ABSTRACT OF THE DISCUSSION

HELD BY THE FACULTY OF ACTUARIES

The President (Mr J. S. R. Ritchie, O.B.E., F.F.A.): The form of this meeting is an interactive discussion. The audience are invited to ask questions of the authors as we go along, as well as making contributions.

Concerning the authors, Mr Richards graduated from Heriot-Watt University with a degree in actuarial mathematics and statistics. Since 1990 he has worked in life assurance both in the United Kingdom and in Germany. He runs his own consultancy, specialising in the analysis of mortality and other demographics. Mr Ellam graduated from Manchester University in 1970 with a degree in mathematics. He was then, and continues to be, employed by Standard Life in a variety of roles, the latest being as mortality research actuary, with particular emphasis on annuitant mortality. Mr Makin graduated in mathematics from the University of Edinburgh in 1996. He worked for Scottish Amicable until 2001, and then for Scottish Widows until 2005, before moving to the Prudential in the middle of that year. He looks after the annuity pricing function and the mortality risk and research unit within the Prudential's U.K. actuarial department.

Mr Miller joined Scottish Provident in 1983 and qualified in 1988. He worked mainly in valuation and financial reporting until he joined Scottish Widows in 1998. He has since worked in various actuarial roles at Scottish Widows, latterly focusing on their individual capital assessment (ICA). He joined the *bancassurance* business of the Royal Bank of Scotland Group in 2006, where he has been involved mainly in product development. He has also had various involvements with the Profession, over the years, on research groups, committees, working parties and as an examiner. Mr Lu has postgraduate degrees in medical microbiology from the University of Leicester and in actuarial science from Heriot-Watt University. He has worked for Watson Wyatt and for Legal & General, and is currently working for Synesis Life, specialising in the bulk buyout of annuities. Ms Hubbard has recently qualified with the Institute of Actuaries, and is currently working as a group insurance actuary for Axa Australia, based in Melbourne. She was previously working in France for the Axa Group Risk Management Department, specifically dealing with life risks, including longevity and mortality.

Mr K. A. Miller, F.F.A. (Panel member; introducing the paper)**:** The genesis of the paper being presented by the Faculty's Mortality Research Group could be viewed as being contained in various papers, presented since 2004, with which three of the authors were involved (Willets *et al.*, 2004; CMIB, 2004, 2005c, 2005a, 2006a; and Richards *et al*., 2006).

Willets *et al*. (2004) considered the outlook for longevity, with particular focus on:

— 20th century trends in the U.K., including the cohort effect;
— international comparisons;
— medical advances and changes in causes of death; and
— the possible impact of continuations of trends.

The CMI papers explored the use of stochastic models for mortality projections, and introduced the profession to penalised spline (or *P*-spline) methods and models, which included making projection software available.

Richards *et al.* (2006) developed the use of *P*-splines, and forms the basis of Section 10 of this paper, explaining the use of *P*-spline regression to fit models to mortality data.

Turning to this paper, the main aims, outlined in Section 1, are to:

— compare the trends in mortality rates for a number of countries, both at an aggregate level and by cause of death;
— understand the key drivers of historic trends in the different countries;

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— carry out projections for the various countries using the *P*-spline models and the CMI software;
— look for evidence of cohort effects in countries other than the U.K.;
— assess the projections in terms of possible changes in mortality rates by cause of death;
— carry out a high level critique of the *P*-spline projection methodology; and
— look at models which actuaries can apply to their portfolio experience data to separate time trends from cohort-based patterns.

Section 2 sets out the format and the source of data used for our modelling, which was the Human Mortality Database (at www.mortality.org); a rich source of mortality data for many national populations, maintained jointly by the University of California (at Berkeley) and by the Max Planck Institute for Demographic Research in Rostock.

Figure D.1 is referred to in Table 1, and it shows the availability of population data for various countries between 1755 and 2005.The data go back to 1755 for Sweden and back into the 1800s for many other countries. It shows that the most recent data available for each country are not the same, and, for this reason, we have used the most recent 40 years' data for our modelling, and have also truncated the data to ages between 40 and 100 — to focus on adult mortality and to avoid data peculiarities at advanced ages, as the data at these ages are often modelled, rather than observed.

Sections 3 to 9 give some background to the mortality experience over the 20th century in the seven countries chosen. Table 2 shows the life expectancy at age 65 for males and females in each country. It shows some wide disparities in life expectancy 'at retirement'. It is notable that life expectancy for England and Wales is bottom for females and second bottom for males. This implies that there is still plenty of room for increases in U.K. longevity, despite recent strong improvements. It is also notable that the differences in mortality between genders remains pronounced, despite faster improvements for males recently; the differences between the sexes are larger than the differences between the various countries considered.

One particular point of note relating to Japan is the relatively high smoking prevalence for males shown in Table 3. Despite this, expectations of life have risen more quickly than in other countries. It is possible that the impact of this smoking (which is mostly in the post-war generations) is not yet feeding through to expectations of life at age 65. However, the large difference between male and female life expectancies in Table 2 is likely partly to reflect the large differences in smoking prevalence.

Section 10 explains the use of *P*-splines, as already mentioned, whereas Section 11 sets out the results of applying *P*-spline regression to the various national data.

One way to assess the relative strength of cohort effects is to compare the Bayesian Information Criterion (BIC) under age-cohort and age-period models. The BIC is a statistical criterion which balances:
(a) the closeness of fit of the observations to the fitted values; with
(b) the complexity of the fitted model.

A model with a lower BIC value is better fitting, and would indicate the dominance of that model's primary characteristic over that of an alternative model. Note that saying that feature A dominates feature B does not mean that feature B is not present, merely that feature A is stronger in explaining observed patterns than is feature B. Table 5 shows BIC values for age-cohort (AC) and age-period (AP) *P*-spline models. A positive number in the BIC: AC-AP column indicates that period effects dominate cohort effects, whereas a negative number indicates that cohort effects are dominant (marked in bold type).

The results of fitting the models are shown in the paper, in Tables 4 to 7, as mortality improvement heat maps, with year of birth on the x-axis and year of observation on the y-axis, where:
— high improvements in mortality are shown in light grey; and
— lower improvements in mortality are shown in progressively darker greys, and mortality deteriorations are shown in black.

