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**TRENDS IN AGE- AND PARITY-SPECIFIC
FERTILITY IN AUSTRALIA**

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TRENDS IN AGE- AND PARITY-SPECIFIC FERTILITY IN AUSTRALIA

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Abstract

Examination of fertility rates in Australia indicates a fall over time in both period and cohort fertility. Period total fertility has been below replacement level for twenty-five years, while cohorts completing their fertility in the first decade of the 21st century are likely to have around replacement-level fertility. Policy-makers and others in Australia are concerned about the potential for further fertility decline, given the impact this would have on population age structure and growth rates.

This paper tests the hypothesis that the recent fall in fertility is due solely to changes in age-specific first-birth rates, resulting from delayed parenthood and increased levels of childlessness. Age- and parity-specific fertility rates for the period 1991–2000 are constructed. These show that recent fertility declines are driven by changes in first- and second-birth rates, rather than first-birth rates only, while rates for higher-order births remain relatively constant. One implication of this is an increasing prevalence of childlessness and one-child families in Australia.

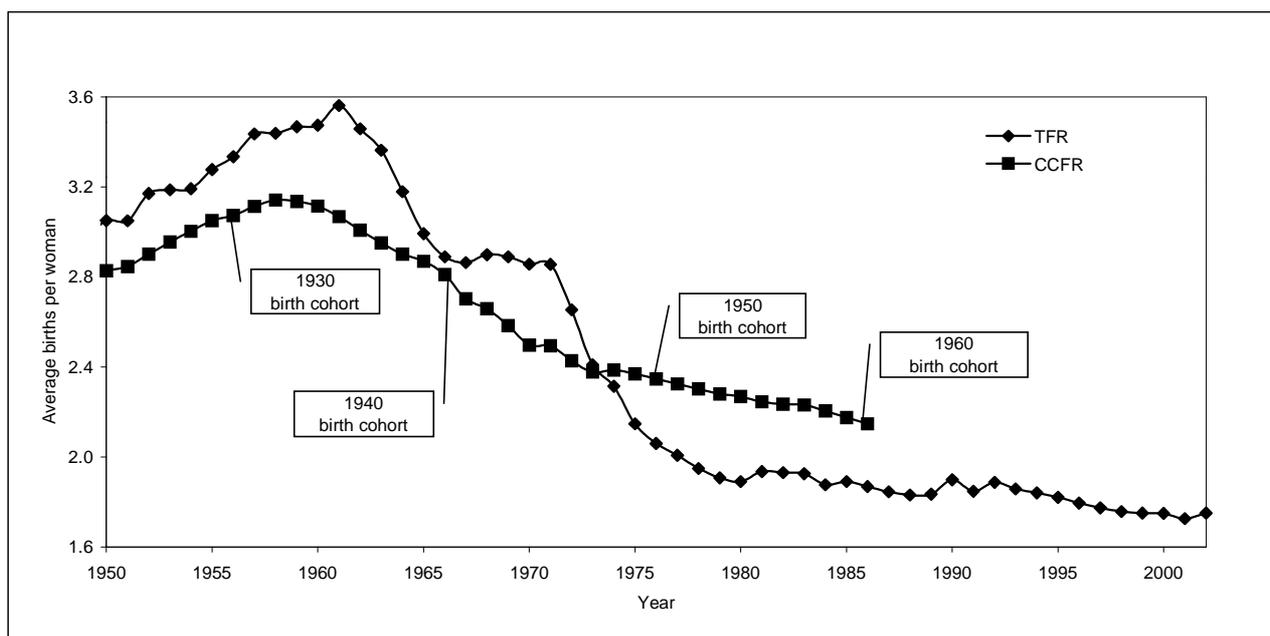
The author uses the 1991–2000 age- and parity-specific fertility rates as the basis of four different projections of fertility. The likelihood of each of these projections given past trends in fertility is considered.

Fertility in Australia—an overview

Period fertility

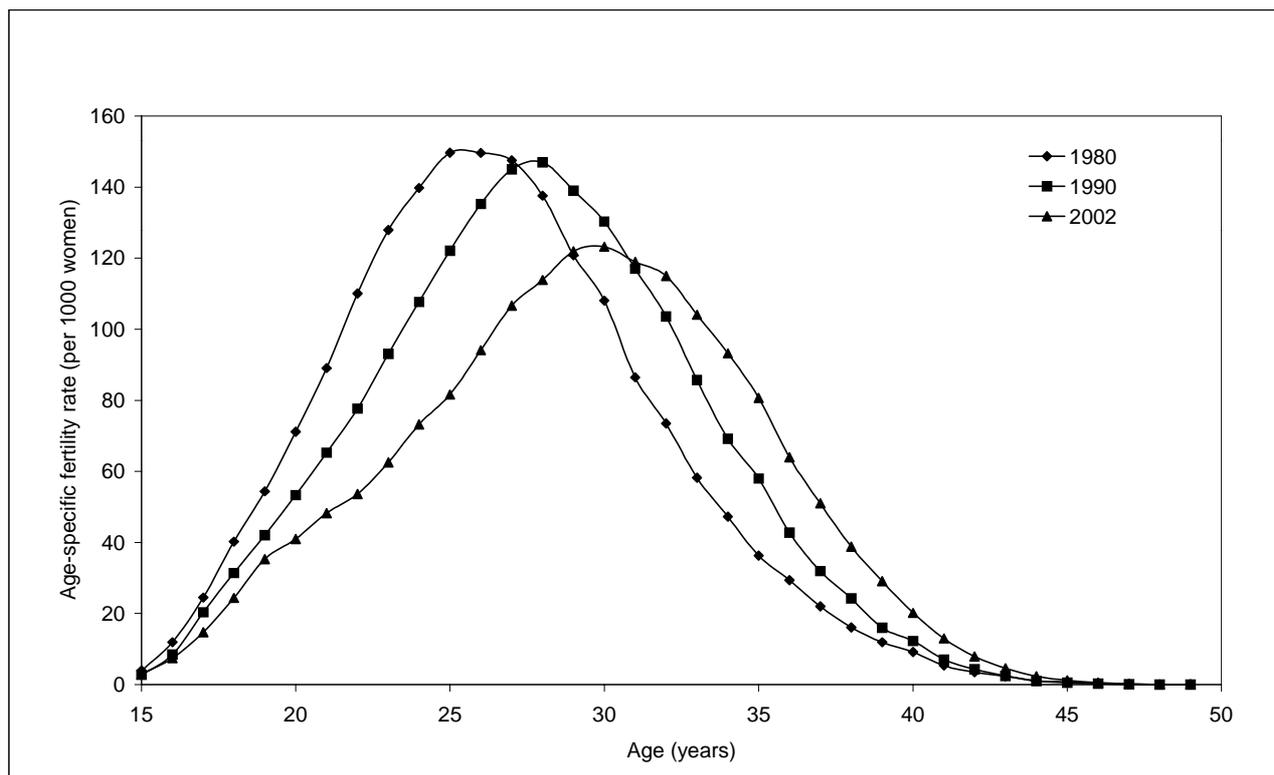
In 1961, at the height of the postwar baby boom, Australia's total fertility rate (TFR) stood at 3.56 births per woman, more than twice the 2002 level of 1.75. Most of the decline in fertility over this period occurred in the first two decades from 1961. Fertility fell sharply in the early 1960s, plateaued briefly at around 2.9 births per woman from 1966 to 1971 and then again plummeted. The TFR stabilised at around 1.8–1.9 births per woman in the 1980s, however in the 1990s fertility again began to decline, this time much more slowly. Australia's TFR over the period 1950–2002 is shown in Figure 1.

