Demographic projections

This technical paper sets out the assumptions and methodology used by the Commission in its demographic models, the data used to calibrate them, and the nature of scenarios explored.

The economic effects of ageing depend primarily on the relative number of the future old. Estimates of population ageing can be derived using well-established population models that make assumptions about the future paths of fertility, mortality and net migration.

The Commission developed several demographic models to:

- consider scenarios other than those used in the PC-M series (chapter 2), reflecting the considerable uncertainty about future fertility rates, mortality rates and net overseas migration;[1]
- understand what would have happened had Australia's past demographic trends been different. This explains the demographic pressures underlying Australia's present ageing trends. For example, what would have happened if the rise in fertility that occurred after the Second World War had not occurred?; and
- provide separate estimates of Indigenous and non-Indigenous populations for the Northern Territory, given the distinctive demographic trajectories of these sub-populations.

The models are available publicly (see attached CD) — and can be used to explore assumptions different to those adopted by the Commission.

1.1 The cohort-component model

The standard approach to demographic projections is the cohort-component model, which is a stock–flow model of the population by age groups. It recognises that in moving from a population at a given date to a new population one year later, there are a set of inflows and outflows.

[1] For example, in its own population estimates produced in 2003, the ABS generated 54 alternative projections based on varying combinations of assumptions to reflect this underlying uncertainty.

The cohort-component model is a rigorous way of handling these flows, based on assumptions about future trends in mortality, migration and fertility. There are several steps to the model. At the national level, these involve determining:

- how many survivors there are from the previous year's population;
- the number of births in Australia that survive to be 0 years old in the projection year (the influence of fertility); and
- the impact of net overseas migration (less deaths to migrants that occur after they arrive, but before the end of the relevant projection year).

Each of these components is discussed below.

The base population

The starting point for population projections is the base year population. This is the population at 30 June 2004 classified by age and sex. This is denoted by $P_{x,s\ t}$, where x is the age, running from 0 to *max*-1 with a last open ended age interval of *max+* (in this case 100+), s is sex and t is the end of the fiscal year 2004.

Calculating deaths in the base population

Ignoring births and net overseas migration for the moment, the numbers in each age–sex sub-population remaining in year t+1 is estimated by applying survival rates to base year sub-populations:

$$P_{x+1,s,t+1} = P_{x,s,t} \times (1 - Q_{x,s,t}) \quad \text{for } (x+1) = 1 \text{ to } max\text{-}1$$

where $Q_{x,s,t}$ is the probability that someone aged x in year t will die over the next year.[2] So for example, if there were 10 000 people aged 10 years old at 30 June 2004 and one in 1000 of these were expected to die over the next year, the population of 11 year olds at 30 June 2005 (before gains from net migration) would be 9990. The population estimate for the last open-ended age interval is different because people aged 99 year olds become 100+, while many 100+ years olds survive to remain 100+ one year later. Accordingly, the population estimates (before accounting for net overseas migration) for the last age group is:

$$P_{\max,s,t+1} = P_{\max-1,s,t} \times (1 - Q_{(\max-1),s,t}) + P_{\max,s,t} \times (1 - Q_{\max,s,t})$$

[2] In this context, the relevant age is not *exact age* (as in a standard life table), but rather *age at last birthday* (that is, someone whose age, A, is in the interval $x \le A < x+1$).

These calculations all require death probabilities, Q (or one minus survival rates). These are derived from age-specific central death rates and assumptions about the distribution of the probability of death over a year. Q can be calculated through a series of subsidiary calculations (which make up so-called 'life tables'). In most model projections, the Commission had direct estimates of Q_x derived by the ABS, or assumed some pattern of change over time from a base year series of Q_x.

However, for one set of mortality scenarios the Commission needed to derive Q_x from central death rates. Following a request from the Commission, age-specific central death rates ($m_{x,s,t}$) for calendar years 2002 to 2051 were estimated by Heather Booth from the Australian National University using the Lee-Carter method based on past data trends.[3] Central death rates record the number of deaths of a person aged x (at last birthday) over a calendar year divided by the mid-calendar year population of people aged x. The Booth data are in single year increments to age 89 with a last open age interval of 90+. As this report is particularly concerned with ageing issues, the Commission derived estimates of central death rates from 90 to 99 and 100+ by relating the Booth estimates for each projection year to 2000-2002 ABS life table data (applying so-called 'relational' methods — Rowland 2003; Hannerz 2001). Then Q_x estimates corresponding to these central death rates were produced by constructing life tables for each projection year and sex (box 1.1).

[3] The Lee and Carter (1992) model is a special case of principal components. It is used by the U.S. Census Bureau as a benchmark for their population forecasts, has been recommended by the U.S. Social Security Technical Advisory Panel and has been widely adopted in academic demographic forecasts of mortality (Girosi and King, 2003, p 36). See Booth and Tickle 2003 for more detail and background on these mortality projections. For a more general discussion of the Lee Carter method and its benefits, see Tuljapurkar, Li and Boe, 2000; Preston, 1991; Wilmoth, 1996; Haberland and Bergmann, 1995; Lee, Carter and Tuljapurkar, 1995; Lee and Rofman, 1994; Tuljapurkar and Boe, 1998; and NIPSSR, 2002). Other methods, some with apparent advantages over Lee-Carter, are also now being applied, such as functional data analysis (Hyndman and Ullah 2005 and Hyndman 2004).

Box 1.1 **Generating Q_x from central death rates**

First, the mortality rate, or the probability of dying between *exact* ages x and x+1, ($q_{x,s,t}$) was calculated. Unlike central death rates, $q_{x,s,t}$ is based on the population at the start of the calendar year (so 1 January 2002 in the base year), rather than the midpoint. Consequently, those deaths that have occurred up until the midpoint have to be added to the midpoint population to give an estimate of the starting population. This depends on assumptions about the distribution of deaths over the year, which depends on the age of people.

- Babies are much more likely to die soon after birth rather than later in the year. While there are alternative methods, the PC adopted that of Shahidullah (2001, p. 14) and the London Health Observatory (2001). q_0 was calculated as $m_0/(1+(1–f)m_0)$. f is the separation factor, defined as the share of infant deaths in year t occurring to infants born in the previous year. f is much less than 0.5 because most deaths occur in the first 4 weeks of life. The value of f used was 0.14 (from ABS 2002d).
- For the last open age interval, the probability of death (q_{100+}) is one, since over that interval the future probability of death is 100 percent.
- For other ages there are several common approaches. The PC used that of Greville (Ng and Gentleman 1995), which is based on the observation that there is a roughly linear relationship between the natural log of death rates (m_x) and age (x). Denoting the slope of this line as ln C, the mortality rate can then be calculated as: $q_{x,s,t} = m_{x,s,t} / [1 + m_{x,s,t}(0.5 + (m_{x,s,t} - \ln C)/12)]$. The ABS (2001c) notes that ln C could be assumed to be around 0.95, which was the parameter used by the PC.

Second, the numbers of an assumed starting population of 100 000 surviving at exact ages ($l_{x,s,t}$) is calculated as $l_{x+1,s,t} = l_{x,s,t}\ (1 – q_{x,s,t})$.