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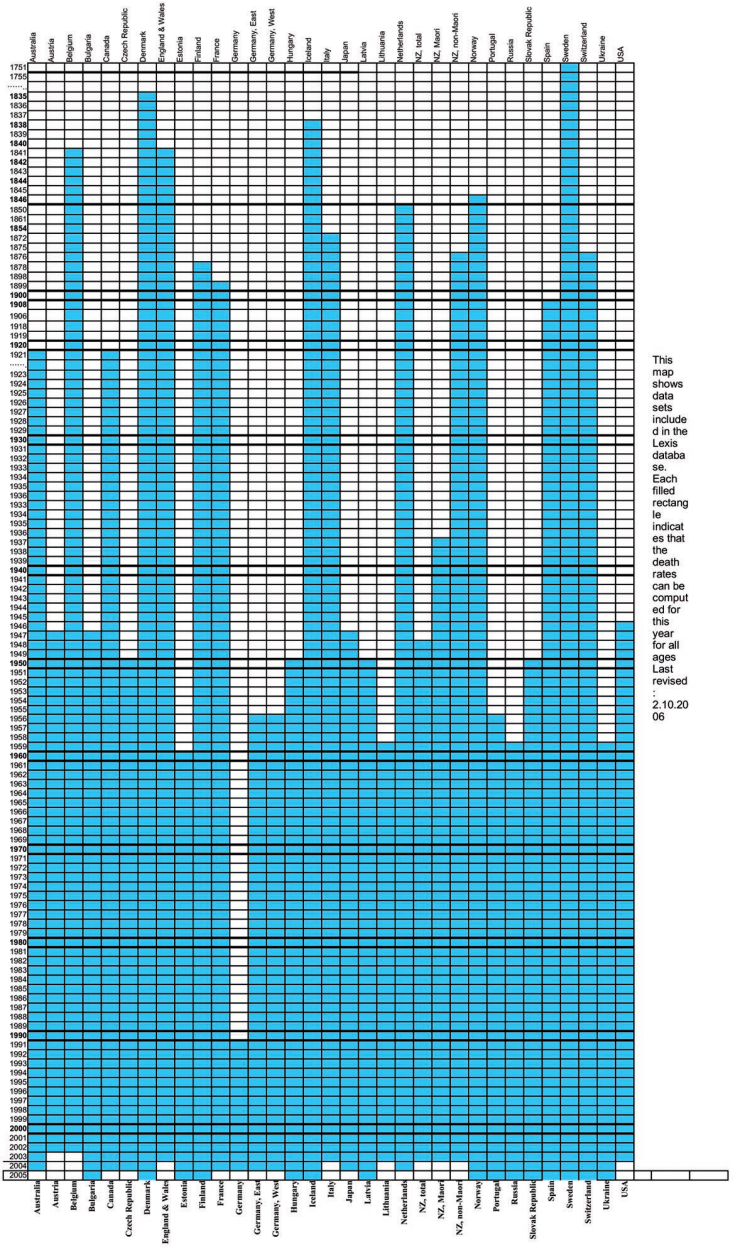

Figure D.1. Map of population data availability by year and by country

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Figure 4 shows cohort effects for females, as well as for males, in England and Wales. It also shows evidence of cohort effects for both sexes in Germany — appearing stronger for females. These effects appear, despite the use of age-period penalties in the model fitting. The dashed line shows age 65 for each cohort.

Figure 5, with the United States of America at the top and Canada on the bottom, is striking for the difference in pattern between two neighbouring countries with similar levels of wealth. Canada seems to have managed faster improvements for most generations at most points in time.

Cohort effects are clearly visible in Figure 6, as vertical patterns for males in both Japan and France, despite the use of age-period penalties in the model fitting. The heat map for Japanese females stands out as the lightest, indicating consistently high rates of improvement. In Figure 7 both model fits have been used for Sweden. Cohort effects are only visible for Swedish females at the top right, 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. For people aged 65 to 74, the two leading causes of death are circulatory diseases and cancers. In 1980, circulatory diseases were the leading cause of death for this age group in all the countries considered. By 2000, reductions in the proportion of deaths due to this cause, together with increases in cancer deaths, led to cancers being the leading cause of death for males in Canada, France and Japan, as shown in Tables 9 and 10.

Table 11 shows that, for people aged above 75, circulatory diseases were the leading cause of death in 1980. Despite similar trends as for those aged 65 to 74, circulatory diseases were still the leading cause of death, by a significant amount, in all countries in 2000 — although, by this time, they generally accounted for less than half of the total deaths.

In the two decades up to 2000, the key trends in causes of death for the countries investigated could be summarised as:

(1) a fall in death rates relating to circulatory diseases, which trend looks set to continue into the future;
(2) a fall or a stabilisation in death rates relating to cancers;
(3) a stabilisation in death rates relating to respiratory diseases;
(4) a stabilisation in death rates relating to 'other causes', except in the U.S.A.; and
(5) a relative independence of trends of deaths caused by the four broad categories.

Section 14 considers communicating mortality trends using a cause of death interpretation. Table 16 shows the number of years required to achieve various scenarios of reductions in mortality equivalent to the reductions in causes of death shown, as indicated by a 50th percentile *P*-spline projection on England and Wales data. For example, for a male aged 70, a reduction equivalent to the complete eradication of circulatory and cancer deaths was projected to occur after 37 years, from a *P*-spline projection.

Although these periods look very short for some of the scenarios, it is misleading to think that a particular *P*-spline projection requires the elimination of a major cause of death to come true, and that it is, therefore, unrealistic or unlikely. One view, which is entirely consistent with falls in the incidence of particular causes of death in certain age bands, is that much of the improvement seen to date might simply be a delay in the onset of these causes of death. At the extreme, if everyone's ultimate cause of death remained the same, but the age of onset was merely delayed by a few months each year, then this would have the same effect as the *P*-spline mortality improvements, while keeping the relative roles of the causes of death entirely unchanged.

We advocate viewing mortality improvements as having three components by cause of death:

(1) a delay in onset;
(2) a reduction in incidence; and
(3) a genuine elimination or near-elimination.

We also suggest that there are four potential 'brakes', acting in the opposite direction:

(1) an increase in incidence of an existing cause of death;

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(2) a resurgence;
(3) an acceleration of onset; and
(4) wholly new causes of death.

Examples of each of these components are given in the paper.

Projections of the various causes of death could complement current methods of projecting aggregate mortality. However, cause-of-death assessments should be interpreted with care, due to the high risk of mis-classification.

In Sections 15 and 16 we carry out a high-level critique of the *P*-spline projection methodology. Back testing of the projections (as was done by the CMI Mortality Projections Working Party) shows credible results for French males. The projection from 1982, using data from 1982 projected forward to the current time, is shown in Figure 9. The mid projection, the 2½% and the 97½% percentiles are also shown, with the actual data shown as the dots.

One possible criticism of *P*-spline projections is what they can do to the structure of mortality by age. This is demonstrated in Figure 11, which shows the age structure of the fitted force of mortality for males in England and Wales over the period 1961 to 2002. The black lines are fitted values based on the actual data, the grey lines are the projected values.

The left panel shows improvements which have occurred and the continuation of this improvement trend for later years, although there appears to be a qualitative difference between the 2015 line (shown in solid grey) and the later ones. The curvature of the age progression is preserved in the 2015 projection, but it appears to be lost in the later ones. Indeed, long-term projections using *P*-splines can tend to flatten the mortality curve against age.

Other models allow the separation of time trends from cohort-based patterns. In Section 17 we applied a simple Poisson model to grouped death counts in population data, and in Section 18 we applied a survival model to individual level data in a life office portfolio. Statistical tests were used to show just how much better a model including a time-trend effect fitted U.K. male population data compared to a model without. It was also clear that a model which separates mortality improvements for this data set into both cohort and time components fitted best of all.

The corollary of this is that mortality improvements are primarily composed of cohort effects, but that a significant residual component is time based. This appears to vindicate the current life office practice of using a 'floor percentage' or 'underpin' for mortality improvements in annuity reserving. However, one must always remember that a valuation basis is about future improvements, for which the past experience may not be relevant.

