Low Fertility and Prospective Living Standards in Australia

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ABSTRACT

In this paper, a practical application of the theory of optimal saving and consumption in a small open economy, we calculate the impact on future living standards in Australia of reductions in the total fertility rate (TFR). A range of TFR’s are considered. A clear conclusion emerges, that decreases in fertility need not have a negative impact on living standards. We argue that this conclusion can be extended to other economies as well as Australia. In addition, the paper contributes to the method of applying the theory of optimal saving and consumption.

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JEL Classification: E2, J1
I Introduction

In many countries fertility has declined in recent years to astonishingly low levels. Most notable are Germany and Italy, where the total fertility rate (TFR) had declined to 1.3 and 1.2 respectively in the period 1995-2000. In Australia fertility has also decreased, but not, at least yet, to such low levels. In 1998 the TFR in Australia was 1.76, a decrease from 1.9 for the 1990-1995 period. Continuation of low TFR’s will increase old age dependency. This prospect has led to widespread concern about future living standards. As David Weil has pointed out, “It has become a commonplace observation that the ratio of dependent elderly to working age adults will rise over the coming decades…and that this rise in old-age dependency will mean lower consumption for one or both of these demographic groups”, Weil (1999, p. 251). Weil, however, shows that “this is not necessarily true”. To shed further light on this issue, this paper projects the impact of low fertility on the future living standards of Australian residents. The results strengthen the support for Weil’s conclusion. Decreases in fertility will not have a negative impact on current or future living standards.

To assess the impact of low fertility on living standards in the future, we project future levels of consumption per person using a wide range of low fertility scenarios. Recourse to a range of low fertility scenarios is useful because it appears that there has been little success in explaining or predicting fertility and so there can be no consensus on the future pattern in total fertility rates in Australia or other OECD economies. For

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* We thank Rebecca Kippen and Peter McDonald for calculating the demographic projections used in this paper.

† We define living standards as consumption of goods and services per person. Easterlin (2000) discusses broader measures of living standards and warns against assuming a high interdependence between real per capita GDP and other dimensions of the standard of living.
example, Bongaarts (1999) argues that the decreases currently observed in fertility are temporary. At the other extreme, Golini (1998) has seen sufficient reason to look for a practical minimum to the total fertility rate. He suggests a rate of 0.8. Uncertainty about the future pattern of fertility in Australia is exacerbated by the wide range in recent experience amongst comparable western industrialised countries. The TFR’s of OECD countries are spread fairly evenly from the low values for Germany and Italy to the relatively high TFR’s of 2.0 for the US and New Zealand. Thus Germany and Italy are not the only alternatives. Because of the absence of a most likely outcome it is best to explore a range of possibilities.

The range of possibilities we explore includes the extreme case of an immediate fall of the total fertility rate to zero. Such a population will die out. This extreme case, which we label the Doomsday projection, is an interesting lower bound on our projections. Although it is beyond the range of realism, it has a curiosity-value and, as will be seen, can be argued to strengthen our main conclusion.

We suggest that although the paper focuses on one country, the conclusions we draw for the effect on living standards of low fertility are of broader relevance. The prospect of low fertility rates is a possibility for many countries. Furthermore, the range of variation in the demographic projections we consider is so great and the conclusion, that living standards need not suffer, so consistent across these projections that using the Australian population as a starting point does not restrict the generality of the conclusions. At the theoretical level, we see the paper as contributing to the method by which the theory of optimal consumption over time can be used to assess the effect of prospective demographic change on living standards. This method draws on and extends the methodology established in earlier papers, especially Cutler et al (1990), Elmendorf and Sheiner (2000) and Guest and McDonald (1998), (forthcoming).

Our method, a practical application of the theory of optimal saving and consumption in a small open economy, extends the analysis of Cutler et al (1990) and Elmendorf and Sheiner (2000) in three main ways. First, we use a social welfare

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2 We also use a vintage production function. However compared with the more standard production function with homogenous capital, in considering the impact of low fertility the vintage production function does not lead to any significant difference as far as living standards are concerned. Another difference with Cutler et al is that the weights we use for consumption demand by age group are lower for the oldest age
function in which living standards are compared with a reference level, specified as the previous year’s living standard. Our application of this social welfare function prevents a decrease in current living standards.\(^3\) Thus it can be seen as protecting the living standards of those living at the beginning of the simulation period. The case for including reference consumption in the social welfare function is made in Section V. Second, our simulations do not assume a steady state as the initial starting point nor do they impose an arbitrary length on the transition period to a new steady state. And there is no requirement that the economy end up in a steady state. Because of this they can more accurately measure the optimal saving and consumption paths for an actual economy beginning at an actual point in time and progressing along a demographic path based on projections supplied by demographers. Third, we focus on the projected levels of living standards. This focus allows us to draw more definite conclusions from our analysis than could Cutler et al (1990).\(^4\)

As noted above, recently, David Weil (1999) has analysed the effects on living standards of a transition to a lower rate of population growth. He compares steady state growth paths with different rates of population growth. His model is of a closed economy without capital and without the path over time of consumption chosen optimally. He shows that in the neighbourhood of the population growth rate that maximises living standards (i.e. the golden-rule level of population growth), population growth rates one percent greater or smaller make little difference to living standards. Furthermore, along the adjustment path from the steady state with high population growth to the steady state with low population growth there is a consumption dividend, due to the immediate favourable effect on dependency of a reduction in the fertility rate. This paper can be seen as extending the results of Weil’s analysis, by introducing capital as a factor of production, international capital movements and optimal consumption smoothing.

Some limitations of the model should be noted. First, employment is determined by multiplying fixed employment-population ratios by population age groups. Thus

\[^3\] Subject to the proviso that it is feasible for living standards in the future to be higher, see discussion below.

\[^4\] Consider especially the criticisms of Akerlof, p. 59, and Bailey, pp.65-6, in discussing the Cutler et al paper and the guarded response of Summers on p.68.
employment is not influenced by the reward from working nor by shifts in the demand for labour. It would be an interesting extension to endogenise employment to allow for changes in the supply and demand for labour that are sustained for several years or more. Second, the rate of total factor productivity is assumed constant. There is no strong evidence that total factor productivity is significantly affected by population growth. Third, the influence of human capital on labour productivity is brought into the model only in as far as the relative productivity differentials across age and gender groups, which are included, reflect differences in human capital stocks across age and gender groups. Fougere and Merette (1998), (1999) have presented an interesting endogenous growth model with endogenously determined human capital, from which they derive a positive relation between ageing and human capital formation. However they do not present any empirical evidence to support this relation. While it would be interesting to extend the model and our simulation exercises to endogenise labour supply, total factor productivity and human capital formation, the model in this paper can be seen as a relatively straightforward benchmark case. Furthermore, given the lack of a consensus that the mechanisms we ignore are quantitatively important for evaluating the impact of low fertility, our benchmark case is a reasonably accurate reflection of current knowledge.

