Modelling Global Demographic Change:
Results for Japan

Warwick J. McKibbin
Australian National University,
The Brookings Institution
and The Lowy Institute for International Policy

and

Jeremy Nguyen
Australian National University

This paper is part of a joint research project coordinated by Ralph C. Bryant at the Brookings Institution and Warwick J McKibbin at the Australian National University. This project is supported by the Economic and Social Research Institute of the Japan Cabinet Office as part of their series of International Collaboration Projects. This paper is a revised version of a paper presented at the Conference of the International Collaborations Projects in Tokyo in February 2004. It has benefited from comments by Ralph Bryant, Kanemi Ban, Ales Cerny and participants at the Conference. The research summarized here draws extensively on closely related research with Ralph Bryant and Delia Velculescu at Brookings and Hamid Faruqee at the International Monetary Fund, to whom the authors are indebted for their intellectual contributions to this paper.
Modelling Global Demographic Change: Results for Japan

Abstract

In earlier papers (McKibbin and Nguyen (2001, 2002)) we introduced demographic features into the MSG3 model of the world economy, following the approach of Bryant and McKibbin (2001). In this paper we use the same theoretical technique to develop a series of models based on a consistent database from a simple two country symmetric theoretical model to the complete 4 country MSG3 model, which represents the empirical characteristics of Japan, United States, Rest of OECD and Rest of World. We explore a stylized decline in fertility similar to that experienced by Japan since the 1950 (exactly the same shock as the stylized shock used in Bryant (2004)). We first explore the properties of the theoretical model with both a global and a single country shock. This gives similar results to that found in the basic framework underlying the Bryant (2004) approach. We then move from the simplest fully optimizing framework to increasing add complexity to the model until we build a model of Japan. We explore the same shock across the models of increasing complexity in this paper and compare our results to the Bryant approach. We find that although the basic insights from the sequences of theoretical papers in the Brooking-ANU project continue to hold, the quantitative results change significantly as the model is adapted to have more characteristics of Japan.

In a final section, we use the complete model to explore the likely impacts on Japan of the demographic change already experienced from 1970 and look to the likely changes to be experienced out to 2040.

Warwick J. McKibbin
Economics Division
Research School of Pacific & Asian Studies
Australian National University
ACT 0200 Australia
and
The Brookings Institution
1775 Massachusetts Ave, NW
Washington DC 20036
USA

Jeremy Nguyen
Economics Division
Research School of Pacific & Asian Studies
Australian National University
ACT 0200 Australia
1. Introduction

Many countries in the world economy are undergoing significant demographic change, or are projected to over coming decades. Table 1 illustrates the expected changes in old age dependency ratios of a number of countries between 2000 and 2050 as projected by the United Nations in 2000 Revision of the population projection. While these demographic shifts are substantial, none is more dramatic than those projected for Japan where the elderly dependency ratio rises from 37.4% in 2000 to a projected 93.7% by 2050. This substantial projected change in the demographic structure of Japan is likely to have a significant impact on the Japanese macro-economy. Yet there is a complex story behind the many facets of the change in demographic structures and how these might impact on an economy. In addition, Japan has already experienced several decades of demographic change and it is interesting to explore what impacts demographic change has already had on the Japanese economy.

This paper has a number of goals. It first sets out a methodology for capturing key aspects of the macroeconomic story in a global economic model. We focus on the impacts on labour supply, consumption and saving responses and then how in general equilibrium these responses impact on investment, trade and capital flows and asset markets. The basic approach extends the methodology of Blanchard (1985), Weil (1989), Faruquee, Laxton, and Symansky (1997) and Faruquee (2000a, 2000b, 2003a, 2003b) to modelling consumption and saving behaviour. The extension to allow for children follows Bryant et al (2001, 2002, 2004) and McKibbin and Nguyen (2002). This paper is part of a series of papers jointly researched with Ralph Bryant and his colleagues using the Multimod approach to modelling and a team at ANU working with the MSG3 approach to modelling. The Bryant series of papers has tended to focus on critical theoretical extensions to the basic approach and to explore key sensitivities of the theoretical approach, more recently focussing on pension systems and fiscal implications of demographic change. The approach of McKibbin and Nguyen has been to attempt to implement the theoretical breakthroughs into more realistic models of the global economy. The focus in particular is to develop an empirical model of Japan for understanding the quantitative as well as qualitative issues facing the Japanese macro-economy. This paper focuses on the demographic transition in Japan. The next stage of this project is to explore how the demographic transition being experienced in the rest of the world is likely to impact on the Japanese economy.

