Fifty years of United Kingdom national population projections: how accurate have they been?

Chris Shaw
Office for National Statistics

This article considers the accuracy of the official national population projections made for the UK over the last fifty years. The findings take account of the revisions to population estimates following the 2001 Census and are largely similar to the findings of a previous review carried out after the 1991 Census. The total population has been projected reasonably accurately but this is largely a chance result of compensating errors in the assumptions of fertility, mortality and net migration. The largest differences between projected and actual populations are for the very young and the very old, while projections of the working age population have been comparatively accurate. Fertility and mortality errors have reduced in more recent projections, while migration errors have grown. However, this may simply reflect the volatility or stability of the respective time-series at the time the projections are made. Changes in estimates of the past and current size of the population (highlighted by the revisions made to population estimates following the 2001 Census) are also shown to play a part in explaining projection error.

Background

The primary purpose of the national population projections is to provide an estimate of the future population of the UK as a common framework for planning in a number of different fields. The projections are based on assumptions judged to be the best that could be made at the time they are adopted. However, due to the inherent uncertainty of demographic behaviour, any set of projections will inevitably be proved wrong, to a greater or lesser extent, as a forecast of future demographic events or population structure.

It is often said, however, that projections are not forecasts. So, strictly speaking, a population projection is simply the outcome of a given set of assumptions and (aside from the possibility of computational error) cannot be 'wrong'. However, as argued elsewhere,[1] the makers of projections which will be used to develop government planning 'must accept the responsibility that [the projections] will be used as forecasts.' This article, therefore, considers how well the principal national projections have performed as forecasts or predictions of the future population. (Variant projections – see Box One – based on alternative assumptions are also produced[2] but are not discussed further in this article.) To that end, the terms 'projections' and 'forecasts' are used interchangeably in this article and the term 'errors' is used to describe differences between projected and actual demographic change. A full description of other terms used in this article is provided in Box Two.

Periodic reviews of the accuracy of past projections are useful both for projection makers (in identifying areas where improvements may be made) and for projection users (in giving an indication of the uncertainty associated with forecasting demographic variables). An obvious time for carrying out such reviews is when population estimates are rebased following a new census. It is at that time, that the size and age structure of the population should be best estimated. A previous review was published in 1994 following the results of the 1991 Census.[3] The present article follows the 2001 Census rebasing and the subsequent revisions made to population estimates in 2003 and 2004.

This is also an appropriate time to take stock of national population projections as responsibility for their production was transferred in January 2006 from the Government Actuary's Department (GAD) to the Office for National Statistics (ONS). GAD became responsible for the production of the official UK national projections in 1954 and the final projection produced by GAD was the current 2004-based set published in October 2005. This article, therefore, considers the performance of fifty years' of national projections. The analysis in this article is based on a historical projection database created in 2006 and available on the GAD website (see Box three).

The national population projections are produced for the UK and each of its four constituent countries. This article considers only the projections made for the UK as a whole. However, where possible, equivalent analyses to those presented in this article have been prepared for each of the four countries and these will be made available on the GAD website.

Box one

Variant projections and stochastic forecasting

Considering the performance of past projections is one way of demonstrating the uncertainties inherent in population forecasting. Another way is by providing 'variant' projections based on alternative assumptions about future fertility, mortality and migration to those assumed in the principal or central projection. In the UK, such variant projections are routinely produced to accompany each set of new projections.[2]

The purpose of these variants is to illustrate plausible alternative scenarios and *not* to represent upper or lower limits for future demographic behaviour. Indeed, the cohort component method used in the UK (and almost universally) to produce population projections does not allow statements of probability, or confidence intervals, to be ascribed to them.

Internationally, growing attention is now being given to stochastic projection methods which aim to give users information about the expected accuracy of projections. Typically, stochastic forecasts use probability distributions for indicators of fertility, mortality and migration which are derived from some combination of three approaches:

- analysis of past projection errors (as discussed in this article)
- expert opinion (expert views on UK confidence intervals have been obtained from the National Population Projections Advisory Panel[A])
- time-series analysis

ONS are now considering the use of such methods in the UK.

A See www.gad.gov.uk/Population/2004/methodology/expert.htm

Box two

Terminology

In this article, we look at how the projections have performed as predictors of future population change. For a number of different *variables* (total population, TFR, births etc), we have analysed the projection error according to forecast duration. Two main related measures are considered, the mean error and the mean absolute error.

The *projection error* is calculated to be the projected value of a variable minus its actual value as currently estimated. (These 'actual' values may, of course, in some cases have been revised or be subject to further revision, for example, following Censuses.) A positive error is, therefore, an *overprojection*, that is, the projected value exceeded the actual value and a negative error is an *underprojection*. However, overprojections of deaths are shown as negative numbers in Figure 2 as they contribute to an underprojection of the size of the total population.

The *forecast duration* is the difference between the base year of the projection and the calendar year for which the particular variable is projected. For example, the 1981-based projection of the total population at the year 2001 has a forecast duration of twenty years. For the analyses of births and TFR in Figure 4 and deaths and life expectancy at birth in Figure 5, adjoining mid-year projections have been averaged to provide calendar year figures which are compared to actual calendar year data. The migration analysis in Figure 6 is slightly different. In this case, the comparison of actual and projected data is on a mid-year to mid-year basis and the 1981-based projection for 1981–82 is defined as having a forecast duration of one year, etc. Projection assumptions are compared with actual estimates of migration and other changes (see Box four); this could only be done on a mid-year basis as 'other changes' estimates are not available for calendar years.

For each projection error and forecast duration, we have a series of *observations*. So if we are considering the accuracy of projections of the total population twenty years ahead, we have the 1985-based projection for 2005, the 1983-based projection for 2003 and so on. The number of observations obviously depends on the forecast duration. The longer the forecast duration, the fewer observations we have. We can look at the accuracy of projections one year ahead for all the projections in the database, but we can only assess the accuracy of projections thirty years ahead from the 1975-based and earlier projections.

The *mean error* is the average of the projection errors for a particular set of observations and the *mean absolute error* is the average of the projection errors irrespective of sign. For example, suppose we only have observations from the 1971-based, 1973-based and 1975-based projections for the projection error for a particular variable thirty years ahead. If these errors were +10 per cent, +5 per cent and -3 per cent respectively, then the mean error is 4 per cent and the mean absolute error is 6 per cent. The mean error gives us a measure of *bias*; it tells us that, on average, this variable was overprojected by 4 per cent. The mean absolute error gives us a measure of *precision*; it tells us that, on average, the difference between the projected value and the actual value was 6 per cent. In this article we only present these mean errors where we have a minimum of five observations.

The number of observations depends not only on the forecast duration, but also on the variable we are looking at. We have near complete information on all the variables of interest back to the 1971-based projections. But we also have information on some variables from some earlier projections. In this article, we have generally tried to use the maximum amount of information available to us. But this means there are sometimes inconsistencies in the analysis of related variables. For example, we have information on projected births, but not the assumed TFRs, for pre-1971 projections. So we can analyse the accuracy of birth projections for slightly longer durations than we can for the TFR and we have more observations for shorter durations. But it needs to be borne in mind that the fertility assumptions made at the peak of the 1960s baby boom had particularly high errors, so including 1960s projections in a particular analysis may inflate estimates of error.

Box three

Historic projections database

Comprehensive details of past national population projections are available from the historic projections database available on the Government Actuary's Department's website.[A]

GAD became responsible for the production of the official UK national projections in 1954. Projections were produced every year from a 1954-based set until the 1979-based set. They were then produced every second year until the 1991-based set. There was then a 1992-based set, since when 'full' projections have again been produced every second year until the 2004-based set. In the intervening year between full projections, 'interim' sets of national projections may be produced. An interim set of 2001-based projections was produced shortly after the publication of the first results from the 2001 Census and an interim set of 2003-based projections was published in 2004 following significant revisions to the starting population on which they were based.

The database provides detailed information on most national population projections produced since the early 1970s. It includes the projections made at two yearly intervals from the 1971-based set to the 1991-based set, followed by the 1992-based and all subsequent sets. This section of the database contains projections for both the United Kingdom as a whole and for the four constituent countries. For the 2000-based set onwards, variant projections are provided as well as the principal (central) projections.

For all projections from the 1971-based set to the 1998-based set, the database gives projected populations by five-year age group as well as components of change and summary indicators such as total fertility rates and (period) life expectancy. These older projections are presented in the same format as has been used for more recent projections, which were made available online at the time of their publication. In addition, the 2000-based and later sets also include more detailed results, such as assumed age-specific fertility and mortality rates.

Only very limited information survives from the projections made before the 1970s. But the database includes, for the UK and England & Wales (combined) only, projected populations by five-year age group from the first (1954-based) official projection made by GAD and every second projection from the 1955-based set to the 1969-based set.

For any enquiries about the historical projections database, please contact natpopproj@ons.gsi.gov.uk

A For further details see www.gad.gov.uk/Population_Projections/Historical_population_projections.html

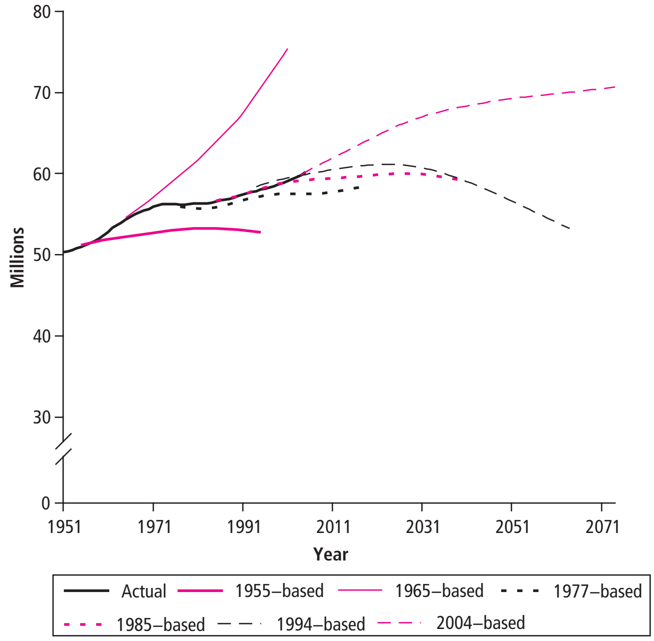
Projections of the total UK population

Figure 1 shows the future population of the UK from projections made at roughly ten year intervals during this 50 year period. Clearly, the six projections shown are very different from each other!