Third, a measure of mortality patterns that refers to age at last birthday, rather than exact ages (as in $l_{x,s,t}$) is required since statistical data is gathered on an age at last birthday basis. This measure is the average number of people alive *between* exact ages, $L_{x,s,t}$. It is formed from averaging l in the x and x+1 age categories for all ages except for the first years of life and the last open ended age category. Accordingly, $L_{x,s,t} = 0.5(l_{x,s,t}+l_{x+1,s,t})$. L_0 was calculated as $0.14\ l_0+0.86\ l_1$ recognising that the probability of death is higher earlier than later. The last age category was estimated as discussed below. Ratios of L are survival rates of people. Thus $L_{40,t}/L_{39,t}$ is the share of people aged 39 (on a last birthday basis) at 30 June 2002 who will survive to be 40 years old by 30 June 2003.

Finally, Q can be derived as one minus the survival rates based on L. Accordingly, $Q_x = (1- L_{x+1,}\ /L_x)$ up to Q_{99}. In order to estimate Q_{100+}, Q_{100} to Q_{130} was first approximated as $Q_x = \min(1, Q_{x-1} *Q_{99} /Q_{98}))$. Then L_{100} to L_{130} were estimated as $L_x = (1-Q_{x-1})L_{x-1}$. Accordingly L_{100+} was calculated as $\sum_{x=100}^{130} L_x$ and L_{101+} as $\sum_{x=101}^{130} L_x$. Then Q_{100+} was calculated as: $1-L_{101+}/L_{100+}$. The probability that a baby dies in the first year after birth, Q_b, is calculated as $1-L_{0,s,t}/l_{0,s,t}$.

Births

Births are calculated using calendar year age-specific fertility rates and the relevant sub-populations of fertile women. The fertile years are from 15 to 49 years (with any births to women of other ages added to the lower and upper limits of this age range). It is necessary to average the populations of the relevant females in the t and t+1[th] years to reflect the fact that females aged x at time t have an average age of x+½.

For example, in the base year of 30 June 2004, the average age of 15 year old females is 15½ years old. At 30 June 2005, those females aged 15 years were on average 14½ years old at 30 June 2004. By averaging these two sub-populations, the average number of females aged 15 years old in the period from 30 June 2004 to 2005 is obtained. Births are calculated by multiplying the two sub-populations by the relevant age-specific fertility rates.

Accordingly, Births (B_t) can be derived as:

$$B_t = \frac{1}{2}\left(\sum_{x=15}^{49} F_{x,T} \times P_{x,f,t+} + \sum_{x=15}^{49} F_{x,T+1} \times P_{x,f,t+1} \right) / 1000$$

where births (B_t) occur over fiscal year ending t+1, and $F_{x,T}$ is the calendar year (T) fertility rate of females aged x.[4] For example, to determine the number of births for the projection year ending 30 June 2003:

$$B_{2001-02\ to\ 2002-03} = \frac{1}{2}\left(\sum_{x=15}^{49} F_{x,2002} \times P_{x,f,2001-02+} + \sum_{x=15}^{49} F_{x,2003} \times P_{x,f,2002-03} \right) / 1000$$

Male births are calculated as:

$$B_{m,t} = \frac{\alpha}{1+\alpha} B_t$$

where α is the ratio of male to female births (set to 1.05). Female births are found as a residual.

Some live births subsequently die. The population aged zero at t+1 is calculated by subtracting deaths of babies, so that:

$$P_{0,s,t+1} = B_{s,t} \times (1 - Q_{b,s,t})$$

4 The calendar year T for B_t is from t-½ to t+½ years. For example, for calculating births over 2003-04 to 2004-05 (termed $B_{2003-04}$), T would be the calendar year 2004 and T+1 would be the calendar year 2005.

where Q_b is the probability of death over the first year from birth.

The contribution of net overseas migration

(Net) overseas migrants are assumed to arrive on average at the midpoint of the relevant projection year. Thus for the projection year ending 30 June 2005, migrants are assumed to arrive on average at midnight 31 December 2004. This means that half the migrants aged x years old arriving during the projection interval will be x+1 years old by 30 June 2005, while half of those arriving aged x+1 years old will still be x+1 years old by 30 June 2005. Because migrants are arriving on average half way through the year, only half the year's probability of death is applied. Accordingly, the contribution to population increase (CP) at the end of June in the t+1 projection year is:

$$CP_{x+1,s,t+1} = (0.5\times NOM_{x,s,t})(1-0.5Q_{x,s,t}) + (0.5\times NOM_{x+1,s,t})(1-0.5Q_{x+1,s,t})$$

for x+1=1 to max-1 years, where $NOM_{x,s,t}$ is the level of net (inwards) overseas migration over the year from t to t+1. The contribution of migrants to the population aged zero years is:

$$CP_{0,s,t+1} = (0.5\times NOM_{0,s,t})(1-0.5Q_{0,s,t})$$

The contribution of migrants to the population aged max^+ years is:

$$CP_{max^+,s,t+1} = 0.5\times NOM_{max-1,s,t}\times(1-0.5Q_{max-1,s,t}) + (NOM_{max^+,s,t})(1-0.5Q_{max^+,s,t}) .$$

1.2 Sources of data and assumptions used for the national projections

An expert group formed by the Commission suggested the base case parameters for the national projections (chapter 2). The Commission tested the implications for ageing of various high and low cases flanking the base case assumptions.

Net overseas migration

For most demographic variables, the major problem in projections is determining a realistic set of future scenarios, but there are generally few problems in the measurement of the actual variable. This is not true in the case of net overseas migration because there are significant problems in measuring the duration of stays and departures of migrants (chapter 2).

Only long-term (over a year) and permanent departures and arrivals are included in the calculation of net overseas migration. However, some short term arrivals and departures are in fact long-term or permanent departures and arrivals, and vice versa. For instance, a significant share of long-term arrivals who record an intention to stay for one than one year in Australia (and are thus included as a migrant in net overseas migration) actually stay for less than this period. The ABS makes adjustments for some of these problems. For example, the original estimates of net overseas migration (inwards) for 2002-03 was 154 225. This fell by 25 percent after adjustment to 116 498 (ABS 2004i). However, problems with the recording of stays and departures by migrants means that there remains significant uncertainties about the real underlying level of net migration.

This difficulty is compounded by tempo effects associated with the future movements of long-term visitors, which could affect projected future levels of net overseas migration (McDonald and Kippen 2002a). The net level of long-term visitors has been strongly rising in Australia. During a period of growth in such visitors, inflows of new visitors must exceed outflows of past visitors, since outflows are drawn from a smaller group of earlier arrivals. However, this could change were net visitor levels to stabilise in the future. The degree to which outflows would catch up with inflows would then depend on the conversion of long-term visitors to permanent immigrants. If conversion factors were low, then outflows would approach inflow levels, and the contribution of long-term visitors to net migration would fall significantly from present levels. All things being equal, this would reduce net overseas migration from present levels. Of course, if conversion factors were higher, this effect is considerably weakened. This issue adds an additional source of uncertainty to future migration levels.

On the recommendation of the expert group, the Commission assumed net overseas migration inwards of 115 000 for each year from 2004-05 in the base case. A fixed age structure for net migration — provided by the ABS — was assumed for all projection years.

For the high case, migration increases linearly from 115 000 in 2004-05 to 140 000 in 2014-15, and then stays fixed at 140 000.

For the low case, migration decreases linearly from 115 000 in 2004-05 to 90 000 in 2014-15, and then stays fixed at 90 000.