In Section 2, the recent experience and future projections of demographic change in Japan are summarized. In Section 3, a small stylized analytical model, similar to that in Bryant and McKibbin (2004) is developed. This is a very simple framework using approximations of multiple cohorts, based on a symmetric two country world where both countries are calibrated to the US economy. This simplified model is important for understanding the key analytical drivers. It is also consistent with the model developed by the Bryant team which is based on the
analytical approach of the Multimod model. Results for a stylized demographic shock are analyzed in section 4. In Section 5, starting with an almost common basis across the two modelling frameworks, we then add the empirical rigidities found in the MSG3 model (such as a mix of optimizing and backward looking households and firms) to the simple model and compare the theoretical representation to the MSG3 approach to the simple analytical model. Because of the symmetric nature of the model we are able to explore the impact of a stylized fertility decline that occurs in a single country (a large open economy) versus one that occurs globally (the world is a large closed economy). In section 6, we then extend this approach to a 4 country version of the MSG3 model in which the full macroeconomic and demographic representations of the four regions (United States, Japan, Rest of the OECD, and developing countries) are modelled. The real country asymmetries are captured in this more complete model. The model of Japan in this framework is the standard MSG3 model of Japan with 2 sectors of production (energy and non-Energy). This empirical representation of Japan is then simulated using the same stylized fertility decline as in the analytical model but in the context of the Japanese economy. This gives an insight into the impact of the stylized demographic change that is the same shock as used in Bryant (2004) for comparison purposes when moving from a simple theoretical representation of a generic economy to a model that is based on Japanese data. In Section 7, we derive and simulate the actual demographic change projected by the United Nations 2003 Population projections together with the historical experience of Japan to explore the likely contribution of the actual decline in Japanese fertility rates from 1970 to 2030. A conclusion and future directions for research are contained in Section 8.

2. Demographic Change in Japan

There is already a large and growing literature on the many aspects of demographic change in Japan\(^1\) although few of these papers focus on the international aspects of Japan’s demographic shock. Exceptions are the recent work by Faruqee (2000a, 2003b). In this paper we

---

explore the issue of demographic change in Japan using a global modelling framework with a number of important decisions endogenous to the model, such as labour supply, human wealth accumulation, consumption and saving decisions, asset accumulation, investment demand and a full portfolio of asset prices.

The consequences of Japanese demographic change on Japan is however only part of the story, since global demographic change is likely to also impact on the Japanese economy in the coming decades. Future papers using the techniques applied in this paper will take a more global view, focussing on both the demographic shock in Japan and the demographic changes projected in the rest of the world.

Table 2 presents a more detailed breakdown of the demographic transition in Japan from 1950 to 2050. This is based on the 2002 Revision of the United Nations population projection (mid case) which contains substantial revisions compared to the earlier 1998 revision which was the basis of McKibbin and Nguyen (2002). It is clear from this table that the demographic adjustment in Japan is well under way.

A characteristic of the changing demographics in Japan is the decline in fertility with births per year (in thousands) falling from 2073 in 1970-75 to 1213 in the latest available data for 1995-2000. This is projected to decline to 940 by 2040-2050 and translates into a birth rate decline from 1.92% to 0.75% by 2015, although there is significant uncertainty about these types of projections. Another characteristic of the Japanese demographic transition is the increased life expectancy from 63.9 years at birth in 1950 to 80.05 by 1995-2000 and this is further projected rise to 87.9 by 2040-2050. Despite this increased longevity, the death rate per thousand is expected to rise from 956 in 1995-2000 to 1593 in 2040-50. This rise in the crude death rate is because the elderly are an increasing share of the total population. All of these factors work in the one direction of an increasingly aging Japanese population. In contrast to many other countries these demographic trends also imply a shrinking Japanese population beginning this decade.

2 See Lee (2003) for a discussion.
3. A Theoretical Framework for Incorporating Demographic Change in a Multi-Country Model

There are two parts of the theoretical framework used in this paper. The first uses the MSG3 multi-country model and the second embeds in this general equilibrium model, a theoretical approach to modelling demographic change. In this section we will first summarize the MSG3 model and then present the demographic assumptions.

