APPENDIX

E

Uncertainties in life expectancy projections

Chapter 1 of this report includes a discussion of population projections and dependency ratios. One of the key factors affecting these projections is the assumption for life expectancy. But the future path of life expectancy is uncertain. This Appendix examines the extent of that uncertainty. It is drawn from a lecture the Chairman of the Pensions Commission gave at Cass Business School in April 2005. At that time the most up to date Government Actuary's Department (GAD) estimates of life expectancies were the 2003-based projections. The lecture therefore analysed uncertainty around these projections. This Appendix does the same, and then shows how the new 2004-based projection fits within the uncertainty range we proposed around the 2003-based projection.

The Appendix covers 5 issues:

1. Background to the life expectancy projections
2. How uncertain are projections of life expectancy?
3. Comparison of the Pensions Commission's hypothetical range of uncertainty and GAD's 2004-based principal projection
4. Latest developments from the Continuous Mortality Investigation (CMI)
5. Conclusions and recommendations

1. Background to the life expectancy projections

There is uncertainty over the average life expectancy of entire age cohorts. Figure E.1 sets out how the GAD estimates of life expectancy for a man aged 65 have developed in the past 50 years and GAD's principal projections (as at 2003) for the next 50. (Although the analysis presented in this Appendix focuses mainly on life expectancy for men, similar trends and issues exist for women.) As Figure E.1 shows, GAD's principal projections have changed radically in the past, with major upward revisions between the 1983-based and 2003-based projections.

The future path of life expectancy will depend upon the future path of age-specific mortality rates. GAD projections depend on mortality rate assumptions. To understand uncertainty in life expectancy, we therefore need to understand how wide a reasonable range of assumptions relating to mortality rate developments might be, and how these would translate into life expectancy uncertainty.

Figure E.2 sets out how life expectancy at 65 would evolve if mortality for men over 65 declined from now on at 1%, 2% or 3% per year. It illustrates that there is uncertainty even as to the life expectancy of today's 65 year olds, but that that uncertainty rapidly increases as we look further into the future. Figure E.3 shows the historic record of mortality rate declines in the UK for older age groups over the last 50 years. Across the whole 50 year period, mortality rate declines have tended to be in the 1-2% per year range, but in the 1990s declines of 2-3% have been observed for men aged between 60 and 90 and for women aged between 60 and 80.

Figure E.4 shows how the GAD 2003-based principal projection fitted within alternative future assumptions for mortality rate decline. For a few years the 2003-based principal projection is close to the 2% line, but it then diverges down to the 1% line, falling just below it by 2050. This reflects GAD's assumption in its 2003-based projections that mortality rate declines would gradually decelerate (halving every 25 years), thus producing a long-term projection with a "limit to life" of the average man of about 22 years beyond age 65. [GAD's new assumptions for the 2004-based principal projection are discussed in Section 3.]

2. How uncertain are projections of life expectancy?

The question then is: how uncertain should we consider this principal projection? And how indeed, do we set about estimating the degree of uncertainty? At least two approaches are possible.

One is to consider alternative expert points of view about future potential medical advances and about whether a biologically given "limit to life" exists. Lectures at the Cass Business School in Spring 2005 set out the two sides in the debate.[1] On one side Professor Jay Olshansky and others suggest that life expectancy could level off or even decrease in the 21st century given factors

[1] See *The Uncertain Future of Longevity*, Watson Wyatt/Cass Business School Public Lectures on Longevity, March 2005.

such as the rise in obesity levels and the potential effects of infectious diseases. This school of thought believes that there is an absolute limit to how far life expectancy can go on rising. On the other hand, experts such as Professor James Vaupel suggest that life expectancy is set to continue to increase at a rapid rate. He reports that there is no indication that a change in the trend of increasing life expectancy is in sight.

