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## **Demographic Change in the Asia-Pacific: The Effect on Average Living Standards**

Ross S. Guest  
Griffith University  
Australia

### **ABSTRACT**

This paper applies a simulation model to identify the impact of prospective demographic change on average living standards over the next fifty years in each of twelve Asia-Pacific countries. The impact on living standards depends on the country's stage of demographic transition. For countries that are already experiencing population ageing, such as Japan, Singapore, Australia and New Zealand, impending demographic change has an immediate negative impact on living standards. But young countries such as Indonesia, Malaysia and Philippines, derive a dividend from impending demographic change that could, with an appropriate saving response, impact positively on living standards for at least the next fifty years.

*Keywords: demographic change, population ageing, living standards, national saving*  
*JEL : E21, J11, O11*

## **Demographic Change in the Asia-Pacific: The Effect on Average Living Standards**

### **1. Introduction**

While Japan still has the highest old age dependency ratio of all Asia-Pacific countries, some other countries are rapidly catching up, most noticeably Singapore and South Korea, with China also not far behind. Countries in the Asia-Pacific such as Australia and New Zealand currently have relatively old populations – older than Singapore, South Korea and China - but their rates of further ageing in the coming decades will not be as fast as in the latter three countries. Malaysia, Philippines, Indonesia and Vietnam, on the other hand, are examples of countries that not only have younger populations but whose populations are expected to become even younger in the next two or three decades before they begin the demographic transition towards older populations.

The purpose of this paper is to evaluate the effects of prospective demographic change on average living standards across twelve Asia-Pacific countries that currently represent the spectrum of different stages of demographic transition. The demographic transition refers to the change in the age distribution of the population caused by, first, lower infant mortality rates and increased longevity, and later in the transition, a lower total fertility rate (Bloom et al., 2003). These demographic changes were the result of social and economic development, including improvements in medicine and public health (ibid.). This process contributed to the baby boom-bust scenario in the developed world, East Asia and some developing countries since World War II. Some countries enter the demographic transition earlier than others, which implies that countries face different patterns of optimal living standards and saving. Guest and

McDonald (2005, forthcoming) have considered the effect on optimal saving rates of prospective demographic change for four Asian countries. The present paper extends that work by applying a somewhat different model<sup>1</sup>, by shifting the focus to living standards and applying it to a range of twelve countries that can be classified in three groups according to their current and prospective demographic patterns.

In evaluating the economic burden of population ageing it is not simply the share of older people in the population that matters. Also important is the labour force participation rate (LFPR) of older workers, the growth rate of the labour force and the consumption needs of older people (in terms of health care for example) relative to younger people. South Korea has a high LFPR of older workers which will, assuming it remains high, cushion the impact of its rapidly declining labour force growth rate and rapid increase in its old age dependency ratio. Singapore on the other hand has a relatively low old age LFPR which would exacerbate its rapidly falling labour force growth rate and its rapidly rising old age LFPR.

Various issues associated with the economics of demographic change in East Asia have been considered in the literature. See, for example, Mason, ed. (2001), and Bloom et al (2003). The focus in this paper is on the implications for living standards only. Other important implications of demographic change are not considered explicitly. For example, population ageing has important implications for a government's fiscal position through the costs of public pensions, public health and aged care. It is widely anticipated that these fiscal costs will necessitate rising tax rates in the absence of changes to labour force participation rates or productivity. Any

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<sup>1</sup> The present version extends the model in Guest and McDonald (2005, forthcoming) by allowing for traded and non-traded goods and hence allowing for a flexible real exchange rate; and by finding optimal paths that start and finish in a steady state (the prior model did not specify an initial or final steady state). In the present model prospective demographic change is treated as a shock to which the economy adjusts by following a path to a new steady state. For an application of the present model to a world economy consisting of nine regions, see Guest and McDonald (2004).

increases in tax rates can be expected to have disincentive effects on labour supply via reductions in after-tax incomes, thereby exacerbating the costs of ageing. The present paper does not attempt to quantify these effects. Other potential limitations of the simulations are discussed in Section 7.

## **2. Demographic projections**

The demographic projections are derived from the United Nations (2002) Revision of world population projections by age and sex. The twelve Asia-Pacific countries chosen for comparison are Australia, China, Indonesia, Japan, North Korea, South Korea, Malaysia, New Zealand, Philippines, Singapore, Thailand, Vietnam. For each country the demographic assumptions used are: “medium” fertility and “normal” migration and “normal” mortality as defined and discussed in United Nations (2002).

Employment projections by age and sex are calculated from the International Labour Organisation (ILO, 2001) database: Key Indicators of the Labour Market (KILM). These data provide labour force and population by age group for each country in the world for the latest year – typically 1999 or 2000. From these data the age-specific labour force participation rates (LFPR) for each of the twelve countries are calculated, and are given in Table 1. These age-specific LFPRs are taken to be the age-specific employment to population (L/N) ratios. This effectively assumes zero unemployment, which implies that we are ignoring the effect that different age-specific unemployment rates, even if they were assumed constant over time, can have on aggregate employment when the age distribution changes. The other important caveat with respect to the LFPRs is that they are assumed to be constant over time. This is unlikely to be the case but because we cannot reliably predict the magnitude, or perhaps even direction, of future movements in LFPRs the assumption of constancy seems a reasonable starting point.

The LFPRs are important for the effect of demographic change on consumption possibilities. There is quite a wide variation in the LFPR ratios between countries as is evident from Table 1; and therefore the impact of a given change in demographic patterns on countries could be quite different. For example, South Korea has the lowest LFPR for young people (15-24 year olds), equal to 31.3%, and China has the highest, equal to 79.1%. These two countries also have the lowest and highest LFPR for the bulk of the workforce, that is, those in the 25-64 age group. However, South Korea has much higher LFPR than China for older workers – those over 64 year of age. The latter means that, assuming these LFPR remain constant, the effect of a higher proportion of old people on consumption possibilities will not be as great for South Korea as it will be for China, other things equal.