The potential scale of errors in long-term population forecasting, and the crucial importance of the level of fertility in determining future population size, are clearly demonstrated by the 1955-based and 1965-based projections.

Figure 1 **Actual and projected population, 1951–2074**

United Kingdom



The 1955-based projection (the second official projection to be made by GAD and the first for which we have information up to forty years ahead) produced the lowest future population sizes of any official projection. The projected population for 1995 was under 53 million, over five million below the actual figure. While mortality improvement, and probably net migration, were also underestimated in this projection, by far the major explanation is that the 1960s baby boom was not foreseen. A similar failure to anticipate the baby boom has been observed in some other western countries where records of old projections are available.[4]

As fertility rates gradually rose from the mid 1950s to the mid 1960s, so the official projections made higher assumptions about future fertility and the projected future population rose dramatically. The actual TFR rose steadily from 2.28 in 1955 to reach a peak of 2.97 in 1964. Although we have extremely limited information on the assumptions made at the time, the 1965-based projection must have assumed (explicitly or implicitly) that the TFR would remain at around three children per woman. In fact, it fell sharply from its 1964 peak to a (then) record low level of 1.69 in 1977. Again, similar errors were made in other countries. An analysis of projections made in Western countries shows that birth rate predictions made in the 1960s were up to 80 per cent too high.[5]

In the 1965-based projection, over 1.5 million births were projected for the year 2000, well over double the actual figure. As a result, the 1965-based (and 1964-based) projections produced the highest future population sizes of any official projections. According to these projections, the UK population was going to be around 75 million by the year 2000 when it would be increasing by almost one million a year. The population at 2000 turned out to be just 59 million. To put this in context, the 1965-based projection for the year 2000 was far higher than our current principal projection for the year 2074 even though we are now, once again, allowing for continual population growth over the next seventy years.

By the time of the 1977-based projections, replacement level fertility was assumed for the long-term. This projection also assumed long-term net outward migration whereas the mid 1960s projections had assumed modest net inward flows. Although the 1977-based projection did envisage a rising population over the next forty years, the projection of 57.7 million for the year 2011 was the lowest made for that year in any official projection.

Fertility assumptions have been reduced further since the 1977-based projections and are now well below replacement level. However, this has been more than offset by higher life expectancy and migration assumptions. As a result, the projected future population has tended to increase in successive projections, especially over the last ten years. However, until the 2004-based set, the assumption of long-term below replacement level fertility meant that the population was eventually expected to peak in size and then begin to decline. But the increases in life expectancy and migration assumptions made in the 2004-based projections mean that the latest projections envisage a continually increasing population over the next seventy years.

Sources of error in projections

Errors in projections of the total population are mainly a consequence of errors in the projections of the three components of population change (births, deaths and net migration). However, as noted in Box Four, revisions to the population estimates on which the projections were originally based also contribute to projection error. Figure 2 shows the errors in the projected total size of the UK population at mid-2005 for selected projections beginning with the 1971-based set, broken down into these various components.

The estimated population of the UK at mid-2005 was 60.2 million. The projections made over the previous thirty-four years had ranged from a maximum of 64.3 million in the 1971-based set (6.8 per cent too high) to a minimum of 57.5 million in the 1977-based set (4.4 per cent too low). Aside from the 1971-based set, all projections made in the 1970s and 1980s underprojected the total population in 2005. Since the 1991-based set, there have been errors in both directions.

Figure 2 shows that the errors in the 1970s and 1980s projections were due to overprojections of births offset by errors in the projections of deaths and net migration. (Note that the generally 'negative' errors shown for deaths mean that too *many* deaths were projected. These errors are shown as negative in the graph as they lead to the future population size being underestimated.)

Generally, the total errors in births, deaths and migration diminish with successive projections as they cover shorter periods of time (the 1971-based projection for 2005 covers a thirty-four year period, but the 1975-based projection for 2005 covers only a thirty year period, etc). Indeed, the birth and death errors from the 1996-based and 2000-based projections have been relatively small.

However, for projections made between the 1991 and 2001 Censuses, there was a substantial, and consistently growing, base population error. The 2001 Census showed that the population estimates rolled forward from the 1991 Census (on which the projections made between the Censuses had been based) had increasingly overestimated the population of the UK (see Box Four, Figure A). This base population error showed that *past* net migration had been overestimated and, hence, 1991–2000 migration estimates were revised down following the 2001 Census. However, the base population error was offset by the continuing underprojection of *future* net migration during this period. And for the 2000-based projection (the last before the 2001 Census), the subsequent revisions to population estimates are by far the major source of error in the projection for the year 2005.

Headline assumptions

Table 1 summarises the headline assumptions regarding fertility, mortality and migration made in the projections at four yearly intervals from the 1971-based set up to the latest 2004-based set. The total fertility rate (TFR) and the (period) expectation of life at birth (EOLB) provide convenient summary measures of the age-specific fertility and mortality rates assumed for future years. The TFR gives the average number of children that would be born to women if they were to experience the age-specific fertility rates assumed for the year in question throughout their childbearing years. Similarly, the (period) expectation of life at birth gives the average number of years that new born boys or girls would live if they were to experience the assumed age-specific mortality rates of the year in question throughout their lives.

There are analogous *cohort* measures for both fertility and mortality. In particular, it is important to note that the *period* expectations of life shown in Table 1 do not allow for actual or assumed changes in mortality rates beyond the year in question. For example, as shown in Table 1, the period expectation of life at birth in 2001, based on the mortality rates actually experienced in that year, was 75.8 years for males and 80.5 years for females. However, allowing for the improvements in mortality which have already occurred between 2001 and 2005 and which are currently assumed (in the latest 2004-based projections) to occur beyond 2005, an average boy born in 2001 could, in fact, expect to live to nearly 86 and an average girl to over 89. More information on the difference between period and cohort life expectancies is available on the GAD website.[6]

Information on the assumed cohort levels of fertility and life expectancy are routinely provided in the reference volumes accompanying each set of national projections.[7] Indeed, fertility assumptions are formulated on a cohort rather than period basis with annual TFR figures being derived from the assumptions made about the average family size of women born in particular years. However, the actual final value of these cohort statistics cannot be known for many years to come (in the case of life expectancy, not until all members of the cohort have died). Comparison of actual and projected assumptions on a cohort basis is therefore not straightforward and is not attempted in this article.

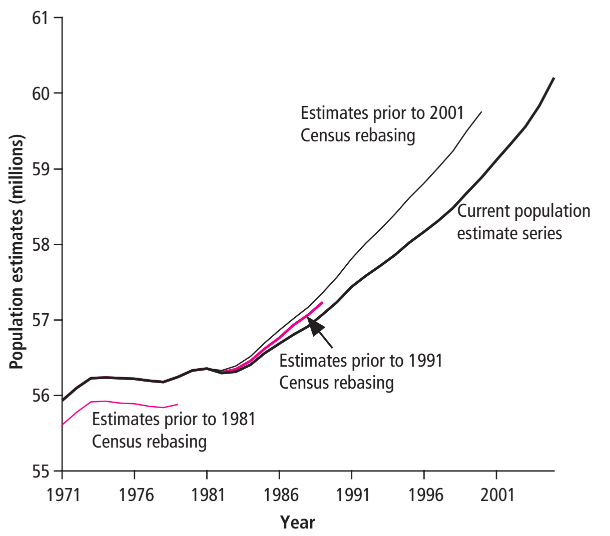
Table 1 shows that fertility assumptions have been gradually reduced over the last thirty years from an above replacement assumption in the 1971-based set (and undoubtedly even higher levels in the projections made in the 1960s) to the present long-term assumption of 1.74 children per woman. Mortality assumptions became more pessimistic in the early 1970s, but since the 1977-based set consistently higher assumptions about future life expectancy have been adopted. And assumptions about future net migration have changed dramatically. All projections made in the 1970s and early 1980s assumed long-term net outward migration in line with the long-term historical trend for the UK to lose population through migration.[8] However, the latest projections assume that net inward migration will continue at levels that were never experienced in the UK prior to the last few years.

Box four

Revisions to population estimates

Changes to the expected future course of fertility, mortality and migration are not the only potential sources of error in population projections. Each projection is based on the latest estimate of the size of the population and its age structure. However, these estimates can be subject to later revision. Each census provides a new benchmark for rebasing the annual population estimates, removing errors which have accumulated during the annual updating process, due to gaps or imperfections in the data available. Figure A illustrates the revisions that have been made after the last three censuses.

Figure A Revisions to population estimates



Note
The graph shows estimates up to 1980 based on the 'home' population definition. This differs slightly from the 'total' population series actully used as the basis for projections up to the 1979-based set. See text of Box four for further explanation.

These revisions are generally small relative to the other sources of error in the projections. However, normally they grow in significance during the intercensal period and therefore tend to be at their greatest immediately prior to the carrying out of a new census. For example, the original mid-1989 population estimate of 57.2 million was revised upwards to 57.4 million following the 1991 Census although it was later revised back down to 57.1 million (that is, below the original estimate) after the 2001 Census. The effect of rebasing after the 1981 Census was somewhat different. In this case, the main impact was an upward revision of about 300,000 to the mid-1971 population base.

However, the most significant revisions followed the 2001 Census which revealed the population to be significantly smaller than had been expected based on the estimates rolled-forward from 1991.[A] So the original mid-2000 population estimate of 59.8 million used as the base for the 2000-based projections has subsequently been revised down by almost a million to 58.9 million.