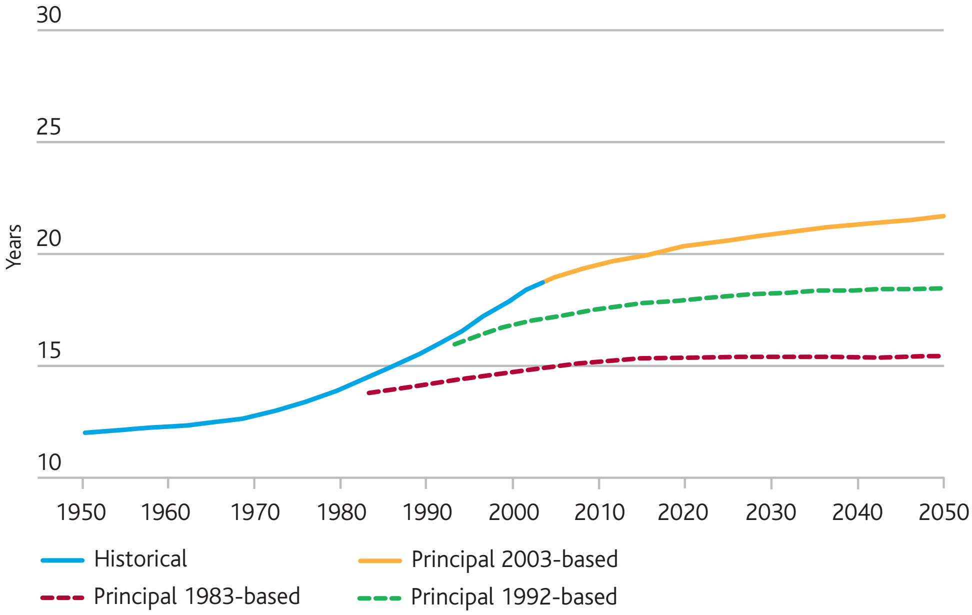
Figure E.5 is a reasonable representation of their philosophies, Vaupel arguing that life expectancy at birth and at 65 is likely to continue rising by roughly one year every four years, Olshansky arguing that life expectancy in developed countries will soon level off. But of course these are simply two positions: the fact that they exist gives us no basis for assuming that more extreme positions are impossible (and indeed there are some scientists who predict an accelerating rather than merely constant rate of improvement, with major breakthroughs in genetic science). And the fact that these two points of view exist gives us no basis for using their views to define a specific confidence level.

An alternative approach is to try to use past variations in forecasts as a basis for stochastic analysis, applying forecast changes/errors to the future principal projection to produce a distribution of future possibilities. This was the approach used to generate the fan chart that Mervyn King discussed in his lecture *"What Fates Impose"* [Figure E.6]. The fan chart was intended simply to highlight the importance of the issue. But it poses the question: is it actually possible to calculate confidence intervals of future life expectancy projections in a mathematical fashion? Are we dealing with mathematically modellable risk or inherent uncertainty?

To consider that question the Pensions Commission and GAD have together conducted analysis of how uncertainties in mortality rate projections might drive variability in life expectancy projections. We began by assuming that our degree of uncertainty about future mortality rates would increase the further away the forecast year is. And we hypothesised an error rate function geometric in form, i.e. error rate of 1% per year compounding [Figure E.7]. If this is the potential uncertainty function looking forward, male life expectancy at 65 today could lie anywhere between 17.7 and 20.5 years compared with the principal projection estimate of 19 years. But by 2040 the range could be 17.2-26.7 years around a base case of 21.3 years.