Following Cutler et al. (1990) and Elmendorf and Sheiner (2000) the employment and population numbers are weighted to account for, respectively, age-specific differences in labour productivity and consumption needs. Labour productivity of middle-aged workers is higher than that of both younger and older workers and this is reflected in their relative wages. In the absence of reliable data for all regions on labour productivity by age, we adopt as an expediency the age-productivity relation in Miles (1999), where the productivity weight is a quadratic function of age:  $0.05\text{age} - 0.0006\text{age}^2$ . Consumption needs also vary by age – in particular, education and medical expenses. To allow for this, we apply the consumption weights in Cutler et al (1990); that is 0.72 for 0-19 year olds, 1.0 for 20-64 year olds and 1.27 for over 64 year olds. Both productivity weights and consumption weights are non-gender specific.

In reality, age-specific weights for both labour productivity and consumption will vary among regions. However, we assume that they do not, on the basis that we lack reliable data on region-specific weights. Given that our aim is to isolate the impact

of different rates of fertility on living standards, the view taken is that it is preferable to assume that parameters do not vary between regions where there is an absence of reliable data to the contrary. We also apply this principle in also assuming the same steady state labour productivity growth rate (1.5%) among regions (discussed further below).

The aggregate weighted L/N ratio for each region is the support ratio (Cutler et al., 1990). A decrease in the support ratio implies a diminished capacity to meet a given level of consumption needs per capita. An increase in the support ratio implies the opposite. Figure 1 plots the support ratios for the twelve countries. Three patterns of support ratios can be identified. The first is a support ratio that declines monotonically from 2001 onwards. This applies to Japan, Singapore, Australia and New Zealand. These are countries that are already ageing and by 2050 they will be much older than they are now. The second pattern is a support ratio that rises a little in the next decade and then, like the first pattern, declines to a level well below its level in 2001. This applies to China, Thailand, South Korea and North Korea. These are countries that will become younger for the next decade or so but will finish up significantly older than they are now. The third pattern is an inverted U-shape pattern describing a period of gradual increase in the support ratio lasting several decades followed by a period of gradual decline, such that by 2050 the support ratio will be at much the same level as it is now. This pattern applies to Vietnam, Indonesia, Malaysia and Philippines, although in the case of Philippines the support ratio in 2050 is noticeably higher than it is in 2001, implying a higher employment to population ratio in 2050 than in 2001.

These patterns of the support ratios drive the paths of living standards for each country. If the support ratio is lower (higher) at the end of the projection period than it

is at the beginning it implies that consumption possibilities will end up being lower (higher).

In order to ensure that the economy converges to a new steady state, it is necessary that the population becomes stable at some point. This is imposed by assuming that the demographic projections described above are applied only for the period 2000 to 2050, at which point the rate of growth of aggregate weighted employment and population are assumed to remain constant at the growth rate of the actual aggregate weighted population in 2050. This simplification is justified on the assumption of a positive rate of discount (see below), which diminishes the impact of demographic changes in the distant future on optimal values of economic variables in the near future.

### **3. The model**

The model used here to simulate the macroeconomic effects of the demographic transition in the Asia-Pacific is a two good Cass-Ramsey-Solow model. It is a variation on the two good model in Obstfeld and Rogoff (1996). The important features of the model are described in this section. More detail, along with a full list of equations and variables, is given in the Appendix.

#### **3.1 Firms**

Output of traded and non-traded goods is produced according to vintage, Cobb-Douglas technology with constant returns to scale. This is a variation to the Obstfeld and Rogoff (1996) model. While the vintage capital model, appropriately calibrated, yields the same long run solution as the homogeneous capital model (Solow, 1960), there can be differences in the short run response to shocks of, for example, a demographic nature (Guest, forthcoming). For a generic comparison of vintage and

homogenous capital models see Greenwood (1977). One practical reason for adopting a vintage rather than homogeneous capital model is that it obviates the need for adjustment costs in investment.

As in the two good model in Obstfeld and Rogoff, 1996, it is assumed that non-traded (N) goods cannot be capital goods, only consumer goods, which implies that the output of N goods is equal to the consumption of N goods. There are two reasons for this assumption: it simplifies the solution procedure (see Appendix) and it captures the observation that consumption goods and services have a higher non-traded component than do traded goods.

A second variation to the Obstfeld and Rogoff (1996) model is the assumption that capital is not perfectly mobile which is consistent with extensive evidence. For a discussion of the various explanations of imperfect capital mobility see Gordon and Bovenberg (1996); and for a survey of the evidence on the Feldstein-Horioka puzzle as an indicator of imperfect capital mobility see Coakley, Kulasi and Smith (1999). We also observe that countries – small countries in particular - face a risk premium that depends on their existing stock of foreign debt (see Juttner and Luedecke (1991) for the case of Australia).

Steady state labour productivity growth is exogenous and constant at 1.5% per annum for all regions. This implies two things – first, that there is no influence of demographic change on technical progress and, second, that there is no convergence of labour productivity among the nine regions. On the effect of demographic change on technical progress both the theoretical and empirical evidence is ambiguous, as discussed by Cutler et al. (1990, p. 38). Hence the assumption here of zero net effect of demographic change on total factor productivity growth seems to be a reasonable position to take for simulation purposes.