Total fertility rates (TFRs)

Projections of future fertility are often based on past trends in the TFR. The TFR is a synthetic measure of fertility, calculated as the average number of children women will bear during their lifetimes *if* they experienced the age-specific fertility rates that apply in a given year at each age of their reproductive lives. It is a useful measure for international comparisons of fertility since it ignores age distributions of fertile women and is simple to construct. However, past trends in the TFR may provide misleading indicators of future fertility for several reasons.

- As in all demographic variables, past trends may not pick up changing attitudes to having children or the effects of new policies (such as recent measures to address some of the costs of having children).
- There has been a significant and still continuing shift in the time in their lives when Australian women bear children (the age profile of fertility). Age specific fertility rates have been falling rapidly for younger women, and this has, after a lag, been followed by increased fertility rates for older women. This tempo effect (box 1.2 and chapter 2) means that during the transition to a stable age profile of fertility, the TFR initially falls and then, so long as the completed fertility rate (CFR)[5] does not fall too greatly, rises somewhat in the long run.

Box 1.2 **The tempo effect**

The effect of delay on the total fertility rate is called the *tempo* effect by demographers. Examining its importance requires information on age-specific and parity-specific fertility rates (ie the extent to which women have different *given* number of children, such as none, 1, 2 and so on). While these data are often incomplete or unavailable, some studies have been undertaken. Research has revealed strong distorting effects of postponement in European countries and the US (Sobotka 2003, 2004). For example, the TFR fell to below 1.5 in the Netherlands in 1983 and 1984 before resuming a gradual rise to 1.72 by 2000. In contrast, the CFR was 1.87 for the 1952 cohort, which has gone through their most fertile years during the TFR trough.

Reflecting the problems in interpreting the TFR, it has been argued that the concern over below-replacement fertility in the United States over the previous 25 years had been largely misplaced because, after adjusting for the rising age at childbearing, the underlying level of (completed) fertility was essentially constant at very close to two children per woman throughout this period (Bongaarts and Feeney 1998, p. 2).

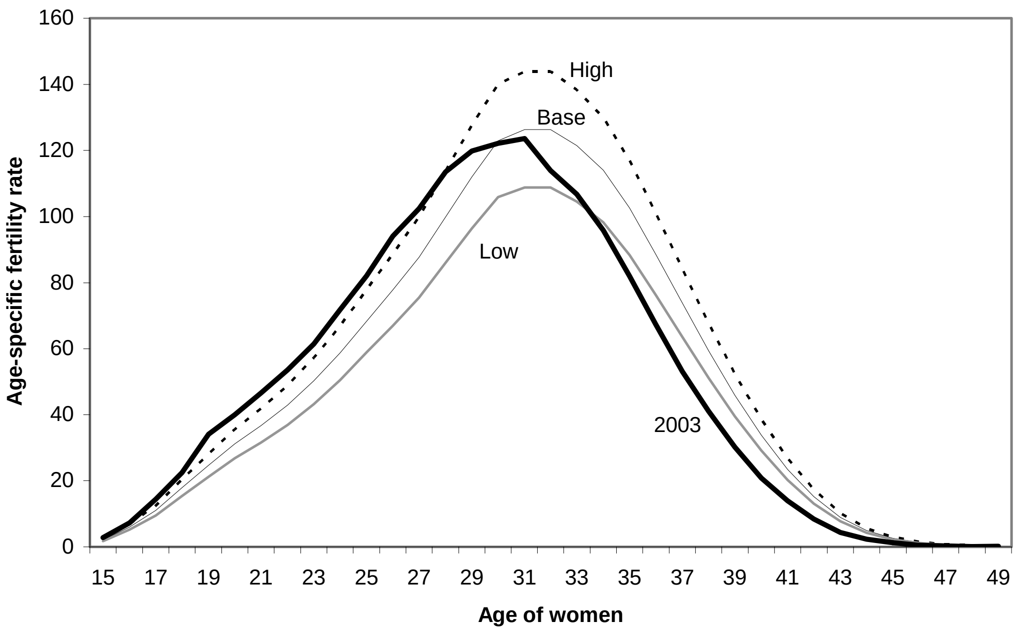
In an Australian context, Kippen (2003) has undertaken simulations that demonstrate that the distortions to the TFR from tempo effects can be pronounced.

On advice from its expert group, the Commission assumes that the TFR will begin to rise slightly over the next few years. This is also consistent with the Australian

5 CFRs measure the *actual* life time average number of births per woman of given generation.

fertility projections produced by the UN.[6] In the base case, the TFR is assumed to increase by 0.005 per year from its level of 1.754 in 2003 until 2012, and then increase by 0.001 for the next year, reaching a stable TFR of 1.8 in 2013 (and therefore a long-run CFR also of 1.8). The age–specific fertility rates associated with these TFR were provided by the ABS (figure 1.1). They reflect the continued reduction in the age-specific fertility rates of younger women (to around 30 years old) and increasing age-specific fertility rates for older women.

Figure 1.1 **The age profile of fertility under different scenarios**
Base, high and low in the long run compared with the 2003 levels



Data source: Unpublished data from the ABS for 2003, ABS estimates for the base case and Commission estimates for the high and low scenarios using Rowland's suggested scaling method (2003, p. 448).

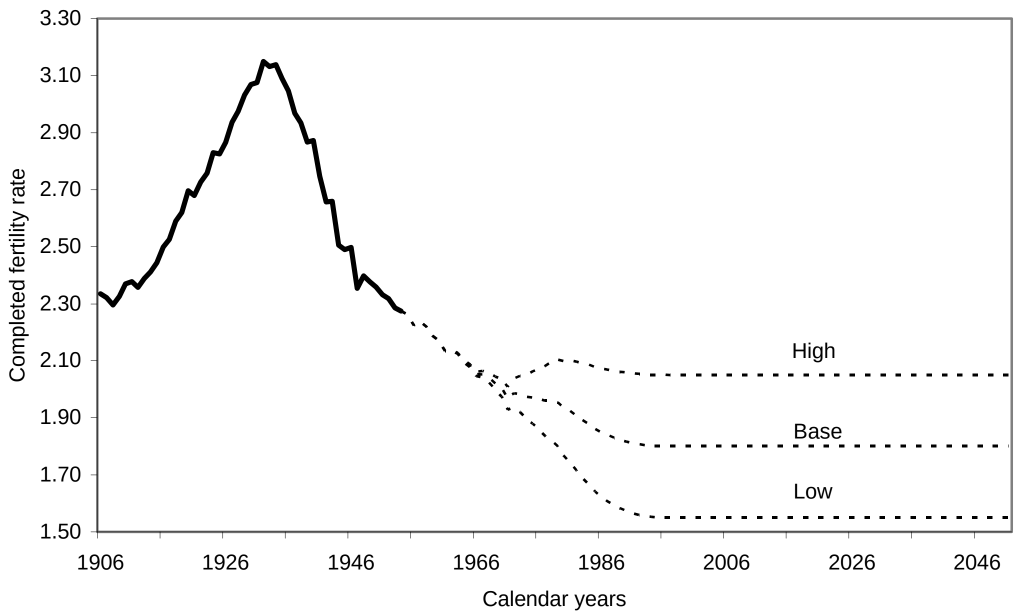
It should be noted that this projected pattern of fertility is still (realistically) associated with a decline in CFRs (figure 1.2) and that it reflects movements in age-specific fertility rates that are quite plausible given historical patterns. To give some indication of the implications of a CFR of 1.8 for the proportion of women at various parity levels, this CFR would, for example, be consistent with: a reduction in the proportion of women having four or more children at the end of their fertile lives from the 1996 levels of 14.5 per cent to 7 per cent; a reduction of the proportion of women with three children from 25.6 per cent to 18 per cent;

6 The tempo effects are more delayed in the UN estimates. The UN (2003) projects a TFR that initially falls to just below 1.70 before gradually increasing to 1.81 by 2035-40 and stabilising at 1.85 by 2045-50.

maintenance of the share of women with two children at 39 per cent; a rise in the proportion of women having only one child at the end of their fertile lives from 10.2 to 18 per cent and finally a rise in the proportion of women that remain childless from 10.7 per cent to 18 per cent. Such a distribution in parities is credible, though clearly policy and other social trends could generate different outcomes. In particular, a concern among demographers is that parity 3 and above contributes roughly half of the CFR, and yet these parities are most affected by postponement of child bearing and social and economic trends affecting women.