5 Ignoring the influence of business cycle fluctuations on employment seems appropriate for the long period of time used in our projections, over which the impact of business cycle fluctuations will tend to net out.

6 There are several mechanisms through which demographic change may influence employment-population ratios. Increasing longevity and labour shortages due to increased dependency may increase employment-population ratios. On the other hand increasing living standards may decrease employment-population ratios.

7 Cutler et al (1990), argued that an emerging labour shortage will increase the rate of technical progress. As they point out, this idea goes back at least to Habakkuk (1962). Boserup (1965) argues that population pressure associated with increasing population led to technical progress. In as far as a high dependency ratio of an aged population may cause population pressure on output, the Boserup view is perhaps consistent with Habakkuk/ Cutler et al. On the other hand, as Cutler et al (1990) point out, Simon (1981), Wattenberg (1987) and Sauvy (1948) suggest that low population growth reduces the rate of total factor productivity growth because innovation becomes less profitable and the aged population is less “dynamic”. The cross-country evidence in Cutler et al (1990) is not very strong.

8 We also do not specify an overlapping-generations framework and so cannot make explicit comparisons of welfare between generations, unlike say Fougere and Merette. However, because we allow for consumption demands and labour productivity to vary by age, our main conclusion can be re-expressed as the living standards of later generations need not suffer if fertility falls.

9 Human capital formation, especially by women, may influence fertility. We ignore such a link. However such a link would be dominated by the range of assumptions we consider about future fertility rates.
In section II the model is presented. The demographic assumptions and the assumed parameter values are described in sections III and IV respectively. Section V discusses and defends our choice of the social welfare function. Section VI presents the simulated paths of living standards for demographic projections based on TFR’s of 1.75, 1.65, 1.3 and 1.0. In Section VII we discuss why demographic measures, such as dependency ratios, are not reliable guides to the impact of demographic change on living standards. In Section VIII we consider the Doomsday projection based on a total fertility rate of zero, which implies that the population dies out in 100 years. Section IX concludes the paper.

II The model

In assessing the impact of low fertility on living standards, in all simulations living standards are socially optimal subject to the production and international borrowing constraints implied by the small open economy model. Socially optimal paths are of interest in their own right. However there is an additional reason for this focus in this paper. For any particular assumption about fertility and thus any particular projection of population over the projection period there are an infinite number of possible paths of living standards. In order to compare the implications for living standards of different assumptions about fertility it helps to be able to associate a unique path of living standards with each particular assumption about fertility. To define that unique path of living standards, an attractive assumption to make is that this outcome of living standards is the best possible, i.e. the socially optimal. For if it was an outcome which was thought to be possible to improve upon then one could argue that the particular fertility assumption was being short-changed or undervalued in a comparison with the implications of other fertility assumptions. By comparing the best outcomes there is a reasonable uniformity across the comparisons. We are in this way comparing like with like, best with best. The differences are due to the differences in the assumption about fertility.\(^{10}\)

\(^{10}\) Another reason for comparing socially optimal paths is that they may be the best forecast of what actually may happen. This argument has greater force because of the long run nature of our simulations. Over long periods of time one may expect socially optimal outcomes to dominate because of the incentive provided by those outcomes being the best.
The model is a Ramsey model with heterogeneous consumers and workers, a reference level of consumption, and a putty-clay vintage production function. We adopt the small open economy model, which is reasonable for Australia.\textsuperscript{11} This model is based on the standard one-good, small open economy model with many periods, see for example Obstfeld and Rogoff (1996, pp.60-2), modified to facilitate simulation of actual economies (including a positive rate of technical progress and a putty-clay vintage production function) and to allow for a changing demographic structure.\textsuperscript{12}

The future living standards we calculate are based on the decisions of a social planner to maximise a social welfare function, given by

\[ V = \sum_{j=1}^{h} \left( N_j \left( \frac{C_j}{P_j} - \chi \frac{C_{j-1}}{P_{j-1}} \right)^{1-\beta} \left( \frac{1 + \rho}{1 - \beta} \right)^{1-\beta} \right) + N_h \omega \frac{W_h}{N_h} \frac{(1 + \rho)^{1-h}}{(1 - \gamma)} \]  

(Symbols are defined in Table 1.) The social welfare function is the sum of the utility levels generated from consumption running up to \( h \) periods in the future and of the level of wealth at the end of the \( h \) periods. As implied by the use in the social welfare function of consumption per consumption unit (= \( C/P \) with \( C \) aggregate consumption and \( P \) total population measured in consumption units), aggregate consumption is assumed to be allocated to people according to their consumption demand weights discussed in Section III. Wealth at the end of the period is allocated equally between people defined in natural units. The utility function includes a reference level of consumption, specified as the level of consumption per consumption unit in the previous period. Thus the utility function allows for habit formation in consumption. In all the simulations in this paper we set \( \chi = 1 \). The rate of time preference is assumed constant over the planning horizon. It is determined by

\textsuperscript{11} The particular paths produced by the simulations are checked to ensure that they do not call into question the assumption of a perfect world capital market. For example, the “best” path could require a current account deficit at some point of such a large size as to strain the credibility of assuming continued access to the world capital market at an unchanged interest rate.

\textsuperscript{12} In the Obstfeld and Rogoff section cited in the text, some of output, called government spending, is assumed not to add to consumption, investment or the accumulation of overseas assets. Our model does not
\[ \rho = (1 + r)(1 + a)^{1-\alpha} - 1 \]  

(2)

This choice of \( \rho \) implies that a period of balanced growth in the exogenous variables of the model will imply that the ratio of consumption to output will approach a constant value.\(^{13}\) Our chosen form of the social welfare function is discussed further in section IV.

The social planner faces the following constraints. First domestic expenditure, foreign borrowing/lending and output (GDP) are related by an international budget constraint for each period

\[ Y_j = I_j + C_j + D_{j-1}(1 + r) - D_j \quad \text{for } j = 1, \ldots, h. \]  

(3)

The world rate of interest, at which the economy can lend or borrow unlimited amounts, is assumed constant over the projection period. Second, output is related to the inputs of labour and capital by the production constraint for each period

\[ Y_j = \sum_{k=1}^{T} \left[ (1 - \delta)^k A_{j-k}^\alpha I_{j-k}^{1-\alpha} Y_{j-(k-1)}^{1-\alpha} \right] \quad \text{for } j = 2, \ldots, h. \]  

(4)

Output in period 1 is exogenous.\(^{14}\) The production function is a putty-clay vintage production function with constant returns to scale.\(^{15}\) The constant rate of total factor productivity increases the efficiency parameter, \( A \), of new capital goods at the rate \( a \). The substitution possibilities at the time that the capital goods are constructed follows the Cobb Douglas form. There is a one period gestation from construction to operation for capital goods. Once installed capital goods have a fixed capital-labour ratio. During their

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\(^{13}\) The combination of our demographic projections and our assumption of an unchanging retirement age do not yield a balanced growth path, in that the aggregate employment/population ratio tends to a decreasing path. However experimentation shows that, given the length of the projection period in the simulations this violation of balanced growth does not have a significant impact on the behaviour of variables such as consumption and saving in the first fifty years of the projection.