I have covered the key conclusions as I have gone along, but those which we believe are the most important are:

— The differences in mortality between genders remain pronounced, despite faster improvements for males recently; the differences between the sexes are larger than the differences between the various countries considered.
— The cohort effect exists for females as well as for males in the U.K., and it is evident in various other countries.
— Although mortality improvements in England and Wales have been particularly strong, there seem few grounds for assuming that they will slow down or stop soon. The low international ranking suggests that continued strong improvements are very possible, with the example of Japanese females showing that low mortality is no barrier to future improvement.

We, the authors, certainly do not see our paper as the last word on longevity, and the intention of the paper is to stimulate debate. The Research Group is looking to develop further any suggestions or comments.

In introducing his paper (Willets, 2004), Mr Richard Willets made reference to an article in *The Actuary*, which described those who compile mortality statistics as 'geeky'. That paper represented the second major paper on this subject in five years. Since that time there have been regular papers on this subject, with references to its importance being made in each of the last few Faculty and Institute Presidents' Addresses. Later in 2007, a professional seminar on

mortality issues will be held, and it would appear that mortality studies have moved from a preserve for the 'geeks' to again be a mainstream part of actuarial work.

Reference

CMIB (Mortality Sub-Committee) (2005c). Responses to working paper 3. Working paper No. 11.

Mr J. L. C. Lu, F.I.A. (Panel member; also introducing the paper)**:** The intention of this presentation is to share with you some of the fascinating observations which I have come across while doing this research.

We have been talking about improvements in mortality. Part of our work was to see which components of death we have been able to prevent.

Let us look at what kills people. We have investigated trends of cause of death in seven countries: in the U.K., the U.S.A., Japan, France, Canada, Sweden and Germany, and have looked at male and female experience by age. We have categorised the causes of death into four groups:

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

We define the circulatory system to be the system which covers the heart as well as the blood vessels, which carry blood from the heart and circulate it round the rest of the body and back to the heart. This covers 40% of the deaths of males in the 65 to 75 years age group. We define the respiratory system to be the lungs, the trachea and the windpipe. This is a system which captures oxygen from the atmosphere, then passes it to the blood, and then the heart pumps it round. This covers 10% of deaths in the male 65 to 75 years age group.

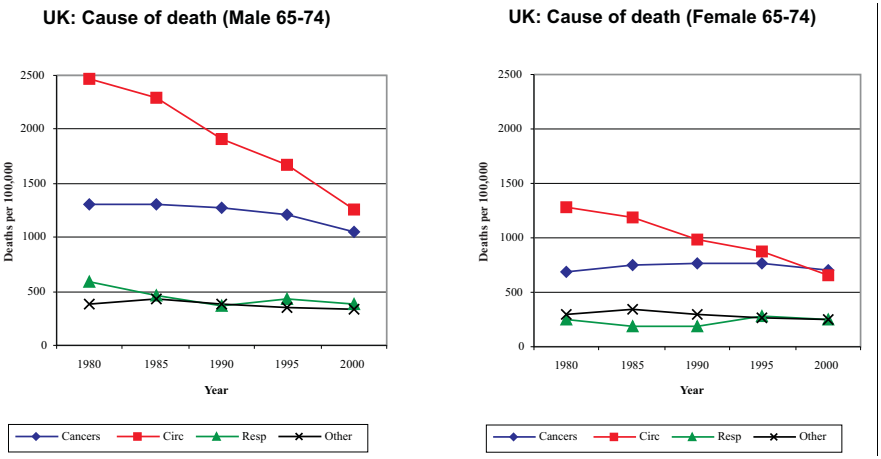
Then 38% of deaths are due to cancers, and 'other causes' account for 12% of deaths. By using these groupings, we have covered the key major causes of death.

The advantage of these groupings is that they reflect the underlying functions of the body and the characteristics of the causes of death. They also reduce the probability of errors of diagnostics. It is quite easy to make a mistake in diagnosis between a block in the heart artery and the pulmonary artery. There is, however, a far smaller chance of a mistake in diagnosis between a cancer death and a circulatory death. A large proportion of circulatory deaths is because of blockages in the system. For example, blockages in the heart (heart attacks) or head (stroke) can be fatal. However, not all blockages in the circulatory system cause death. If you get a blockage in the circulatory system of your finger, it will feel numb, not cause death.

To return to the two key observations, the first one which I find interesting is a dramatic decline in deaths relating to circulatory diseases between 1980 and 2000. It happens for all of the seven countries which we have observed. For example, for U.K. males aged 65 to 74 years, between 1990 and 2000, the total fall in mortality was 18%, of which 14% was because of circulatory diseases, heart and blood vessels, and the other 4% was because of cancer, respiratory and 'other' diseases.

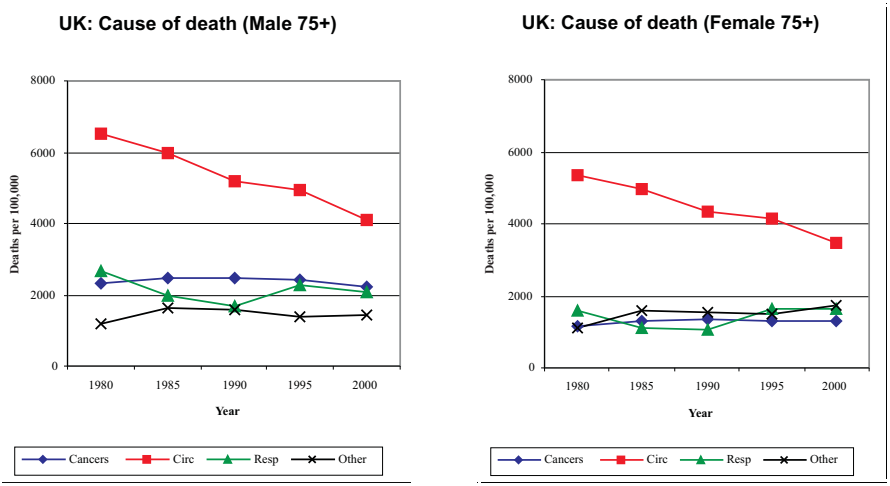
This brings me to the second observation, that of a relatively modest decline in deaths relating to cancers, respiratory diseases and 'other' diseases. These observations transcend gender, as you can see in Figure D.2; they transcend age groups, as you can see in Figure D.3, for the 75 plus age group, whereas Figure D.2 was for ages 65 to 74; and they also transcend nations, as you can see in Figures D.4, for France and Japan, and D.5 for the U.S.A. and Canada. However, there are some interesting features in Figure D.4. If we look at the death rates levels for France and Japan in 2000 for circulatory diseases, they are about 500 deaths per 100,000 population. In the U.K. they are between 1,000 and 1,500. It does show why this gives the impression that there is still scope for improvement for the U.K.