Figure 1.2 **Completed fertility rate**

1906 to 2051 female birth cohorts[a]



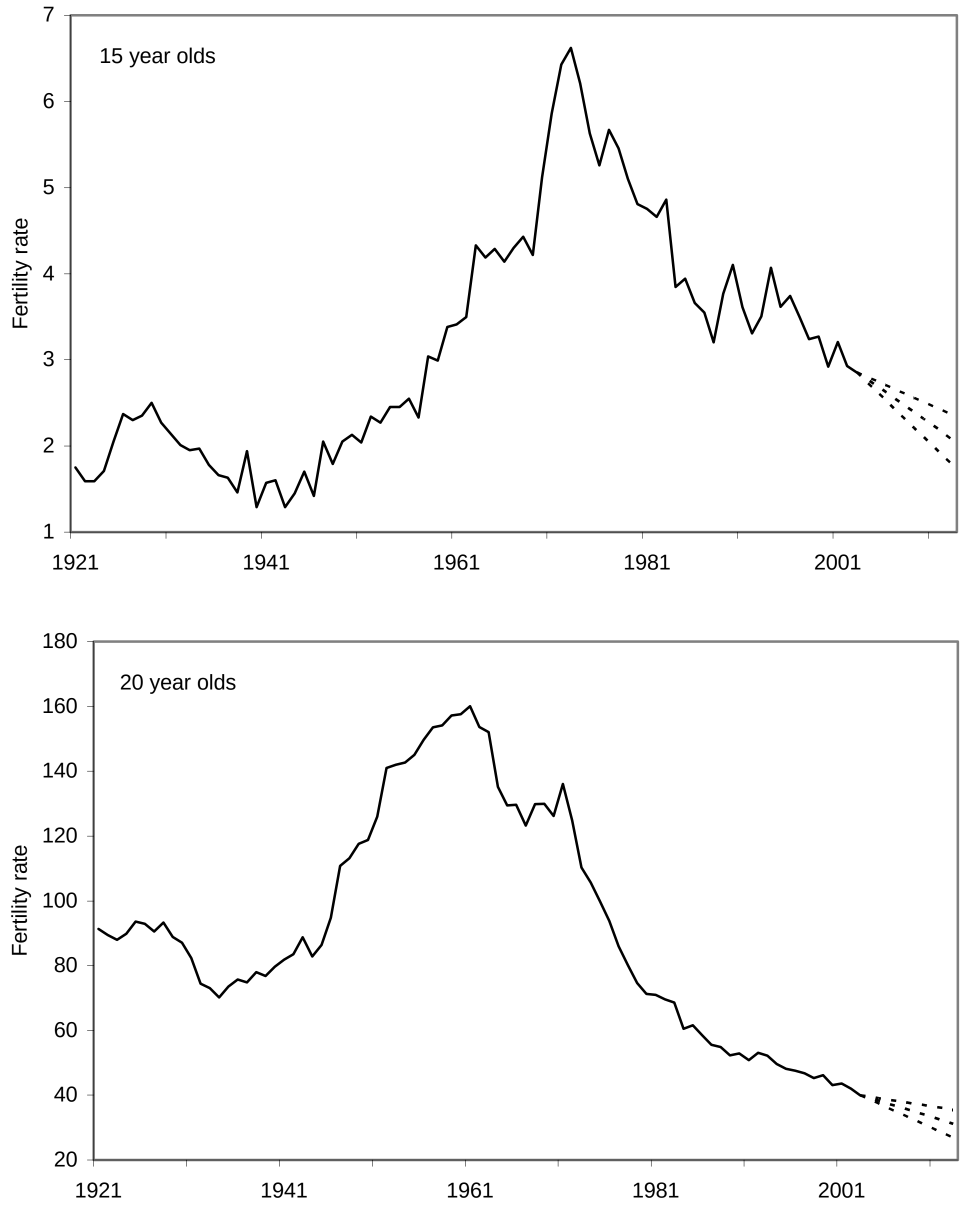
[a] The completed fertility rate is the average lifetime number of children per woman of a given birth cohort. The data up to 1954 is based on historical data, while data for subsequent years are at least partly estimates since they rely on forecasts of age-specific fertility rates for some out years.

Data source: Unpublished data from the ABS based on age-specific fertility rates and projections of age-specific rates made by the Commission.

Because of such uncertainties it is important to consider different scenarios. Quite different future fertility patterns may plausibly emerge. Figures 1.3 to 1.5 show the trajectories of high and low scenarios around the base case, compared with historical trends for a broad range of ages. Such outcomes are less likely than the base case, but are still feasible.