3.1 The MSG3 Model

The MSG3 multi-country model is based on the theoretical structure of the G-Cubed model outlined in McKibbin and Wilcoxen (1999)\(^3\). More details can be found in Appendix 1. A number of studies—summarized in McKibbin and Vines (2000)—show that the G-cubed model has been useful in assessing a range of issues across a number of countries since the mid-1980s.\(^4\) Some of the principal features of the model are as follows:

- The model is based on explicit *intertemporal* optimization by the agents (consumers and firms) in each economy.\(^5\) In contrast to static CGE models, time and dynamics are of fundamental importance in the G-Cubed model.

- In order to track the macro time series, however, the behaviour of agents is modified to allow for short run deviations from optimal behaviour either due to myopia or to restrictions on the ability of households and firms to borrow at the risk free bond rate on government debt. For both households and firms, deviations from intertemporal optimizing behaviour take the form of rules of thumb, which are consistent with an optimizing agent that does not update predictions.

---

\(^3\) Full details of the model including a list of equations and parameters can be found online at: www.gucubed.com

\(^4\) These issues include: Reaganomics in the 1980s; German Unification in the early 1990s; fiscal consolidation in Europe in the mid-1990s; the formation of NAFTA; the Asian crisis; and the productivity boom in the US.

\(^5\) See Blanchard and Fischer (1989) and Obstfeld and Rogoff (1996).
based on new information about future events. These rules of thumb are chosen to generate the same steady state behaviour as optimizing agents so that in the long run there is only a single intertemporal optimizing equilibrium of the model. In the short run, actual behaviour is assumed to be a weighted average of the optimizing and the rule of thumb assumptions. Thus aggregate consumption is a weighted average of consumption based on wealth (current asset valuation and expected future after tax labour income) and consumption based on current disposable income. Similarly, aggregate investment is a weighted average of investment based on Tobin’s q (a market valuation of the expected future change in the marginal product of capital relative to the cost) and investment based on a backward looking version of Q.

- There is an explicit treatment of the holding of financial assets, including money. Money is introduced into the model through a restriction that households require money to purchase goods.

- The model also allows for short run nominal wage rigidity (by different degrees in different countries) and therefore allows for significant periods of unemployment depending on the labour market institutions in each country. This assumption, when taken together with the explicit role for money, is what gives the model its “macroeconomic” characteristics. (Here again the model's assumptions differ from the standard market clearing assumption in most CGE models.)

- The model distinguishes between the stickiness of physical capital within sectors and within countries and the flexibility of financial capital, which immediately flows to where expected returns are highest. This important distinction leads to a critical difference between the quantity of physical capital that is available at any time to produce goods and services, and the valuation of that capital as a result of decisions about the allocation of financial capital.

As a result of this structure, the MSG3 model contains rich dynamic behaviour, driven on the one hand by asset accumulation and, on the other by wage adjustment to a neoclassical steady state. It embodies a wide range of assumptions about individual behaviour and empirical regularities in a general equilibrium framework. The interdependencies are solved out using a computer algorithm that solves for the rational expectations equilibrium of the global economy. It is important to stress that the term ‘general equilibrium’ is used to signify that as many interactions as possible are captured, not that all economies are in a full market clearing
equilibrium at each point in time. Although it is assumed that market forces eventually drive the world economy to a neoclassical steady state growth equilibrium, unemployment does emerge for long periods due to wage stickiness, to an extent that differs between countries due to differences in labour market institutions.

### 3.2 A Theoretical Approach to Modelling Demographics

The theoretical framework used in this paper is based on that of Bryant and McKibbin (2001), applied to the MSG3 multi-country model which is summarized in Appendix 1. For the purposes of this paper, the MSG3 model has been extended to include demographic considerations, such that economic agents in the model now possess finite life-spans, and their incomes vary as they age. Specifically, economic agents progress from being financially dependent children to eventually being adults who are financially responsible for their own children. This section draws heavily on Faruqee (2000a, 2000b), who extended the Blanchard (1985) model of finitely-lived agents to include aging considerations. It is very similar to Bryant and Velculescu (2002) and Bryant (2004) in the way in which children are modelled. A key difference however it that in this paper we assume that all adults are assumed to bear the cost of providing support for children rather than having this support depend on the adult’s age.

