any context. It is equally important to understand your data and the factors which could have led them to being realised in the way which they have been realised, as well as the way in which it is reasonable to expect them to be realised in the future.

Choosing the country, so that the data analysed were likely to present materially different outcomes, enabled the authors to illustrate how differing cultural, economic and population

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influences can affect changes in longevity, while simultaneously testing the efficacy of various modelling techniques.

Mr J. R. Ellam, F.F.A. (replying)**:** A number of points on which I should like to comment came out of the discussion.

The opener highlighted our framework for looking at changes in mortality rates, the three factors of delay, reduction in incidence and genuine elimination. This is a possible area for more research from our group. He also referred to Figure 10, which compares cohort improvements with *P*-spline model improvements, and this had already been highlighted at the Faculty meeting. In the light of the differences, can we still believe in the quick reduction in improvement rates implied by the cohort model?

Mr Goford said that we should have been more definite about the need for a floor. As a group, we have no doubt that there should be a floor, and we agree with his statement. My reasoning would be that, as explained in CMIB (2002), "An interim basis for adjusting the '92' Series mortality improvements for cohort effects" was that the cohort model was superimposed on the existing model, which gave next to no improvement at older ages. Now we are saying that that is not likely to be the case, and so there should be a floor. I do not know how big the floor should be either. The need for a floor is a consequence of using that particular model. If, instead, a *P*-spline type model is used, which is actually projecting something in a statistical or scientific way, then it, in itself, does away with the need for the floor.

It is interesting to hear that our work on international comparisons has already been useful for discussions with actuaries in other countries, and may well be again in the future. Mr Cocevar's contribution, based on the Italian experience, was useful, coming from someone with local knowledge. He reinforced a possible common theme in improvements, namely smoking. He said that a smoking ban has been introduced in Italy. In England the smoking ban in public places has come in very recently, but in Scotland it has been in existence for at least a year. There is already evidence in Scotland of a noticeable reduction in heart disease cases going to hospital, just one year on. Mr Reynolds referred to looking at other countries. What would we see in Russia? What would we see in Africa? However, one of the problems for performing any analysis could be the quality and the reliability of the data.

The Senior Vice-President referred to the need to make binding decisions now. He said that it would be good to be able to look out for five years, and then reassess the position. It is good for pension schemes to do that. It is good for companies to do that. It is good for the Government to do that. However, an insurance company which has underwritten annuities cannot do that. They have to price, and then to reserve, with what they know now, as there is no source of extra funds. I was pleased to hear that he wants to do more research on the subject, and wants to sponsor the Faculty Research Group to do this.

Mr Sweeting referred to Figure 9 and the wide divergence between the fifth and the 95th percentiles. I agree with his point, and wonder how you demonstrate to a sponsor that that is a reasonable range of outcomes.

One thing which Mr Lu showed us, which was perhaps prompted by the discussion on this paper held at the Faculty, was his adjusted improvement basis models, which produced lower expectations of life than either of the *P*-spline methods produced. His projection used some information and some knowledge to make adjustments based on what we know, rather than just using a straight mechanistic approach. Is this the way forward?

We feel that the *P*-splines are a bit strong. When we look at the *P*-spline projections based on ONS data, they are very strong. There is another factor which needs to be explained. We say that the population is the average socioeconomic class, and that the insured population is biased towards higher socioeconomic groups. Generally speaking, we think that higher socioeconomic groups of people will have greater improvements in mortality than the population as a whole. Yet we see that the *P*-spline model, based on ONS data, is producing greater improvements than the one based on assured lives data.

The Senior Vice-President (Mr N. B. Masters, F.I.A.): This is my opportunity to express our

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thanks to all the speakers and to the authors. The authors have done a terrific job in their paper. These are useful and helpful techniques which we can apply across different territories. Thank you very much for all of that.

Russia has been mentioned. Perhaps I could add to that places like China, India and Brazil, because, frankly, these are probably where the majority of the population is going to be, going forward. By the time we get to 2050, we ought to know what the Chinese demography is going to look like.

I should like to thank those who have contributed and the opener and closer.

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