Figure 1.3 **Age-specific fertility rates**

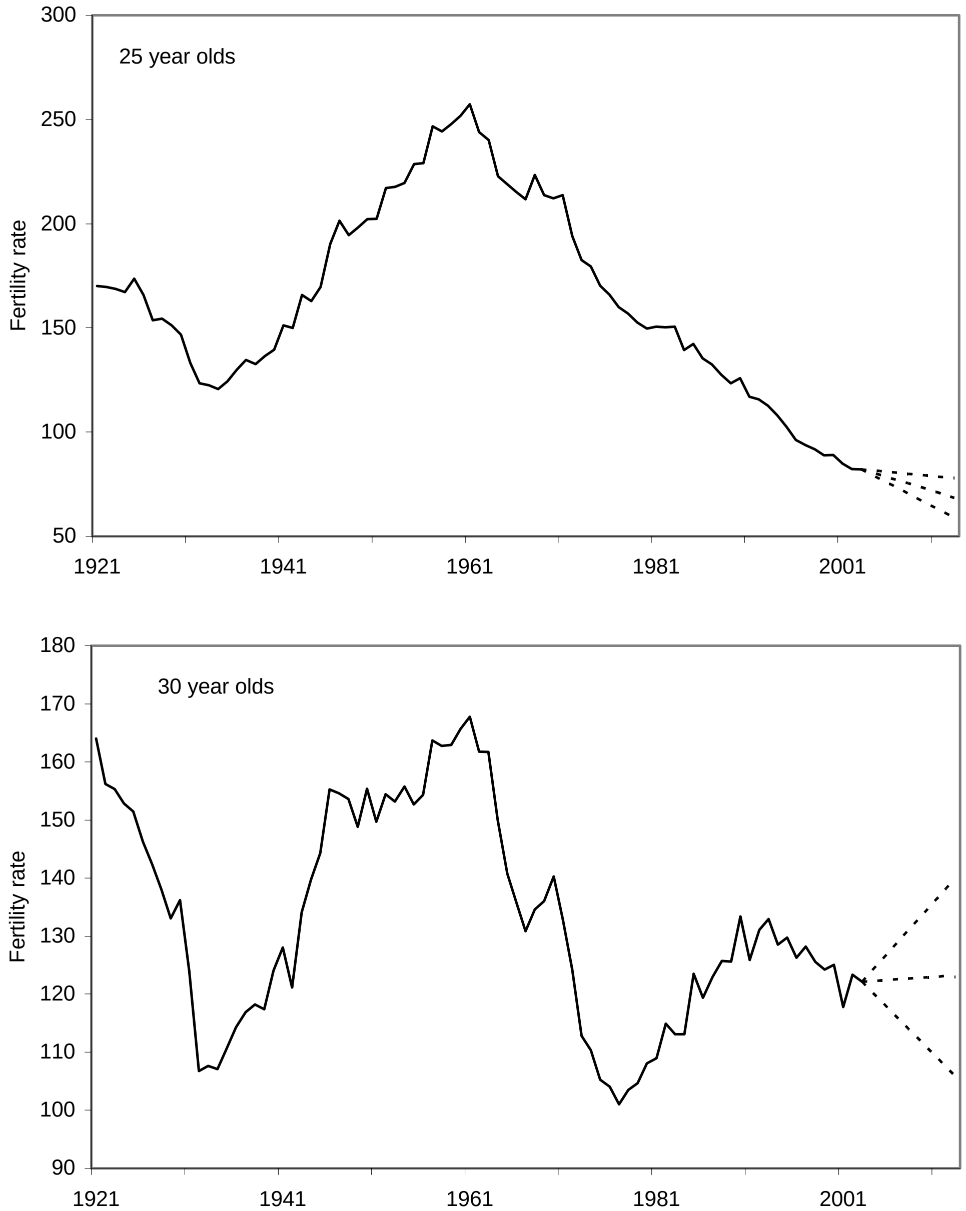
15 and 20 year olds, 1921 to 2013



Data source: Unpublished data from the ABS on age-specific fertility rates and projections of age-specific rates made by the Commission.

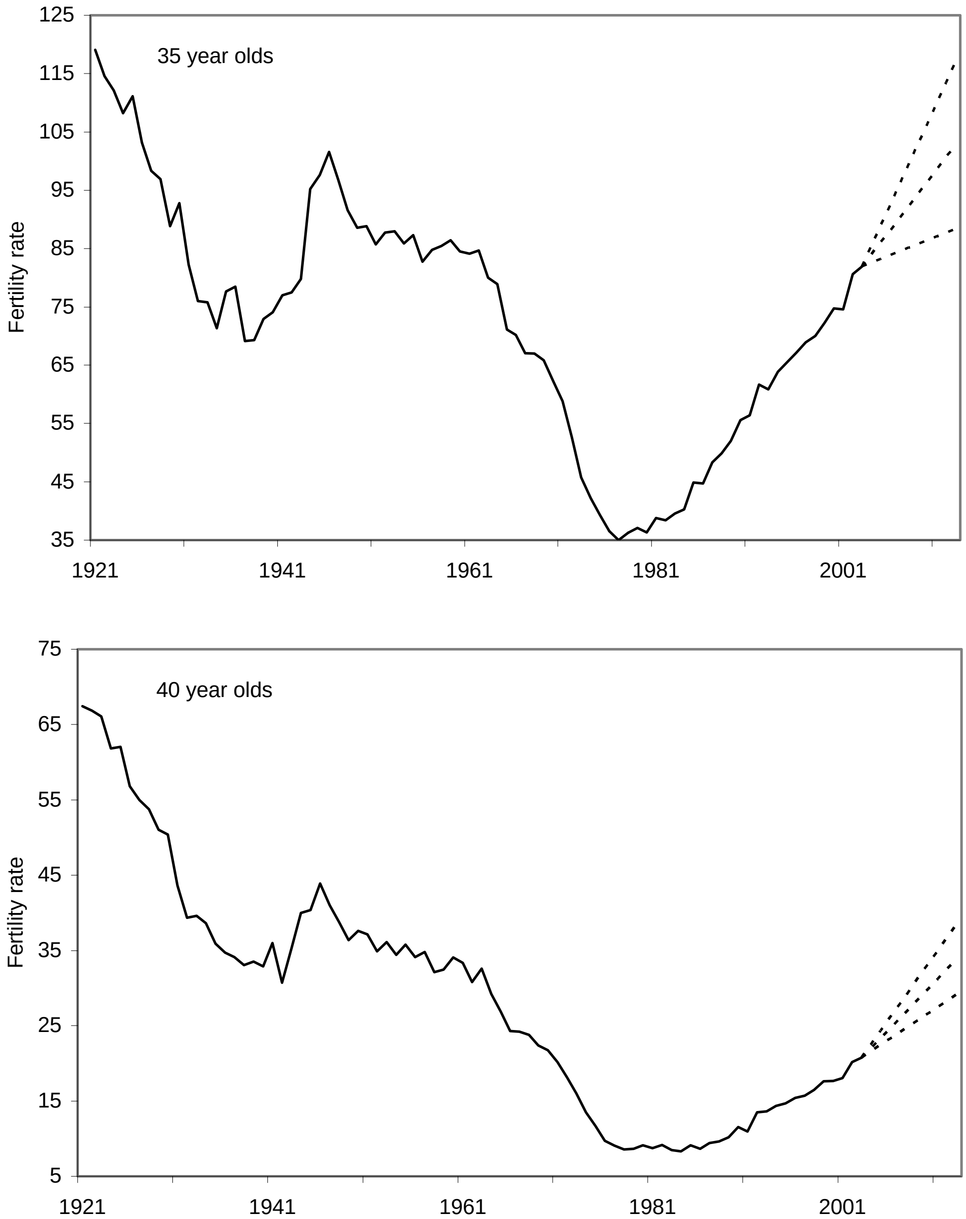
Figure 1.4 **Age-specific fertility rates**

25 and 30 year olds, 1921 to 2013



Data source: Unpublished data from the ABS on age-specific fertility rates and projections of age-specific rates made by the Commission.

Figure 1.5 **Age-specific fertility rates**
35 and 40 year olds, 1921 to 2013



Data source: Unpublished data from the ABS on age-specific fertility rates and projections of age-specific rates made by the Commission.

In the low case, the TFR decreases linearly from its 2003 level to 1.55 in 2013. The age-specific rates associated with this TFR in 2013 were estimated as $ASFR_{x,low} = ASFR_{x,base\ case} . (1.55/1.8)$, where x is years of age from 15 to 49. The age-specific rates for years 2004 to 2012 were linearly interpolated. The low scenario reflects less growth in fertility rates for older women and stronger declines in fertility rates for younger women. It is consistent with some of the projections suggested by

Kippen (2004) on the basis of parity data. It suggests a slightly accelerating reduction in the CFR.

In the high case, the TFR increases linearly from its 2003 level to 2.05 in 2013. The age-specific rates associated with this TFR in 2013 were estimated as $ASFR_{x,high} = ASFR_{x,base\ case} . (2.05/1.8)$, where x is years of age from 15 to 49. The age-specific rates for years 2004 to 2012 were linearly interpolated. The high case reflects relatively modest future reductions in fertility rates for younger women, combined with large increases in fertility rates for older women associated with the tempo effect. Despite this, this scenario still (realistically) suggests a fall in the CFR.