'Home' and 'total' population

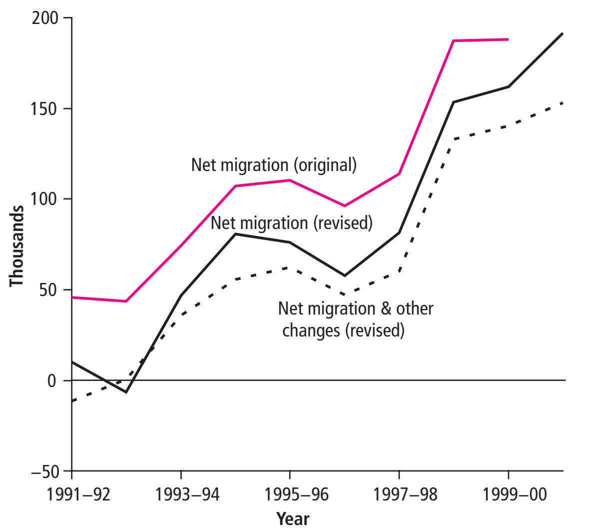
A further complication in assessing the accuracy of older projections is that, up to 1980, population estimates were published both for the 'home' population and for the 'total' population. The 'total' population was larger, primarily as it included UK armed forces stationed abroad. Since 1980, only a single set of population estimates has been produced. These are consistent with the old 'home' population definition, that is, excluding UK armed forces stationed abroad. However, prior to 1980, the higher total population series was used as the base for national projections. The difference between the total and home population estimates gradually reduced from about 250,000 at mid-1955 to about 60,000 by mid-1979.

Revisions to migration estimates

Revisions to population estimates are often due to errors in the estimation of migration which is by far the most difficult component of population change to measure. Revisions to population estimates are, therefore, often accompanied by revisions to migration estimates. In particular, following the overestimation of the population revealed by the 2001 Census, the estimate of net international migration for the whole of the 1991–2001 intercensal period was revised downwards by a total of about 350,000.[B] In addition, some 209,000 of the 1991–2001 discrepancy remains unexplained. This is included in the 'other changes' category in official components of change tables along with changes in the number of Armed Forces and other adjustments.

Figure B compares the original migration estimates for 1991 to 2001 with the revised migration estimates and with the 'migration plus other changes' series. In this article, to ensure a comprehensive coverage of all elements of population change, projections of net migration have been compared with current estimates of net migration plus other changes.

Figure B Revisions to migration estimates following 2001 Census

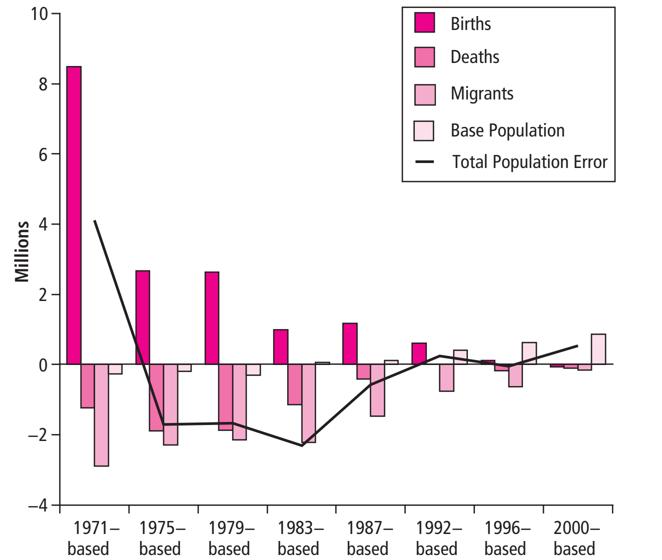


Fertility and mortality rates

Estimates of births and deaths are considered to be measured very accurately and are rarely subject to any kind of revision. However, estimated fertility and mortality rates change when revisions are made to the population denominators. Potentially, therefore, significant revisions to the estimated number of women of childbearing age or to the estimated size of the elderly population could affect the analysis of fertility and mortality trends on which assumptions are based. In practice, however, past revisions to population estimates have tended to be focussed on young adult males and so the effect of revisions on fertility and mortality assumptions has been minor.

A Office for National Statistics (2004) *Methodology for producing revised population estimates for 1992 to 2000.* Available from www.statistics.gov.uk/about/data/methodology/specific/population/PEMethodology/
B Office for National Statistics (2003) *Revised international migration estimates 1992–2001 ONS First Release* (12 June 2003).

Figure 2 Error in projected UK population at 2005 by component, selected projections



Total population

Figure 3 shows the bias and precision estimates (see Box Two) for the projections of the total population of the UK. The mean error (Figure 3a) is positive except at a few durations around twenty years ahead, that is, there has been a tendency for the UK population to have been overprojected. As we will see later in the article, this has arisen primarily because births have tended to be overprojected. Subsequent downward revisions to population estimates following the 2001 Census also played a part. This has more than offset the effect of a general overprojection of deaths and underprojection of net migration.

The precision chart (Figure 3b) shows, as might be expected, that the projection error increases with time. On average, the mean absolute error has been about half a million after eight years and about one million after sixteen years. The peaks in the precision chart at ten, fifteen and twenty years duration simply reflect the fact that we have extra observations for these durations from projections made in the 1950s and 1960s where errors were relatively high. There is a steeper gradient in the line for durations beyond twenty years ahead. By definition, we only have information on these longer durations from older projection sets.

The very oldest projections in the database enable us to give error estimates for thirty and thirty-five years ahead. The latter is strongly

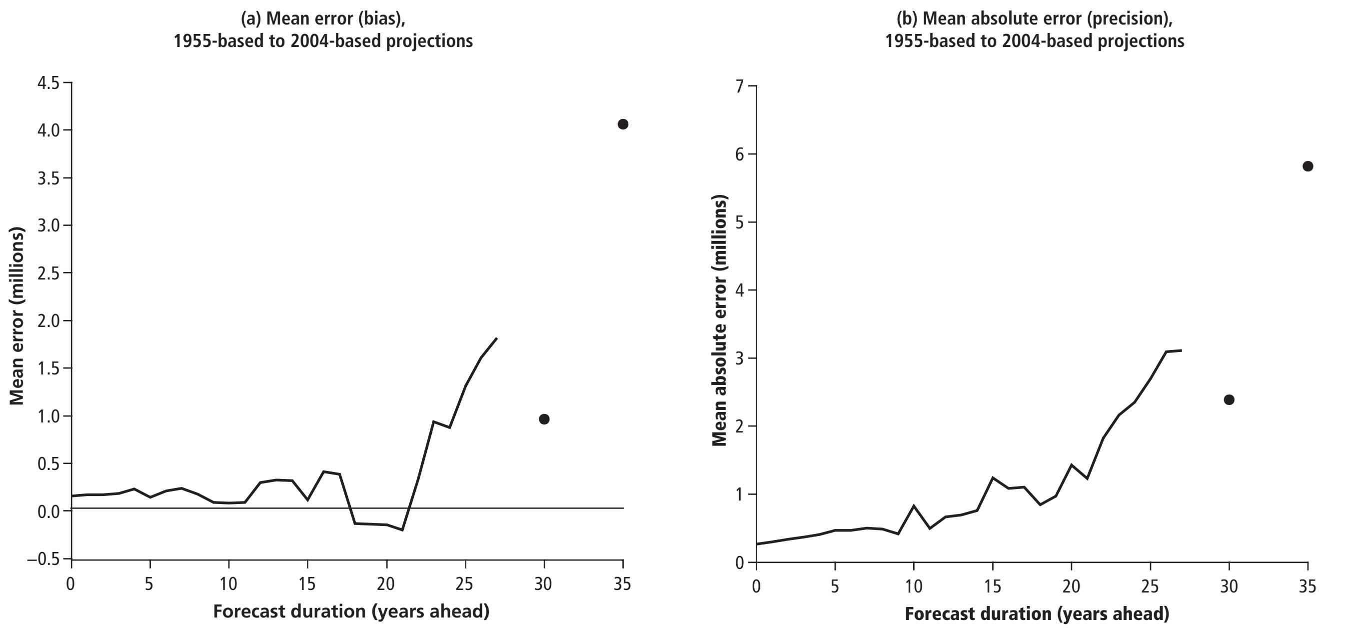
Table 1 Assumptions in past population projections

United Kingdom

	Base year for projections								
	1971	1975	1979	1983	1987	1992	1996	2000	2004
Total fertility rate									
Projection for 1991 (actual = 1.82)	2.34	2.12	2.12	1.90	1.89	-	-	-	-
Projection for 2001 (actual = 1.63)	2.33	2.12	2.12	2.05	2.00	1.90	1.76	1.65	-
Projection for 2011	2.32	2.12	2.12	2.10	2.00	1.90	1.80	1.73	1.73
Projection for 2021	-	-	-	2.10	2.00	1.90	1.80	1.74	1.74
Period expectation of life at birth (males)									
Projection for 1991 (actual = 73.1[1])	71.0	69.8	70.2	71.6	73.0	-	-	-	-
Projection for 2001 (actual = 75.8[1])	71.9	70.4	70.6	72.3	73.8	75.4	75.3	75.7	-
Projection for 2011	72.6[2]	71.0	71.1	73.0	75.1	76.8	76.9	77.4	78.5
Projection for 2021	-	-	-	73.7	75.6	77.6	77.9	78.6	80.2
Projection for 2031	-	-	-	73.8	75.7	78.2	78.5	79.3	81.4
Period expectation of life at birth (females)									
Projection for 1991 (actual = 78.6[1])	77.6	76.1	76.4	77.6	78.7	-	-	-	-
Projection for 2001 (actual = 80.5[1])	78.6	76.7	76.9	78.3	79.7	80.6	80.2	80.4	-
Projection for 2011	79.4[2]	77.4	77.3	78.9	80.2	81.9	81.5	81.6	82.3
Projection for 2021	-	-	-	79.6	80.5	82.7	82.6	82.8	83.9
Projection for 2031	-	-	-	79.8	80.5	83.2	83.3	83.6	85.1
Net migrants (000s)									
Projection for 1991 (actual = 10[3])	–50	–32	–30	–27	0	-	-	-	-
Projection for 2001 (actual = 163[3])	–50	–32	–30	–27	0	50	65	155	-
Projection for 2011	–50	–32	–30	–27	0	25	65	135	145
Projection for 2021	-	-	-	–27	0	0	65	135	145

Note: The calendar year assumptions are the average of those for the adjoining mid-year to mid-year periods e.g. the assumptions for 1991 are the average of those for 1990–91 and 1991–92.
1 Actual data for 1991 and 2001 are based on the mortality rates for those single years and differ slightly from the three year averages given in Table 5.1 (page 60).
2 Projection for 2010–11
3 Three-year averages used because of fluctuations in annual data. 1991–93 used instead of 1990–92 as no estimate is available for 1990 on the present method of calculation of total international migration estimates. These actual figures do not include any allowance for 'other changes' (see Box four).