Figure 1 Total fertility rate (TFR), 1950–2002, and completed cohort fertility rate (CCFR), 1924–60, Australia



Source: ABS 1999b, ABS various years/b, author's calculations.

The drop in the TFR in the 1960s and 70s was the result of falls in fertility at nearly all ages. Between 1961 and 1966, age-specific fertility rates declined by around 20 per cent for each age between 19 and 47 years. Between 1971 and 1979, fertility at each age declined between 20 and 60 per cent, with the greatest falls occurring for women aged 40 years and over. However, in the 1980s, fertility at older ages began to increase while declines at younger ages continued. The result was a stabilisation of the TFR over this period, with rises in fertility at ages 27 years and above compensating continuing fertility declines for women in their teens and early twenties. In the 1990s falls in fertility at the younger ages continued apace while increases in fertility at the older ages slowed considerably, resulting in a decline in the TFR. Figure 2 shows age-specific fertility rates for the years 1980, 1990 and 2002. A comparison of the age-specific fertility rates for 1980 and 1990 shows a substantial shift to older age fertility, even though the TFRs for these years, 1.89 and 1.90 births per woman respectively, were virtually the same. Between 1990 and 2002, falls in fertility at the younger ages were no longer being fully compensated by increases in fertility at the older ages.

Figure 2 Period age-specific fertility rates, 1980, 1990 and 2002, Australia

Source: ABS 1999b, author's calculations from ABS various years/a and ABS various years/b.

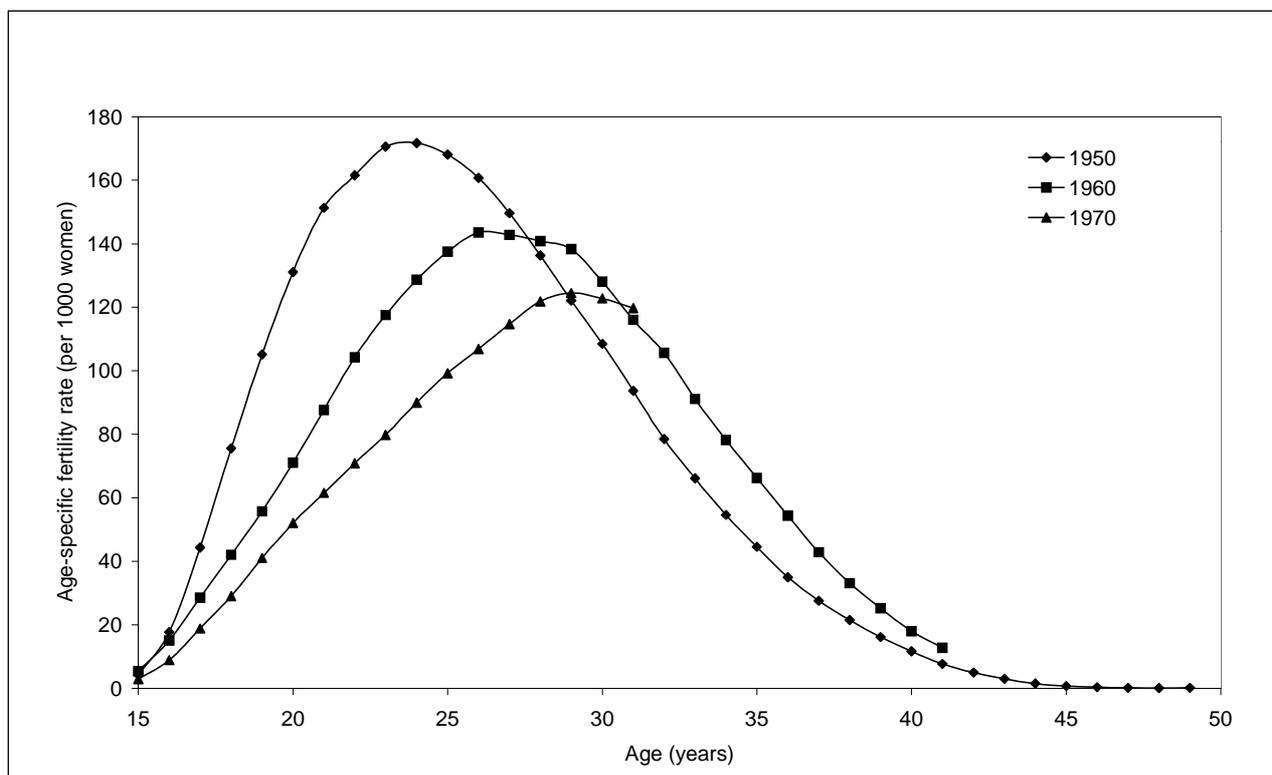
Cohort fertility

The total fertility rate and period age-specific fertility rates are useful measures in that they can be used to quantify current fertility experience. However they do not relate to the experience of any actual individual or group; women bear children over time, not cross-sectionally. In addition, cross-sectional fertility measures can be misleading in that falls in period fertility may be the result of delayed childbearing (tempo) rather than reduced parity (quantum) for any particular group of women. In order to consider the experience of actual women, the fertility of birth cohorts can be traced through time.