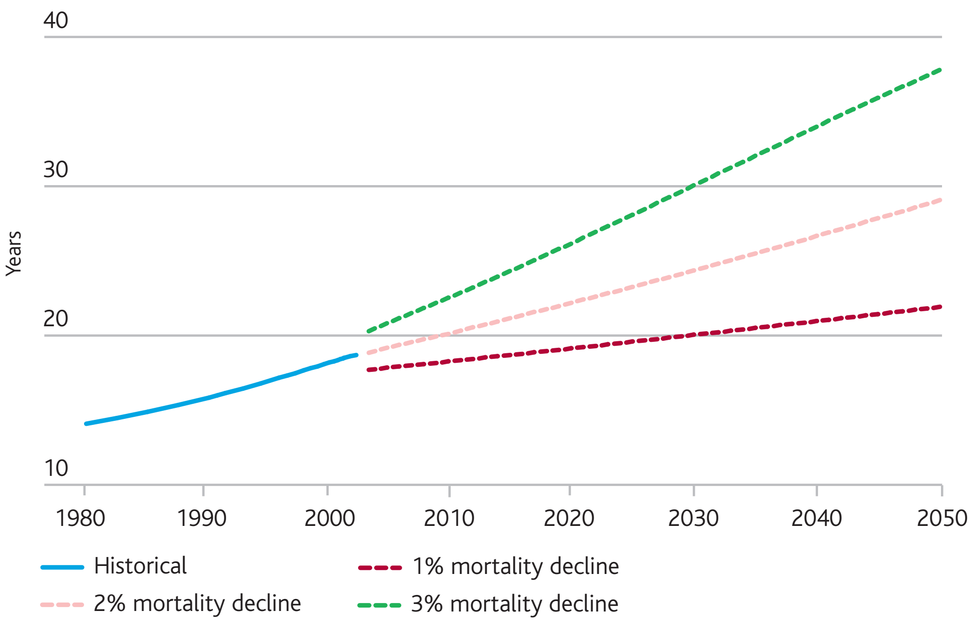
We then analysed the errors/changes to forecast which have actually emerged between GAD's 1983 and 2003-based projections [Figure E.8]. For years prior to 2003 we are comparing the 1983 forecast with an actual result: for years after 2003 we are comparing the 1983 forecast with the 2003-based forecast. Interestingly, the errors and changes do follow the hypothesised pattern of increasing uncertainty over time, but with somewhat higher error rates than our simple +/-n% model above would suggest. Looking forward from 1983 to 2014, estimates of mortality rates for men aged 65 and 75 were 46% and 43% higher than the rates we now forecast.

Figure E.1 Male cohort life expectancy at 65



Source: GAD, UK

Figure E.2 Male cohort life expectancy at 65: impact of future mortality rate declines



Source: GAD, UK

Note: Mortality declines are annual figures i.e. a 2% decline indicates a 2% reduction in mortality every year.

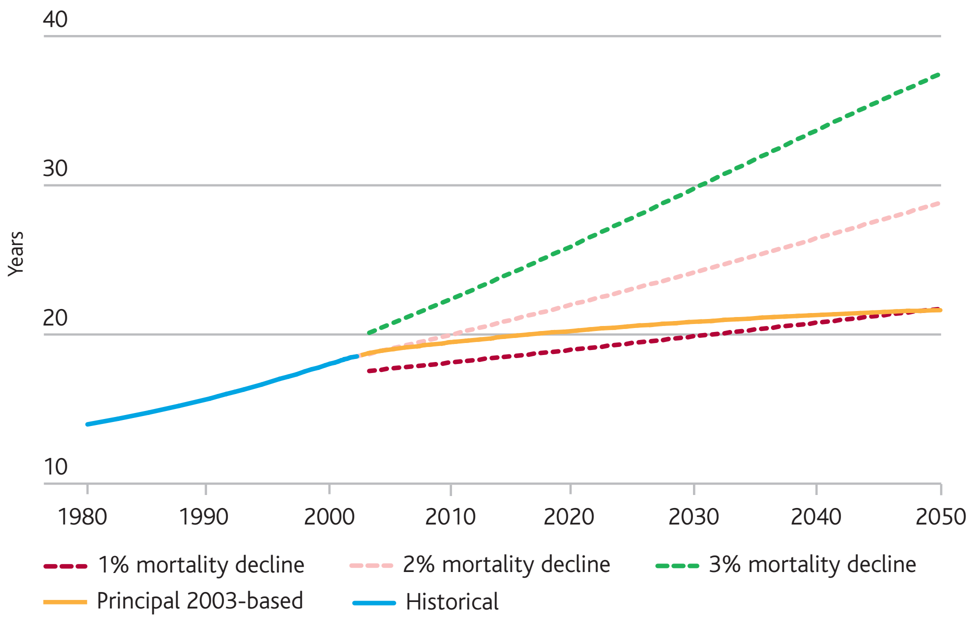
Figure E.3 Past mortality declines at older ages