From Figure D.5, it appears that some observations point to a socio-economic phenomenon



Source: Own analysis of ONS data

Figure D.2. Causes of death by gender (ages 65 to 74)



Source: Own analysis of ONS data

Figure D.3. Causes of death by gender (ages 75+)

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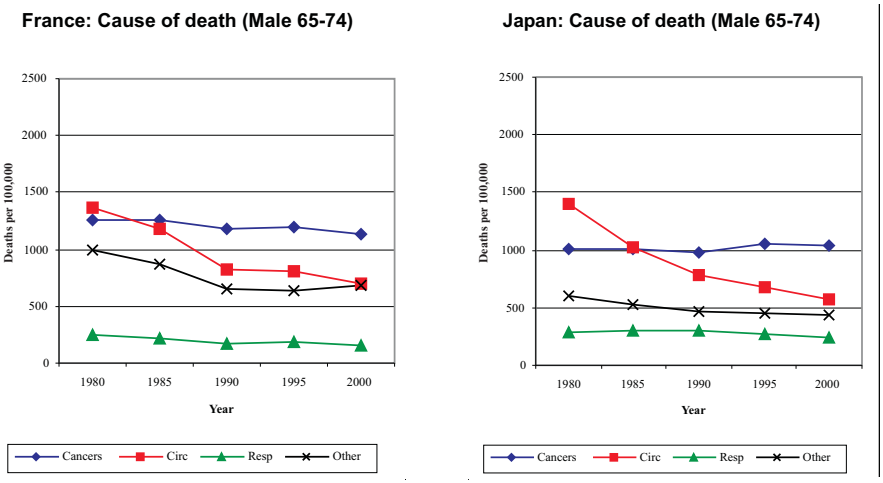
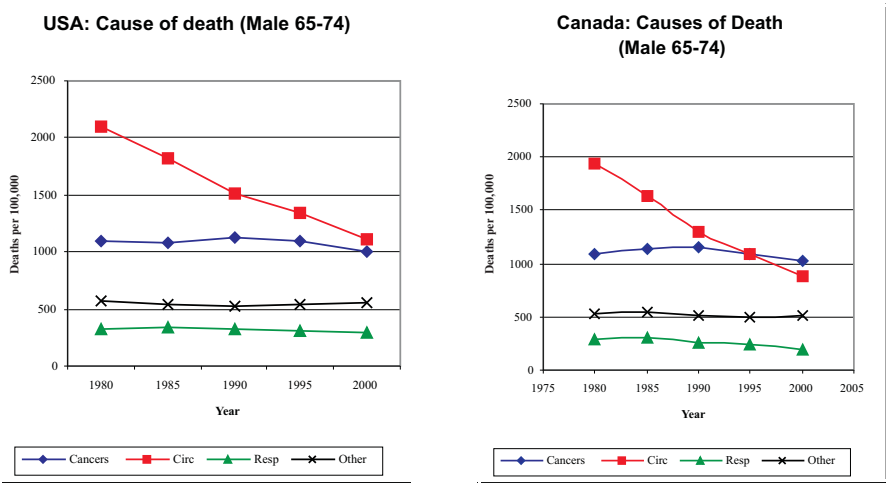


Source: Own analysis of ONS data

Figure D.4. Causes of death by country (France and Japan)



Source: Own analysis of ONS data

Figure D.5. Causes of death by country (U.S.A. and Canada)

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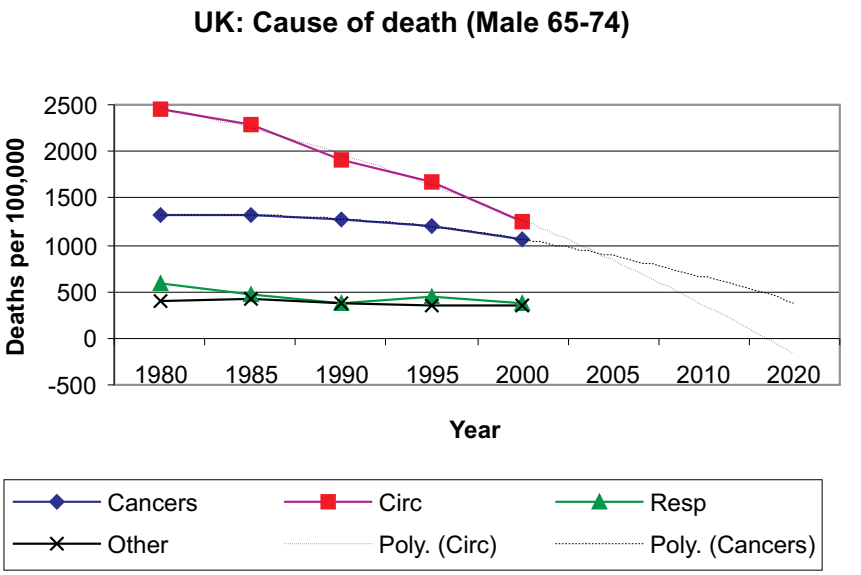

Source: Own analysis of ONS data

Figure D.6. Projection of causes of death

that higher social classes appear to be some years ahead of the trends. Canada appears to be about five years ahead of the U.S.A. for circulatory diseases. Also from Figure D.5, it looks as if the major causes of death across time are relatively independent. You do not see one cause decreasing and another increasing, which would lead us to think that, for instance, people are escaping heart attacks, but are dying of another cause. I am sure that, at a more microscopic level, these things do happen, i.e. there is interaction between deaths across time from one disease to another. However, it is not clear from the data which we have assessed.

Figure D.6 shows some simple projections which highlight the dangers of projections on mortality trends. Based on these simple projections, by 2020 there should be a negative number of people dying from heart attacks! There is a place for projecting causes of death in mortality projections, but we have to be careful to not read too much into these.

A possible contribution which we can make is to project death rates directly. There are already some examples of this in medical journals. These use more information than just projecting total death rates. We can use these projections as a tool to speak to other people, for example medical staff, who are interested in understanding potential changes in the causes of death.

There are challenges, the foremost being data reliability. Some researchers suggest that there is a 9% discrepancy between clinical diagnosis and autopsy diagnosis, i.e. a 9% difference between what the medical staff believed the cause of death to be and what was actually found to be the cause of death when the body was sent for autopsy. However, even this statistic must be taken with caution. The same research highlighted that the discrepancy could be lower. One of the reasons why cases are sent for autopsy is because these are complex causes of deaths, so that the actual discrepancy over all deaths should be lower. Broader groupings (i.e. increasing the

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Table D.1. Why do people stop dying of heart diseases: medical or not? (Contribution to improvement in heart attack mortality)

	Examples	Scotland	England & Wales
Medical treatment	Treatment for heart failure, heart attack, hypertension Secondary prevention, aspirin, CABG	40%	42%
Not medical treatment	Smoking cessation Improvement in the level of blood pressure, cholesterol, deprivation, other	60%	58%

Adapted from Capewell *et al.* (1999, 2000), Unal *et al.* (2004)

grouping of deaths from four groups) should reduce errors. We also need to be careful about the relevance of data to the insured populations. There are differences between social classes which will need adjustment.

We have assumed independence of risk, as the risks appear to be independent. However, more work will need to be done on this, and to understand whether or not there are interactions. There must be some, because a reduction in smoking will, for example, save lives through lower incidences of heart attack deaths and cancers. This, however, does not appear to have shown up in the data analysis which we have done.

It will also be interesting to understand the underlying causes of mortality improvement. We know that heart attack cases have fallen, but why? Why do people stop dying of heart attacks? Is it a fall in occurrences or a fall in fatality rates, i.e. is it because people stop suffering from heart attacks or that people still get them, but more of these people survive? It has been shown that two-thirds of the improvements in mortality from heart attacks is due to the prevention of occurrence; the remaining third is due to reduced fatality rates.