Figure 3 Accuracy of projections of total population size



influenced by the inclusion of the 1965-based projection of the population at 2000. This projection, made at the peak of the baby boom, overprojected the population at 2000 by nearly 16 million! While errors of this size are clearly untypical, they are useful in illustrating the considerable errors that can occur in projections in exceptional circumstances. Generally, it should be borne in mind that the results for longer durations are only based on a small number of observations (results are only shown where we have a minimum of five) and can be skewed by the influence of one or two projection sets. For example, the underprojections at around twenty years ahead seen in the bias chart are largely due to the influence of large negative errors from the 1983-based projection.

An analysis of the accuracy of United Nations and World Bank projections in western countries has shown mean absolute errors for the total population rising to around five per cent after twenty years.[9] The mean absolute error of the projected total UK population twenty years ahead from the projections considered in this article is slightly lower at about 2.5 per cent (see Figure 8a). This may be partly due to the UK's relatively large population size. Larger populations may be easier to project as the relative importance of migration (the most uncertain of the components of population change) tends to increase with smaller population size.

Fertility

Total fertility rate

Figure 4a shows the key changes that have been made over the last thirty years to the assumptions about the future total fertility rate (see also Table 1). The 1971-based projections (the earliest in the historical database for which we have details of assumed fertility *rates*) assumed that the TFR would remain fairly constant with an assumed long-term level of just over 2.3.

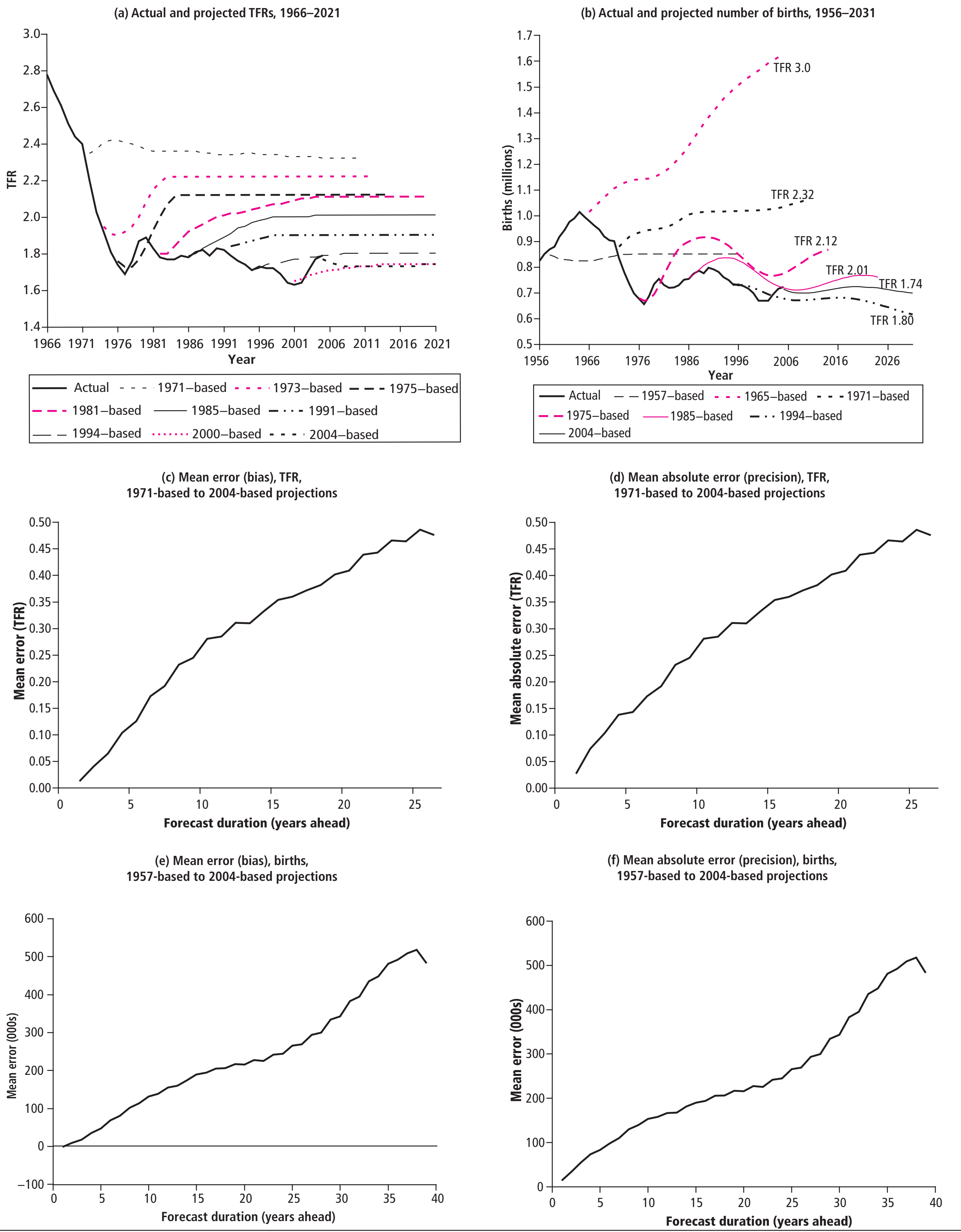
The long-term assumption has been gradually reduced in subsequent projections. A lower long-term assumption of just over 2.2 was used in the 1973-based projections, but the reductions in short-term assumptions were substantially greater. It was again reduced, to around 2.1, in the 1975-based projections. This is approximately 'replacement level' fertility – the level which leads to the long-term 'natural' (that is, ignoring migration) replacement of the population. The 1985-based projections were the first to assume long-term fertility at below replacement level. Since then, there have been further reductions with the present long-term assumption of 1.74 children per woman first adopted in the 2000-based projections. The long-term assumption was not changed in the current 2004-based set, but higher short-term assumptions were adopted following the rise in fertility seen in the last few years.

Since the 1973-based set, all projections (aside from the current 2004-based set) have assumed some upturn in fertility rates from contemporary levels. Over the last thirty years, it has generally been thought that the TFR is likely to understate the underlying 'true' level of fertility because of the effects of delayed childbearing. This is because period measures of fertility such as the TFR are affected by changes in the timing of births as well as their number.[10] Logically, postponement of childbearing cannot continue indefinitely and, when this process ends, period fertility rates are likely to rise. However, this does not appear to be the explanation for the recent rise in the TFR (an increase of 0.15 between 2002 and 2005). Fertility rates have been rising at all ages over 20 and the mean age at childbearing continues to increase. But whether or not this recent increase is a temporary 'blip' (a similar rise in the late 1970s was not maintained) or heralds a sustained higher level of fertility remains to be seen.

Births

Figure 4b shows the actual and projected number of births. Generally, trends in the projected number of births follow those for the assumptions made about the TFR (the long-term TFR assumption for each projection is shown on the chart). However, the future number of births depends on the (projected) future number of women of childbearing age as well as the assumptions made about fertility rates. This explains why, for example, future births are higher in the 2004-based projections than in the 1994-based set even though the long-term TFR assumption is lower (1.74 compared with 1.80). The projected population of women of childbearing age is much higher in the 2004-based projections because net migration at these ages has been, and is assumed to continue to be, much higher than was assumed ten years ago (see below).

Figure 4 Accuracy of fertility assumptions



Although we do not have details of the underlying assumptions of fertility rates for the projections made in the 1950s and 1960s, we do have information on the projected number of births. The 1957-based and 1965-based projections are included in Figure 4b and give striking examples of the kinds of errors that can occur in fertility forecasting. The 1957-based projections completely failed to anticipate the forthcoming 1960s baby boom, although it did rather well at projecting births thirty to forty years hence! Conversely, the 1965-based projections did not foresee the rapid fertility decline that would follow the baby boom, then at its peak. Indeed, as noted above, the results of the 1965-based projections are consistent with the long-term TFR remaining at around 3.0. The result was a continual rise in the projected number of births reaching 1.6 million by 2005 (the actual number turned out to be just over 0.7 million) and the very large errors in the projection of the total population noted above. As also noted above, the large errors made in fertility forecasts around the baby boom period were not confined to the UK.[5]

Bias and precision

Figures 4c and 4d show the accuracy of the TFR assumptions according to forecast duration. For this analysis, based only on 1971-based and later projections, the mean error is consistently positive, that is, fertility levels have almost always been overprojected. Indeed, virtually the only instances of underprojection have been at durations of five years or less (see the 1975-based and 2000-based projections in Figure 4a for examples). This means that Figures 4c and 4d are virtually identical at later durations. However, as we saw above, the earliest official projections made in the 1950s, which did not foresee the 1960s baby boom, are important counter examples of underprojection. It is also worth noting that if the rise in the TFR seen over the last few years continues, then recent projections which have assumed a long-term TFR of 1.74 will also turn out to be underprojections. Over the period covered by the analysis in Figure 4d, the mean absolute error in the TFR assumptions rose to about 0.2 after eight years and about 0.4 after twenty years.

Figures 4e and 4f shows the corresponding errors for projections of births. In this case we have information from all projections back to the 1957-based set. However, this means that errors are 'inflated' by the inclusion of the projections made around the baby boom period. These become increasingly dominant in determining the mean errors at longer durations (note the increasing gradient of the graphs at durations over twenty-five years ahead). Nevertheless, these are useful in showing the potential errors that can occur in exceptional circumstances.