	Male						Female					
Age	1950s	1960s	1970s	1980s	1990s	Average 1950-2002	1950s	1960s	1970s	1980s	1990s	Average 1950-2002
60-70	0.4%	1.0%	1.2%	2.8%	2.7%	1.6%	1.5%	0.6%	0.4%	1.7%	2.4%	1.3%
70-80	0.2%	0.0%	1.6%	1.8%	3.1%	1.4%	1.3%	1.1%	1.3%	1.1%	2.3%	1.4%
80-90	0.7%	0.6%	0.6%	1.6%	2.0%	1.1%	1.4%	1.3%	1.4%	1.6%	1.3%	1.4%
90+	1.3%	0.6%	0.6%	1.0%	0.7%	0.9%	0.9%	1.1%	0.7%	1.7%	0.1%	0.9%

Source: GAD, England and Wales

Notes: 1950s' improvement compares age-specific mortality rates averaged over 1960-62 with those averaged over 1950-52. A similar method is used for other time periods.

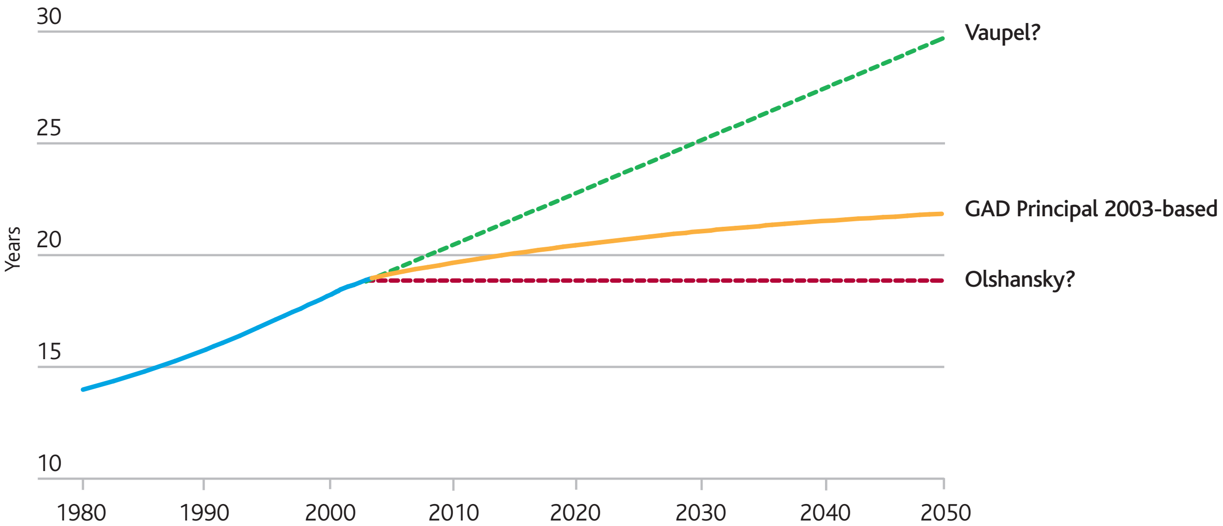
Figure E.4 Male cohort life expectancy at 65: mortality declines and the GAD 2003-based principal projection