The completed cohort fertility rate (CCFR) for Australia is also shown in Figure 1. In many ways, the story of Australian cohort fertility is similar to that of period fertility. The CCFR has been declining for all cohorts born since 1932, although no cohort with complete or near-complete fertility has yet experienced a CCFR below replacement level. The 1932 birth cohort bore, on average, 3.14 children per woman. This has declined to 2.15 children per woman for the 1960 birth cohort and is projected to decline further for later cohorts. The lower fertility of women born in 1960, compared to that of women born in 1932, was the result of falls in fertility of up to 50 per cent between the ages of 18 and 40 years. The most dramatic declines occurred for women in their twenties. Later birth cohorts have not yet completed their fertility, however comparisons of changes in fertility at the younger ages can be made. From 1960 to 1970, cohort fertility fell at all ages 30 years and under. This decline is continuing for later cohorts at younger ages for which data are available. The fall in cohort fertility is associated with delayed first birth. For example, in the 1986 Census the proportion of women aged 30 years (born 1955–56) with zero parity was recorded as 26 per cent. For women aged 30 years in 1996 (born 1965–66) this proportion had increased to 38 per cent.

Figure 3 shows age-specific fertility rates for women born in 1950, 1960 and 1970. The birth cohort of 1960 experienced much lower levels of fertility at the younger ages than did the cohort of 1950 and only slightly higher levels of fertility at the older ages. Women born in 1970 have lower fertility at every age up to 30 years of age than either women born in 1950 or 1960. Although fertility at ages 30 and over is likely to be higher for this cohort, it is unlikely that it will increase to the extent required for replacement-level fertility.

Figure 3 Cohort age-specific fertility rates, 1950, 1960 and 1970, Australia



Source: Author's calculations from ABS 1999/b, ABS various years/a and ABS various years/b.

Fertility by age and parity

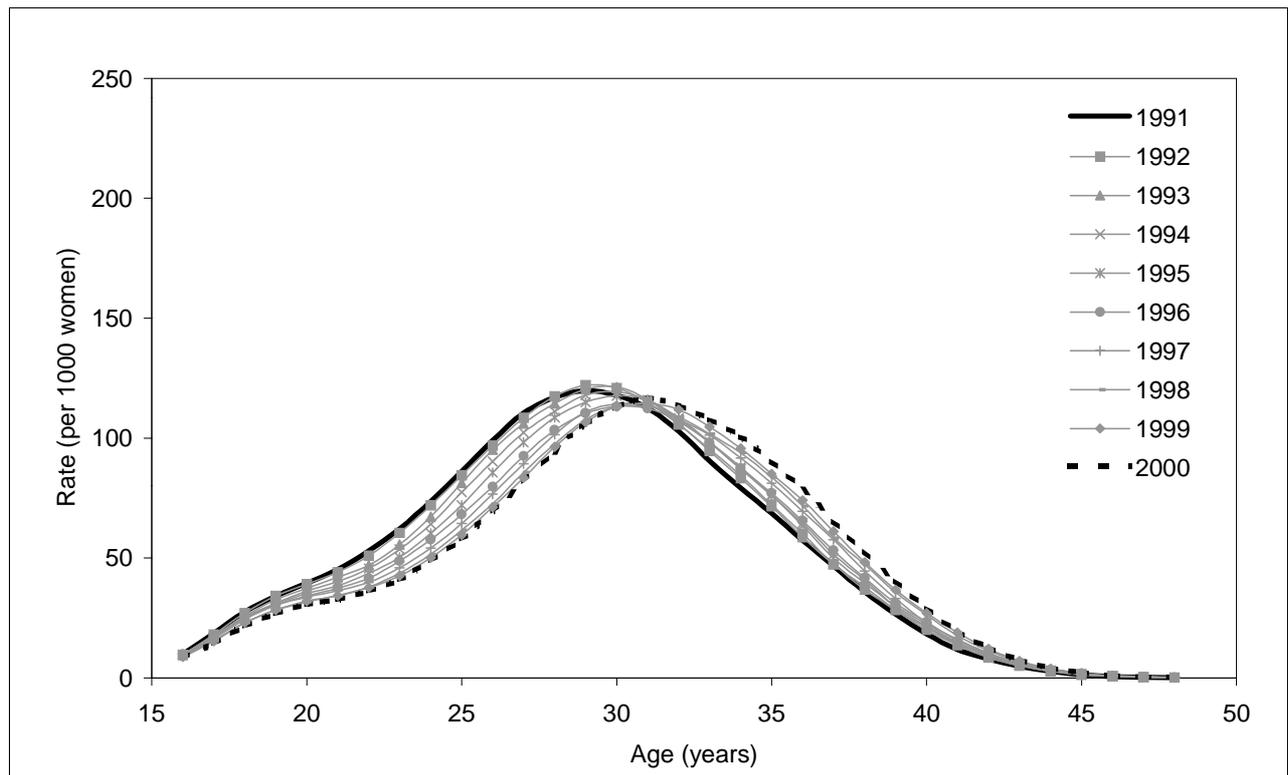
Ideally, Australia would have available a long series of annual births recorded by maternal age and previous parity in order for age- and parity-specific fertility rates (APFRs) to be calculated. This would allow examination of both period and cohort rates by parity over time. Unfortunately, while the total previous number of children borne by the mother is recorded in all birth registers of the Australian states and territories (with the exception of Victoria), only Queensland, South Australia, Western Australia and Tasmania code this information. This means that the necessary parity data are available through the registration system for less than 40 per cent of Australian births.