\(^{14}\) In the simulations in this paper output in year 1 is set equal to actual GDP for Australia in 1999.

\(^{15}\) With substantial decreases in population, the net effect on returns to scale is the result of a race between decreasing congestion costs and the loss of economies of scale. The constant returns to scale assumption presumes that this race is a dead heat.
operating life, capital goods depreciate in that their labour requirement and the output they produce decrease at a constant rate $\delta$ over time. After $T$ periods of operation capital goods are scrapped. The socially efficient age of scrapping for a capital good is determined as the age when its average product of labour is equal to the marginal product of labour on new capital goods. Under this rule $T$ is determined by the world interest rate. Units of labour are measured in efficiency units that allow for differences in productivity by age and gender. Third, in any period the total amount of labour allocated to vintages of capital is constrained by the exogenously determined aggregate level of employment according to

$$L_j = \sum_{k=1}^{T_j} (1 - \delta)^{k-1} L_{j+1-k}$$

for $j=2,…,h$. (5)

Fourth, terminal wealth is determined by the sum of capital stock and foreign assets at the end of period $h$ according to

$$W_h = \left[\sum_{k=h-T+1}^{h-1} (1 - \delta)^k I_{h-k}\right] - D_h$$

(6)

The solution to the model is derived from the first order conditions for maximising (1) subject to (3) to (6). The simulations use these equations. The model has the well-known properties of the small open economy model. In particular, Fisher separation holds, that is investment levels and thus output levels are determined independently of the allocation of consumption across time periods. Consumption smoothing generated by maximising the social welfare function causes consumption per person to grow at a fairly constant rate. However the growth of output per person varies with changes in the employment/population ratio. Thus to bridge the gap between

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16 This rule presumes that new capital goods are constructed. In the Doomsday case there are periods in which no capital goods are constructed and then $T$ is determined differently. This is explained in the section on the Doomsday case.

17 Strictly speaking, consumption per consumption unit.
consumption and output, the optimal proportion of GDP saved is influenced by changes in the demographic structure.

The first order conditions determine investment in the following way. The condition that the marginal product of investment equals the cost of capital determines the capital/labour ratio on the new vintage of capital by

\[
k_j = \frac{I_j}{I_{j+1}} = \left[ \frac{\alpha A_j}{E_j} \right]^{\frac{1}{1-\alpha}} \quad \text{for } j=1-T, \ldots, h-1 \tag{7}\]

where \( E_j \), the cost of capital in period \( j \), is determined by

\[
E_j = \frac{1}{\sum_{k=1}^{T} (1+r)^{-k} (1-\delta)^{k-1}} \quad \text{for } j=1-T, \ldots, h-T \tag{8}\]

and

\[
E_j = \frac{1-(1+r)^{j-h}(1-\delta)^{h-j}}{\sum_{k=1}^{h-j} (1+r)^{-k} (1-\delta)^{k-1}} \quad \text{for } j=h-T+1, \ldots, h-1 \tag{9}\]

The cost of capital is lower in the last \( T-1 \) years of the projection period because investment in those years contributes to terminal wealth. The age of the oldest capital good used in period \( j \) is determined by the equality of the average product of labour on the oldest capital good with the marginal product of labour on the new capital. This gives

\[
T = \frac{-(1-\alpha) \ln(1-\alpha)}{\ln(1+\alpha)} \tag{10}\]

The number to be employed on the newest vintage is equal to aggregate employment growth plus labour released from old vintages because either their capacity contracts due to depreciation or they are scrapped. This gives

\[
L_{j+1} = L_{j+1} - (1-\delta)L_j + (1-\delta)^T L_{j+1-T} \quad \text{for } j=1-T, \ldots, h \tag{11}\]

\(^{18}\) Investment is assumed to have a one period gestation lag from construction to first use date.
Employment on the newest vintage determines the level of investment according to

\[ I_j = k_j I_{j+1} \quad \text{for } j=1,\ldots,h-1 \]  

(12)

With investment and employment determined, output is determined by the production function, (4).

For consumption, the condition that the marginal rate of substitution between consumption in adjacent periods equal the world rate of interest implies that the path of consumption per consumption unit satisfies

\[
\frac{(N_j/P_j)}{(N_h/P_h)} \left( \frac{c_h}{c_j} \right)^\beta + \chi \frac{(N_{j+1}/P_{j+1})}{(N_h/P_h)} \left( \frac{c_h}{c_{j+1}} \right)^\beta (1+r)^{-j} = \frac{(1+r)^{h-j}}{(1+\rho)^{h-j}}
\]

for \( j=1,\ldots,h-1 \)

(13)

where

\[ c_j \equiv \frac{C_j}{P_j} - \chi \frac{C_{j-1}}{P_{j-1}} \quad \text{for } j=1,\ldots,h \]  

(14)

The inclusion of terminal wealth in the social welfare function implies for optimality that terminal wealth satisfy

\[ W_h = \omega^{1/\beta} (P_h/N_h)^{(1-\beta)/\beta} C_h \]  

(15)

Equations (2) to (15) determine the optimal path of living standards for the projection period.

III The demographic projections

To assess the impact of reductions in fertility we used the following demographic projections for Australia.\(^{19}\) (The implied population for Australia in 2050 is in brackets. The population in 1999 is 19.0 million.)

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\(^{19}\) For Australia as a high immigration country, the assumption made about the rate of net immigration is important. In all of our population projections except the Doomsday projection we relate the rate of net
Base – as in ABS (1998), namely a total fertility rate of 1.796 for 1996 decreasing to 1.75 by 2006 at which rate fertility remains for the rest of the projection period. (28.5 million)

TFR 1.65, namely a total fertility rate of 1.75 in 1999 falling by 0.02 per year to 1.65 by 2004, at which rate fertility remains for the rest of the projection period. This fertility assumption is argued by McDonald and Kippen (1999) as “justified” on the basis of recent trends in industrialised economies. It is similar to the fertility assumption in the projections by Thorburn (1999). (27.4 million)

TFR 1.3, namely a total fertility rate of 1.75 in 1999 falling by 0.045 per year to 1.3 by 2009, at which rate fertility remains for the rest of the projection period. (24.0 million)

TFR 1.0, namely a total fertility rate of 1 throughout the entire projection period, from 1999 onwards. (20.5 million)

Doomsday, namely a total fertility rate of 0 throughout the entire projection period, from 1999 onwards. In this projection, it is also assumed that net immigration into Australia is also zero throughout the entire projection period. The population would die out in 100 years time. (9.0 million falling to zero in 2100)

For mortality rates we use the standard ABS assumption. This is an increase in life expectancy of 0.4 years for every 5 years.