With respect to the zero convergence assumption, Barro and Sala-i-Martin (1995, p.26) report that the hypothesis of absolute convergence – where poor countries catch-up with rich countries in their GDP per capita, without allowing for any control variables – has received mixed empirical support.<sup>2</sup> In this paper, zero convergence in total factor productivity is assumed because, in our initial simulations, we found that all but a very small rate of convergence tended to swamp the effects of differences in fertility rates that we were attempting to isolate. As a result of this, and the uncertainty in the empirical literature about productivity convergence, zero convergence is regarded as a reasonable assumption for the objectives in this paper.

The effects of ageing on output growth in the model are, therefore, restricted to the effects on the productivity-adjusted employment levels. This occurs through both a change in the age distribution and the growth of the workforce. A change in the age distribution of the workforce affects the productivity of the workforce as a result of the productivity weightings described in the previous section. A reduction in the growth rate of the workforce has two effects on output growth. There is an initial capital deepening which raises output and a long run reduction in output that is determined by the employment elasticity of output.

### **3.2 Consumers**

Each country is populated by infinitely lived dynasties of people who differ in two respects: their ages and therefore their age-specific consumption demands differ; and that not all consumers exhibit forward-looking behaviour. All consumers are faced an

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<sup>2</sup> The hypothesis of conditional convergence, which controls for various characteristics of economies, has received stronger empirical support. However, even the testing of this weaker hypothesis faces some serious econometric problems. See Durlauf and Quah in Taylor and Woodford eds. (1999) for a comprehensive discussion of the theory and empirical tests of convergence hypotheses.

intratemporal maximisation problem which is solved by optimally allocating a given value of consumption, measured as an index, between traded and non-traded goods.

Not all consumers, however, are intertemporal optimisers. Rather 30% of consumers are rule-of-thumb consumers, meaning that they always consume a fixed proportion of their income; these consumers have the same age distribution as the intertemporal optimisers. The notion of rule-of-thumb consumers is now quite common in applied economy-wide models; in the context of population ageing see, for example, the application of the MSG3 model in McKibbin and Nguyen, 2001 and the OECD's MINILINK model in Turner et al., 1998. It is designed simply to allow aggregate consumption projections that capture the reality that an unknown proportion of consumers do not exhibit forward-looking behaviour. The alternative to the rule-of-thumb approach is to try to directly model the causes of myopic behaviour such as liquidity and wealth constraints, and other saving motives. The rule-of-thumb approach can be seen as a somewhat ad hoc way of capturing this reality.

The consumers who optimise intertemporally are outward looking, as in Carroll et al. (1997), in that each consumer compares their consumption against the consumption of others (in the same country) in deriving their utility. Carroll et al. (1997) cite a range of evidence from the literature, both theoretical and empirical, in support of two alternative forms of what they call "comparison utility".<sup>3</sup>

The consumption path for the economy is a weighted average of the consumption paths of the intertemporal optimisers and the rule-of-thumb consumers.

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<sup>3</sup> One form of comparison utility is the "outward-looking" model that we adopt here. The other form is the "inward-looking" model in which consumers compare their consumption with their own past consumption rather than the consumption of others. Both forms of comparison utility generate a type of habit formation in consumption which implies the sort of persistence in consumption that we observe in the data. This is the main motivation for adopting comparison utility in this paper and from that point of view it does not matter whether we adopt the outward-looking model or the inward-looking model.

#### **4. The simulation method**

The solution procedure is to first calibrate an initial steady state which implies that both population and employment are initially growing at constant rates. The demographic projections are then introduced as unanticipated “shocks”. Cutler et al. (1990) argue that “it is not obvious how best to model [demographic change] as a single shock” (p.23). The approach they and others typically adopt is to assume that the population has been stable at which point a demographic shock occurs so that employment and population follow the projections described above. Following the shock, it is assumed that consumers and firms know the future demographic structure and choose optimal consumption and investment levels accordingly.

Once the initial steady state is defined, the optimal path in response to the demographic shock is determined by finding the new initial value of the consumption index that leads to the steady state.

#### **5. Living standards**

Living standards are defined as aggregate consumption per equivalent person. The impact on living standards of a demographic shock is the net result of three effects: the dependency effect, the capital widening effect and a labour productivity effect, see Elmendorf and Sheiner (2000)<sup>4</sup>.

Higher (lower) overall dependency (the combination of youth and old age dependency) implies fewer (more) workers per person, which reduces (increases) consumption possibilities. The capital widening effect refers to the impact of a change in the rate of growth of employment on the level of investment needed to maintain a given capital-labour ratio. Lower (higher) employment growth increases (decreases)

consumption possibilities. The labour productivity effect refers to the temporary change in labour productivity resulting from the temporary change in capital labour ratios as a result of a demographic shock.

Table 2 summarises the effect of demographic change on living standards over the period 2001 to 2100 for each of the twelve countries. The last 50 years, from 2050 to 2100, are included to illustrate the effect of the assumption of a constant support ratio over this period; the effect is to ensure that living standards approach a steady state by 2100 at which time the full effect of the demographic shock has been realised.

The three distinct patterns of support ratios, described above, are reflected in three distinct responses of living standards. The first group of countries whose support ratios had already begun falling by 2000 – Japan, Singapore, Australia and New Zealand – suffer an immediate negative impact on living standards. Two of these countries, Singapore and Japan, suffer the largest ultimate negative effect on living standards. This is because they suffer the largest decline in their support ratios. The second group of countries whose support ratios do not begin declining for the next decade or two and in some cases even increase a little over that period – China, Thailand, South Korea and North Korea – enjoy a small boost to their living standards for the first decade or two of the projection period. It is noteworthy that South Korea faces a relatively sharp negative in living standards after the first two decades reflecting the relatively sharp decline in its support ratio. For the third group of countries, who face little or no ageing of their populations over the next 50 years – Vietnam, Indonesia, Malaysia and Philippines – prospective demographic change is positive for living standards (with the exception of Vietnam which faces a small negative impact which does not occur until the decade from 2040 to 2050).