However, in 1991 the Australian Institute of Health and Welfare's National Perinatal Statistics Unit (AIHW NPSU) established the Perinatal Data Collection. This database also collects information on birth order, for all states and territories. Using these data, APFRs can be calculated for each year 1991 to 2000, the last year for which data are currently available. Age- and parity-specific fertility rates are calculated as the annual number of births to women of age a and parity i in year y , divided by the mid-year population at risk of such a birth; that is, the mid-year female population aged a of parity i (see Appendix A for detailed calculations).

Figure 4 shows APFRs for women with zero parity; that is, rates of first birth. These fertility rates follow the trend for age-specific rates in general, in that fertility is falling under age 30 years and increasing over age 30 years, although not to the same extent. For example, the first-birth rate at age 24 years declined from 73 per 1000 to 48 per 1000 from 1991 to 2000, while the first-birth rate at age 34 years increased from 78 to 100 over the same period. The peak in first-birth fertility occurs around age 29–31 years in each year.

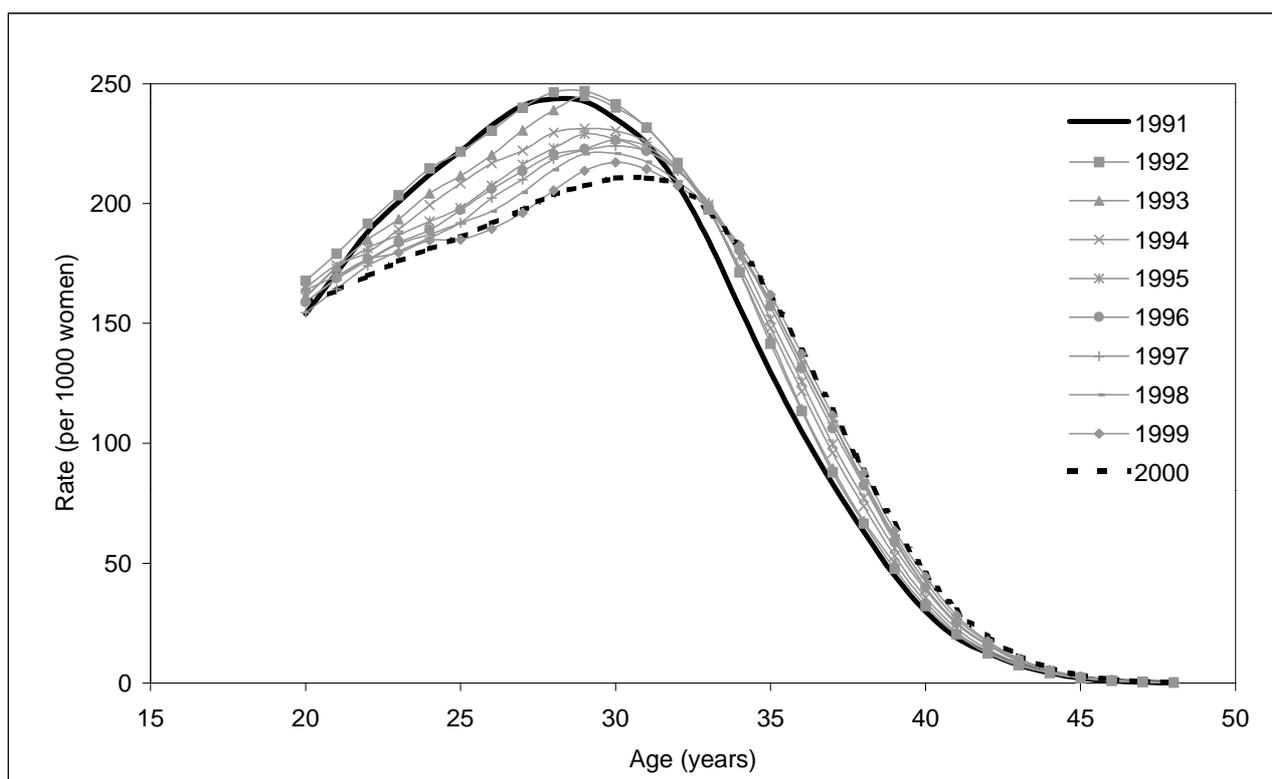
Rates of first birth are relatively low at all ages and did not exceed 125 births per thousand women over the period 1991–2000.

Figure 4 First-birth rate (women of zero parity), 1991-2000, Australia (3-year moving average)



Source: Author's calculations from ABS 1999/a, ABS 1999/b, ABS various years/a, ABS various years/b, AIHW NPSU 2001 and 2003.

Age- and parity-specific fertility rates for women of parity one are shown in Figure 5. Again rates declined substantially over time for younger women and increased for older women during the 1990s. The striking feature of these fertility rates is how high they are for women in their twenties and early thirties. The rate of second birth for women with parity one exceeds 150 per 1000 for all ages between 20 and 34 years over the period in question. Women in their late 20s experienced second-birth rates of close to 250 per thousand in the early 1990s. This illustrates the strength of the two-child family norm in Australia, with women moving quickly from first to second birth. Fertility rates for women with parity one are higher at all ages than for women with zero parity or parities above one.