#### 3.2.1 Adult Population

We begin by considering the adults in the population. In each period, a cohort of children matures and joins the adult population. The size of the newly matured cohort, at time $s$, with respect to the existing adult population, $N(s)$ is referred to as the maturity rate, $b(s)$. The maturity rate and its relationship to the population of children will be addressed in another section, below. Following Blanchard, we make the simplifying assumption that at any time $s$, all

---

6 Bryant and Velculescu (2002) show the sensitivity of the results to this assumption. We are unable to implement this in the more complex model of Japan below and therefore use this assumption in the simple theoretical model for comparison purposes.
agents in the economy face the same mortality rate, \( p \), defined here as the probability of any given agent dying before the next period. The number of adults who matured at a previous time \( s \), who are still alive at a subsequent time \( t \) is given by:

\[
\begin{align*}
n(s, t) &= b(s)N(s)e^{-pt} \\
N(t) &= \int_{-\infty}^{t} b(s)N(s)e^{-pt} \, ds
\end{align*}
\]

where \( N(t) \) represents the adult population size, at time \( t \).

Taking the derivative with respect to time yields an equation governing the evolution of the adult population size over time:

\[
\frac{\dot{N}(t)}{N(t)} = b(t) - p
\]

The above equation has a simple interpretation: the adult population grows at a rate determined by the maturity rate less the mortality rate.

### 3.2.2 Child Population

In every period, a cohort of children is born. If we think of the adult population as representing the set of potential parents, then it follows that the size of a newly born cohort will depend upon

---

7. Blanchard notes that the assumption of a common mortality rate is a reasonable approximation for adults within the ages of 20 to 40. The fact that children and retirees, whose behaviour is of interest in studies of population aging, fall outside of this age bracket certainly indicates that the issue requires further attention.
the current adult population size and the birth rate, \( b_m \). The expression for the number of children born at time \( s \) who are still alive at a later time \( t \), is thus given by:

\[
m(s, t) = b_m(s)N(s)e^{-p(t-s)}
\]

The aggregate number of children, \( M(t) \), can be calculated by summing the number of surviving children, who were born recently enough that they have not yet reached adulthood. If we let \( \Delta \) represent the fixed number of years from when a child is born to when it reaches adulthood, i.e. the period of childhood\(^8\), then:

\[
M(t) = \int_{t-\Delta}^{t} m(s, t) \, ds
\]

Differentiating with respect to time:

\[
\dot{M}(t) = -pM(t) + b_m(t)N(t) - b_m(t-\Delta)N(t-\Delta)e^{-p\Delta}
\]

(Note that in the final exponential, \( p\Delta \) refers to the period of childhood multiplied by the mortality rate, it does not represent a change in \( p \)).

### 3.2.3 Relationship Between the Birth Rate and the Maturity Rate

Of the children who were born at time \( t-\Delta \), those who survive will mature at time \( t \), at which time they are added to the adult population. Thus, the maturity rate at time \( t \) is dependent on the birth-rate, and adult population size, of \( \Delta \) years past; as well as the mortality rate.

---

\(^8\) In the simulations that follow, the period of childhood is defined as the first 16 years of an agent’s life; upon reaching his or her 16\(^{th}\) birthday, the agent becomes classified as an adult.
\[ b(t)N(t) = b_m(t - \Delta)N(t - \Delta)e^{-p\Delta} \]

Now, we know that:

\[ N(t - \Delta) = N(t)e^{\int_{t-\Delta}^{t} h(s) - p\, ds} \]

so given the birth rate of \( \Delta \) years ago, and the maturity rates over the last \( \Delta \) years, we can determine the current maturity rate:

\[ b(t) = b_m(t - \Delta)e^{\int_{t-\Delta}^{t} h(s)\, ds} \]

Since the maturity rates over the last \( \Delta \) years will be dependent on previous values of the birth rate, we can see that the rate of maturity is predetermined by any given series of birth rates.