Mortality

Life expectancy at birth

Figures 5a and 5b show the key changes that have been made since the 1971-based projections to the assumptions about future life expectancy at birth (see also Table 1). As with Table 1 (discussed above), this analysis relates to *period* rather than *cohort* life expectancy.

As can be seen from the charts, period life expectancy has increased at a fairly uniform rate over the last forty years. However, the projections made during this period have assumed that there would be a reduction in the rate of improvement, so life expectancy has been consistently underprojected. Similar errors have been observed in projections made throughout the world,[5,9] perhaps stemming from a belief by demographers that the main causes of life expectancy improvement in the 20th century (for example, reduction of infant mortality to low levels, control of infectious diseases for young adults) were one-off gains that could not be repeated. In practice, however, these have been replaced by rapid mortality improvements at older ages with the result that overall life expectancy improvement has been maintained.

The 1971-based projections are again the earliest in the historical database for which we have details of assumed mortality rates. Life expectancy assumptions were actually reduced in the early 1970s with the 1977-based projections having the most pessimistic outlook of all. These projections assumed a very modest improvement in life expectancy to about 71 years for males and 77 years for females by 2017. In practice, these levels were actually reached in the early 1980s. Since then, virtually every set of projections has adopted more optimistic mortality assumptions than the previous one. A detailed account of the development of mortality methodology and assumptions up to the 1990s is provided elsewhere.[11] Further upward revisions to life expectancy assumptions in the most recent projection sets mean that official projections now assume that overall mortality improvement in the future will be comparable to that actually experienced over corresponding periods in the past.[12]

Figure 5 Accuracy of mortality assumptions

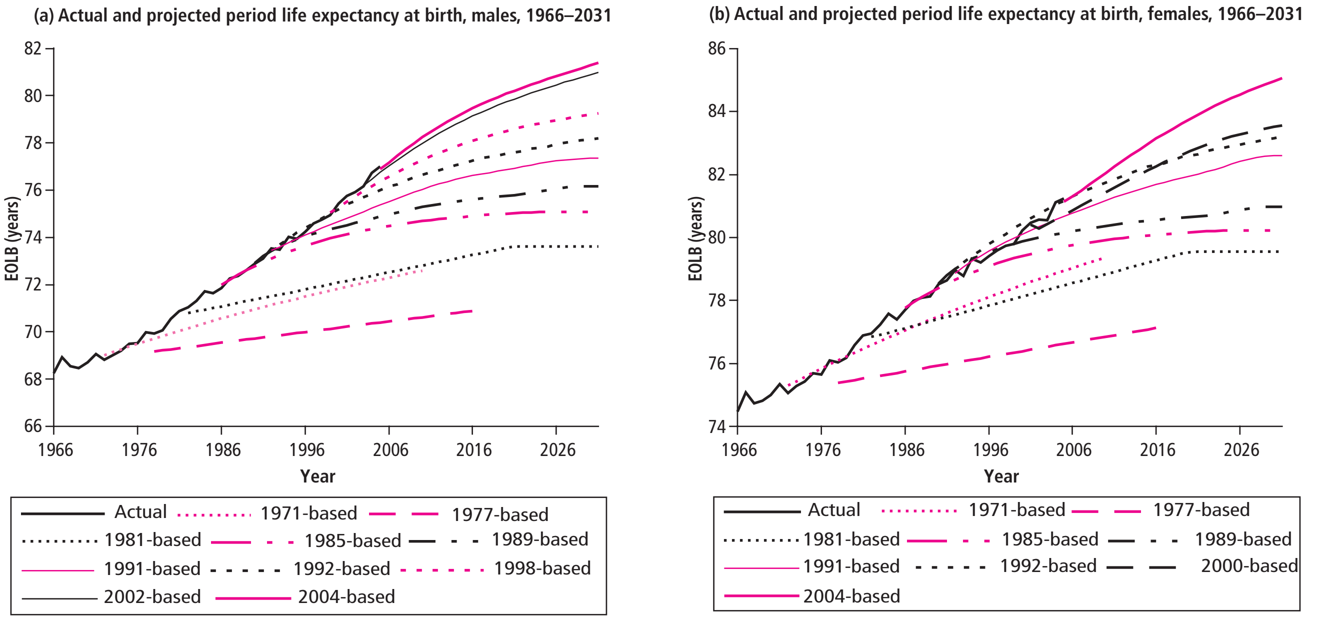
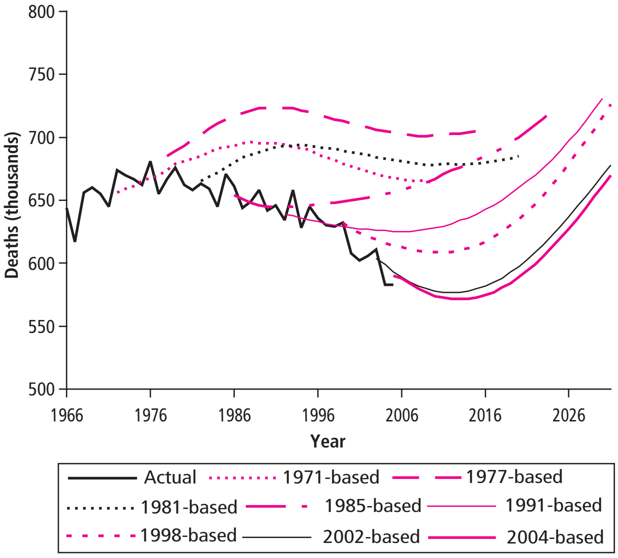


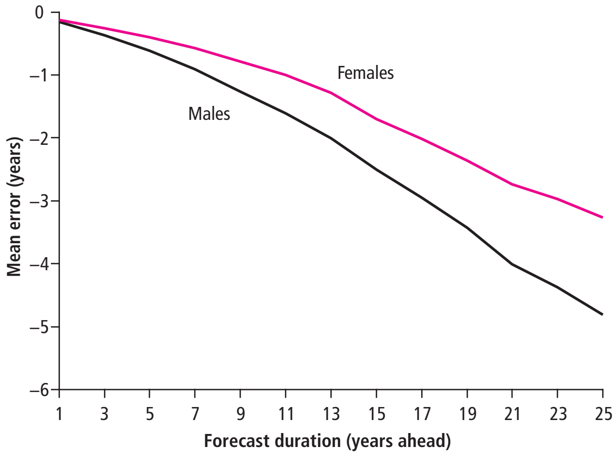
Figure 5 continued

Accuracy of mortality assumptions

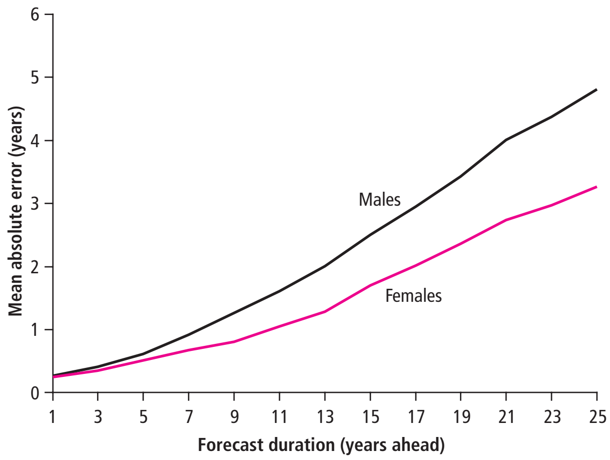
(c) Actual and projected number of deaths, 1966–2031



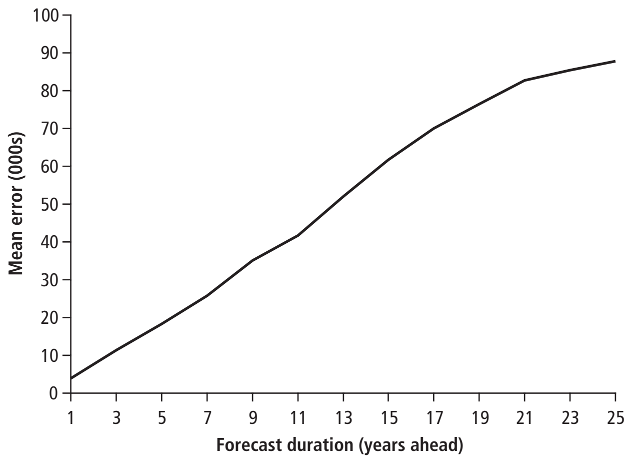
(d) Mean error (bias), life expectancy at birth
1971-based to 2004-based projections



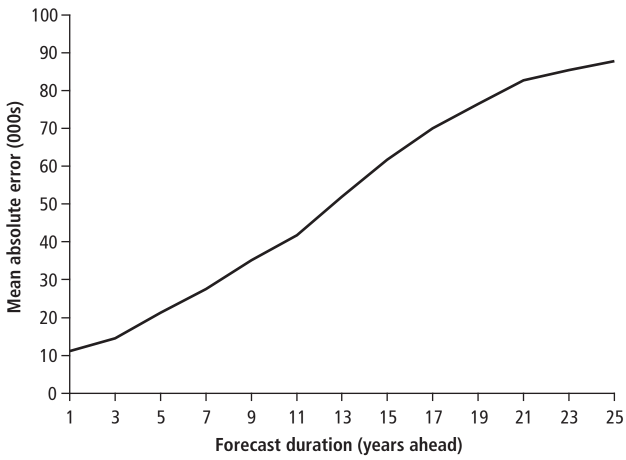
(e) Mean absolute error (precision), life expectancy at birth
1971-based to 2004-based projections



(f) Mean error (bias), deaths
1971-based to 2004-based projections



(g) Mean absolute error (precision), deaths,
1971-based to 2004-based projections



Deaths

Figure 5c considers the actual and projected number of deaths. Unfortunately, although some information survives about the projected number of births and net migration from the projections made in the 1950s and 1960s, we do not have similar information for deaths. And even where we do have births and migration data, we do not have the population numbers for each year from these earliest projections, so it is impossible to derive the death projections by subtraction either. Therefore, Figure 5c is also limited to the 1971-based and later projections.