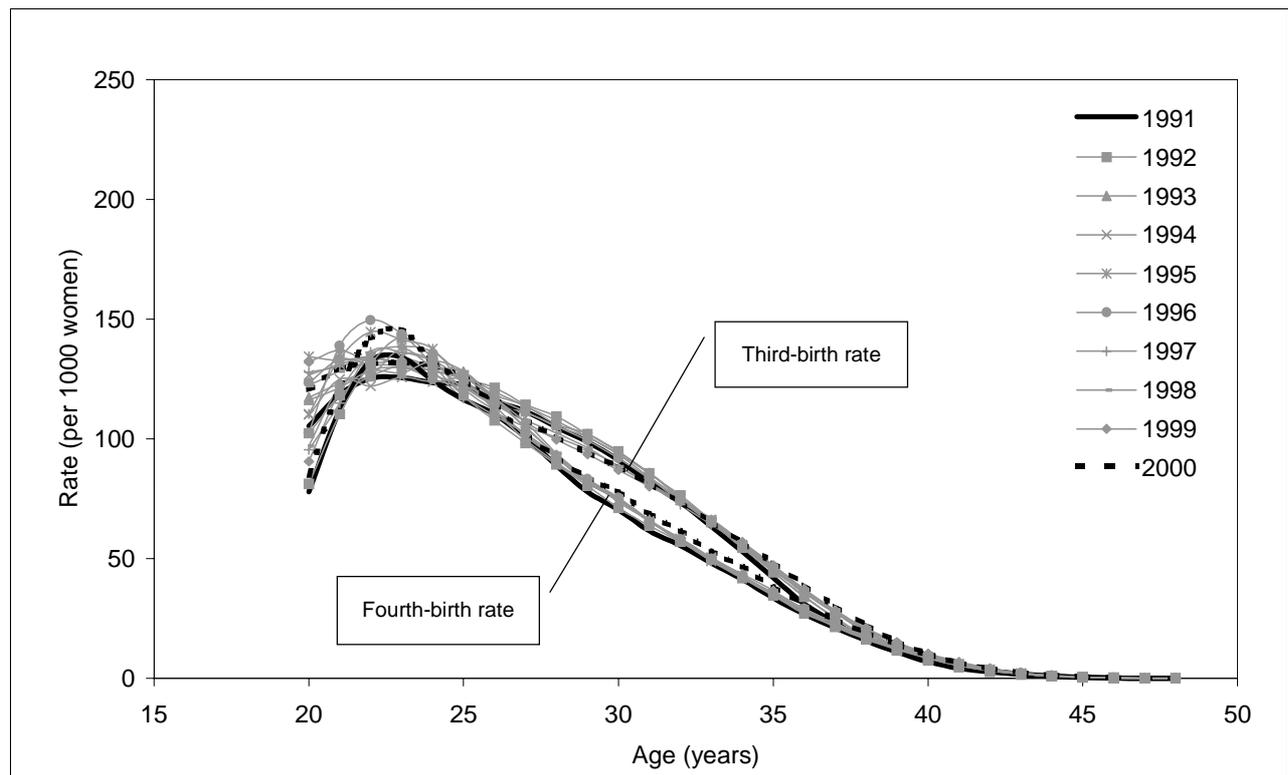
Figure 5 Second-birth rate (women of parity one), 1991-2000, Australia (3-year moving average)

Source: Author's calculations from ABS 1999/a, ABS 1999/b, ABS various years/a, ABS various years/b, AIHW NPSU 2001 and 2003.

Fertility rates for women of parity two and three are shown in Figure 6. Rates for parity four plus are not shown but follow the same pattern. Fertility rates for women with parity two and above are low and decline from the early twenties. These rates have remained relatively constant over the period 1991–2000, indicating that the decline in fertility over this period is due to delayed first and second births, rather than delayed higher-order births. However if first and second births are delayed in a context where the probability of a higher-order birth declines steadily with age, the result is a fall in the number of women achieving parities of three and above. In the recent past, women with three or more children have contributed considerably to completed fertility levels in Australia. McDonald (1998) has argued that the relatively high levels of fertility in Australia, compared with levels experienced in some European countries, result from the higher proportion of women in Australia with three or more children.

First- and second-birth rates are still changing over time, with declines at the younger ages and increases at older ages. These changes will result in increasing proportions of childlessness and one-child families, decreasing proportions of women with higher-order births, and lower levels of total period and cohort fertility.

Figure 6 Third-birth rate (women of parity two) and fourth-birth rate (women of parity three), 1991–2000, Australia (3-year moving average)



Source: Author's calculations from ABS 1999/a, ABS 1999/b, ABS various years/a, ABS various years/b, AIHW NPSU 2001 and 2003.

Reasons for fertility decline

As in many other developed countries, the dramatic fall in fertility in Australia is associated with shifting family size norms, the changing nature of relationships, greater availability of effective fertility control methods and higher levels of education and labour force participation of women (Jain and McDonald 1997).

From the early 1960s, more effective methods of birth control became available, allowing women more control over the timing and number of their births. The oral contraceptive pill became available in Australia in 1961 and was widely used from the late 1960s, and sterilisation was widely used from the 1970s. Several legal decisions around 1970 resulted in greater access to legal abortion from that time.

In 1971, 27 per cent of Australian women aged 15–24 were in education (Jain and McDonald 1997). By 2001 this figure had jumped to 56 per cent (ABS 2002). Research in Australia shows a strong correlation between education and age at first birth and completed fertility. For example, analysis of the Negotiating the Life Course Survey (McDonald et al 1999) found that women born 1945–64 experienced, on average, a delay of 0.75 years at age of first birth for every extra year of education between the ages of 15 and 24 years. The analysis also found that parity of women of the same age at the time of the survey was lower for those with higher levels of education.

In 2001, 72 per cent of women aged 20–44 were in the labour force, up from 31 per cent in 1961 and 45 per cent in 1971.

Australia's fertility, both period and cohort, is still high compared to fertility in many other developed countries. However there is evidence that Australian women, on average, have lower completed fertility than they anticipated when young. For example, Bracher and Santow (1991) have found that women married in the period 1966–86 had a completed family size 0.4 of a child lower, on average, than originally desired when first married.

Is Australia's fertility too low?

While fertility in Australia has been below replacement level since the mid-1970s, fertility levels have not been an issue until recently. Debates about population in Australia have essentially been debates about immigration. There are several reasons for this.