The prospective patterns of dependency implied by these population projections is summarised by the support ratios, introduced by Cutler et al (1990), shown in Chart 1. The support ratio is employment divided by population. In Chart 1 employment is measured in efficiency units, determined by relative wages for the age and gender groups.
in the base year, 1999, (see Guest and McDonald (forthcoming) for details). Population is measured in consumption units, based on the relative demands by age group for private and government provided consumption in 1997. We calculate consumption demand weights following the method of Cutler et al (1990). However our calculations give different values. We compare our numbers with those of Cutler et al (1990) in Table 2. The largest difference is for older people. We calculate smaller weights for older people because we assume, based on the household expenditure survey, a weight of 0.75 for the private consumption of old adults, compared with 1.0 assumed by Cutler et al (1990). They give no basis for their figure of 1.0. The estimates of Schultz and Borowski (1991, p.97) for the US imply a weighting for the private consumption of old adults of 0.85, suggesting that the Cutler et al (1990) weights for old adults are too large, even for the US.\textsuperscript{20} The support ratios are presented as an index with 1999=100.

Chart 1 shows the actual support ratio from 1971 to 1999 and then the prospective support ratios from 1999 to 2065 for our five demographic projections. Since the early 1980’s the support ratio has moved in a favourable direction, reflecting the entry into the workforce of the large cohorts born in the three decades following the second world war. However, in the near future for the Base projection Australia will suffer a demographic turnaround, in that the support ratio peaks in 2004 and will then decrease for the rest of the period shown, to 2065. This decrease is relatively rapid to about 2050 and then becomes a more gentle decrease (and continues decreasing gently to 2199, the last year of the demographic projection). The TFR1.65 projection is almost identical to the Base case. For the other three projections, the effect of assuming a lower total fertility rate is to postpone the time of the demographic turnaround. The peak years for the support ratios are 2008 (TFR1.3), 2014 (TFR1.0) and 2019 (Doomsday). Also the lower the total fertility rate to which we move the higher the peak. For the Doomsday projection the support ratio peaks at 12.6% above its 1999 level. The later and higher peaks of the support ratio for the low projection cases confers on society a consumption dividend below, we assume zero net immigration to assure the dying out of the population.)\textsuperscript{20} Our previous work shows that the different weights make very little difference to the path of living standards, see Guest and McDonald (2000). For the US, Elmendorf and Sheiner (2000) assume a weight for old people that increases in the future with projected increases in Medicare spending to 1.45 by 2040.
through the saving of consumption expenditures on children. The importance of this for future living standards will be seen below.

IV The choice of parameter values

The assumed values for the parameters are reported in Table 3. Their basis is described in more detail in Guest and McDonald (forthcoming).

For the production function the values of $\forall$, the elasticity of output with respect to capital, and $*$, the rate of depreciation, are based on typical empirical estimates and are the same as those used by Barro and Sala-I-Martin (1995, p. 83). The value of $a$ is calculated from fitting the production function with the assumed values of $\alpha$ and $\delta$ to Australian data over the period 1965 to 1999. The value of $A$ in the first year of the projection period is set such that the implied value of GDP for 1999 is equal to the actual value of GDP for 1999. This procedure calibrates the production function to actual data for the Australian economy.

The world rate of interest, $r$, is set to the value used by Barro and Sala-I-Martin (1995, p. 124).

For the social welfare function $\exists$, the reciprocal of the elasticity of intertemporal substitution, is set at 2.0. $T$ is set to generate a terminal value of wealth to consumption equal to the exogenously given value for Australia in 1999 of 2.6, using (15). The acceptability of these values should be judged, along with the value for $\rho$, on the implied time-paths of $C/P$. This is discussed in Section V.

The planning horizon, $h$, is chosen to be long enough so that the path of optimal national saving to output, $S/Y$, for the period up to the year 2050 is sufficiently close to the path that would obtain for an infinite horizon. The criterion for "sufficiently close" is that a further extension of the horizon would change the value of $S/Y$ in the year 2050 by less than a level of tolerance specified as 0.1 percentage points.

V Including reference consumption in the social welfare function

In this section we discuss our choice of the social welfare function. Our discussion is based on the view that in choosing a social welfare function it is the implied
path of living standards (C/P) that matters. Thus whether our choice of the social welfare function with reference consumption is accepted as the basis of a socially optimal plan for society depends on one’s view of the implied path of C/P.\footnote{This includes our technique for choosing the rate of time preference, which is a component of the social welfare function. To a possible criticism that it is wrong to base the choice of a valuation function on the characteristics of the production function and the world interest rate, our answer is to look at the implied path of C/P. Social welfare functions and the rate of time preference are means to an end, that is a means to determine optimal living standards. They are constructed concepts.}

Two important characteristics of the social welfare function we choose are as follows:

1. The rate of time preference is constant and set such that a period of balanced growth in the exogenous variables of the model will cause C/Y to approach a constant value.

   The reason for this choice of the rate of time preference is that it allows the projection period to be set sufficiently long such that outcomes in first 50 years are independent of the terminal condition. An implication of this assumption, which is commented on below, is that people in the future will enjoy higher living standards, given that the trend rate of growth of labour productivity is positive.

2. There is a reference consumption level, or reference living standard, against which the actual level of consumption is evaluated and this reference level is the previous period’s level of consumption per consumption unit. This is sometimes described as habit formation in consumption. Furthermore the level of reference consumption in the first year of the projection period is set equal to the actual level of consumption in that year, that is in 1999.

   Setting the level of reference consumption in the first year of the projection period equal to the actual level of consumption in that year protects the living standards of people currently alive.\footnote{There are scenarios of future demographic change and labour productivity growth for which it is not feasible to have no cuts ever in living standards. These are scenarios with large increases in dependency and/or low rates of future labour productivity growth. So to project living standards on the basis described above, their feasibility has to be checked. If unfeasible then some modification would be required. (As will be seen, for all our projections no such modification is required.) One such modification would be to set the}
way is that it recognises the widely held view that people strongly dislike cuts in their living standards. To illustrate the implications for the profiles of living standards for the Base projection with and without reference consumption included in the social welfare function, consider Chart 2. With reference consumption in the social welfare function, C/P grows from its actual level for 1999, normalised at ln(100), at a rate of 1.20 per cent per year for the period to 2050. By comparison, with no reference consumption in the social welfare function, the optimal level of C/P in 1999 is 5.8 per cent below the actual level, implying an immediate cut in living standards of 5.8 per cent. Subsequently C/P grows faster than the case with reference consumption, at an annual rate of 1.43 per cent per year.\(^{23}\) However it is not until 2003 that this faster growing path catches up with actual living standards in 1999 and it is not until 2022 that it catches up with the path implied by the social welfare function with reference consumption. Thus the shortfall in living standards suffered by those alive at the beginning of the projection period is quite large and persists for a lengthy period if reference consumption is excluded.