Because assumptions about future life expectancy have been too pessimistic, the future number of deaths has been consistently overprojected. As noted above, the most pessimistic assumptions of all were adopted in the 1977-based projections. In these projections, it was envisaged that there would be around 700,000 deaths a year at the beginning of the 21st century. But in the event, the actual number fell below 600,000 in 2004 and 2005.

However, although the projected level of deaths has been gradually reduced as successively more optimistic mortality assumptions have been adopted, it is worth noting that the projected steep rise in deaths from around the year 2015 has been a consistent feature of all recent projections. This projected trend is largely a consequence of the sharply increasing number of people reaching elderly ages which will inevitably occur because of the ageing of the large cohorts born after the Second World War.

Bias and precision

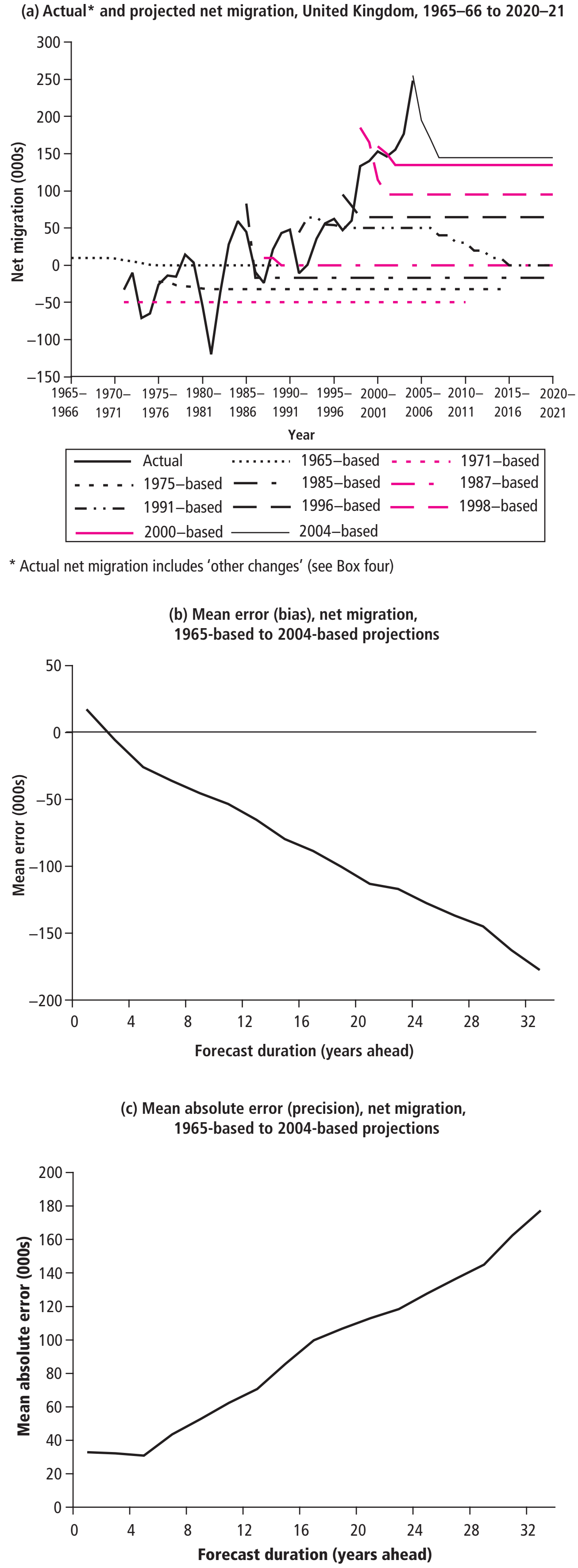
Figures 5d and 5e show the accuracy of the life expectancy assumptions according to forecast duration. Although there are some examples of short-term errors in the opposite direction (for example, Figure 5b shows that the 1992-based projection overestimated female life expectancy up to the year 2003), the mean error is consistently negative. There are no instances in this data set of overprojections of life expectancy beyond twelve years ahead, so Figure 5e is a mirror image of Figure 5d at later durations. Over the period covered by this analysis, the mean absolute error in the life expectancy assumptions for males rose to about one year after eight years duration and about two years after thirteen years duration. Errors for females were somewhat lower, reflecting the fact that life expectancy has not increased as much for women as it has for men since 1971.

Figures 5f and 5g show the corresponding errors for projections of total deaths. The mean absolute errors of 50,000 deaths after thirteen years and nearly 90,000 thousand after twenty-five years clearly have important consequences especially, as we shall see below, for the projected population at older ages. However, they are much lower than the corresponding birth errors seen in Figures 4e and 4f. This emphasises the point that errors in fertility assumptions have the greatest potential for causing large long-term errors in the projection of the total population. Analysis of Netherlands projections data[13] has similarly found errors in mortality forecasts to be around one third of those in fertility forecasts. One might expect mortality to be easier to predict than fertility (or migration) as the only uncertainty relates to the time that death occurs and people have little choice about this! In contrast, there is choice and uncertainty about the number of births women have (or the number of times people migrate) as well as the timing of these events.

Migration

Figure 6a shows the major changes that have been made to *net* migration assumptions in official projections (see also Table 1). [Some illustrative information on assumed *gross* migration flows is available for recent projections[14] but does not exist for earlier sets.]

Figure 6 Accuracy of migration assumptions



The chart begins with the 1965-based projections, the earliest for which we have migration information.[15] The 'actual' data shown in the chart are the estimates of 'net migration and other changes' covering one mid-year to the next used in the preparation of official mid-year estimates. These data are available from 1971–72. 'Other changes' (see Box Four) have been included so that all factors contributing to population change are covered in this article.

During this period, net migration to the UK has fluctuated considerably but with a clear upward trend. The UK lost population through migration for most of the 1970s and only began to experience regular net inward flows from the early 1980s. The upward trend accelerated in the 1990s and after a levelling off around the turn of the century reached a record high in 2004–05.

In the 1965-based projections, it was assumed that following an initial modest net inflow, the UK would experience net zero migration from the mid 1970s onwards. Projections made over the following twenty years all assumed net *outflows* from the UK with the largest assumed long-term net outflows (of 50,000 each year) in the 1971-based and 1973-based sets. The 1991-based projections were the first to assume net inward flows for the medium-term, but it was not until the 1996-based projections that it was assumed that these inward flows would be maintained throughout the projection period. Migration assumptions have continued to rise since then with the 2000-based projections being the first to assume annual net inward flows of over 100,000 a year. Although, following the 2001 Census, a significant downward revision was made to estimates of international migration for the 1990s (see Box Four), migration assumptions have now risen even higher. The latest (2004-based) projections assume a long-term net inflow to the UK of 145,000 persons a year, the highest migration assumption ever made in official UK projections.

Although there has been a clear upward trend in net migration over this period, and a very strong one over the last fifteen years, all official UK projections have assumed that net migration will remain at a constant level in the long-term with that level normally being reached only a few years after the base year of the projection. This is a typical feature of migration assumptions internationally.[16] It almost certainly reflects the extreme difficulty in predicting changes in migration more than a few years ahead rather than any belief amongst demographers that migration is actually likely to remain constant at any particular level. Probably most projection makers subscribe to the view of the leading American demographer Michael S Teitelbaum that 'projecting immigration is impossible, but unavoidable!'[17]

Bias and precision

Figures 6b and 6c show the accuracy of migration assumptions according to forecast duration. It should be stressed that these analyses are affected by revisions to migration estimates (see Box Four). For example, projections made between the 1991 and 2001 Censuses were based on the original series of migration estimates made prior to the 2001 Census (see Box Four, Figure B). Following the 2001 Census, these estimates were revised downward significantly. It is not possible to say what the projection assumptions would have been had the 'correct' revised migration estimates been known at the time, but this overestimation of net migration clearly made the projection assumptions higher than they would otherwise have been. But even though the migration assumptions made in, say, the second half of the intercensal period were 'inflated' because of the errors in the original migration estimates, they have still underprojected future net migration (at least up to 2005) as shown in Figure 6a. The short-term error in these particular migration projections would therefore have been *greater* had they been based on the historical migration time-series as now estimated.

Figure 6b shows that net migration has actually tended to be overprojected for one year ahead. However, this is heavily influenced by the effect of the downward revisions to migration estimates that followed the 2001 Census. At longer durations, net migration has been consistently underprojected. One of the few exceptions to this is the 1965-based set which overprojected net migration up to the mid 1980s (see Figure 6a). Also none of the projections made in the 1960s or 1970s anticipated the large net outward flow which occurred in 1981–82. Of course, annual net migration figures fluctuate far more than births or death, and it is impossible to predict such extreme fluctuations in advance.

Over the period covered by this analysis, the mean absolute error in net migration assumptions has been around 60,000 after ten years, 100,000 after twenty years and 150,000 after thirty years. These are higher than the corresponding errors for deaths (Figure 5g), but lower than those for births (Figure 4f). In the short-term, the migration errors mainly affect the projected population at young working ages (see below). But, insomuch as these errors affect the projected number of women of childbearing age, they will also have an impact on the projections of future births. However, because migrants are predominantly young, errors in the migration assumptions have had much less effect (even at the longest forecast durations considered in this article) on the projections of future deaths.