First, there has been a reluctance on the part of policy-makers and others to address the issue of fertility. The decision whether or not to have a child has been regarded as a private one, that should not or could not be influenced by government in a liberal democracy (Hugo 2000). The sensitivity of this issue is illustrated by the following example. In 1999, the Premier of the State of Victoria, Jeff Kennett, stated in a speech to an all-girls school that 'women are not producing enough offspring to...maintain our population levels'. This was said in the context of an argument for higher immigration, not an argument for higher fertility. However Kennett was lambasted by the media and others for 'telling girls that their duty is to breed' (in Shaw 1999).

Second has been the dominance of immigration in Australian thinking about population. This is understandable given that about one quarter of Australia's population was born overseas and that Australia still has one of the highest net migration rates in the world. It is widely perceived that any demographic problems resulting from low fertility and other factors can be solved by simply boosting immigration. Comments such as 'immigration can help keep our country young' and 'increased immigration levels can be a solution to many of the problems Australia faces in the long term' have been common over recent years (McDonald and Kippen 1999).

Third is the fact that the TFR, although below replacement level, is still relatively high. This, combined with the population momentum resulting from Australia's extended postwar baby boom, means that births will continue to exceed deaths for the first two or three decades of the 21st century. Population ageing will not accelerate until the second decade of the 21st century. Something which may become a problem in two or three decades is well outside the time frame of most governments.

Around the late 1990s, a growing awareness began among policy-makers in Australia of the importance of fertility in influencing population age structure and growth rates, and the importance of taking a long-term view, several decades at least, of demographic trends.

It has been realised that immigration will not 'keep our country young' and that immigrants are not perfect demographic substitutes for births. The degree of population ageing is more effectively ameliorated by maintaining fertility levels rather than increasing immigration.

There has also been a growing awareness that decisions about whether or not to have a child, and the timing of births, are not decisions made in isolation, but in an institutional context, influenced by many outside factors. Policies designed to stop fertility falling further need not involve appeals to women's 'patriotic duty' or methods designed to force women back into the home but may include electorally popular 'family-friendly' policies that make combining work and family life easier.

Future fertility

Concern about Australia's birth rate does not (or should not) centre around the current level of fertility. Projections show that if fertility remains where it is, or stabilises at a slightly lower level, then, combined with current levels of net migration, the population will stabilise within the next few decades with a sustainable age structure (McDonald and Kippen 1999). The concern is whether fertility will continue falling, perhaps to the very low levels experienced in some countries of Europe. Although it is impossible to conjecture with any certainty about future levels of fertility, projections can be made based on past cross-sectional and cohort trends.

The real questions are whether fertility under age 30 years will continue to decline and whether any such decline will be matched by increased fertility over age 30 years as cohorts move through to those ages. Over the recent past, fertility at older ages has been increasing for successive cohorts, but not to the extent required to compensate for falls in fertility at younger ages. Although no cohort with completed fertility has fewer than two births on average per woman, the trend shows a steady decline in completed fertility. The falls in fertility at younger ages are continuing. This suggests that falls in fertility at younger ages are not simply the result of delayed births that will occur at some point in the future, but rather indicate a shift to smaller completed family size.

Projections of fertility in Australia

There have been relatively few projections of Australian fertility in recent years. Those that have been made are generally based on projections of period age-specific fertility rates.

Official population projections for Australia are produced by the Australian Bureau of Statistics (ABS). In their most recent publication, the ABS (2003) use a high, medium and low fertility assumption. In the high assumption the TFR is assumed to increase slightly to 1.8. The ABS argues that this may occur given that fertility has 'fluctuated between 1.7 and 1.9 babies per woman since the late 1970s'. Under the medium and low assumptions, the TFR falls to 1.6 and 1.4 births per woman respectively before stabilising. Under all three scenarios, the mean age of fertility is projected to continue rising.

The Retirement Income Modelling Unit of the Federal Treasury (Bacon 2000) has projected age-specific fertility-rate trends using curve fitting, resulting in a gradual decline in the TFR to 1.65 in 2010 and 1.56 by 2050.

McDonald and Kippen (1999) have projected fertility of 1.65 births per woman by 2008. They state that this 'seems justified' based on then-current levels of fertility in other industrialised countries, many of which have fertility rates lower than Australia's, and fertility rates in Australian capital cities, which averaged around 1.65 in 1998.

Projecting age- and parity-specific fertility

In this paper I make four different assumptions about the future of APFRs for women with parity zero and parity one and assess what impact these have on Australia's age-specific fertility rates over the period to 2015. In all projections, rates for women with parities two and over are assumed to remain constant, in line with Australian experience over the period 1991–2000 (see Appendix B for calculations).