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<sup>4</sup> Elmendorf and Sheiner refer to a capital intensity effect which we call a labour productivity effect

The lower part of Table 2 gives the effect of demographic change in terms of equivalent steady state labour productivity growth due to technical progress. Take Japan for example. Table 2 shows, in the top portion, that by 2020 the cost to living standards from population ageing is 10.5%.<sup>5</sup> That is, living standards will be 10.5% lower than they would have been had demographic change not occurred. We then ask the question: what would be the minimum annual rate of steady state productivity growth, due to technical progress, that we would have to assume to wipe out this loss to living standards? The answer to that question is found by the number for Japan in 2020 at the bottom of Table 2. This number is 0.5%, meaning that provided technical progress was sufficient to imply a steady state rate of productivity growth equal to 0.5% per annum, living standards would rise in absolute terms despite population ageing. Note that due to compounding, the numbers get even smaller the further out we take the calculation. For example, by 2100 we would have only required technical progress equivalent to steady state labour productivity growth of 0.25% in order to fully offset the cost of population ageing.

One can conclude from this that population ageing will reduce the growth of living standards in coming decades, quite significantly for the more rapidly ageing countries of Japan, Singapore, Australia and New Zealand. However, it can also be said that there is unlikely to be a reduction in the absolute level of living standards, unless technical progress falls to unprecedented levels.

## **6. Policy implications**

In developing countries, most of which are experiencing population ageing, there is a popular view that it is necessary or optimal to increase current rates of national saving

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because it is perhaps more descriptive for this model (see discussion below).

to smooth out the costs of population ageing over time. This view is typically expressed through the media in the form of calls to raise public saving through higher tax rates and increase private saving through superannuation. It is argued that higher current rates of saving, and therefore lower current living standards, will reduce the costs to living standards in the future. In New Zealand this view has been embodied in government policy through the creation of the New Zealand Superannuation Fund, whereby budget surpluses are being generated and deposited into a government managed fund to be made available to meet pensions in the future.

The notion of smoothing out the costs of ageing through tax smoothing, as applied in New Zealand for example, has a basis in economic theory to the extent that Barro (1979) showed that smoothing tax rates minimises the deadweight losses from taxation. On the other hand, economic theory also suggests that future living standards ought to be discounted if living standards are expected to rise over time through technical progress. The issue of the appropriate social discount rate for long term social planning is discussed by Cline in Portney and Weyant eds. (1999). While there is controversy over the appropriate rate, it is generally agreed that it should be positive as long as technical progress is expected to occur. A positive rate implies some discounting of future living standards.

The model applied here generates a path for the optimal saving rate in response to the demographic shock that is consistent with the path for optimal living standards. Hence the model can be used to evaluate the case for increasing the national saving rate in response to population ageing. The model has a social discount rate of 5% which is equal to the steady state interest rate. An interest rate of 5% is fairly typical in

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<sup>5</sup> We are referring throughout this discussion to optimal living standards – that is to living standards assuming the optimal response to population ageing is followed.

these models and, in order to generate a steady state, it is necessary to set the discount rate equal to the interest rate.

Table 3 shows the effect of the demographic shock on optimal saving as a percent of GDP for each country over the projection period, relative to that in 2001. The table indicates that for most countries it is optimal to build up some saving in anticipation of population ageing. But this applies much less, if at all, to countries for which ageing is well underway. In Japan, for example, it is optimal to reduce saving immediately in response to the demographic shock and saving remains below its level in 2001. This is because the process of population ageing in Japan, and in general, implies a more slowly growing labour force which has lower capital requirements and therefore requires less saving. Similarly, for Australia and New Zealand there is a very small and short lived rise in optimal saving followed by a fall. For the group of countries for whom population ageing is furthest in the future – Vietnam, Indonesia, Malaysia and Philippines – the period of higher optimal saving lasts for several decades. However, even for these countries, the magnitude of the change in optimal saving is not large, being generally less than one percent of GDP different to the initial level of saving.

These results are somewhat at odds with the popular perception that it is the rapidly ageing countries who ought to increase their saving rates. For these countries the time to raise saving rates on account of population ageing may have passed. Their slowly growing labour forces do not require large accumulations of capital. Rather, it is the countries for which ageing is some way off that require a build up of capital and therefore higher saving rates. This conclusion must be qualified, not least by the possibility that saving rates may not have been optimal in the past in which case there may be a case for a catch up in saving as a second best response to ageing. For

example, if Australia and New Zealand have been undersaving in the past and therefore have not accumulated an optimal amount of capital, there may be a case for saving more now than would have been the case had they been saving more in the past. There may be many reasons why countries are currently under-saving, such as distortions in the tax system, myopia, and overspending by governments. There may therefore be reasons why countries ought to increase their saving rates. But no allowance is made for these factors in the model. Subject to this qualification, the magnitudes throughout Table 3 do suggest that big increases in saving rates (say more than one percent of GDP) are probably not required in response to expected demographic change. This is relevant when evaluating calls for increases in tax rates or private saving rates through superannuation as a response to population ageing.

## **7. Limitations**

The limitations of the simulations and the resulting conclusions arise from the assumptions in both the model and the data. The approach taken in the simulations is to ask a counterfactual: if the economies of the countries were the same in all respects except their state of economic development<sup>6</sup>, what would their different demographic projections imply about their future living standards? The reason for holding so many things constant across countries is that, first, we can be a good deal more confident about demographic projections than we can about future values of many other exogenous variables and parameters. This is because the demographic projections in the next few decades are largely determined by current fertility and mortality rates and to some extent by future values of these variables that we know change very slowly.