Even though our social welfare function protects the living standards of those currently alive, it could be argued that it treats people alive in the future too generously. For example, intertemporal equity could be argued to require living standards never to rise, that is to set a constant living standard for the entire projection period. This would treat all people, whenever they live, equally. To do this would require bringing forward all the consumption to be expected from higher labour productivity in the future. In principle a small open economy could do this, by running a massive current account deficit in early years, to be paid off as labour productivity rose. However to take this approach has implications that would strain our method. First the choice of the terminal condition and the terminal year would become important. Assuming that labour productivity grows over time, the longer the projection period envisaged the greater the level of reference consumption in the first year of the projection period low enough to satisfy the feasibility constraint. This approach would imply that the cut in living standards is taken in the first year of the projection period. That may not be thought socially optimal. It is easy to imagine a more gradual downward adjustment of living standards.

\(^{23}\) Note that the steady state rate of growth of labour productivity, given our numerical assumptions, is 1.43 \((= (1+a)^{1/(1-\alpha)})\). Without reference consumption, the optimal level of C/P jumps initially so that C/P grows at the steady state rate. With reference consumption, the growth rate of C/P gradually approaches and then passes the steady state rate.
constant living standard. So the “optimal” living standard would depend on the arbitrary choice of the time horizon. Second, an explicit incorporation of uncertainty into the framework would be required to account for two aspects. One is the risk of default that would arise with large debt to foreign residents. Another is the uncertainty about the future rate of growth of productivity. If the growth of labour productivity slowed down then foreign debts could become a massive burden. Third, taking a global context, it is not possible for all economies to run current account deficits. For these reasons we accept for our simulations the fairly generous treatment given to people alive in the future by our social welfare function.

In summary, the case for our social welfare function is that it smooths consumption over time and protects the living standards of those people alive at the beginning of the projection period. We noted above that our choice of the rate of time preference treats generations in the future generously because it implies that the consumption path chosen would deliver to them a higher standard of living. However our choice of reference consumption protects today’s living standards. Thus the combination of these two assumptions leads to outcomes which give a required minimum amount of protection to the living standards of those people alive at the beginning of the projection period. One could go further and weight more heavily the interests of those currently alive, but in any event there is a strong case for going at least this far, that is for including reference consumption in the social welfare function.

There is in addition a by-product of our choice of social welfare function that helps in comparing the simulations in this paper. For the simulations considered in this paper, our social welfare function generates optimal values of C/P in the first year that are virtually identical with the actual value of C/P in 1999 for the Australian economy. This introduces a constancy across simulations which makes comparison of the implications of different assumptions such as different rates of fertility and immigration easier.

To illustrate an implication of the social welfare function that, fortunately, is irrelevant to the analysis of this paper, in Chart 2 we show the entire path of C/P through

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24 This is not a necessary implication of the social welfare function. For example, applying it to Singapore, a country with a massive current level of saving equal to about 50 per cent of GDP, leads to the optimal level of C/P in the initial year of the projection significantly above the actual level, see Guest and McDonald (2000)
to the end of the projection period. The path shows that an implication of specifying reference consumption as lagged consumption is that at the end of the projection period the growth rate of \( \frac{C}{P} \) increases. In the last three years of the projection period the annual growth rates of \( \frac{C}{P} \) are 2.49, 2.72, 3.05, 3.62 and 5.06, compared with a growth of 1.20 per cent over 1999 to 2050. This increase is because an increase in \( \frac{C}{P} \) in any year but the final year has a decreasing effect on utility in the subsequent year, by becoming the reference level. In the final year this does not occur and so final year \( \frac{C}{P} \) is more valuable in the social welfare function. In our analysis below of the implications of low fertility we focus on the first 50 years of the projection period and so this growth spurt in \( \frac{C}{P} \) in the final years can be reasonably ignored.

There is another implication of the social welfare function that is worth noting, even although our parameter values prevent it actually occurring. In principle our social welfare function could lead to consumption being shifted away from periods with large numbers of old people. This is because old people are “inefficient” in converting consumption to social welfare. Our consumption weights imply that 1.19 units of consumption given to a person 75 years or older will yield the same amount of social welfare as one unit of consumption given to a younger adult. Many, see especially Sen (1973, pp.15-23), would find it ethically indefensible to reduce consumption levels in periods when there are many “inefficient” consumers, that is, in our context, periods with many older people. However in the simulations illustrated in Chart 2 consumption is not shifted away from periods with large numbers of old people. In neither of the simulations does the relatively small numbers of older people in early periods bring consumption forward. Instead on the optimal path with reference consumption, consumption in year one is chosen to be at the lowest level consistent with the exogenously-set initial value of the reference consumption level.\(^\text{25}\) Thus, for our cases of an increasing proportion of old people over time, the inclusion of reference consumption prevents this “unethical” distribution of consumption.

\(^{25}\) If reference consumption is excluded \((\chi=0)\) then a high enough value of \(\beta\) is sufficient to prevent consumption being shifted away from periods with a high number of older people. Simulation suggests that the required \(\beta\) is not high. 0.9 or more will do.
VI Low fertility and living standards

Using the model and parameter values described above, our projections of future living standards for four population projections are shown in Chart 3. As discussed above, to mimic an infinite horizon, the projections are for a 170 year projection period. However in reporting results we concentrate on the period up to 2050.

Clearly, from Chart 3, the feasibility of no cuts in living standards is satisfied for all four projections. Indeed the striking result illustrated in Chart 3 is that the level of fertility makes very little difference to the path of future living standards. The annual growth rates of living standards over the period 1999 to 2050 range from 1.20 per cent for the Base projection to 1.32 per cent for TFR 1. The reduction in fertility from Base, in which the TFR is 1.75, to the projection of TFR 1.65 has virtually no effect on living standards. Further reductions to TFR 1.3 and TFR 1 actually increase future living standards, although only slightly. The greatest increase, for the TFR 1.0 projection, is, by 2050, only 6.6 per cent above the Base projection.