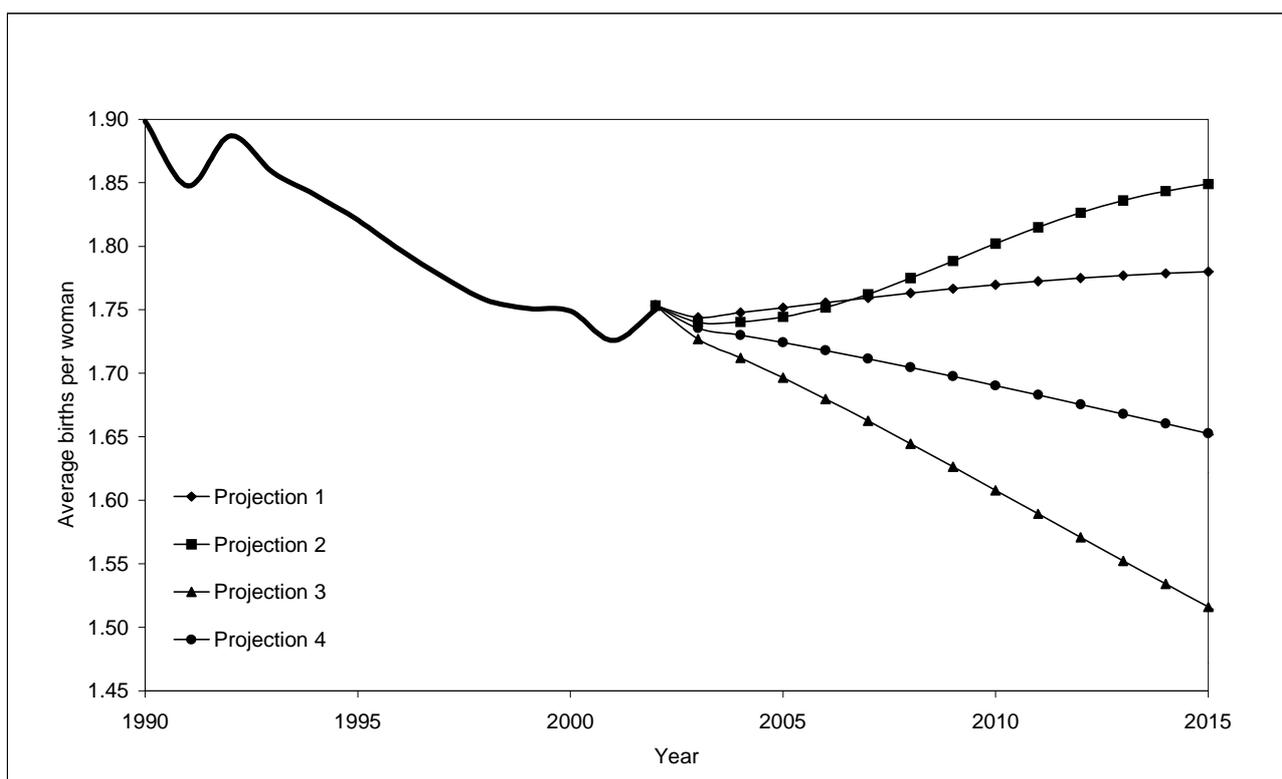
The four assumptions are:

1. age- and parity-specific fertility rates remain constant at 2000 levels;
2. the postponement of fertility halts; that is, fertility stops declining at younger ages but continues increasing at older ages with cohorts born from the late 1970s all experiencing the same projected fertility schedule;
3. age- and parity-specific fertility rates continue to change at the rate experienced over the period 1991–2000; and
4. age- and parity-specific rates continue to change, but at a slower pace.

Results

The TFRs resulting from each projection are shown in Figure 7. Under projection 1, with age- and parity-specific rates held constant, the TFR increases slightly from 1.75 in 2002 to 1.78 in 2015 and a slight shift to older age fertility results. This is because of changes in the proportions of the population by parity. For the cohort born 1970–71, 18 per cent will have zero parity, 16 per cent will have borne one child, 39 per cent will have two children and 18 per cent and 9 per cent will have three and four or more children respectively at the end of their childbearing years, resulting in a CCFR of 1.87 births per woman.

Figure 7 Total fertility rate, 1990–2002 and projected total fertility rate, 2002–2015, Australia



Source: ABS various years/b, author's calculations.

Under projection 2, fertility rates at younger ages stabilise while those at the older ages continue to increase. This results in a steady increase in the TFR from 1.75 in 2002 to 1.85 in 2015. The CCFR declines slowly from 2.15 births per woman for the 1960 birth cohort to 1.91 for women born in 1970–71.

Under projection 3, the TFR declines to 1.52 in 2015. Because of continuing shifts in first- and second-birth rates, proportions of the population with parity zero and parity one continue to increase. For example, in 2000, 22 per cent of women aged 35 were childless and 17 per cent had one child. By the year 2015, under the assumptions of projection 3, these proportions increase to 27 per cent and 22 per cent respectively. Put another way, in 2000, 61 per cent of 35 year-old women had at least two children. By 2015 this is projected to drop to 51 per cent. Under projection 4 the TFR declines to 1.65 in 2015 and the shift to older age fertility continues, but at a slower rate.

Conclusion

Outcomes of the above four projections range from the TFR falling to 1.52 in 2015, to the TFR increasing to 1.85 in 2015. Fertility rates in Australia show no sign of stabilising and the fertility of recent cohorts shows no sign of convergence. Given these recent fertility trends both projections 1 and 2 are unlikely outcomes. If current shifts to lower and older age fertility continue (projection 3), even if at a slower pace (projection 4), the result will be a continuing decline in both period and cohort fertility.

Population projections for Australia indicate that a long-term TFR below about 1.5 births per woman would be difficult to sustain demographically (McDonald and Kippen 1999). Therefore it is in the interests of Australian policy-makers to consider ways in which the decline in fertility may be halted. Given that the fall in fertility is the result of changes in first- and second-birth rates, research designed to identify ways of facilitating the transition to first birth, and the transition from first to second birth would seem to be prudent.

Acknowledgement

The author would like to thank Dr Elizabeth Sullivan, Director of the National Perinatal Statistics Unit of the Australian Institute of Health and Welfare, for providing unpublished births data from the National Perinatal Statistics Unit's Perinatal Data Collection.

Appendix A Method for calculating age- and parity-specific fertility rates, Australia, 1991–2000

Data:

1. births by maternal single year of age by parity (up to parity 4+) for each year 1991–2000 (AIHW NPSU 2001 and 2003);
2. births by maternal single year of age for each year 1991–2000 (ABS various years/b);
3. female population by single year of age for each midyear 1991–2000 (ABS various years/a);
4. and parity distribution of females by single year of age for 1996 (ABS 1999/a).

Births by maternal age by parity for each year 1991–2000 were adjusted to equal annual births by maternal single year of age recorded by the ABS.

Assumptions:

births are evenly distributed throughout the calendar year and across each single year of age; no births occur outside the age range 15–49 years; and migration and mortality are not differential with respect to parity.

Method:

Project the population classified by age and parity forward from 1996 to 2000, and backward from 1996 to 1991, by adjusting at each step for age and parity transitions.