The PC's demographic model allows the choice of other TFR scenarios, but imposes the same shape (not level) of the age profile of fertility (as in Rowland's 2003 model).

Life expectancy

There have been significant historical reductions in mortality rates, which are widely projected to continue. However, as noted in chapter 2, there are several methods for projecting mortality, with differing implications for the extent of such reductions. For example, Heather Booth's forecasts (commissioned by the PC) using the Lee-Carter method results in bigger reductions in mortality rates than those underlying the ABS B series. On the other hand, Hyndman (2004) has shown that Lee-Carter methods can exaggerate future reductions in mortality (at least for the United States).

In the PC-M series, the Commission has adopted the mortality rates (Q_x) underlying the ABS B series as its base case. This results in a male and female life expectancy of 84.2 and 87.7 years respectively by 2050-51. The Commission considered several other scenarios (with implied life expectancies shown in table 1.1).

- A low gain in life expectancy (PC Low series), in which life expectancy for males and females only rises to 83 and 86 years respectively by 2050-51;[7]. For example, lower gains might be precipitated by rising obesity rates and associated increases in diabetes II. Climate change, antibiotic resistance and new diseases (such as SARS) may also have unexpected impacts on mortality.
- A high gain in life expectancy (PC High series), in which life expectancy for males and females rises to 92.2 and 95 years respectively by 2050-51. These might reflect new medical technologies and lifestyle responses by people to

[7] This is a departure from the ABS practice in the 2003 population projections, which included only the possibility of medium or high gains in life expectancy.

emerging risks, such as diabetes II. The gains considered in this scenario are the same as the life expectancy gains used by the ABS in its series A projections, but the age-specific mortality patterns are slightly different. In particular, the PC high series uses a higher value of Q100+ to maintain the usual shape of the mortality profile by age.

- The ABS A series mortality rates;
- High, medium and low options estimated by Heather Booth from the Australian National University.

The projection program accompanying the report allows other assumptions by users to be assessed as well.

Table 1.1 **Life expectancies associated with various scenarios**

	2004-05		*2050-51*	
	Males	*Females*	*Males*	*Females*
	years	years	years	years
PC-M / ABS B series	78.4	83.6	84.2	87.7
PC Low series	78.4	83.6	83.0	86.0
PC High series[a]	78.4	83.6	92.2	95.0
Booth Medium series	78.2	83.4	88.0	92.2
Booth Low series	77.1	82.1	83.3	86.4
Booth High series	79.3	84.6	92.4	97.7
ABS High series	78.4	83.6	92.2	95.0

a Although the ABS high series and the PC high series have the same life expectancies, they have a different underlying mortality pattern.

Source: Based on data provided by Heather Booth from the Australian National University, unpublished estimates of Qx from the ABS, and Commission estimates.

Alan Hall (DR51) notes that a useful way of assessing the impact of mortality on the age-distribution is to consider the age structure of the synthetic life table population (table 1.2). This method usefully abstracts from short term influences — such as baby booms or epidemics — that can affect the age structure of a population over the medium term. Mortality-based age structures derived from a life table will only be equivalent to the actual age distribution if the population is stationary (not changing in numbers or age structure), with zero migration (Rowland p. 307). Table 1.2 confirms that much of the future ageing of the population is due to mortality gains already made (noting that the aged dependency rate of the *projected actual* population in 2004-05 is only 19.5 per cent). It also shows that potential for even older age structures in the very long run relative to those likely to be encountered in 2050-51, especially in scenarios in which life expectancy gains to that year gave been large. For example, the potential long-run age dependency rate under Booth's high case (given the life table for 2050) is around 62 percent, whereas the projected observed dependency rate for 2050-51 is 10 percentage points less. The dependency ratios predicted on the basis of mortality rates at 2050 are close to those of population projections to 2151 (chapter 2).

Table 1.2 **The aged and total dependency ratios associated with life table mortality rates versus projected populations**

	2004-05		*2050-51*	
	ADR	*TDR*	*ADR*	*TDR*
Using Life tables[a]				
PC-M / ABS B series	36.9	67.7	45.4	76.0
PC Low series	36.9	67.7	42.4	73.0
PC High series	36.9	67.7	58.8	89.1
Booth Medium series	36.1	67.0	52.1	82.5
Booth Low series	34.3	65.2	42.8	73.4
Booth High series	38.0	68.8	61.6	91.8
ABS High series	36.9	67.7	58.6	88.8
Projected populations				
PC-M	19.5	48.5	42.7	69.8
PC Low series	19.5	48.5	38.4	65.3
PC High series	19.5	48.5	49.5	76.5
Booth Medium series	19.4	48.5	43.5	70.3
Booth Low series	19.4	48.4	39.5	66.6
Booth High series	19.5	48.6	52.6	79.5
ABS High series	19.5	48.5	50.5	77.5

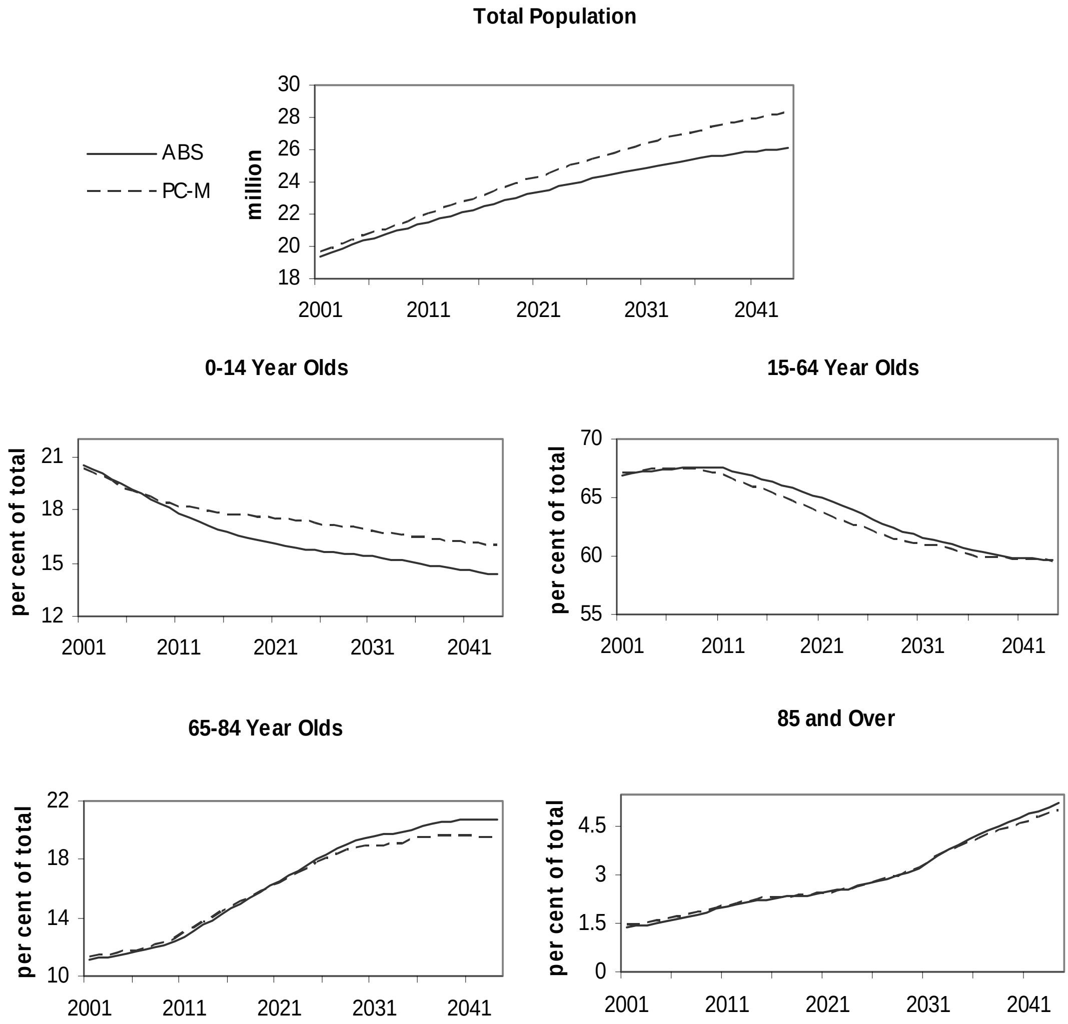
a The life table dependency ratios are based on adding up Lx for males and females for the old and young and comparing with the sum of Lx for people aged 15-64 years. Alan Hall (sub. DR51) and Rowland (2003) provide more information on the methods and interpretation.