### 3.2.4 Adult Consumption

Adults attempt to maximise the expected utility derived from their lifetime consumption. Adults must take into account the uncertainty of their life-spans and thus they discount their planned future consumption by the probability that they may not survive through to future periods. Assuming a logarithmic utility function, each agent will maximise the following:

\[ \max \int_{v_1}^{v_2} \ln c(s, v) e^{-(\theta + p)v} \, dv \]

subject to the budget constraint:

\[ \dot{w}(s, t) = [r(t) + p]w(s, t) + y(s, t) - c(s, t) \]

where \( c(s, t) \) is the consumption, at time \( t \), of an adult who matured at time \( s \), \( \theta \) is the rate of time preference, \( w(s, t) \) is the financial wealth that an adult who matured at time \( s \) holds at time \( t \); and \( r(t) \) is the interest rate earned on financial wealth. In addition to interest payments, adults also
earn a rate of \( p \) on their holdings of financial wealth, due to the assumption of a life insurance market, as in Blanchard. Children do not play a part in the life insurance market, nor do they earn interest, as they are assumed to hold no financial wealth.

The optimal consumption path for an adult can be shown to be:

\[
(13) \quad c(s, t) = (\theta + p)\left[w(s, t) + h(s, t)\right]
\]

where \( c(s, t) \) is the consumption, at time \( t \), of an adult who matured at at time \( s \), and \( h(s, t) \) represents the human wealth of the adult. An adult’s human wealth is defined as the present value of the adult’s expected income over the remainder of his or her lifetime:

\[
(14) \quad h(s, t) = \int_t^\infty \left[ e^{-\int_t^v r(i) + p \, di} y(s, v) \right] dv
\]

At any time \( t \), then, the sum of financial wealth and human wealth—\( w(s, t) \) and \( h(s, t) \)—represents an adult’s total wealth: the means by which the agent can pay for his or her future consumption. Adults consume a proportion of their total wealth each period, the proportion being determined by their rate of time preference, and their likelihood of perishing before the next period.

Aggregate adult consumption, aggregate financial wealth and aggregate human wealth are simply the sums of the consumption, financial wealth and human wealth for all adults in the economy.

\[
(15) \quad C_N(t) = \int_{-\infty}^t c(s, t)n(s, t) \, ds
\]

\[
(16) \quad W(t) = \int_{-\infty}^t w(s, t)n(s, t) \, ds
\]

\[
(17) \quad H(t) = \int_{-\infty}^t h(s, t)n(s, t) \, ds
\]

where \( C_N(t) \) represents aggregate adult consumption, \( W(t) \) is aggregate financial wealth, and \( H(t) \) is aggregate human wealth.
The adult aggregate consumption function can be shown to be given by:

\[ C_N(t) = (\theta + p(t))[W(t) + H(t)] \]  

\[ \text{(18)} \]

### 3.2.5 Labour Supply, and Demographic Considerations

Empirically, one of the key economic characteristics that changes with age is the income that a person receives. We thus introduce age-earnings profiles into the model, such that an agent’s income is determined by his or her age. Further, we assume that only adults earn labour income, and that children are dependent upon adults. Faruqee (2000a) utilises hump-shaped age-earnings profiles for adults, fitted to Japanese data using non-linear least squares (NLS). Intuitively, the hump-shaped profile of age-earnings reflects the fact that young adults generally have incomes that are increasing as the young individuals age and gain more experience. After a certain age, however, earnings decline, reflecting first the decreasing productivity associated with aging, and then eventually reflecting retirement behaviour.

Individual income is not specified as suddenly dropping to zero, at a given retirement age, for two reasons. Firstly, in practice, people typically retire at various ages, and some retirees continue to earn alternative forms of income even after retirement. Secondly, a discontinuous age-earnings profile introduces complications with respect to implementation in the MSG3 model.

We model the evolution of income over the lifecycle by beginning with the assumption that individuals are paid a wage for each unit of effective labour that they supply. We also assume that effective labour supply is a function of an individual’s age and of the current state of technology. Aside from aging considerations, note that as time passes, the technological progress in the economy has a positive effect on the value of effective labour supplied by all agents.

The effective labour supply, at time \( t \), of an agent who has been an adult since time \( s \), is given by:

\[ l(s,t) = e^{\alpha t} \left[ a_1 e^{-\alpha_1(t-s)} + a_2 e^{-\alpha_2(t-s)} + (1 - a_1 - a_2) e^{-\alpha_3(t-s)} \right] ; \quad (a_i > 0, \alpha_i > 0 \text{ for } i=1 \text{ to } 3) \]  

\[ \text{(19)} \]
The $e^{\mu t}$ component (where $\mu$ is the rate of technological progress) captures productivity increases due to advancements in technology. The remaining terms represent the non-linear functional form used to estimate the hump-shaped profile. The $a_i$ and $\alpha_i$ parameters are estimated, based on empirical data, using NLS\textsuperscript{9}. The hump-shaped effective labour supply specification will in turn lead to a hump shaped age-earnings profile.