Let $B_{i,a,y}$ = number of births to women of parity i and age a in year y ,

$P_{i,a,y}$ = number of women of parity i and age a at mid-year y , and

$$D_{i,a,y} = \frac{P_{i,a,y}}{\sum_i P_{i,a,y}} = \text{proportion of women aged } a \text{ in year } y \text{ who are of parity } i.$$

$$\text{Then } P_{i,a,1996} = D_{i,a,1996} \sum_i P_{i,a,1996}.$$

Because $\sum_i P_{i,a+1,y+1} \neq \sum_i P_{i,a,y}$ due to migration and mortality, transitions to the next (or previous) age and year by parity need to be adjusted to take this into account.

$$\text{Let } B_{i,a+1,y+1}^* = B_{i,a+1,y+1} \left[\frac{\sum_i P_{i,a,y}}{\sum_i P_{i,a+1,y+1}} \right].$$

Let, for $i = 0$,

$$P_{0,a+1,y+1}^* = P_{0,a,y} - 0.375B_{0,a,y} - 0.125B_{0,a+1,y} - 0.125B_{0,a,y+1}^* - 0.375B_{0,a+1,y+1}^*$$

for $i = 1, 2, 3$,

$$P_{i,a+1,y+1}^* = P_{i,a,y} + 0.375B_{i-1,a,y} + 0.125B_{i-1,a+1,y} + 0.125B_{i-1,a,y+1}^* + 0.375B_{i-1,a+1,y+1}^* \\ - 0.375B_{i,a,y} - 0.125B_{i,a+1,y} - 0.125B_{i,a,y+1}^* - 0.375B_{i,a+1,y+1}^*$$

and, for $i = 4+$,

$$P_{4+,a+1,y+1}^* = P_{4+,a,y} + 0.375B_{3,a,y} + 0.125B_{3,a+1,y} + 0.125B_{3,a,y+1}^* + 0.375B_{3,a+1,y+1}^*.$$

$$\text{Then } P_{i,a+1,y+1} = P_{i,a+1,y+1}^* \left[\frac{\sum_i P_{i,a+1,y+1}}{\sum_i P_{i,a,y}} \right].$$

These equations can be rearranged to project the population by age and parity backward from 1996 to 1991.

$$R_{i,a,y} = \frac{B_{i,a,y}}{P_{i,a,y}} = \text{age- and parity- specific fertility rate in year } y$$

$$F_{a,y} = \sum_i D_{i,a,y} R_{i,a,y} = \text{age-specific fertility rate in year } y$$

Appendix B Method for projecting age- and parity-specific fertility rates, Australia, 2002–2015

Age- and parity-specific fertility rates for 2000–02 were estimated so that the implied age-specific fertility rates were equal to those calculated by dividing births at age x by female population aged x .

To calculate future age-specific fertility rates ($F_{a,y}$), when age- and parity-specific fertility rates are projected, the future distribution of women by parity ($D_{i,a,y}$) is required, as

$$F_{a,y} = \sum_i D_{i,a,y} R_{i,a,y} .$$

Since it is assumed that no fertility occurs outside the age range 15–49 years,

$$D_{i,a,y} = 1 \text{ for } i = 0 \text{ and for } a < 15 ,$$

$$D_{i,a,y} = 0 \text{ for } i = 1, 2, 3, 4+ \text{ and for } a < 15 , \text{ and}$$

$$R_{i,a,y} = 0 \text{ for all } i \text{ and for } a < 15 .$$

For $i = 0$,

$$\begin{aligned} & D_{0,a+1,y+1} \\ &= D_{0,a,y} - 0.375D_{0,a,y}R_{0,a,y} - 0.125D_{0,a+1,y}R_{0,a+1,y} - 0.125D_{0,a,y+1}R_{0,a,y+1} - 0.375D_{0,a+1,y+1}R_{0,a+1,y+1} \text{ For} \\ &= \frac{1}{1 + 0.375R_{0,a+1,y+1}} \left[D_{0,a,y} - 0.375D_{0,a,y}R_{0,a,y} - 0.125D_{0,a+1,y}R_{0,a+1,y} - 0.125D_{0,a,y+1}R_{0,a,y+1} \right] \end{aligned}$$

$i = 1, 2, 3$,

$$\begin{aligned} & D_{i,a+1,y+1} \\ &= D_{i,a,y} - 0.375D_{i,a,y}R_{i,a,y} - 0.125D_{i,a+1,y}R_{i,a+1,y} - 0.125D_{i,a,y+1}R_{i,a,y+1} - 0.375D_{i,a+1,y+1}R_{i,a+1,y+1} \\ &+ 0.375D_{i-1,a,y}R_{i-1,a,y} + 0.125D_{i-1,a+1,y}R_{i-1,a+1,y} + 0.125D_{i-1,a,y+1}R_{i-1,a,y+1} + 0.375D_{i-1,a+1,y+1}R_{i-1,a+1,y+1} \\ &= \frac{1}{1 + 0.375R_{i,a+1,y+1}} \left[\begin{array}{l} D_{i,a,y} - 0.375D_{i,a,y}R_{i,a,y} - 0.125D_{i,a+1,y}R_{i,a+1,y} - 0.125D_{i,a,y+1}R_{i,a,y+1} \\ + 0.375D_{i-1,a,y}R_{i-1,a,y} + 0.125D_{i-1,a+1,y}R_{i-1,a+1,y} + 0.125D_{i-1,a,y+1}R_{i-1,a,y+1} \\ + 0.375D_{i-1,a+1,y+1}R_{i-1,a+1,y+1} \end{array} \right] \text{ For } i \end{aligned}$$

$= 4+$,

$$\begin{aligned} & D_{4+,a+1,y+1} \\ &= D_{4+,a,y} + 0.375D_{3,a,y}R_{3,a,y} + 0.125D_{3,a+1,y}R_{3,a+1,y} + 0.125D_{3,a,y+1}R_{3,a,y+1} + 0.375D_{3,a+1,y+1}R_{3,a+1,y+1} \\ &= \frac{1}{1 - 0.375R_{3,a+1,y+1}} \left[D_{4+,a,y} + 0.375D_{3,a,y}R_{3,a,y} + 0.125D_{3,a+1,y}R_{3,a+1,y} + 0.125D_{3,a,y+1}R_{3,a,y+1} \right] \end{aligned}$$

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