There is also a question about whether the reductions are caused by improvements in medical practice or otherwise. Table D.1, which is adapted from the papers shown, suggests that medical treatment accounts for just 40% of the improvement in fatalities in Scotland and England and Wales. Some of the non-medical reasons are improvements in blood pressure which are not due to medications, the increase in people who stop smoking, improvements in cholesterol and improvements in lifestyle. Some of these improvements are due to improvements in living or working conditions. For example, in the 1950s only 5% of the households in the U.K. had central heating. Today it is 98%. People also have better nutrition.

What strikes me is that this 60% non-medical improvement helps to reduce circulatory diseases, but does not seem to help reduce the other diseases: cancer, respiratory and others. I find that surprising, because, before doing this analysis, I thought that everything fell together.

In conclusion,we have been relatively successful in reducing death rates for circulatory diseases compared with other diseases, due to medical and non-medical reasons. Improvements are likely to continue, looking at the trends. The challenge for the future is, however, to predict future mortality, given the observed trends and information. There is still a great deal of work to be done.

Mr R. C. Willets, F.F.A. (opening the discussion)**:** In the U.K., the pace of improvement in life expectancy at retirement is faster now than it has ever been at any point in our past. In the past 15 years we have seen broadly the same improvements in mortality rates for men of some older ages as we saw in the previous 150 years. For older males in the U.K., the pace of change now is something like 20 times as rapid as the average pace of improvement from the middle of the 19th century to the middle of the 20th century.

Only one thing appears to be improving more rapidly than life expectancy in retirement, and that is the rate at which actuarial papers on mortality and longevity are being produced.

However, the paper which we are discussing stands out from the crowd, firstly because of its quality, and, secondly because of the breadth of the topics which it covers. It is rare for a piece of research in this area to cover, not only the underlying drivers of mortality improvement, such as trends in cigarette smoking prevalence, different causes of death, and in a range of different countries, but also to consider the practical application of statistical projection methodologies and a whole host of other interesting insights.

I found the descriptions in Sections 3 to 9 of the different factors which have shaped the environments in different countries in which mortality improvements have occurred particularly interesting. I think that, in an ideal world, I would have liked the sections to have been linked more strongly to the descriptions of the actual improvements given in Section 11, although I do appreciate that it can be far from straightforward to draw inferences about patterns of mortality improvement from trends in the underlying risk factors, such as smoking.

In Section 11, and later in Section 19, the issue of whether period effects or cohort effects dominate in different countries is discussed. The authors, and Mr Miller in his presentation, are at pains to point out that the dominance of one feature does not mean that the other one does not exist. However, to me it seems very clear, especially in the U.K., that both period and year of birth have been extremely significant factors in determining patterns of mortality improvement.

In reality, the pace of improvement for people born in different birth cohorts has varied significantly, but also the pace of change has accelerated over time for people born in both high improvement and low improvement cohorts. I wonder whether it might be more useful to test the strength of cohort effects seen in different countries rather than to compare the strength of period and cohort effects in the same country.

In Section 13 trends for different causes of death are analysed. I think that the key point to note from this discussion, and Mr Lu has drawn out this point in his presentation, is the dominance of circulatory causes, such as heart disease and strokes, as a determinant of aggregate trends. I think that the role of circulatory disease mortality in determining trends warrants far more attention.

In the U.K. at the moment, the pace of improvement in circulatory disease mortality has been accelerating at a near-linear rate since the early 1970s, and the pace of acceleration is showing no signs of abating. For some birth cohorts, mortality rates are now reducing at close to 7% p.a. When you consider some of the forces driving the reductions in this area, the potential for further significant reductions is evident. For instance, the volume of statins prescribed for controlling cholesterol levels is actually increasing by around 30% year on year. Mr Lu referred to the paper Unal *et al.* (2004), which decomposed the improvements which we have seen. For England and Wales that paper looked at the period from 1981 to 2000. If you look at the total volume of statins prescribed over the whole of that 19-year period, I am sure that it comes to less than what was prescribed just in the last year alone. So, since the period on which the paper was based, there has been a significant shift in the environment affecting mortality improvements in relation to heart disease and strokes.

The number of angioplasty operations for heart disease is growing by something approaching 20% p.a. Also, after a period of stabilisation, cigarette smoking prevalence is again falling. The bans on smoking in public places may add further impetus to this trend. The Health Protection Agency in England has estimated that relatively modest reductions in average population levels of blood pressure, cholesterol and smoking, down to levels seen in other European countries, could reduce heart disease mortality by 50%.

Professor Roger Boyle, the Government's Director of Heart Disease and Strokes, has even suggested that premature death from heart disease could be eliminated by 2014; that is six years before Mr Lu's projection. However, if you analyse what some projection bases, which are used implicitly, assume about trends in circulatory disease mortality, they seem to be very much at odds with current and likely future trends. By my reckoning, the medium cohort basis implicitly assumes that the pace of improvement in circulatory causes will decline very sharply over the next ten years.

In Section 14 I was pleased to note that the authors counter the view that the *P*-spline projections actually require the elimination of certain causes of death, because, as the authors

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explain, this simply is not the case. I think that the most notable feature of Section 15 is Figure 10, which shows the disjoint between recent trends and the medium cohort projection.

My view is that the medium cohort projection, even with a low floor on the improvement rate or underpin, is actually out of sync now with past trends and likely future developments. I suggest that, in most cases, it is no longer a suitable best estimate or a realistic basis to use for placing a value on pension scheme or annuity liabilities. As a result, the liabilities of final salary pension schemes in the U.K. may still be significantly understated.

By my reckoning, if the improvements which we are seeing actually continue to accelerate at their current pace, the understatement could be as great as £175 billion. Even if the pace of change slows as circulatory causes become less common and other causes of death prove more difficult to reduce, the present understatement could be in the region of about £75 billion. These are clearly very significant numbers.

For us, as a Profession, papers of this kind are helping to improve our understanding of this key area.

Dr I. D. Currie (a visitor, Heriot-Watt University)**:** The method of modelling and projecting using two-dimensional *P*-splines was introduced by myself and my colleagues Paul Eilers and Maria Durban in a conference paper (Currie *et al.*, 2003), and a full paper followed (Currie *et al.*, 2004b). The methodology is thus in its infancy, and so I very much welcome the thorough road testing which the method has been subjected to in the paper.

I would like to make two general remarks: the first concerns modelling mortality; while the second concerns projecting it. I emphasise that I see these two processes as being distinct, though by no means independent.

A statistical model should lead to an understanding of the underlying structure of the data. To paraphrase Alexander McCall Smith's Mma Ramotswe, a traditionally built statistical model does this with parametric terms for specific effects, and parametric terms for age, period and cohort effects are commonly used in mortality models. Examples are the age-period-cohort and Lee-Carter models. On the other hand, a smooth model tries to remove statistical noise by some kind of local averaging, thereby exposing the underlying structure of the data. If there are cohort effects in the data, then you can find them either traditionally by explicit modelling or, as in the paper, by smoothing. Cohort effects can be found either by smoothing along the age and time axes or along the age and year of birth axes. Both methods will expose the underlying patterns which are so evident in Figures 4 to 7.