Individual labour supply can be re-written as:

\begin{equation}
\dot{l}(s,t) = \sum_{i=1}^{3} l_i(s,t)
\end{equation}

where:

\begin{equation}
l_i(s,t) = e^{\mu t} a_i e^{-\alpha_i (t-s)} \quad (a_i > 0, \alpha_i > 0)
\end{equation}

and:

\begin{equation}
a_3 = (1 - a_1 - a_2)
\end{equation}

Thus, the evolution of an adult’s labour supply over time is given by:

\begin{equation}
\dot{l}(s,t) = \sum_{i=1}^{3} (\mu - \alpha_i) l_i(s,t)
\end{equation}

Aggregate effective labour supply in the economy for any time $t$, $L(t)$, is the sum of the effective labour supplied by all adults in the economy:

\begin{equation}
L(t) = \int_{-\infty}^{t} n(s,t) l(s,t) \, ds = \sum_{i=1}^{3} L_i(t)
\end{equation}

---

\textsuperscript{9} Values used in this paper for Japan are as estimated by Faruqee for Japan: $a_1 = 0.073$, $\alpha_1 = 0.096$, $\alpha_3 = 0.085$ and $a_1 = a_2 = 200$. In the theoretical model, to be consistent with Bryant (2004) we use the US parameters for both
where:

$$L_i(t) = \int_{-\infty}^{t} n(s,t)l_i(s,t) \, ds$$  \hspace{1cm} \text{(25)}$$

It can then be shown that:

$$\dot{L}(t) = L_1(t) + L_2(t) + L_3(t)$$

$$= (\mu - \alpha_1 - p)L_1(t) + (\mu - \alpha_2 - p)L_2(t) + (\mu - \alpha_3 - p)L_3(t) + e^{\mu t} b(t)N(t)$$  \hspace{1cm} \text{(26)}$$

The intuition behind the equation above is that the aggregate labour supply of the economy changes as the entire population ages, and also as new agents mature into the labour force.

Figure 1 shows the Alternative approximations for the age earnings profile for the United States. Figure 2 shows the data for the Age Earnings profiles in Japan from 1970 to 1997

3.2.6 Intergenerational Transfer

In our stylised model, children differ from adults, in that they do not provide labour supply (and thus do not receive payment for labour) and they do not hold financial wealth. Children are dependent upon their parents; each child receives an intergenerational transfer every period, $c(t)$, which is completely consumed by the child. As they do not make any consumption decision, but rather just entirely consume their transfer, we do not need to account for their human wealth.

We assume that $c(t)$ grows at the rate of productivity growth, $\mu$—as the economy becomes more efficient in production, children benefit.

$$c(t) = c_0 e^{\mu t}$$  \hspace{1cm} \text{(27)}$$

countries: $\alpha_1 = 0.08152$, $\alpha_2 = 0.12083$, $\alpha_3 = 0.10076$ and $a_1 = a_2 = 200$. 
The simplest specification\textsuperscript{10} for adult transfer payments is to assume that adults share the burden of supporting children equally, i.e.

\begin{equation}
  j(s, t) = j(t)
\end{equation}

where \( j(s, t) \) is the payment that an individual adult, who became an adult at time \( s \), is liable for at time \( t \). Note that transfer payments are bound by the following budget constraint, which constrains aggregate child receipts to equal aggregate adult payments:

\begin{equation}
  c(t)M(t) = \int_{-\infty}^{t} j(t)n(s, t) ds
\end{equation}

Thus:

\begin{equation}
  j(t) = \frac{c(t)M(t)}{\int_{-\infty}^{t} n(s, t) ds}
\end{equation}

\begin{equation}
  j(t) = c(t)\delta(t)
\end{equation}

Aggregate consumption for the whole economy, then, is the sum of aggregate adult consumption and aggregate child consumption:

\begin{equation}
  C(t) = (\theta + p)[A(t) + H(t)] + c(t)M(t)
\end{equation}

### 3.2.7 Income and Human Wealth

Previously, individual human wealth was defined as the expected present-value of future income over an adult’s remaining lifetime. Having defined the profile of labour supply over the lifecycle, we can now be more explicit with respect to income. An adult’s income is after-tax labour income, plus government transfers, less lump sum taxes and intergenerational transfers:

\textsuperscript{10} Bryant and Velculescu (2001) for example make most expenses for children fall on younger adults whereas we assume that adults of all ages contribute equally.
where \( y(s,t) \) denotes the income, at time \( t \), of an adult who matured at time \( s \); \( l(s,t) \) is the individual effective labour supply; \( \tau(t) \) is the marginal tax rate; and \( w(t) \) is the wage paid per unit of effective labour. We assume that the distribution of lump sum taxes, \( tx \), and government transfers, \( tr \), is uniform across the population, thus the year of an individual’s coming of age is not a determinant of either of these two variables.

We define aggregate adult income as:

\[
Y(t) = \int_{-\infty}^{t} y(s,t)n(s,t) \, ds
\]

Taking the time derivative of \( h(s,t) \), after substituting in the expression for individual income, we obtain:

\[
\dot{h}(s,t) = [r(t) + p]h(s,t) - [1 - \tau(t)]w(t)l(s,t) - [tr(t) - tx(t) - j(t)]
\]

The intuition for the equation above is that as time passes, future earnings are no longer as distant in time, and should therefore be discounted by a lesser magnitude—this explains the \((r + p)\) growth—while at the same time, some income has just been received, and thus can no longer be considered part of human wealth—this explains why the current period’s income is subtracted.

We can show that the evolution of aggregate human wealth is governed by the following relationship:

\[
\dot{H}(t) = r(t)H(t) - Y(t) + h(t,t)n(t,t)
\]

The intuition behind the equation above is that aggregate human wealth changes over time as future income draws nearer, thus \( H \) grows at the rate of \( r \); the presence of death, and hence \( p \), does not affect aggregate human wealth, because insurance companies redistribute the wealth of the dead. Further, in each period, people receive income, and having been received, it can no
longer be considered human wealth. The last term on the right hand side represents the new human wealth that the newly-matured cohort brings to the economy, each period.

4. Theoretical Results

This section uses a stylized model based on the theoretical specification of the MSG3 model with some key simplifications. We assume first that they are no backward looking agents. Thus consumption and investment is assumed to be undertaken by fully optimizing agents. Indeed if the probability of death was zero, this model would be a fully Ricardian model in which the rate of time preference determines the real rate of interest at each point of time. The introduction of a probability of death (as in Blanchard (1985)) implies a finite lifetime for all agents and the pure Ricardian equivalence propositions not longer apply.

In the calibration here we follow Bryant (2004) and choose the birth rate of children of 2.50408% per year and an infant mortality rate of 0.075%. This generates an adult maturity rate of 2% per year. We also assume that the adult mortality rate is 0.15% and productivity growth in the economies is 2% per year.

To solve the model, we first normalize all quantity variables by each economy's endowment of effective labour units. In the case of some variables such as population we normalize by per capita rather than effective units. This means that in the steady state all real variables are constant in these units although the actual levels of the variables will be growing at the underlying rate of growth of population plus productivity. Next, we must make base-case assumptions about the future path of the model's exogenous variables in each region. In all regions we assume that the long run real interest rate is 5 percent, tax rates are held at their 2002 levels and that fiscal spending is allocated according to 2002 shares. Population growth rates vary across regions as per the 2000 World Bank population projections.

A crucial group of exogenous variables are productivity growth rates by sector and country. The usual baseline assumption in the MSG3 and G-Cubed models is that the pattern of technical change at the sector level is similar to the historical record for the United States (where data is available). In regions other than the United States, however, the sector-level rates of technical change are scaled up or down in order to match the region’s observed average rate of
aggregate productivity growth over the past 5 years. This approach attempts to capture the fact that the rate of technical change varies considerably across industries while reconciling it with regional differences in overall growth. In the model in the final section of this paper we attempt to do this more realistic baseline projection, but for the simple models in the next few sections, we assume that all sectors and countries grow at the same underlying rate of productivity growth of 2% per year. It is important to note that this is a different approach to Bryant (2004) in which the model starts in steady state. In the current paper we assume that the model is on the stable transition path towards a steady state, given the data set we calibrate to.