Source: GAD, UK

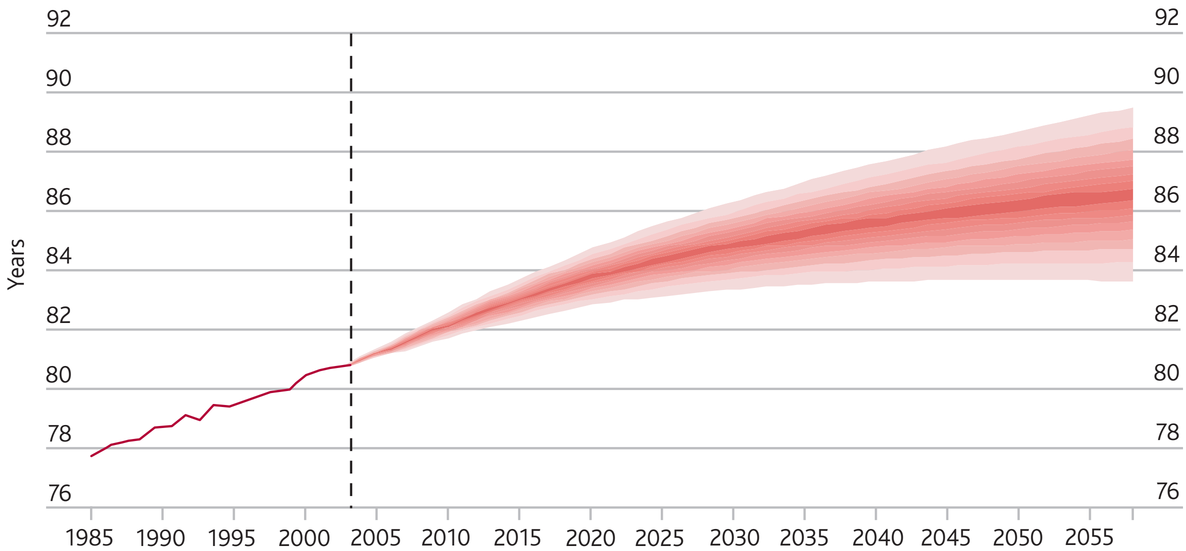
Note: Mortality declines are annual figures i.e. a 2% decline indicates a 2% reduction in mortality every year.

Figure E.5 Male cohort life expectancy at 65: optimists and pessimists



Source: GAD and Pensions Commission estimates, UK

Figure E.6 Female period life expectancy at birth: range of uncertainty



Source: *What Fates Impose*, lecture by Mervyn King, British Academy, 2004

Figure E.7 Error rates in mortality and life expectancy projections: model results

If mortality rate errors, as a percentage of forecast mortality rates, were		Then life expectancy forecast errors would be	Mean male life expectancy at 65 forecast for 2005	2020	2040
1 year ahead	+/-1				
2 years ahead	+2.01/-1.99				
3 years ahead	+3.03/-2.97	Lower mortality	20.5	23.5	26.7
20 years ahead	+22/-18	Base case	19.0	20.3	21.3
n years ahead	$+[(1.01)^n - 1] * 100/$ $-[1-(0.99)^n] * 100$	Higher mortality	17.7	17.8	17.2

Source: GAD, UK

Figure E.8 Actual past differences in mortality rate forecasts

	Mortality rates forecast/measured in year								
	1984	1985	1986	...	1994	...	2004	...	2014
	Actual vs 1983 forecast						2003 forecast vs 1983 forecast		
Male at age 65	-8%	-0%	-3%	...	-17%	...	-41%	...	-46%
Male at age 75	-4%	-1%	-4%	...	-17%	...	-28%	...	-43%
Male at age 85	+2%	+3%	+1%	...	-6%	...	-12%	...	-24%

Source: GAD, UK

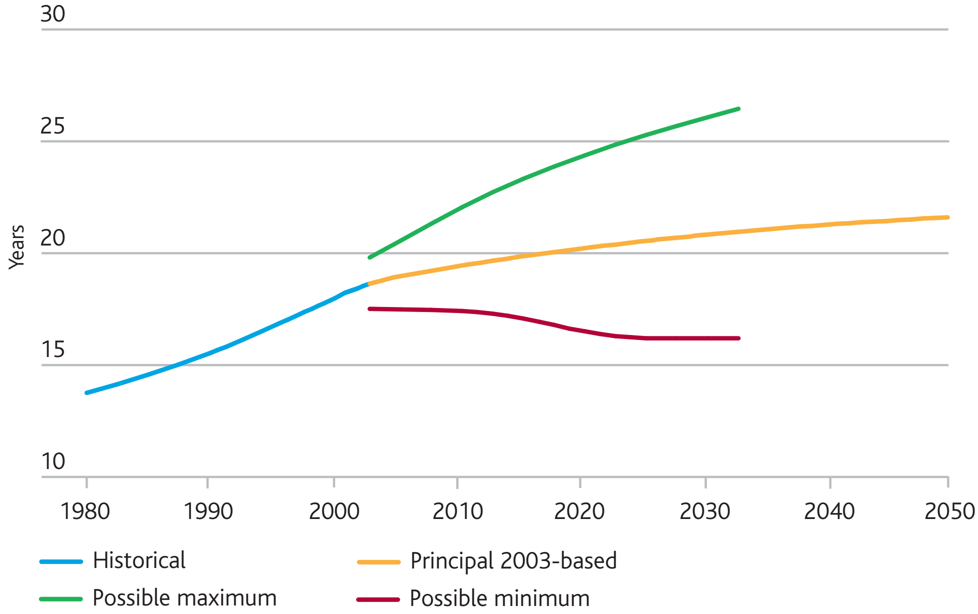
Finally we use the actual error rate profile looking forward from 1983 to estimate the range of uncertainty looking forward from 2003. Figure E.9 shows the results, which illustrate:

- If the errors/changes which have already emerged since the 1983 forecast define the maximum error possible looking forward one year, two years, three years, n years etc;
- And if this error potential is symmetric;
- Then male life expectancy at 65 today could lie in a range 17.6-19.9 years, but by 2033 it could be within a range 16.3-26.5 years.

It is vital, however, to interpret these mathematical estimates of the range of uncertainty correctly. There are four points to consider:

- First, we are dealing with inherent uncertainty not risk. We are not sampling a definitively existing underlying universe. Nor are we even observing a sequence of changing actual variables over time. We are simply comparing our forecast made in one year with our forecast made in another. The Commission therefore tends to the conclusion that we have here no real basis for making a mathematically precise estimate of confidence ranges. Using confidence interval statements to communicate expert judgements may still be valuable, but solely as a communication device.
- Second, we cannot be certain that the maximum error rate potential is revealed by the 1983-2003 comparison. We know that our estimate of the male 65 year old mortality rate in 2014 has fallen by 46% in the 20 years between 1983 and 2003. But it could perhaps fall still more by the time we get to 2014. For any year more than 20 years in the future there is no reason to believe that changes to the forecast between 1983 and 2003 define the maximum possible error, even if past performance carries implications for the future.
- Third, we need to think through whether the error potential looking forward is symmetric around the base case or asymmetric. When the Commission concluded this analysis we suspected that the range was asymmetric around the 2003-based principal projection. In the past 20 years of course the errors have been all one way. That does not necessarily imply that they will be one way in the future: our principal projection may now be a best average expectation. But note that the symmetrical application of uncertainty in Figure E.9 implies a lower bound that predicts actual falls in life expectancy, while the range of scientific and medical dispute is predominantly between stability and further increases. And note that the 2003-based principal projection already assumed a limit to life, albeit over a longer term than was assumed in 1983. The Commission's judgement was that around the 2003-based principal projection we were more likely to see errors that increased life expectancy than decreased it.

Figure E.9 Male cohort life expectancy at 65: estimates of uncertainty



Source: GAD and Pensions Commission estimates, UK

Note: Figure shows the uncertainty in 2003-based forecasts if already apparent 1983 errors/changes are the maximum possible and if error potential is symmetrical.

- But finally, the Commission suspects that over the next 20 years we are unlikely to see the emergence of errors quite as large as emerged within the first 20 years after 1983. Between 1983 and 2003 the principal projection was changed from a very strong version to a weaker version of the limit-to-life hypothesis. And errors as large and in the same direction as emerged between 1983 and 2003 would now, looking forward, imply actual acceleration of mortality rate declines and life expectancy increases, not just a continuation of the trend. The Commission's judgement was therefore that the 2003-based principal projection was likely to prove more accurate over the next 20 years than the principal projection did between 1983 and 2003. But beyond the next 20 years, compared with a base case that assumes a rapidly decelerating mortality rate decline, there is no reason to believe that errors could not be as large as they were in the past.