And what of forecasting? Knowledge of mortality far into the future is a necessity for defined benefit pension schemes and for annuity products, but it is abundantly clear, from the very thorough background research which has gone into the paper, that knowledge of future mortality is not, and cannot be, an exact science. Future mortality depends on a whole range of interlocking factors. It is hard to believe that the negative effects of smoking were largely unknown until Doll's work in the 1950s. Our very own King James VI wrote a pamphlet in 1604, 'A Counterblast to Tobacco', which includes a description of the problem of competing risks. I quote: "if a man smoke himself to death with tobacco (as many have done) then some other disease must bear the blame for that fault." King James goes on: "so do old drunkards think they prolong their days by their swine-like diet, but never remember how many died drowned in drink before they be half old." In our own time: "Increased obesity rates are likely to lead to a rise in onset of related chronic diseases, ..." (from ¶9.4), but quite what the effect on future mortality will be is still unclear. So, let us be humble before the task before us; no matter how sophisticated the mathematics, or how detailed the background research, we still will not get it right. The confidence intervals provided by *P*-splines may be wide, but at least they bring a sharp dose of statistical reality to the forecasting problem.

I congratulate the authors for a marvellously researched and fascinatingly written paper. The method of two-dimensional *P*-splines is not some universal medicine or black-box for the modelling and forecasting of mortality. It is a statistical model, so that it describes some data sets better than others, and provides plausible forecasts for some data sets, but not for others. There are other methods. Now that the Faculty of Actuaries Mortality Research Group has shown us

what it can do, perhaps it could turn its attentions to some of the other methods for tackling this vital, but most difficult, problem.

Professor A. D. Wilkie, C.B.E., F.F.A., F.I.A.: I shall comment on three things. I was particularly interested in what was said by the opener about medium cohort forecasts not being very suitable ones. From a practical point of view, if an actuary is going to value a pension scheme and has to value it using some deterministic basis in order to get a single present value to put into some account somewhere, it is only reasonable, nowadays, that some deterministic forecasting model should be used.

Smaller consultancies are bound to use something which they can use fairly readily. They do not have the resources or the knowledge to do the sort of work which a large consultancy or a life office might be able to do. The practical thing which I would do is to use the '00' series of life tables, rebase the medium cohort forecast to the year 2000, and carry on from there. I do not know whether that is a good or a bad one, but I think that it is about the only one which the practical actuary can use at present. The Profession, in my view, has been most remiss in saying: "We do not know how to do forecasting, so we shall not do it at all."

If we cannot forecast mortality rates at all, then we cannot value pension funds at all, and any insurance company writing any annuity business is being totally irresponsible unless it simply stops writing annuity business. However, insurance companies are not doing this, of course, and we can see why.

My second comment is to do with the cause of death. The level of cancer deaths in the different graphs is often shown as percentages, not absolute levels. They are at the same sort of level in different countries, but, as I understand it, the causes, the particular sites of cancers, vary very much between different countries. Lung cancer has been important in Britain, but is declining significantly. I think that I am right that stomach cancer is very important in Japan. I do not understand why different sites for cancer should be of different importance in different countries, though smoking obviously has an effect on lung cancer. That is an area for possible further investigation.

My third point is about forecasting. Just as one needs some central or best estimate deterministic forecast, so it is useful, also, to have some way of wrapping an uncertainty around that, but in a path-dependent way, so that you can simulate sample paths of mortality.

As I understand the *P*-spline method, confidence intervals are quoted for the future, but it is not saying that there is a 25% chance of going along a particular route. There is 25% chance of being at that point at any future point in time, but they are all extremely dependent. What one wants is something where one can simulate independent sample paths.

The model shown by the authors in the last sections of the paper, which have not had any significant discussion so far, look very useful. One sees an indication of how one might go ahead and do this, but the authors do not quote any parameters, and they do not give any indication of the residuals, or whether there are any remaining patterns in the residuals.

What one would like is a model where the parameters which are fitted explain the data in such a way that the residuals in two dimensions are all suitably random. However, they may not be; they may still be connected. If you are doing simulations of forecasting, you cannot comfortably simulate each age independently. There is a strong tendency to assume that it is the parameters which you are forecasting, possibly as well as the residuals. I can see plenty more opportunities for more thought and more work about that particular aspect.

The President (Mr J. S. R. Ritchie, O.B.E., F.F.A.): In response to the challenge from Professor Wilkie about the Actuarial Profession not helping in terms of future projections;we are, in fact, planning to give some assistance to help actuaries and others to pick a projection basis which will actually be appropriate to the circumstances of the case at which they are looking — in other words, to have some kind of library from which they can pick something which may be helpful to them. There is definitely work in progress on that; and it is useful, for the record, for it to be stated clearly. We realise that we have some responsibilities to help as best we can in the uncertainties for the future.

Mr M. R. Kipling, F.I.A.: I should like to respond to the first point made by Professor Wilkie from the point of view of someone who has no great technical expertise in the stochastic modelling of mortality, but who, nevertheless, has to value portfolios of deferred annuities and guaranteed annuity options. These portfolios contain a large number of lives in their 30s, 40s and 50s, some of whom will live for another 60 or 70 years. The rate of longevity improvement in the relatively longer distant future is particularly important when valuing these portfolios.

The approach which we chose to adopt, in the absence of any recommended projection, was to run the CMI *P*-spline model at the 50th percentile (fitted to assurance mortality), and to derive from that a relatively simple matrix of decennial improvements in future age cohort mortality rates. We then blended this in at the current time with the most recently experienced rates of age-cohort improvement in our own experience and in population mortality. Finally, we adjusted away any aspects of the resulting matrix which we thought were unrealistic; for example, the behaviour above age 90, where the *P*-spline projections do some rather strange things, and the rates of improvements for younger cohorts, 20, 30 or 40 years into the future, where we applied an upper bound to make the matrix less of a step change from the medium cohort projection.

We ended up with a 'personal' triangle of projected mortality improvement rates, shaped by taking into account all of the information available to us. When we get the library about which the President was talking, we may make further changes to our matrix.

When it came to doing things like ICAs, which required a more extreme projection, we looked at the 95th percentile of the CMI *P*-spline model, and again made various adjustments to shape it, to give us something which we felt happily represented a 95th percentile future experience.

I believe that any actuaries who have to value annuities, and, in particular, deferred annuities and guaranteed annuity options, should come up with their own tables of future improvements, taking into account all the relevant information which is available. This should then be presented, with explanations, to the life office board or the pension scheme sponsor, most probably in both a best estimate and an extreme form, to bring out the range of possible outcomes. Finally, adjustments may need to be made to take into account any different opinion which that sponsor or the board may have on the more subjective assumptions.

Ms C. Macintyre (a visitor)**:** I work for the General Register Office for Scotland, and we produce the population projections in conjunction with colleagues in the Government Actuary's Department.

It would be particularly useful for us to involve the authors in a stage of consultation which is going to happen in summer 2007. Something on which we, particularly, have questions is the explanations for the consistent difference which there is between Scotland and the rest of the U.K. in life expectancy.

It struck me that it would be useful for us to build up a series of alternative scenarios which we could discuss with our health department, so that it had some information which it could use to address the issues of what scope there is for closing this gap. I believe that it would be useful, particularly, to look at the causes of death.

Professor A. J. G. Cairns, F.F.A.: I have a question for the authors. I have done some work on my own on this kind of modelling, looking at national mortality data sets. One of the issues which has become apparent in the research, but which I have not really had time to look at yet or to resolve, is potential inaccuracies in the data which violate the assumptions of the statistical model.