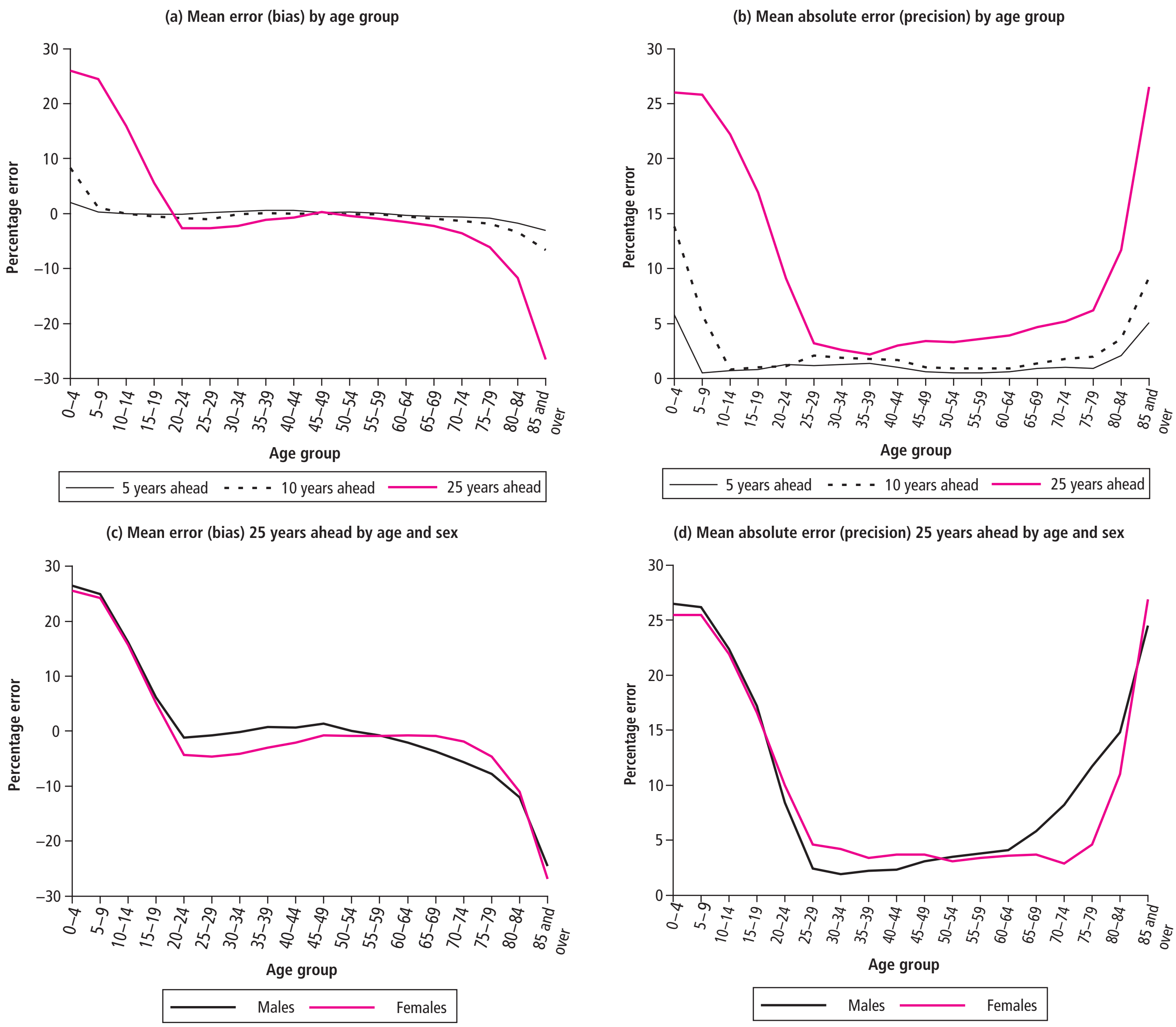
Age and sex

In the preceding sections of this article, we have considered separately the accuracy of the assumptions made about future fertility, mortality and migration. Earlier, Figures 1 to 3 illustrated the combined effect of the errors in these assumptions on the projected total size of the population. However, many users of projections will be more concerned about the effect on the projected size of particular age groups. This is considered in Figure 7. These analyses are based on all the projections from the historical database from the 1955-based set to the 2000-based set except in a few cases where the required data were not available (see footnote to Figure 7).

Figures 7a and 7b show the errors in the total population of each age group for five and ten years ahead as well as the much longer-term duration of twenty-five years ahead. Although the various components interact with each other, the overprojection of the population at the youngest ages is largely attributable to the overprojection of fertility seen in Figure 4, while the underprojections at the oldest ages are largely due to the overpessimistic mortality assumptions shown in Figure 5. Figure 7b shows that the average absolute error five years ahead for both the youngest (0–4) and oldest (85 and over) age groups was about 5 per cent. At ages 5–80 average errors five years ahead were much smaller (between 0.5 and 1.5 per cent).

As would be expected, errors were consistently higher at longer durations. For the oldest and youngest age groups, average errors twenty-five years ahead (based on nine projections from the 1955-based set to the 1979-based set) exceeded 25 per cent. The errors for the 85+ age group were fairly consistent across these nine projections. However, for the 0–4 and 5–9 age groups, errors varied considerably with the 1965-based set (made at the height of the baby boom) overprojecting the number of 0- to 14-year-olds at mid-1990 by over 60 per cent. Again, errors twenty-five years ahead were much smaller (between 2 and 4 per cent) at ages 25–64. Errors in the migration assumptions are the main factors at these ages. Because mortality is low at these ages, errors in the mortality assumptions are of relatively little consequence. And, by definition, the impact of the fertility assumptions twenty-five years ahead is limited to the population aged under 25.

Figure 7 Accuracy of projections by age and sex



Note: Analysis for 5 years ahead based on 24 projection sets from 1955-based to 2000-based.
Analysis for 10 years ahead based on 19 projection sets from 1955-based to 1994-based (excluding 1967-based and 1969-based).
Analysis for 15 years ahead based on 9 projection sets from 1955-based to 1979-based (excluding 1963-based, 1967-based, 1969-based and 1973-based)

Figures 7c and 7d show the errors in the projected population twenty-five years ahead by sex. At young ages, errors are similar for males and females. This indicates that the sex ratio at birth applied in the projections has been borne out in practice. A ratio of 105 boys per 100 girls has been used since the 1989-based projections; a slightly higher ratio was applied in earlier projections. For most of the oldest age groups, average absolute errors have been greater for males than females reflecting the greater underestimation of male mortality improvement discussed above. (Although aggregate results are similar for both sexes for the 85+ age group, this is because larger male errors in the 1970s projections are offset by larger female errors in the available 1950s and 1960s projection sets.)

At young adult ages, the average absolute errors have been greater for females than for males. As noted above, the total errors at these ages are largely a consequence of the underprojection of net migration. The differences between males and females largely reflect the revisions made to post-1981 population estimates following the 2001 Census.

The assumed sex distribution of migrants for population projections is normally based on contemporary estimates of migration flows. However, the overestimation of the population revealed by the 2001 Census (see Box Four) was heavily concentrated amongst males, and subsequent downward revisions to migration estimates have been much greater for males than females.

Dependency ratios

It is worth noting that, for many users of projections it is the relative size of the population in different age groups that is of importance. A crucial demographic indicator is the old age dependency ratio, that is, the number of elderly people in the population relative to the number of people of working age.

The accuracy of projections of the dependency ratio is not considered in this article. However, in relation to the projections considered in this article, underprojections of the elderly population (because of overpessimistic mortality assumptions) will often have been partly offset by underprojections of the working age population (because migration assumptions have been too low). For example, as discussed above, the 1977-based projections adopted the most pessimistic mortality assumptions of any projection set and consequently underprojected the population aged 65 and over in 2002 (twenty-five years ahead) by 14 per cent. However, because the population aged 20 to 64 was also underprojected, the *ratio* of those aged 65 and over to those aged 20 to 64 was 'only' underprojected by about 8.5 per cent.

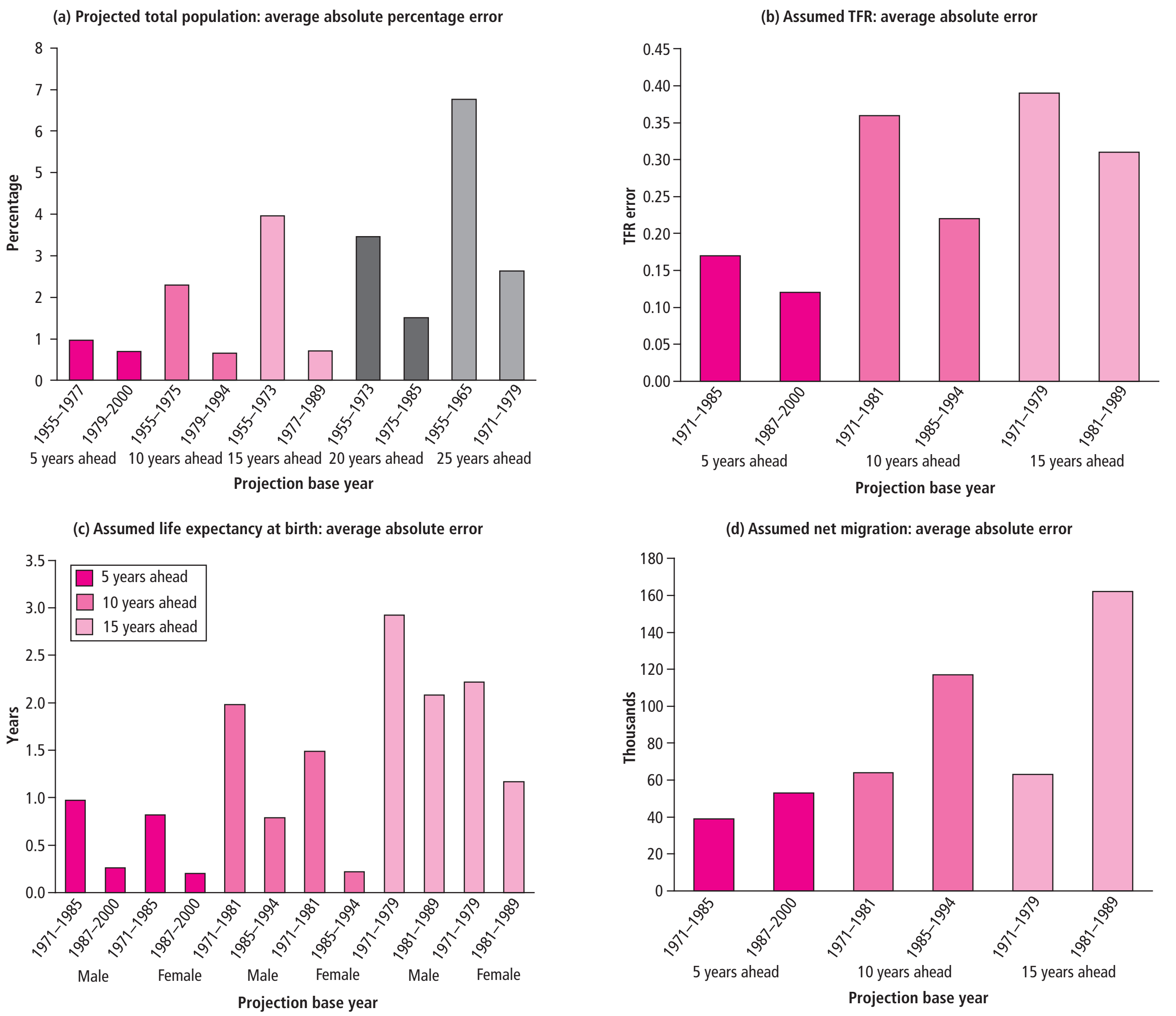
Are projections becoming more accurate?