Source: Based on data provided by Heather Booth from the Australian National University, unpublished estimates of Qx from the ABS, and Commission estimates.

How do the new projections compare with the ABS B series?

The Commission's PC-M series have a higher population than the ABS B series, reflecting the higher fertility and net migration assumptions. They also result in less ageing (figure 1.6).

Figure 1.6 **Differences between the ABS B series and the PC-M series**



Data source: ABS B series data and Commission estimates.

1.3 Northern Territory demographic projections

The cohort-component model is also applied for the demographic projections for Indigenous and non-Indigenous populations of the Northern Territory. When summed, these produce a different estimate of the Northern Territory population than that estimated under the PC-M model. The alternative total for the Northern Territory population is referred to as the PC-NTALT model.

Estimating sub-populations for the Northern Territory involve several complicated methodological and data issues.

Net overseas migration

Zero net Indigenous net migration was assumed for the Northern Territory. For the non-Indigenous population, it was assumed that about 0.3 percent of Australian net inwards migration was directed to the Northern Territory (the assumption used by the ABS in its B series population projections in 2003). This results in net inwards migration of 345 per year. The age structure applying to all Australian net inwards migrants is assumed for overseas migrants to the Northern Territory. In the high migration case, 500 net migrants a year were assumed, while in the low case, 200 were assumed.

Net interstate migration

As well as net migration overseas, people may migrate to and from other States. This is referred to as net interstate migration and is calculated as Northern Territory arrivals minus Northern Territory departures. Several approaches were adopted for net interstate migration, depending on Indigenous status.

Net migration plays a particularly important role for non-Indigenous demography in the Northern Territory. Arrival and departure numbers are large and have significant potential effects on the age distribution of the population. It is quite common for projections — as in the approach used for net overseas migration to Australia — to assume a constant value of net interstate migration with a fixed age distribution for all projection years. However, in the case of the non-Indigenous population, simulations revealed that such a projection method can result in the complete depletion of populations in some age–sex ranges. This is unrealistic as outflows could be expected to fall as the sub-population in a given age–sex range fell, and this would then result in net migration inflows for this age range. To overcome the limitations of this approach, the Commission separately modelled inflows and outflows. This was achieved by estimating inwards and outwards interstate migration *propensities* for each age–sex group and applying these to population numbers. Propensities for outward interstate migration (POIM) from the Northern Territory (used to estimate departures from the Northern Territory) were calculated as:

$$POIM_{x,s} = OIM_{x,s} / NIPOPNT_{x,s}$$

where OIM is outward interstate migration from the Northern Territory and NIPOPNT is the non-Indigenous population of the Northern Territory. The propensities were estimated for five year age intervals from 2001 Population Census data provided by the Northern Territory Government, with propensities for single years of age derived using cubic spline methods.[8] It was assumed that these propensities remained fixed over time.

Propensities for inward interstate migration (PIIM) to the Northern Territory (used to estimate arrivals to the Northern Territory) were calculated as:

$$PIIM_{x,s} = IIM_{x,s} / POPAUS_{x,s}$$

where IIM is inward interstate migration to the Northern Territory and POPAUS is the total population of Australia less the Northern Territory.[9] As above, single year of age propensities were estimated for 2001, and were assumed to remain fixed over time.

These propensities were then applied to one year lagged NIPOPNT (estimated by the Commission) and POPAUS (ABS series B) projections to derive the inflows and outflows of non-Indigenous people in the Northern Territory.

For Indigenous people in the Northern Territory, a fixed annual value for net interstate migration was assumed (similar to the approach used for net overseas migration to Australia), with a fixed age distribution based on age of arrivals versus departures from Census data (provided by the Northern Territory Government).[10] The ABS used the same approach in its projections. This is a feasible approach because net interstate migration by Indigenous people in the Northern Territory is very small, averaging around -75 from 1996 to 2001 (ABS 2004g, p. 17). The base case for Indigenous population projections assumes net interstate migration of -75 for the Northern Territory (as in the ABS's experimental estimates). A low and high case of -100 and -50 respectively was adopted.

Fertility

Fertility is measured as in the Australia-wide projection model. Fertility rates for Indigenous women have been falling rapidly. The age-specific fertility rates for calendar years 2001 to 2003 were estimated from various ABS sources using cubic

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[8] Cubic splines were applied to the cumulative shares of departures by age, and then differenced to obtain propensities by individual year. This ensured that the single year data added up to interval data.

[9] Ideally, POPAUS would exclude Indigenous people, but no long term projections of all Indigenous people are readily available. In any case, the bias resulting from their inclusion is so small as to be irrelevant because of their small share of the overall non-Northern Territory population.

[10] Data were smoothed and interpolated to provide information for single years of age.

splines, with adjustment for birth over counts, as undertaken by the ABS.[11] In the base case it was assumed that in the ensuing years the age-specific fertility rates took 30 years to reach the fertility rates applying to Australia as a whole in 2013, and then stayed fixed. This gave a TFR nearly identical to that used for the relevant years of the ABS experimental estimates to 2009 (for example, in both cases the TFR was 2.4 in 2009). Under the low fertility case, it was assumed that the transition took 20 years, while in the high fertility scenario, it was assumed that it took 40 years.

The fertility rate for non-Indigenous Northern Territory women is much lower than for comparable Indigenous women, but still higher than other Australian women. Under the base case, it is assumed that the age-specific fertility rates take 15 years to reach the anticipated fertility rates applying to Australia as a whole in 2013, and then stayed fixed. Under the low case, the transition is completed in 10 years and in the high case, 20 years.

Paternity

Birth rates where the mother is non-Indigenous and the father is Indigenous are referred to as ‘paternity’ (ABS 1995). Children born from these relationships are counted as part of the Indigenous population. The method for calculating of the number of Indigenous births associated with paternity is similar to that for fertility:

$$B_t = \frac{1}{2}\left(\sum_{x=15}^{49} PR_{x,T} \times P_{x,f,t+} + \sum_{x=15}^{49} PR_{x,T+1} \times P_{x,f,t+1} \right) / 1000$$

where PR is the paternity rate, defined as the number of children of Indigenous fathers that are born to non-Indigenous women per 1000 Indigenous fathers. These births are simply added to Indigenous births associated with fertility. Of course, these births must be subtracted in the projections for the non-Indigenous population.