Turning this around; when you are doing your statistical modelling you are usually making an assumption about the reliability of the data. You have some measure of the average population at different ages. What has become apparent in some of the work which we have done is that the exposure data, the population estimates, are, to some extent, unreliable, because they are estimates. The best estimates which you, perhaps, get are during the census years, and then various methods can be used to interpolate between census years.

Do the authors have any insights to offer on this issue of the accuracy of the exposure data. I

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see it as a possible problem which needs to be thought about in terms of what it means for the models which we are fitting, but also what it means in terms of the projections which we are making, and also in terms of the width of the confidence intervals, for example. I do not have any answers to this at the moment, but I should be interested to know whether the authors have any thoughts on this.

Mr S. J. Richards, F.F.A. (Panel member)**:** The issue of the reliability of population estimates for population data in England and Wales, in particular, has been gone into in a fair amount of detail (see Richards, 2008). In summary, in England and Wales the data for deaths are a good deal more reliable than the population estimates. The reason for this is that the data for deaths are collected continuously by local registrars on a more or less daily basis, with no major issues in late death reporting, whereas the population estimates, as Professor Cairns has pointed out, are just that — estimates. They are based on the decennial census, with the intervening populations estimated between these census years.

There are quite a number of issues surrounding these population estimates, as shown in Richards (2008). As an example, consider the 1919 to 1920 years of birth. Population estimates can be substantially complicated by the very wild swings in fertility which is demonstrated by this period. The year of birth 1919 has very dramatically different mortality rates from the surrounding years of birth. Although the year 1919 is more obviously associated with the 'flu epidemic', it is also associated with a large number of demobbed soldiers returning home. The autumn of 1919 was nine months after the end of the First World War, and saw a fairly large surge in live births in England and Wales. There was a similar effect in 1945 to 1946, after the end of the Second World War. The population estimates have quite a few issues as a result of these fertility swings.

Reference

Richards, S.J. (2008). Detecting year-of-birth mortality patterns with limited data. *Journal of the Royal Statistical Society, Series A*, **171**(1), 1-20.

Mr D. G. Robinson, F.F.A.: The point which I want to make is, and, to an extent, the President has already stolen my thunder, that the Profession should be more proactive on public interest issues. For example, there are some wonderful data and information in this paper on the impact of certain risk factors on mortality. The Actuarial Profession has known for a *very* long time about the damage that smoking does to people's health (see Doll & Hill, 1954), yet has not communicated this outside the profession to any significant extent. If ever there was a public interest issue, this was one which could have had a very significant impact. I regard this as a missed opportunity, and one which can still be put right.

However, I am very pleased now to see the Profession taking the initiative and acting on the serious public interest issues around the new Government Pension Savings Scheme, including the response which appeared recently in the *Financial Times*, and which was reactive. The Profession has a duty to take public interest issues seriously, so I am pleased to hear that there is now a full time member of the Profession who is responsible for communications. I would encourage the Profession now to think about where we can be proactive in our communications on public interest issues, rather than waiting for something to happen, and then reacting to it. The question which needs to be asked is: "Where can the Profession use the information and the skills which we have in the public interest?"

The Profession has come through some difficult times. I think that it is now in the ascendance, and there is an opportunity now to make a real difference in a number of public interest areas.

Mr J. Du Toit, F.I.A.: At the end of the paper the authors look at three different models to test for model risk. The three models which are considered are *P*-spline, GLM and survival models. The three models give different answers on whether period or cohort effects dominate. It was not

quite clear to me whether this was an effect of the data which were used, or whether it emphasises the danger of model risk. Did these findings raise questions about the *P*-spline method?

Mr Richards: Presumably you are referring specifically to the seeming contradiction in the paper which finds, for England and Wales, that the age period model fits better than the age cohort model, whereas Richards *et al.* (2006) found exactly the opposite. The reason for that lies principally in the use of mortality 'data' between ages 90 and 100. The ONS data in England and Wales, or deaths data, are recorded at individual ages, split by gender, from ages 20 to 100 exactly. In contrast, population estimates are only calculated up to age 89.

The population estimates which are actually made available to the human mortality database at ages 90 to 100 are actually artificially constructed. They are not population estimates in the same sense as are the figures below age 90. If you include ages 90 to 100 in your model fitting, then you get the results which we achieved, which is that cohort effects are dominated by period effects. If you leave out the age range with the artificially constructed population exposures, then you get the situation that cohort effects dominate period effects.

One area where you can see this is in Figure 4, where, for males in England and Wales, you can see that, even though the age period spline model knows nothing of cohorts, it still identifies the cohort effect centred around the year of birth 1930. This, perhaps, is one of the weaknesses of using a single statistic like the BIC to make a decision about which effect dominates, and why it is very useful to plot a graph such as in Figure 4, where you can see that cohort effects dominate, because there are no horizontal patterns. That is why this kind of analysis is best done visually, and not just to rely on a single statistic.

It is probably also a very good demonstration of what Dr Currie highlighted, namely that this is a method for local smoothing. If there is a pattern, it will be found if it can be justified by the data. Figure 4 is a good illustration of how an age-period model, which you might naturally expect to highlight or to find period effects, nevertheless finds a very strong cohort effect.

Professor A. S. Macdonald, F.F.A.: I have chaired the CMI's Life Office Mortality Committee since 2002, when the interim cohort projections were produced. That was the first time for 20 years that projection methodology had been considered by the Profession, so I should like to say a few words about how we got to where we are.

It quickly became apparent to the Committee, and then subsequently to the Projections Working Party, that actuaries were not alone in looking into longevity and longevity projections. There were many other highly scientific disciplines, such as statisticians, demographers, gerontologists, health economists, all interested in this question, all publishing at an impressive rate, and it was quite clear that whatever the Actuarial Profession produced in this area would have to stand up to a degree of outside scrutiny, which had, perhaps, not been the case 20 years before.

In the first instance, that meant that, in 2002, we felt that we had to give some indication of the uncertainty surrounding any mortality projection, although we were unable to quantify it, in any statistical probabilistic sense, and the short, medium and long cohort projections were, to a considerable extent, *ad hoc*. Any deficiencies which may be unearthed since 2002, as further work is done, are *largely* because of the limited work which we were able to do before we exposed them in 2002.

It is worth remembering that that was the very first time when uncertainty in longevity projections had been properly exposed to the Profession. In subsequent work, we began to look at several different statistical models. It is an accident of timing that the working paper on the *P*-spline model (CMIB, 2005b) was published some time before the working paper on the other major model at which we looked, the Lee-Carter model (CMIB, 2007). This was purely because of the greater technical difficulties of doing the work for the Lee-Carter model. It has led, sometimes, to the suggestion that the CMI favours *P*-spline models over other models, which I can assure you it certainly does not.

This paper shows very well why the actuary needs a toolkit of models, rather than one favourite model. The success of any particular model in capturing the important features of the

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data depends on many features underlying the data, often hidden in the background. Such features might be the nationality, gender, or even the specific life office or pension scheme being modelled. Bear in mind, also, that the CMIB has access to only very few data sets, essentially its own male assured lives data and national data.