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<sup>6</sup> The state of economic development of a country is represented in the model by the country's steady state capital to output ratio. As explained in the Appendix, the developed countries, being Japan,

Second, we are interested in comparing the different patterns of optimal living standards, rather than deriving precise outcomes for particular countries. The simulations show, for example, the opportunity for countries whose support ratios are still rising to smooth out the resulting gains and avoid the costs of subsequent population ageing – an opportunity that is not available to countries whose support ratios are already falling.

The limitation of the counterfactual arises to the extent that actual differences in country-specific values of parameters, such as labour productivity levels, average capital intensity of industry, elasticities of substitution in consumption and production, and so on, could be sufficiently large to qualitatively alter the relative patterns of optimal living standards.

Two other limitations deserve mention. One arises from the demographic data and another from potential structural flaws that might exist in the model. The demographic data are highly aggregated both across age groups and across the sexes. For consistency, the same data sources were used for all countries: the ILO (2001) data on LFPRs and the United Nations (2002) for population data. The LFPR data are highly aggregated which necessitated the same degree of aggregation of the population data. Also, the LFPRs are assumed to remain constant throughout the projection period which disallows any increase in LFPRs of women that is likely to occur in many countries. Again, these simplifications are acceptable for the purpose of distinguishing broad differences in the patterns of demographic change among the countries, especially if changes such as increasing LFPRs of women apply to all countries.

With respect to potential flaws in the model, these could arise on both the production and consumption side of the model. The structure of the model is quite

simple. On the production side, an obvious simplification is the assumption of exogenous labour supply. As discussed briefly in the introduction, the fiscal costs of population ageing are likely to require higher tax rates which will lower after-tax real wages and therefore induce some substitution of leisure for labour. To properly account for this would require introducing leisure into the utility function. The justification for not doing this is that it is very unlikely to qualitatively alter the relative patterns of optimal consumption given in Table 2.

As discussed in the Appendix, most features of the consumption model have been used widely in the literature, with the possible exception of the assumption that 30% of consumers are rule-of-thumb consumers rather than intertemporal optimisers, which is perhaps a more controversial assumption. While the 30% figure has been used elsewhere in the literature, it is somewhat arbitrary. It is intended to capture the reality that not all consumers are in fact intertemporal optimisers. The effect of this assumption is to accentuate the swings in the optimal saving rate that are required to smooth consumption. Intuitively, this is because the path to the new steady state is driven by the behaviour of the 70% of consumers who are intertemporal optimisers. Hence their smoothing behaviour must be more accentuated to offset the rule-of-thumb behaviour of the other 30% of consumers. Sensitivity tests, not reported, confirm this and also indicate that the qualitative results reported here are not overturned by adopting alternative proportions of rule-of-thumb consumers.

## **8. Conclusion**

The analysis presented here of the impact of prospective demographic change in the Asia-Pacific suggests considerable variation among countries. The twelve countries

analysed can be grouped into three different stages of demographic transition. The countries for which ageing has already begun face a negative impact on living standards from demographic change. However, the group of countries whose populations will get younger before than get older have an opportunity to spread out the consumption dividend from a younger population and therefore enjoy a consumption boost, in comparison with their living standards today, for many decades into the future. For the latter group of countries this can be achieved by small increases – generally around one percent of GDP - in their current saving rates. However, for countries that are already ageing the increase in the current optimal saving rate, if any, is even smaller. These results suggest that the case for increases in current tax rates and superannuation sacrifices, in order to increase national saving as a way of smoothing out the costs of population ageing, is not very strong.

## Appendix

This Appendix describes the analytics of the model and the solution procedure. The model is a variation of the two good model in Obstfeld and Rogoff (1996). Variables are defined in Table 1.

Let  $Y_T$  and  $Y_N$  be output of traded (T) and non-tradable (N) goods, respectively. Let  $V_T$  and  $V_N$  be the number of vintages of capital employed in producing tradable and non-tradable goods, respectively<sup>7</sup>. Assume that output is produced according to a vintage production function with Cobb-Douglas technology:

$$Y_{T,t} = \sum_{k=0}^{V_T-1} \left[ (1 - \delta_T)^k A_{T,t-k} (I_{T,t-k})^\gamma [L_{T,t-k-1} (l_{T,t-k} + \delta_T)]^{1-\gamma} \right] \quad (\text{A1})$$

$$Y_{N,t} = \sum_{k=0}^{V_N-1} \left[ (1 - \delta_N)^k A_{N,t-k} (I_{N,t-k})^\gamma [L_{N,t-k-1} (l_{N,t-k} + \delta_N)]^{1-\gamma} \right] \quad (\text{A2})$$

which can be approximated by

$$Y_T = Y_{T,-1} (1 - \delta_T) + A_T I_T^\gamma (L_{T,-1} (l_T + \delta_T))^{1-\gamma} \quad (\text{A3})$$

$$Y_N = Y_{N,-1} (1 - \delta_N) + A_N I_N^\gamma (L_{N,-1} (l_N + \delta_N))^{1-\gamma} \quad (\text{A4})$$

which, in turn, can be expressed in intensive form where  $y$  is output in efficiency units per equivalent worker.

$$y_T = y_{T,-1} \frac{(1 - \delta_T)}{(1 + x_T)} + i^\gamma \left[ \frac{l + \delta}{1 + l} \right]_T^{1-\gamma} \quad (\text{A5})$$

$$y_N = y_{N,-1} \frac{(1 - \delta_N)}{(1 + x_N)} + i^\gamma \left[ \frac{l + \delta}{1 + l} \right]_N^{1-\gamma} \quad (\text{A6})$$

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<sup>7</sup> We follow the assumption in Obstfeld and Rogoff (1996) that only tradable goods can be transformed into capital. They describe this assumption as “inessential but helpful” (p.204). In our version of their model this assumption allows an analytic solution for  $l_N$  and  $l_T$ ; otherwise numerical methods would be required.