Given the extensive historical database of past national projections now available, an obvious question to ask is whether projections have increased in accuracy through time. One might hope and expect that projections would improve in accuracy as projection makers learn from earlier mistakes, develop greater insight into demographic processes and adopt improved methods. On the other hand, it might be argued that population forecasting becomes ever more difficult as population mobility increases and as living arrangements become ever more complex. There appears to have been comparatively little research internationally on this topic although a couple of studies find little empirical evidence of improvement.[4, 9]

One of the difficulties in drawing firm conclusions, even from the fairly lengthy UK projection database, is that it is virtually inevitable that a major projection error in one set of projections will be repeated not just in the next set, but probably in many projections to come. For example, it is perhaps understandable that all projections made around the 1960s baby boom period assumed that fertility levels would remain high rather than predicting the rapid decline to below replacement fertility levels which actually happened and persists to this day. Similarly, with the long-term historical context of the UK losing population through migration, it is not surprising that the projections made in the 1960s, 1970s and 1980s did not anticipate the period of sustained net inward migration which began in the 1990s. In short, if demographers have not been able to predict a particular demographic change five years in advance, they will not have predicted it ten, twenty or thirty years earlier either.

Figure 8 looks at the available evidence from the UK historical database. In these graphs, the available set of projections is divided into older and newer halves and we compare the accuracy of projections of the total

Figure 8 Accuracy of older and newer projections



population, and the assumptions of the TFR, life expectancy at birth and total net migration. In interpreting results, it should be borne in mind that the particular groupings of projections being compared differ slightly from one analysis to another. If we are looking fifteen years ahead, we can only use projections up to the 1989-based set, but if we are looking five years ahead we can go up to the 2000-based set. Also, the analysis of TFR, life expectancy and net migration is restricted to 1971-based and later projections, but for the analysis of total population we have also been able to include information from some of the projections made in the 1950s and 1960s.

Figure 8a does indeed show that, whatever the forecast duration, projections of the size of the total population have been accurate for more recent projections. This is largely explained by the improved accuracy of fertility assumptions as shown in Figure 8b. The key importance of the fertility assumption in determining the accuracy of long-term projections of total population size was discussed above.

However, one needs to be very careful about interpreting this finding. Fertility rose rapidly prior to the baby boom peak of the mid 1960s and then declined equally quickly over the following ten years. However, since the late 1970s (see Figure 4a), TFRs have remained relatively constant. Obviously, making accurate projections at a time of relative stability is likely to be an easier task than at times when levels are rapidly changing. A method for assessing the accuracy of projections, controlling for the volatility of the base period, is discussed elsewhere.[4]

The opposite situation occurs with net migration. Figure 8d shows that migration assumptions have been less accurate in recent projections than in older ones. However, this might also be expected given the trends since 1971. Migration has always fluctuated, but the sharp upward trend from the early 1990s (see Figure 6a) marked a change from the previous two decades. The projection period covered by the 'older' projection sets shown in Figure 8d is generally limited to the 1970s and 1980s.

Perhaps the fairest comparison is of life expectancy assumptions where actual trends have been fairly consistent over the past forty years. Figure 8c shows that accuracy has improved at forecast durations of five, ten and fifteen years. However, life expectancy has still been significantly underestimated in the most recent projections, especially for males.

Conclusion

Demographic behaviour is inherently uncertain. The number of children we have, how long we live and the number of people who migrate from one country to another are variables that have changed continually in the past and will continue to do so in the future. Even if we understood perfectly the factors that have brought about past changes (which we clearly do not), our ability to predict the demographic future would inevitably remain limited. We do not even know, with complete certainty, the size and age structure of the current population at the time a projection is made and this article has shown that revisions to population estimates can make a non-trivial contribution to projection error. It is therefore important that users of population projections act with a knowledge of their likely limitations and that projection makers provide the information to enable them to do so.

This article has been concerned with the accuracy of past official UK national population projections. There is, of course, no guarantee that past accuracy will be a reliable guide to future accuracy. Indeed, it might be hoped that projections would become more accurate as lessons are learned from past mistakes. There is evidence of some improvement in accuracy in some (but not all) aspects of the UK projections, although this may largely reflect the relative stability of fertility levels over the last quarter of a century. If this stability does not persist, then the prospects for accurate forecasting in the future could get worse rather than better.

It is important to stress that the implications of projection accuracy will differ for different users. As well as having different requirements for the precision of projections, many users will be interested in the population at specific ages rather than the size of the total population. This article has shown that the largest errors by age are for the very young and the very old, caused respectively by errors in fertility and mortality assumptions. In contrast, despite errors in past migration assumptions, projections of the working age population have been much more accurate.

One of the main difficulties faced by projection makers is to decide whether changes in demographic time-series are likely to be short-term fluctuations or the start of a long-term change in level. We face a case in point at the time of writing in considering the upturn in fertility rates seen in the UK since 2001. Given our imperfect understanding of demographic behaviour, it is natural to be cautious about making significant changes in assumptions based on just a few years' data. But this can lead to so-called 'assumption drag', that is, assumptions lagging behind events. However, the alternative risk is that projection makers react too quickly to new trends and make changes which subsequently need to be reversed. This would be disruptive to long-term policy planning.

There is certainly evidence of assumption drag in the UK projections. Indeed, although there has been some reduction in fertility and mortality errors (but an increase in migration errors) in more recent projections, the findings of this article repeat the conclusions of the previous review of UK projections in 1994[3] that fertility levels have tended to be overestimated and migration levels to be underestimated, while mortality assumptions have consistently been too pessimistic. Similar results have been observed in projections made for other western countries. A forthcoming *Population Trends* article will look in more detail at population projections made for other countries.

It is important to stress, however, that there is no inevitability about the direction of these errors. The recent rise in UK fertility could be maintained, perhaps because of the influence of high levels of net migration; life expectancy might stagnate because of increasing obesity levels; net migration may fall back to levels more typical of the UK's history if economic conditions change or more restrictive policies are introduced. Under such circumstances the verdict of future assessments of projection accuracy could be quite different.

References

1. Long J F (1992) Accuracy, monitoring and evaluation of national population projections. From *National Population Forecasting in Industrialised Countries*. Eds: Keilman N and Cruijsen H. Swets & Zeitlinger: Lisse.
2. Shaw C (2002) Variant population projections for the United Kingdom and its constituent countries. *Population Trends* **109**, 15–26.
3. Shaw C (1994) Accuracy and uncertainty of the national population projections for the United Kingdom. *Population Trends* **77**, 24–32.
4. Keilman N (1997) Ex-post errors in official population forecasts in industrialised countries. *Journal of Official Statistics* **13(3)**. Available from www.jos.nu/Articles/abstract.asp?article=133245
5. Keilman N and Pham D Q (2004) *Empirical errors and predicted errors in fertility, mortality and migration forecasts in the European Economic Area*. Discussion Papers 386, Statistics Norway. www.ssb.no/publikasjoner/DP/pdf/dp386.pdf
6. www.gad.gov.uk/Life_Tables/Period_and_cohort_eol.htm
7. Office for National Statistics. *National population projections*. PP2 series. Palgrave Macmillan: Basingstoke.

8. Coleman D and Salt J (1992) *The British Population: Patterns, Trends and Processes*. Oxford University Press: Oxford.
9. Bongaarts J and Bulatao RA (eds.) (2000) *Beyond six billion: Forecasting the world's population*, 41–42. National Research Council: Washington D.C. See www.nap.edu/books/0309069904/html/
10. Smallwood S (2002) The effect of changes in timing of childbearing on measuring fertility in England and Wales. *Population Trends* **109**, 36–45.
11. Office for National Statistics (2001) *National population projections: review of methodology for projecting mortality*, Annex D. NSQR Series No. 8. ONS: London.
12 Shaw C (2006) 2004-based national population projections for the UK and constituent countries. *Population Trends* **123**, 9–20.
13. Keilman N W (1990) *Uncertainty in national population forecasting: issues, backgrounds, analyses, recommendations*. Swets & Zeitlinger: Lisse, p 185.
14. See, for example, *National population projections: 2004-based*, PP2 series no.25 p 42. Office for National Statistics/Government Actuary's Department (2006).
15. However some pre-1965 migration assumptions for England and Wales are reported in: Field JL Past projections: how successful? From *Population projections: trends, methods and uses*. Papers of the Annual Conference of the British Society for Population Studies. Office of Population Censuses and Surveys Occasional Paper 38 (1990).
16. Shaw C (2002) *Latest national migration forecasts in Europe*. Paper for Eurostat Working Party on Demographic Projections. Eurostat: Brussels.
17. See p6 from Howe N and Jackson R (2004) *Projecting immigration: a survey of the current status of practice and theory*. Center for Retirement Research: Boston.