As a result, the Projections Working Party was in no position whatsoever to recommend particular methodologies which could be used in all circumstances, but merely to draw the Profession's attention to the range of different models which were available, and, to some extent, the pros and cons in different circumstances. To apply any methodology in any particular circumstance, as Mr Kipling said, requires some specific understanding of the data. Neither the Working Party nor the CMIB is in a position to do that for every actuary who has this task before him or her.

Ultimately, as Mr Lu suggested, a cause-driven model rather than a purely statistical model would be highly desirable. This is something which the Working Party considered, but applying a cause-driven model to the particular circumstances of a given country, a given gender, or a given life office or pension scheme, requires an even higher level of understanding of what is driving mortality and mortality changes in those particular circumstances. Yet again, we move even further away from a single universally applicable recommendation which the CMIB, or any of its committees, may ever be in a position to make.

Mr A. G. Sharp, F.F.A.: In terms of future research, something which I think would be very useful would be to look at the rates of improvement for different categories, and for different sections of society. This is something implied by the different lines in Figure 1.

This also links into what is happening on the pensions side of the profession. We have the self-administered pension scheme (SAPS) investigation now well under way. Its analysis of observed mortality is going to be subject to ever more analysis in terms of both geographic and, particularly, industry sector splits.

The problem with that will be that, in terms of the SAPS data being long enough to start looking at trends within it, we are still many years away from that, so that we will need to look, perhaps, at a different way to suggest how we might fit different projection bases to it. That leads me to consider, a little more, the library of projection bases which has been mentioned. What we are looking at there is giving actuaries the tools, particularly on the pensions side, but applicable across the profession, to look, when choosing mortality assumptions, separately at base tables and at projection methodology.

Professor Wilkie asked, quite rightly, what the actuary in a small consulting practice is to do. Let us start with the '00' life tables and medium cohort projections. I think that the actuary in a smaller consultancy now, in terms of projections, can do, perhaps, no more than that, but I hope that he or she will soon be in a position, at least, to look separately at the base table, and then to make the link to a suitable projection basis in a more appropriate way.

Dr D. J. P. Hare, F.F.A.: I am speaking as the Chairman of the Faculty Research Committee. It is with great pleasure that, on behalf of the Committee, I thank the authors for the quality of work which they have done. When Mr Richards was talking about this idea some 1½ years ago, I thought that it sounded very interesting. I am glad to say that my reasonable expectations have been more than met, and have been exceeded by the breadth of the work, the interest of the conclusions, the quality of the discussion and the number of people attending the meeting.

I was glad that I detected, in the introductory comments, a flavour of continuity in the group, that you were keen to have ideas which you could take forward. I hope that this is the case. If I may just offer a couple of suggestions for topics to consider, I was interested particularly in the presentation by Mr Lu. The paper seemed to home in on the significance, in terms of rates of improvement, of the main four causes of death, whereas Mr Lu was showing the actual rate by country.

I wonder whether work has already been done on this, or whether there is scope to reflect on those causes of death by country, and then to try to draw some conclusions, particularly for the U.K., in terms of what scope we have to move into line with other countries.

I also wonder to what extent people have looked at the cohort effect through cause of death, and whether there are enough data to look at rates of death by age for different cohorts, and see the movements there. If I am displaying my ignorance and that is already in print, courtesy of Mr Richards or others, then I am sorry. If not, then it might be worthwhile looking into that.

I suspect that there is plenty of other research which could be done, and maybe six people will not be able to do it all. I am happy to say that there are vacancies in the Faculty Research Group.

Mr A. C. Martin, F.F.A.: I have a brief observation concerning Figure 10. Mr Willets mentioned accounting numbers; these are, indeed, very much focusing on medium cohort projections. FRS 17 assumptions are best estimates; this implies a 50-50 chance of inadequacy. I do not think that inadequacy would excuse the illustration of Figure 10. If a journalist got hold of what the Pensions Regulator and the Financial Services Authority were using for reserving purposes, there would be some questions asked. While pension actuaries, particularly, for all but the very largest schemes, will have to use some uncertain projection bases, I think that there is a real onus on pension scheme actuaries to be testing the effects of their projections against the medium cohort. I am not sure whether even the long cohort projection would get into the funnel of doubt of above 97.5% in Figure 10.

However, in terms of future prudent funding projections, I think that we have much to do, and there is a big challenge here for everybody.

I agree with Mr Lu's statement on nutrition. All my friends in the scientific world say that mortality is all down to nutrition.

Mr Richards (replying)**:** I will begin by responding to Professor Wilkie, who asked how pension funds and annuity portfolios can be valued if the Profession shies away from recommending a particular projection basis because of inherent uncertainty. The question can be turned round the other way. If you are faced with fundamental uncertainty over future improvements and a probably irreconcilable problem in fixing on a particular projection model, why do pension schemes continue to grant benefits which are inherently unquantifiable, and why do insurers persist in continuing to write guaranteed annuities? Guaranteed annuities are forming an ever larger proportion of many insurers' balance sheets. It is important to encourage people to recognise the inherent uncertainty over future mortality improvements, and therefore over future reserving requirements, even if it stops at identifying 'known unknowns' without being able to quantify what these things are.

Mr Kipling talked about starting with a portfolio's own data to create a bespoke projection. In fact, this is quite possible with the likes of survival models, which can do a very good job of identifying a wide variety of different risk factors. This includes identifying cohort effects and separating them from any time-based trends. This was done in Section 18 for an actual annuity portfolio from a very kind and public-spirited (yet anonymous) life office.

Professor Cairns raised the question about data reliability for population estimates for the ONS England and Wales data. This is covered in some detail in Richards (2008). Much of the difficulty with population data centres around certain years of birth, and can be ascribed to very strong swings in period fertility.

Mr Sharp asked about the different improvement rates which might be observed in different subgroups in a population. Again, survival models are very capable of identifying the base level of risk for different subgroups, such as gender, socio-economic groups or even U.K. regions. In fact, it is a relatively straightforward extension to test whether or not the broad population improvement rates, say by time, differ for different subgroups. For example, I have done some work which shows quite clear differences in time-based trends for males and females. The same approach can be extended to different socio-economic groups, different regions or whatever risk factor categories you have.

I noticed, with interest, that Dr Hare outlined some other topics of research for the group to undertake. I am sure that I speak for the rest of the group when I say that we would nevertheless like to take a little break from mortality research for perhaps a month or two!

Mr Martin mentioned the role of nutrition in mortality. It is very widely known that smoking is a major component of extra mortality, and, in the U.S.A., it was estimated by Doll & Peto (1981) that one-third of the cancers in that country were because of smoking. However, Doll & Peto also estimated that a further third of human cancers have a direct dietary component or dietary link.

Finally, if I were asked to select one thing to emphasise in this particular paper, it would have to be Figure 10, which is a single cohort drawn from Figure 4.

If you look at Figure 10, you can see that mortality improvements have steadily accelerated over much of the past 30 or 40 years. I should like to finish with the question: "What grounds do we have for believing that this acceleration will slow down, let alone decelerate or stop?"

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The President (Mr J. S. R. Ritchie, O.B.E., F.F.A.): Thank you very much, Mr Richards. I think that the size of the audience and the quality of the contributions in the discussion is a testament to the quality of the paper which has been presented. I should like you to join with me in the normal way in congratulating the authors for presenting such an excellent paper to us.