These paths of future living standards are supported by paths of optimal national saving, investment and current account balances. The paths of optimal national saving for the four fertility assumptions are shown in Chart 4. Each path shows a hump shape, with the peak of the hump occurring in 2017 (Base), 2017 (TFR 1.65), 2025 (TFR 1.3) and 2025 (TFR 1). This hump is due to the ageing of the population in the first 30 years of the 21st century and is discussed in more detail in Guest and McDonald (forthcoming). The percentage of national saving in GDP, measured at the peak of the hump, is greater the lower the total fertility rate, ranging from 21.3 per cent for the Base projection to 26.1 for the TFR 1 projection, compared with 18.8 per cent in 1999 for all projections. That saving can be higher in the low fertility projections without causing a reduction in living standards relative to the Base projection is because in the low fertility projections there is a lower dependency ratio in earlier years. This is due to the smaller proportions of children in their populations in earlier years. As the chart shows, the optimal response to the small proportion of children is to save more.

The optimal disposition of national saving between investment and foreign assets is also related to the demographic pattern. Relative to the Base projection, the low
fertility projections have lower investment levels and in earlier years higher current account balances. The optimal investment levels decrease from a common proportion to GDP in 1999 of 22.6 per cent. The amount of decline to the 2020’s is not great, the share of investment in GDP in the 2020’s ranging from 21.3 per cent of GDP for the Base case to 19.3 per cent for the TFR1.0 case. Thereafter, for the rest of the century, investment tends to remain unchanged for the Base case and to decline such that it averages 19.9 per cent of GDP for the TFR 1.3 case and 18.8 per cent of GDP for the TFR 1.0 case. These lower levels of investment illustrate the Solow effect. They occur because low fertility eventually means less labour and thus less investment. (Note that investment is driven by employment, because of the Fisher separation property, and so is not influenced by consumption smoothing.) Conversely the current account balances are greater for the low fertility projections. They also have hump shapes over the 50 years to 2050. This reflects the hump shape in national saving and is driven by consumption smoothing, that is preparing for the future years of higher dependency. For the four fertility projections, at the peaks of the humps the current account balances are, as percentages of GDP, 2.1 in 2017 (Base), 2.6 in 2017 (TFR 1.65), 3.7 in 2017 (TFR 1.3) and 7.5 in 2026 (TFR 1).

Given the importance in the model of using the world capital market to smooth out the effects of demographic change, it is important to consider the sensitivity of our results to our assumed value of the world rate of interest. We considered two alternative values, namely 3 per cent and 9 per cent. These cover an extreme range of possibilities. For the Base projection, a 3 per cent world interest rate has a favourable effect, raising the annual rate of growth of living standards for 1999 to 2050 from 1.20 per cent to 1.25 per cent. On the other hand, a 9 per cent world interest rate in the Base case lowers the annual rate of growth of living standards to 1.07 per cent. The benefit to living standards in the Base case of a lower world interest rate reflects the fact that in that case the current account balance is negative throughout the projection period. Australia would be borrowing from foreign residents. A lower rate of interest reduces the cost of this borrowing. By contrast, for the low fertility projection of TFR1.0 the path of living standards is little affected by the rate of interest. For TFR1.0, a 3 per cent world interest rate reduces slightly the optimal growth of living standards from 1.32 per cent to 1.29 per cent and the high interest rate of 9 per cent also reduces slightly the growth of living
standards to 1.27 per cent. This is because in the TFR1.0 case the optimal current account balance is negative in early years, to 2008, and then positive. The years of positive current account balance reflect the lack of domestic investment opportunities because of the relatively small employment level. The mix of current account deficit followed by current account surplus is sufficient for the rate of interest to have a negligible effect on living standards.

Thus, our main conclusion, that low fertility does not reduce future living standards, is not changed by considering a range of world interest rates.

VII The shortcomings of demographic measures

In marked contrast to the conclusion we draw, as noted in the introduction, commentators have been pessimistic about the influence of low fertility on living standards. Their views are typically based on demographic measures, for example the decrease in the number of working age people per old person caused by low fertility. By going beyond demographic measures we get different results. Why are the demographic measures misleading?

One way to appreciate the shortcomings of the demographic measures as indicators of the response of living standards to demographic change is to consider the identity that decomposes $C/P$ in the following way,

$$\frac{C}{P} = \frac{C}{P} \frac{Y}{L} \frac{L}{N} \frac{N}{P}$$

The directly observable effects of demographic change is through $N/P$, the ratio of the population in natural units to the population in consumption units, and $L/N$, the ratio of employment in efficiency units to the population in natural units. Population ageing tends to decrease $N/P$, because of the high consumption demands of old people, and to decrease $L/N$, because of the decrease in the proportion of population of working age.\textsuperscript{26} However,\textsuperscript{26}

\textsuperscript{26} There is an effect which partially offsets the decrease in $L/N$. Low fertility will reduce the proportion of younger, lower productivity workers in the workforce and so the working population measured in efficiency units gets a boost on this account from low fertility.
these negative effects on living standards are offset by three mechanisms. Firstly, over
time, labour productivity growth causes a trend increase in Y/L. Second, smaller
investment expenditures due to the smaller capital stock when employment growth is
smaller allows C/Y to be higher. Cutler et al (1990) called this the Solow effect. As an
analogy to the consumption dividend from low fertility, the Solow effect could also be
called an investment dividend. Third, if periods of high dependency are preceded by
periods of low dependency, as they are if a fall in fertility is the driving force, then an
ageing population can be anticipated and C/Y can increase over time. That is a low
consumption ratio during the period of low dependency can facilitate an accumulation of
wealth which can subsequently finance a higher consumption ratio when ageing has
increased the dependency ratio. Through this mechanism, consumption smoothing makes
best use of the consumption dividend. The shortcoming of demographic measures, which
focus on changes in N/P and L/N, is that they ignore the influence on living standards of
the other three effects, which cause changes in Y/L and C/Y. Our simulations show that
this is a serious shortcoming.

Indeed, labour productivity growth, the investment dividend and the consumption
dividend are so strong that the population alive today in Australia does not require any
transfers from people yet to be born or people yet to live in Australia (that is future
migrants) to enable its living standards to grow. To illustrate this point, consider the
Doomsday population projection, reported in the next section.

VIII The Doomsday projection

The ability to protect future living standards from the long run effects of low
fertility by labour productivity growth, the Solow effect and consumption smoothing,
shown in the previous section, is striking. One wonders how far this can go? In this
section we consider an extreme case, that of an immediate and permanent decrease in the
TFR to zero. We also assume no immigration. Thus the population will die out in 100
years time, that being the assumed age of the oldest person in our population projections.
We call this projection the Doomsday projection.