Let  $q_T$  and  $q_N$  be the ratio of new capital to the effective labour available to work on

that capital. For the T and N sectors  $q = \frac{i(1+l)}{l+\delta}$ .

Investment in each of the two sectors is determined by the condition that the marginal product of capital is equal to the user cost of capital,  $r+\delta$ . Therefore

$$q_T = \left( \frac{\gamma}{r + \delta_T} \right)^{\frac{1}{1-\gamma}} \quad (\text{A7})$$

$$q_N = \left( \frac{e\gamma}{r + \delta_N} \right)^{\frac{1}{1-\gamma}} \quad (\text{A8})$$

The real wage,  $w$ , is equal to the marginal product of labour in each sector. That is,

$$A_T^{\frac{1}{1-\gamma}} (1-\gamma)(q_T)^\gamma = w \quad (\text{A9})$$

$$e \left[ A_N^{\frac{1}{1-\gamma}} (1-\gamma)(q_N)^\gamma \right] = w \quad (\text{A10})$$

where  $e$  is the real exchange rate,  $P_N/P_T$ .

The four equations (A7) to (A10) can be solved for the four endogenous variables  $q_T$ ,  $q_N$ ,  $w$  and  $e$ .

#### The consumer's intratemporal maximization problem.

The two good utility model in Obstfeld and Rogoff (1996) is adopted. In this model all consumers have identical intratemporal behaviour, hence a representative consumer can be defined as having an index of total consumption at time  $t$  is defined as (see Table 1 for the full list of variables):

$$c_t = \left[ \mu_t^{\frac{1}{\psi}} c_{T,t}^{\frac{\psi-1}{\psi}} + (1-\mu_t)^{\frac{1}{\psi}} c_{N,t}^{\frac{\psi-1}{\psi}} \right]^{\frac{\psi}{\psi-1}} \quad (\text{A11})$$

where  $\mu_t$  is time varying because the representative consumer's relative preferences for traded and non-traded goods vary with age. This reflects the observation that

preferences for medical and health services, which are essentially non-traded goods, are age-dependent. In particular, we would expect that dependents, who are predominantly the young and old, have a higher demand for non-traded relative to traded goods than do working age people. In the absence of data on age-based consumption of non-traded and traded goods we adopt the following approximation. We assume that the preferences for non-traded goods increase in proportion to the increase in the aggregate dependency ratio, which is equal to the inverse of the (unweighted) support ratio minus 1.<sup>8</sup> Hence  $\mu_t$  can be defined as,  $\mu_t = \mu_0 \left( \frac{L}{N} \right)_t$ .

The solution (see Obstfeld and Rogoff, 1996, p.228 ) yields:

$$c_T = \mu \left( \frac{1}{P^C} \right)^{-\psi} c \quad ; \quad \text{and} \quad c_N = (1 - \mu) \left( \frac{e}{P^C} \right)^{-\psi} c \quad (\text{A12})$$

where

$$P^C = \left[ \mu + (1 - \mu)e^{1-\psi} \right]^{1/(1-\psi)}$$

and where  $P^C$  be the price, in T goods, of a unit of the consumption index.

The consumer's intertemporal maximization problem.

It is assumed that a proportion,  $(1-\xi)$ , of consumers are intertemporal optimisers and  $\xi$  are rule-of-thumb consumers who consume a constant proportion of their income. Both groups of consumers have an identical age structure.

The utility that consumers derive from a given amount of consumption differs according to their consumption demands. The representative intertemporally optimising consumer is a composite individual whose age is the weighted average age of all consumers and who maximizes the following utility function:

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<sup>8</sup> The dependency ratio  $= (N-L)/L = N/L - 1$ , where N is the total population and L is the working age population. The constant term (-1) can be omitted in defining  $\mu_t$ .

$$U = \sum_{t=1}^{\infty} \left[ \frac{c^{opt}}{z^{\omega}} \right]_t^{1-\beta} \frac{(1+\theta)^{1-t}}{1-\beta} \quad j=1,\dots,h \quad (\text{A13})$$

where  $z$  is a reference stock of consumption and  $s$  is the weighted average of the age-specific consumption weights of all consumers at time  $t$ . The age-specific consumption weights are: 0.72 for people under 20, 1.0 for people from 20-64 and 1.27 for those over 64.

In (A13)  $c^{opt}$  denotes the consumption of the representative intertemporally optimising consumer. This consumer is assumed to be outward looking in the sense that their reference stock of consumption,  $z$ , is a function of the average consumption of all consumers across all age groups rather than a function of their own consumption. The parameter  $\omega$  indexes the importance of the reference stock of consumption. Here we set  $\omega=1$  and define  $z_t=c^{opt}_{t-1}$  which is equal to the average consumption of all optimising consumers in period  $t-1$ .

The first order condition for the representative intertemporally optimising consumer is

$$\frac{\frac{\partial V_i}{\partial c^{opt}_t}}{\frac{\partial V_i}{\partial c^{opt}_{t+1}}} = (1+r_{t+1}^C) = (1+r_{t+1}) \frac{P_t^C}{P_{t+1}^C} \quad (\text{A14})$$

where  $r^C$  is the own rate of interest on the consumption index,  $c$ ;<sup>9</sup> and  $r$  is the rate of interest on tradables. Bonds are indexed to tradables so that  $B$  bonds are a claim on  $rB$  tradables per period (Obstfeld and Rogoff, 1996, p.229). Note that in the steady state,

$$P_t^C = P_{t+1}^C \text{ and therefore } r_{t+1}^C = r_{t+1}.$$

<sup>9</sup> The intuition for the difference between  $r$  and  $r^C$  is as follows.  $P^C$  is a monotonic increasing function of  $p$ ; and  $e = P^N/P^T$ . Hence if  $P$  falls over time (i.e.  $P_t^C/P_{t+1}^C$  is rising), then  $T$  goods are becoming more expensive relative to  $N$  goods. Therefore a dollar of expenditure buys fewer traded goods relative to units of the consumption index, than before. Hence the own interest rate on  $T$  goods has to rise to equal a given own interest rate on the consumption index.