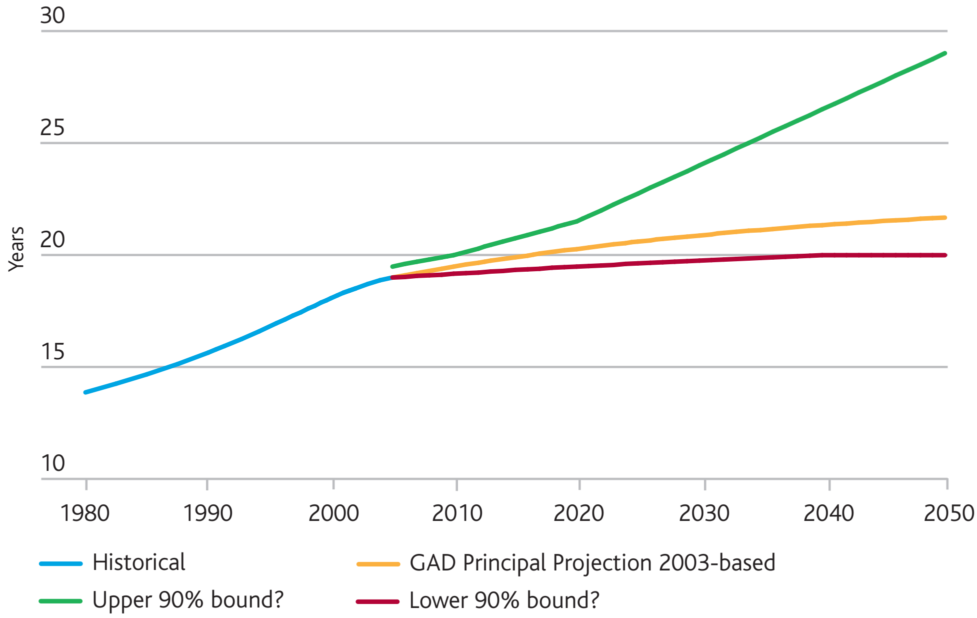
Taking these considerations together, a reasonable judgement on uncertainty **might** be as shown in Figure E.10, with a somewhat predictable development over the next 10-15 years or so, but with increasing uncertainty thereafter, and with male life expectancy at 65 in 2050 anywhere from 20 to 29 years. As a judgement one might say that this range defines a 90% confidence interval. But a judgement is all that would be, since the Commission believes that no mathematically precise definition of risk is possible.

3. Comparison of the Pensions Commission's hypothetical range of uncertainty and GAD's 2004-based principal projection

Since the analysis outlined above was undertaken, GAD has changed the mortality assumption used in the principal projection. The new projections assume that mortality rates at each age will converge to a common rate of improvement of 1% a year at 2029 and continue to improve at that constant rate thereafter. In the 2003-based projections, the rate of improvement was assumed to halve every subsequent 25 years, that is from 1% a year by 2028 to 0.5% a year by 2053. As a result of the new more optimistic long-term assumptions, life expectancy forecasts, for both men and women, have increased significantly.

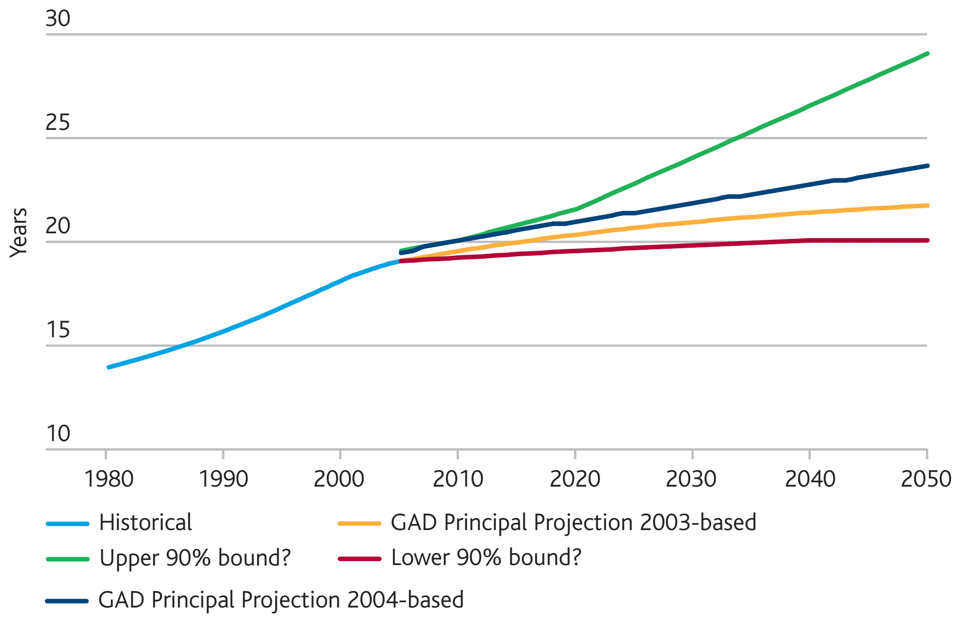
Figure E.11 shows how the new 2004-based principal projection fits within the results of our previous analysis. The 2004-based projection is now closer to the middle of our range of uncertainty than the previous projection, providing support for our hypothesis that the uncertainty range around the 2003-based projection was asymmetric.