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27 To understand intuitively the Solow effect consider the implications for investment of zero growth in
employment and positive growth. With zero growth new workers replace retiring workers.
We investigate the Doomsday projection for theoretical reasons, not because it is a realistic outcome. Its interest lies in shedding further light on how living standards can be protected from declines in fertility by intertemporal optimisation. In particular, the main message of the simulations of the four main scenarios, that decreases in fertility do not pose a threat to living standards, is strengthened by the Doomsday results. This robustness of the results for Australia suggests their general applicability to other high income countries.

In the Doomsday simulation, the population falls to zero in 2099, employment falls to zero in 2069 and workers available to work on new capital goods falls to zero in 2050. The latter implies that investment falls to zero in 2049. These characteristics require an alteration to the equation determining the age of the oldest capital good in use and the age of the expected operating life of new capital goods. In the basic model in Section II, both of these ages are constant and equal. But the Doomsday simulation is more complicated. The decreasing level of employment speeds up the scrapping of capital goods, beginning in year 2007. The investment decision anticipates the implied expected shorter life of new capital goods. The appropriate modifications were made for the simulation.

The terminal wealth condition was also modified in the Doomsday simulation. Because the population dies out in year 2099 we specified the target for terminal wealth as zero. Note that the capital stock will not be contributing to terminal wealth, all capital goods having passed the age of scrapping by 2099, and so the terminal wealth condition in the Doomsday simulation implies that the value of foreign assets is zero at the terminal date.

Because output is zero for the last 30 years of human life in the Doomsday economy, consumption in those years has to be supplied completely from imported goods and services from the rest of the world. We assume that this is technologically possible.28

For the Doomsday simulation the path of living standards, C/P, grows at a slower rate than for the other low fertility projections, at an annual rate for the period 1999 to 2050 of 1.21 per cent. Thus even this extreme case of low fertility does not imply lower

28 There are some consumption services, eg nursing services, that some readers assert to us will always be impossible to entirely import.
living standards. Rather than suffer from reduced living standards, the existing population with no help from additional people can enjoy a healthy growth in living standards, relative to the current level, a continual improvement throughout the 21st century. This result is obviously influenced strongly by the age distribution of the existing population. For example, if, instead, in 1999 the entire population was aged 70 or over then even the current living standard could not be maintained. This is because with such an initial age distribution and with our assumptions about employment, there would be no output produced for the remaining lifetime of the Doomsday economy. Given the terminal wealth condition of zero foreign liabilities, consumption would have to be negative in order to pay off the foreign liabilities that existed in 1999.29 By contrast the simulation shows that the current age structure of Australia has a sufficient number of people below 70 years old to support an increasing standard of living.

The patterns of saving, investment and the current account balance for the Doomsday projection are shown in Chart 5 as ratios per person (consumption unit). The patterns described above can be discerned. Investment drops to zero in 2049 followed by output dropping to zero in 2065. The current account balance peaks in 2044 at 25.7 per cent of GDP, implying a large build up of foreign assets. In 2052 the current account balance moves into deficit and this deficit grows for the rest of the horizon.

As the huge peak in the current account balance suggests, in the Doomsday simulation the residents make great use of the international capital market, lending in their working years and redeeming foreign assets in their retirement years. This implies that the growth of living standards will be positively related to the assumed value of the world rate of interest. This is born out by two additional simulations. Simulation with a world interest rate of 3 per cent implies a lower annual rate of growth of living standards of 1.08 per cent and a simulation with a world interest rate of 9 per cent implies a slightly higher annual growth rate of 1.22 per cent.

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29 This assumes realistically that the capital stock, which would have no domestic labour to operate it, has negligible resale value to foreigners.
IX Conclusion

The simulations in this paper show that decreases in fertility, even to the spectacularly low level of zero, need not reduce living standards in the future. Indeed the tendency is for decreases in fertility to allow a slightly higher rate of growth of living standards. The reasons that reduced fertility will not reduce living standards are increasing labour productivity, the Solow effect and consumption smoothing. Through consumption smoothing, the consumption dividend yielded by the temporary reduction in dependency that occurs immediately following a decline in fertility is redistributed to later periods of high old dependency. These effects are well known. Our paper quantifies their net effect on living standards for Australia.

These conclusions of the effect on living standards of decreases in fertility are based on applying the concept of optimal saving and consumption using a model of the small open economy. From this application, socially optimal paths of future living standards are calculated by simulation. By comparing the impact on these paths of different assumptions about fertility we draw our main conclusion, stated above. We consider four population projections. These projections cover decreases in the rate of fertility from the current rate in Australia of 1.75 to 1.65, 1.3, 1.0 and zero respectively. Our calculations of the implied paths of socially optimal living standards for Australia are summarised in Table 4 by reporting the annual rate of growth from 1999 to 2050. The paths can be compared by simply considering their growth rates of living standards over the future because they exhibit a common level of consumption per person in the initial year of the simulation. This commonality results from including reference consumption in the social welfare function consumption. Relative to the Base case, lower total fertility rates in the future can lead to higher rates of growth of living standards. The largest increase occurs for the case where the total fertility rate is reduced to 1.0. In this

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30 The Solow effect refers to the smaller investment expenditures required when employment growth is lower.
31 For the Solow effect see Cutler et al (1990) and for the consumption dividend see Weil (1999).
32 For the Doomsday case, consumption per person in 1999 is very slightly higher, 0.6 per cent higher, than for the other cases.
case the annual rate of growth of living standards can increase to 1.32 per cent, compared with 1.20 per cent in the Base case.

We also consider the effect of alternative values of the world rate of interest. Because the optimal pattern of lending and borrowing on world capital markets is influenced by demographic change, the impact of alternative values of the world rate of interest varies across our demographic projections. In the Base case, under which Australia should optimally tend to borrow on the world capital market, a lower interest rate confers a consumption gain. Thus, the rate of growth of living standards is raised to 1.25 per cent with a world rate of interest equal to 3 per cent. In contrast, in the Doomsday case, under which Australia would optimally lend on the world capital market, a high world rate of interest confers a consumption gain. More generally, our main result, that low fertility tends to allow higher living standards, is not dependent on the value assumed for the world rate of interest.

These paths of socially optimal living standards were calculated using a social welfare function in which living standards are compared with a reference level, specified as consumption per person in the previous year. The rate of time preference is chosen such that a period of balanced growth in the exogenous variables of the model will imply that the ratio of consumption to output will approach a constant value. This choice of the rate of time preference treats people living in the future generously because it implies that the consumption path chosen would deliver to them a higher standard of living than people alive today. However our inclusion of reference consumption protects the living standards of those alive at the beginning of the projection period. Thus the combination of these two assumptions leads to outcomes which give a required minimum amount of protection to the living standards of current generations. One could go further and weight more heavily the interests of those currently alive, but in any event there is a strong case for going at least this far.