Age-specific paternity rates of Indigenous fathers (PR_x) for June 2001 were estimated from ABS data (2004g) using cubic splines. Under the base case it was assumed that paternity rates grew logistically:

$$\mathrm{PR}_{x,t} = (1 + \frac{1}{1 + \frac{(1/s - 1)}{1.05} \times 1.05^{(t-2001)}}) \times PR_{x,t-1}$$

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[11] The 2001 data were from ABS (*Experimental Estimates and projections, Aboriginal and Torres Strait Islander Australians*, *2004*, Cat. no. 3238.0, p.14). The 2002 and 2003 data were from ABS (*Births Australia*, Cat. no. 3301.0) with adjustment for over counts from the Experimental Estimates publication (p. 76).

with a growth in the first year of s (with s = 0.02 or 2 percent growth). The ABS assumed zero change in paternity rates in the Northern Territory in its experimental estimates to 2009. However, Northern Territory paternity rates are much lower than all other jurisdictions, so this is probably not a realistic assumption over the long projection horizon used by the Commission.[12]

In the high paternity rate case, it was assumed that s = 0.05 and in the low case, s = 0.01.

Life expectancy

The life expectancy assumptions used for Australia as a whole (above) were used to generate non-Indigenous population estimates for the Northern Territory (with high, medium and low life expectancy scenarios for non-Indigenous Northern Territorians set to the equivalents for Australia).

The expected long-term trend for Indigenous life expectancy in the Northern Territory is more difficult to forecast. This reflects several factors.

First, there are inadequacies in data on Indigenous deaths and population estimates that may distort historical trends in life expectancy (ABS 2004h, AIHW 2004, p. 195). These inadequacies appear to be less severe for the Northern Territory (ABS 2004h, p. 11), which probably reflects fewer difficulties in the identification of Indigenous status and smaller migration flows in that jurisdiction. Some commentators — for example, Ring and Firman (1998) — consider that there have been few, if any, improvements in health status and life expectancy in Indigenous Australians in the Northern Territory and Western Australia from the 1980s. Indeed, some sources of mortality have been increasing, such as diabetes (Ring and Firman) and smoking-related lung cancers (Condon et al. 2004a). In its most recent set of experimental projections and estimates of the Indigenous population, the ABS (2004) *assumed* no reduction in age-specific death rates between 1991 and 2009 for Indigenous people in all jurisdictions. However, the ABS emphasise that further research is needed to identify trends. The ABS is presently collaborating with the AIHW to determine whether Indigenous mortality has changed over recent decades. The most recent authoritative study of Northern Territory Indigenous mortality patterns over the period from 1966 to 2001 (Condon et al. 2004b) suggests that, in fact, there have been some beneficial reductions in mortality in that jurisdiction.

[12] For example, the average Australian paternity rate of Indigenous fathers was 6.4 in 2001 compared with 1.0 for the Northern Territory. It should be noted that the ABS explored the implications of trend growth rates in paternity rates of 1, 2 and 5 percent, as well as its base case zero assumption.

The reductions were predictably greatest for infants (with a decline of 85 per cent over the period). Much more modest gains were realised for older Indigenous people (of 30 percent in females and 19 percent in males aged 5 years and over).

Second, there is much uncertainty about how rapidly policy measures aimed at addressing Indigenous disadvantage will begin to work. On the available data, Indigenous Northern Territorians can expect to live around 20 years less than their non-Indigenous counterparts. This provides the potential for substantial catch-up in life expectancy if the underlying causes of elevated mortality rates can be addressed (such as better health services; enhanced housing, education and work opportunities; improved diet; and reduced smoking and substance abuse). For example, Condon et al (2004a) note that enhanced pap test programs among Indigenous women could significantly reduce the high rate of fatalities associated with cancers of the cervix. Governments around Australia are trying to address these underlying causes. The experience of some other indigenous groups — such as New Zealand Maoris and Native Americans — suggest very significant increases in life expectancy can occur over several decades (Ring and Firman 1998).

In the projections undertaken for the Northern Territory, the Commission explores three scenarios for life expectancy.

The medium case

Under this case, it is assumed that it takes 100 years to realise the average life expectancy experienced by Australians as a whole in 2001-02. This implies a gain in life expectancy for males of around 11 years to 2044-45 and 12 years to 2050-51 or about 0.25 years per year (this is equivalent to one of the options selected by the ABS in its experimental estimates). Gains of this magnitude and from the same starting base were realised by the (mainly) white population of Australia over roughly 50 years in the mid 20^{th} century. For example, male Australian life expectancy improved from 57.6 to 69.6 from 1915 to 1976 (61 years), while female life expectancy improved from 65.2 years to 75.7 years from 1927 to 1974 (47 years). So it is clearly *technically* possible for sustained life expectancy gains of this magnitude over periods less than 100 years.

That said, the gains generally eclipse those apparently measured for Indigenous populations in the last 30 years. This scenario requires less rapid gains in infant mortality than found by Condon et al. (2004), but significantly better gains for older Indigenous people, particularly males. For example, it would imply a 50 per cent reduction in mortality rates (Q_x) for males aged 35 years over the 34 year period from 2000-01 to 2034-35, which is much more than the gains occurring over the 34 year period from 1966-67 to 2000-01 for this group.

The overall gain in life expectancy would still leave a large gap in life expectancy between Indigenous and non-Indigenous Northern Territorians.

It should be emphasised that a gain of 11 years in life expectancy does not mean that an average middle aged Indigenous person alive today will benefit from a 11 year extension of life.

The low and high cases

Under the (pessimistic) low scenario, no improvement in life expectancy occurs over the projection horizon.

Under the high scenario, the Commission assumes that it takes 60 years to realise the average life expectancy experienced by Australians as a whole in 2001-02. This implies a gain in life expectancy of around 16 years for males to 2044-45 and 18 years to 2050-51 or about 0.37 years gain per year. This optimistic scenario has lower gains than the highest scenario explored by the ABS in its experimental estimates to 2009 (which assumed gains of 0.5 years of life expectancy per year).

The Commission emphasises the particularly large effects of uncertainty about mortality trends for population projections for the Indigenous population of the Northern Territory. The Commission has included the projection program used to generate Indigenous population estimates and users can nominate alternative assumptions.

Unexplained growth

A major concern of the ABS is that there are discrepancies between populations in successive five year population censuses that cannot be explained by estimated deaths, births, net interstate migration and net overseas migration over the intervening period. In particular, Indigenous populations grow at a faster rate than expected, with annual unexplained growth of 1.6 per cent for Indigenous populations in Australia as a whole from 1996 to 2001 (ABS 2004g, p. 19). Problems in collection of Indigenous demographic statistics represent one reason for this. Another major factor is that some people who once identified themselves as non-Indigenous subsequently identify themselves as Indigenous. However, this problem is much less severe for the Northern Territory, with only 0.3 percent unexplained growth per annum from 1996 to 2001. This issue has been ignored in the projections undertaken here.

Differences with the PC-M population estimates for the Northern Territory

The projections under the PC-M model (as in the B series before them) give a different picture of the total Northern Territory population than that provided by adding together the sub-populations estimated above (PC-NTALT). Overall, the population projected under PC-NTALT is significantly less than the PC-M series for the Northern Territory (about 75 percent of the PC-M series by 2050-51 or around 80 000 less people). Overall, the Commission considers that PC-NTALT provides the best overall view of the Northern Territory population, since it takes account of the different trajectories of the sub-populations.