Reflecting the effects of both asymmetric information in foreign investment and a risk premium, the interest rate is determined by the following simple linear function <sup>10</sup> :

$$r = \bar{r} + \lambda_1(d - d_{-1}) + \lambda_2 d \quad (\text{A15})$$

where  $\lambda_2=0.01$  and if  $(d-d_{-1})>0$  then  $\lambda_1=0.1$ , otherwise  $\lambda_1=0$ . These parameter values are broadly consistent with the empirical evidence in Gordon and Bovenberg (1996) for capital importing countries. It implies that a region with a current account deficit of 5% of GDP and debt equal to 50% of GDP has an equilibrium interest rate that is 1% above the world interest rate. Simulations showed that the size of  $\lambda_1$  and  $\lambda_2$  have some effect on the optimal paths of living standards for a given demographic scenario but have almost no effect on the impact that alternative fertility scenarios have on optimal paths of living standards.

The solution to (A14) given (A15), yields:

$$\frac{\dot{c}^{opt}}{c^{opt}} = \frac{1}{\beta} \left( \frac{\partial r}{\partial d} d + r - \dot{P}^C - \theta + (\beta - 1) \left( \frac{\dot{z}}{z} + p - n \right) \right) - g \quad (\text{A16})$$

The consumers who, as a rule-of-thumb, consume a fixed proportion of their income, have the same consumption as the optimising consumers in the initial steady state but hold that level fixed as a proportion of their income. Hence the ageing shock only affects their consumption only insofar as it alters their level of income, which is the same for all consumers. The consumption of rule-of-thumb consumers is denoted,  $c^{rot}$ ; note that  $c = \xi c^{rot} + (1 - \xi) c^{opt}$ .

The standard national accounting identity gives the equation of motion for debt.

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<sup>10</sup>  $\bar{r}$  is the “world interest rate” that adjusts to ensure that world saving equals world investment. The interest rate,  $r$ , for each region represents the equilibrium interest rate which is both the return on saving and the cost of capital (less depreciation). That is, capital importing regions face a higher equilibrium than do capital exporting regions.

$$\dot{d} = (r(d) - x)d + \frac{c}{\alpha} + i_T + ei_N - y_T - py_N \quad (\text{A17})$$

The steady state implies that  $\dot{d} = 0$  and  $\dot{c} = 0$  which yields the following steady state equations:

$$c = \alpha(y_T + py_N - i_T - ei_N - (r(d) - x)d) \quad (\text{A18})$$

$$\theta = r - \beta g \quad (\text{A19})$$

### Calibration and solution

The production function is calibrated such that capital intensity in the T sector is higher than in the N sector. In particular the capital output ratio in the T sector is assumed to be 1.5 times that in the N sector for all countries. This implies, for the vintage model adopted here, that in the T sector the depreciation rate must be lower and/or the capital elasticity of output higher than in the N sector. We assume the depreciation rate is lower in the T sector. Given the first order condition for investment and the condition that output and capital are in an initial steady state, the depreciation

rate is given by:  $\delta_{T,N} = \gamma \left( \frac{k_0}{y_0} \right)_{T,N}^{-1} - r.$

The only difference in the production technology among the twelve countries is in their steady state capital-output ratios. The steady state capital-output ratio for all industries in aggregate is assumed to be equal to 2.0 for all of the more developed countries, defined here as Japan, Australia, New Zealand, Singapore, South and North Korea, and equal to 1.5 for all of the other countries. These numbers are typical for developed and less developed countries, respectively; see for example, for East Asian countries, Mason, p.224, in Mason ed. (2001). Roughly approximating capital-output ratios in this way is meant to capture the essential reality of the more capital intensive structure of industry in the more developed countries. At the same time it allows for as

little variation as possible between countries at similar stages of industrial development in order to highlight the role of differences in their stages of demographic transition. For the same reason the remaining base case parameter values are common among countries. These are :  $\beta=2.0$ ,  $\alpha=0.3$ ,  $r$  in a steady state  $=0.05$ ,  $g=0.015$ ,<sup>11</sup>  $\xi=0.3$ ,  $\psi=1.0$ .

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<sup>11</sup> A steady state rate of labour productivity growth of 1.5% implies a rate of total factor productivity growth of approximately 1% given the elasticity in the production function.

**Table 1 Symbols for variables and parameters used in the model**


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$N$	Population in natural units
$L$	Labour force in equivalent worker units*
$P$	Population in equivalent person units*
$\alpha$	Support ratio = $L/P^*$
$n$	Growth rate of $N$
$l$	Growth rate of $L$
$p$	Growth rate of $P$
$A$	Total factor productivity
$g$	Rate of steady state labour productivity growth
$Y$	Aggregate output
$D$	Aggregate foreign liabilities, denominated here as debt
$C$	Aggregate consumption
$y$	Output per worker measured in efficiency units ( $Y/L^E$ )
$d$	Debt in efficiency units per worker ( $d = D/L^E$ )
$c$	Consumption in efficiency units per equivalent person ( $c = C/P^E$ )
$\theta$	Rate of time preference
$\delta$	Rate of depreciation
$\gamma$	Capital elasticity of output
$\beta$	The reciprocal of the elasticity of intertemporal consumption
$\lambda_1$	Change in the interest rate per unit change in the current a/c
$\lambda_2$	Change in the interest rate per unit change in debt
$x$	$(1+g)(1+l)-1$
$i$	Investment in efficiency units per worker for T and N goods
$w$	The real wage
$e$	The real exchange rate
$b$	The initial, exogenously given, share of traded goods in GDP
$\mu$	Parameter in consumption index that determines the share of T goods and N goods in the index
$\psi$	Elasticity of intratemporal consumption (between T and N goods)
$\xi$	Proportion of rule-of-thumb consumers
$P_c$	Price, measured in T goods, of a unit of the consumption index
$z$	The reference level of consumption, here set equal to $c_1$
$\omega$	A measure of the importance of the reference stock of consumption
$r^c$	The own rate of interest on the consumption index
$r$	The own rate of interest on tradable goods
$q$	A shorthand variable equal to $i(1+l)/(l+\delta)$ , for T and N goods