Our results are in marked contrast to the inferences that are often drawn in popular discussions on the basis of considering demographic measures. For example, while the numbers of 25 to 64 year olds per person 64 years and older fall by more between 1999 and 2050 the lower the TFR, the rate of growth of living standards is higher. Thus the impression given by the demographic measure is the opposite of the
Why are the demographic measures misleading? The shortcoming of demographic measures is that they ignore the influence on living standards of labour productivity growth, the Solow effect and consumption smoothing. Our simulations show that this is a serious shortcoming. Indeed, labour productivity growth, the investment dividend and the consumption dividend are so strong that the population alive today does not require any transfers from people yet to be born or people yet to live in Australia (that is future migrants) to enable its living standards to grow.

Of course, in as far as the paths can be regarded as socially optimal, they are of interest in addressing the issue of the adequacy of saving in Australia. There has been “widespread support throughout the 1990’s for the proposition that saving in Australia is less than its optimum” (Gruen (2000, p.3)). Our simulations suggest that socially optimal outcomes would be generated by increases in national saving from its level in Australia in 1999 equal to 2.5 percent of GDP by 2017 in the Base case, 2.9 percent of GDP by 2017 in the TFR 1.65 case, 4.4 percent of GDP by 2025 in the TFR 1.3 case and 7.4 percent of GDP by 2025 in the TFR 1 case. Thus lower fertility requires a greater increase in national saving for social optimality but allows more time to reach the higher level. From our simulations and the discussion in this paper, we suggest that the current rate of saving in Australia is adequate in the following sense. First, there is no case for an immediate increase in saving that would require an immediate cut in living standards. This is because with no such increase it is still the case that people living in the future will be better off than people living today. Second, should Australia fall short of the small increases in national saving in the near future as measured by our calculations of the socially optimal rate of saving as defined in this paper, that can be reasonably argued to cause no real loss in social welfare. This is because, as we argued in the paper, our social welfare function treats people alive in the future generously, in that they will be better off than people alive today. So to fall short of the socially optimal rate of saving will simply treat those alive in the future a little less generously. Third, our assumption that

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33 Cutler et al (1990) and Elmendorf and Sheiner (2000) argue that the aging of the US population does not “add force to the arguments for boosting national saving”. We agree with this but go further in suggesting that, for Australia at least, there is on balance no force to the arguments for boosting national saving.

34 This line of argument suggests that even with reference consumption, the social welfare function is not entirely satisfactory. However in our view, based on the implied paths of living standards, which is the appropriate consideration, it is better than the commonly used social welfare function without reference
employment-population ratios are fixed for the future in the face of increasing longevity ignores the possibility that the retirement age will increase with life expectancy. If the retirement age does increase with life expectancy then the optimal increase in national saving is smaller and is associated with a higher rate of growth of living standards, see Guest and McDonald (1999).

The breadth of the assumptions we make about future total fertility rates and the uniformity of the conclusions with regard to the rate of growth of future living standards suggests that our results, although based on the Australian population structure and various macroeconomic characteristics for 1999 in Australia, are broadly applicable to other countries.

For low fertility to be a problem for future living standards it would have to cause some qualitative change to the economy that goes beyond the assumptions of the model. The most obvious case to consider would be a world glut of saving and a world shortage of investment opportunities. This is a topic for further research. However, it should be noted in this context that our results are fairly robust with respect to low interest rates.

Some may question our assumption that the rate of total factor productivity growth is constant, independent of demographic developments. However, as we argued in the introduction, there is no clear evidence on how decreased fertility will affect total factor productivity. Indeed some, eg Cutler et al (1990), and Fougere and Merrette (1998), (1999) argue that ageing and the population slowdown will increase the rate of growth of total factor productivity. From that perspective, our calculations can be regarded as conservative. For a benchmark case, our assumption of a constant rate of total factor productivity growth is appropriate.

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35 The rate we assume, 1 per cent per year, is consistent with trends in the Australian economy over the last 100 years. With this historical support, its continuation does not seem unreasonable.
Table 1 Definition of variables

<table>
<thead>
<tr>
<th>Subscript</th>
<th>Description</th>
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<tbody>
<tr>
<td>C</td>
<td>aggregate consumption</td>
</tr>
<tr>
<td>W</td>
<td>wealth=capital stock plus overseas assets</td>
</tr>
<tr>
<td>I</td>
<td>aggregate investment</td>
</tr>
<tr>
<td>D</td>
<td>overseas debt</td>
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<tr>
<td>r</td>
<td>world interest rate</td>
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<tr>
<td>δ</td>
<td>rate of depreciation</td>
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<tr>
<td>L</td>
<td>aggregate employment in relative efficiency units</td>
</tr>
<tr>
<td>l</td>
<td>employment in relative efficiency units on a vintage of capital in its first period of use</td>
</tr>
<tr>
<td>T</td>
<td>age of oldest capital good in use</td>
</tr>
<tr>
<td>h</td>
<td>terminal period of the maximisation problem</td>
</tr>
<tr>
<td>N</td>
<td>population in natural units</td>
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<tr>
<td>P</td>
<td>population in consumption units</td>
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Table 2 Consumption weights by age group

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<tr>
<th>0-15</th>
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<th>25-39</th>
<th>40-49</th>
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<th>60-64</th>
<th>65-69</th>
<th>70-74</th>
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<td>Cutler et al (1990)</td>
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<td>1.00</td>
<td>1.00</td>
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<td>0.95</td>
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<tr>
<td>Elmendorf and Sheiner (2000)</td>
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<td>1.00</td>
<td>1.00</td>
<td>1.37</td>
<td>1.45</td>
<td>2040</td>
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Table 3 Values of parameters and exogenous variables

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<th>δ</th>
<th>a</th>
<th>r</th>
<th>β</th>
<th>ω</th>
<th>ρ</th>
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<td>0.01</td>
<td>0.06</td>
<td>2</td>
<td>6.788</td>
<td>0.03122</td>
<td>170 years</td>
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Table 4 Annual rate of growth of consumption per consumption unit, 1999 to 2050

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<tr>
<th>Base</th>
<th>TFR 1.65</th>
<th>TFR 1.3</th>
<th>TFR 1.0</th>
<th>Dooms day</th>
<th>Base</th>
<th>TFR 1.0</th>
<th>TFR 1.0</th>
<th>Dooms day</th>
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<tr>
<td></td>
<td>r=3%</td>
<td>r=9%</td>
<td>r=3%</td>
<td>r=9%</td>
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Chart 1 Support ratios, Australia, 1971 to 2065

Chart 2 The impact of reference consumption on consumption per consumption unit, Australia, 1999 to 2168
Chart 3 Optimal consumption per person, Australia, 1999 to 2050

Chart 4 Optimal national saving, 1999 to 2050
Chart 5 The Doomsday Scenario, Australia, 1999 to 2099
References