Figure E.10 Male cohort life expectancy at 65: range of possible uncertainty



Source: GAD and Pensions Commission estimates, UK

Figure E.11 Male cohort life expectancy at 65: range of possible uncertainty around 2004-based principal projection



Source: GAD and Pensions Commission estimates, UK

4. Latest developments from the Continuous Mortality Investigation (CMI)

The Continuous Mortality Investigation (CMI) is the largest single research project organised by the UK actuarial profession. It has been accumulating and analysing data on mortality and morbidity risks arising under life assurance, annuity and pension business for over 80 years. In September 2005 it published proposed new mortality tables (the "00 series" tables) for pensioners in receipt of private pensions, a subset of the total population. The new tables, based on data from the four year period 1999-2002, show mortality rates around 30% lower than those in the previous tables (the "92 series" tables, which were based on data for 1991-94) for both males and females in their late 60s. This represents an improvement rate of over 4% per year in mortality. Mortality rates at older ages have also improved, but less dramatically.

At the same time the CMI presented to the profession its latest thinking on how to take account of uncertainty in future mortality. It stressed the uncertainty surrounding any projections of future mortality. It does not therefore propose to publish a single projection of future mortality, or even a single methodology for doing this, alongside the new tables. Instead it stresses that actuaries and other professionals using mortality projections must consider a range of scenarios to reflect the uncertainty in the projections.

It illustrates this uncertainty with an example based on a simple extrapolation of the recent trends in CMI mortality rates. On these assumptions, a 65 year old man may now expect to live on average until he is 86 years and seven months – an increase of 3.5 years since the previous tables were published. But even if recent trends continue and the model used remains valid, the CMI argues that the range of uncertainty could stretch from 85.5 to 88 years. New trends, or the recognition of trends that have not been identified, could invalidate the model and result in figures outside this range. The CMI thus believes that the range of uncertainty about the life expectancy of a 65 year old **today** is wider than our hypothetical range suggested.

The work of the CMI is continuing. But it notes that there are no magic answers when it comes to projecting future mortality. Its proposed stochastic methodologies should not be seen as a means of supplying definitive answers to questions that have strong subjective elements. This is in line with our own conclusion that there is large inherent uncertainty in future estimates of life expectancy, and that while stochastic techniques can be used to illustrate that uncertainty, they cannot give us quantitatively precise measures of the confidence ranges of future projections.

5. Conclusions and recommendations

Both our work with GAD and that of the CMI have illustrated the large uncertainty involved in estimates of life expectancy: these are considerable even when estimating the life expectancy of a 65 year old man or women today: but the uncertainties increase dramatically as we look into the future. Two sets of recommendations follow:

- Official publications which set out estimates of projected life expectancy should ideally provide not only the best mean estimate, but also the range of possible results which could arise from alternative reasonable assumptions. The GAD publications already include high and low variants: these should be given wider publicity.

- Pension systems (state and private) must be resilient in the face not only of rising life expectancy, but of large uncertainty over how rapid the rise will be. This implies that pre-retirement longevity risk should be shifted from the pension provider to the individual, either via linking future pensionable ages to future presently unknown increases in life expectancy, or by moving to 'Notional Defined Contribution' systems of the sort described in Chapter 1 Section 5.