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**Table 1. Labour force participation rates (%). Males and females combined.**

age	Japan	Sing	Aust	NZ	China	S.Kor	Thai	N.Kor	Viet	Indo	Mal	Phil
15-24	47.0	44.2	68.4	63.3	79.1	31.3	53.4	57.6	75	54	48.9	49.1
25-54	81.9	79.8	79.6	82.1	92.9	74.7	88.8	86.1	90.6	77.6	74.6	77.9
55-64	66.5	43.3	46.9	59.9	55.3	60.5	62.6	59	60.4	66.2	46.2	71.3
over 64	22.0	10.7	5.7	7.1	18.1	33.3	24.7	19.4	34.1	46	32.7	40.8

\*Data are from International Labour Force, Key Indicators of Labour Market, for the year 2000 where available, otherwise 1999 or 1998. It is assumed that the data for "over 64" year olds applies only to ages 65-74; that is, the LFPR for people over 74 is assumed to be zero.

**Table 2. Effects of demographic change on living standards****% change in average living standards relative to the case without ageing\***

	Japan	Sing	Aust	NZ	China	S.Kor	Thai	N.Kor	Viet	Indo	Mal	Phil
2010	-4.3	-4.5	-2.0	-1.1	0.5	1.2	1.5	1.8	6.4	4.0	1.9	5.5
2020	-10.5	-12.4	-5.8	-1.1	-2.8	-1.5	0.5	2.0	8.5	6.4	3.2	10.2
2030	-15.8	-22.1	-10.4	-9.4	-8.7	-8.1	-3.2	-0.4	7.4	7.0	3.5	13.8
2040	-21.5	-28.5	-13.8	-12.1	-14.6	-16.1	-8.0	-4.2	3.9	5.2	2.9	15.2
2050	-25.8	-31.2	-15.8	-12.8	-17.9	-21.7	-11.7	-6.4	-0.3	2.6	1.7	14.4
2100	-28.0	-33.2	-17.0	-13.2	-19.4	-24.7	-13.4	-7.8	-2.3	1.5	1.2	14.4

**Effect of demographic change on living standards in equivalent productivity growth p.a. (%)\*\***

	Japan	Sing	Aust	NZ	China	S.Kor	Thai	N.Kor	Viet	Indo	Mal	Phil
2010	-0.42	-0.44	-0.19	-0.11	0.05	0.12	0.15	0.18	0.66	0.40	0.20	0.57
2020	-0.50	-0.59	-0.28	-0.05	-0.14	-0.07	0.02	0.10	0.44	0.33	0.16	0.53
2030	-0.49	-0.67	-0.33	-0.30	-0.28	-0.26	-0.10	-0.01	0.26	0.24	0.12	0.49
2040	-0.49	-0.63	-0.32	-0.29	-0.34	-0.37	-0.19	-0.10	0.10	0.13	0.07	0.41
2050	-0.46	-0.55	-0.29	-0.24	-0.33	-0.39	-0.22	-0.12	-0.01	0.05	0.03	0.31
2100	-0.25	-0.29	-0.16	-0.12	-0.18	-0.22	-0.13	-0.07	-0.02	0.01	0.01	0.15

\*The upper section of the table shows that by the year 2050 in Japan, for example, population ageing will have reduced living standards by 25.8% from the level that they would have reached if population ageing had no occurred.

\*\*The lower section of the table shows that by the year 2050 in Japan, for example, population will impact on living standards by the equivalent of an annual reduction in productivity growth of 0.46%. This would amount to a reduction from, say, 1.5% p.a. to 1.04% p.a. (Productivity growth is defined as labour-augmenting)

**Table 3. Effects of demographic change on optimal national saving change in optimal national saving as a percentage of GDP, relative to the year 2001\***

	Japan	Sing	Aust	NZ	China	S.Kor	Thai	N.Kor	Viet	Indo	Mal	Phil
2010	-1.6	1.4	0.4	0.1	0.6	0.2	0.6	-0.3	1.5	0.3	1.1	0.6
2020	-2.5	-0.7	-0.7	0.1	-0.2	-0.3	0.4	0.2	0.9	0.5	0.9	1.1
2030	-2.4	-3.7	-1.7	-2.4	-1.6	-2.0	-0.5	-1.6	0.2	0.1	0.1	0.6
2040	-3.8	-4.1	-1.8	-2.2	-2.2	-4.0	-1.7	-2.3	-0.6	-0.7	-0.4	0.1
2050	-4.4	-4.6	-2.2	-2.0	-2.7	-5.4	-2.6	-3.2	-2.7	-2.1	-1.4	-1.2
2100	-3.1	-3.7	-1.6	-1.9	-1.8	-3.8	-1.7	-2.6	-1.6	-1.5	-1.2	-1.1

\*The table shows that in year 2010 in Singapore, for example, demographic change has increased the optimal national saving to GDP ratio by 1.4 percentage points above its level in 2001.

Figure 1. Support ratios