Given these assumptions, we solve for the model's perfect-foresight equilibrium growth path over the period 2002-2200. This a formidable task: the endogenous variables in each of the 199 periods need to be solved out and include, among other things: the equilibrium prices and quantities of each good in each region, intermediate demands for each commodity by each industry in each region, asset prices by region and sector, regional interest rates, bilateral exchange rates, incomes, investment rates and capital stocks by industry and region, international flows of goods and assets, labour demanded in each industry in each region, wage rates, current and capital account balances, final demands by consumers in all regions, and government deficits. At the solution, the budget constraints for all agents are satisfied, including both intra-temporal and inter-temporal constraints.

In this section we introduce a stylized fall in fertility rates to the theoretical model. This follows the same shock as in Bryant (2004). This is shown in Figure 3. The birth rate of children begins to decline from year 1 and reaches a trough of 1.15 percentage points by year 53. This fall in the birth rate of children impacts on the income of adults immediately but

---

11 Since the model is solved for a perfect-foresight equilibrium over a 80 year period, the numerical complexity of the problem is on the order of 80 times what the single-period set of variables would suggest. We use software summarized in McKibbin and Sachs (1991) Appendix C, for solving large models with rational expectations on a personal computer.

12 Note that in the implementation in the 4 country MSG3 model we assume children are up to 16 years of age due to data requirements. In the theoretical model we adopt the Bryant convention of a child being anyone up to age 18. The difference this makes to the results are small.
does not impact on the maturity rate of adults until year 19. The maturity rate (or adult birth rate) reaches a trough of -0.81556 percent points by 71 years into the simulation. The key difference between the simulations in this paper and Bryant (2004) is that in that paper both domestic and foreign countries experience a demographic transition where the foreign country experiences a faster transition. The difference between the two demographic transitions is scaled to be the same in this paper and Bryant (2004). In the current paper we return the birth rates to the original levels after a long period. This has to be done for technical reasons related to the numerical solution technique but doesn’t affect the early stages on the simulations. The key is that the relative shocks are the same in the two studies.

We consider two alternatives regarding this demographic shock. The first is that the shock occurs simultaneously in both countries. This is equivalent to a closed economy because neither the exchange rate nor trade and capital flows will change. We then assume that the shock only occurs in the foreign country to get an insight into the likely impacts of the demographic shock on bilateral trade and asset flows and real exchange rate adjustment.

In the following figures, all results are expressed as deviation from the baseline solution of the model, either in percentage, percentage points or however indicated on the figures.

Results for both countries are contained in Figures 4 through 7. Following Bryant (2004) and earlier papers we label one country “US” for the United States and the other country “ZZ”. These figures show the deviation from the baseline for the global shock (labelled as “closed economy”) which is the same for each country. The figures also show the results for both countries when the shock only occurs in the ZZ economy.

4.1 Symmetric Shock

When the shock is the same in both countries, the assumption of model symmetry shows that there is no change in exchange rates or trade and current account balances. All adjustments are contained within the “large closed economy” experiencing the shock. The shock is a gradual decline in the birth rate. Thus the incomes of households effectively rise in the first 18 years as there are fewer children to support although aggregate consumption need not change since this is a substitution within households. The real economic impacts occur when there are less children
maturing into adults and entering the work force 19 years after the initial shock. Recall that effective labour inputs are calculated using age earnings profiles so that as the cohort of lower birth rate adults move through the workforce, the effective loss of workers is magnified by the loss in workers when they move through more productive years. These missing workers have their biggest per unit impact at around age 40, or 40 years after the demographic shock began but the increasing reduction in numbers of workers means that the demographic transition lasts well past 100 years by which time the initial shocks are returned to zero.

As expected with a significant fall in aggregate workers in the foreign economy, the aggregate macroeconomic variables began to show sharp decline about 40 years after the initial shock. Real GDP is 60% lower after 100 years compared to baseline. Aggregate consumption adjusts more quickly as individual households attempt to smooth their consumption over their lifetime. The story at the individual level is quite different to the aggregate story. In the short run households individually attempt to smooth their consumption given expected future changes in individual income and expected future changes in aggregate variables such as real interest rates that affect their intertemporal decisions. Households initially cut their consumption slightly using the fact that there is less need for spending on children to spread this across future consumption and also in response to lower relative price of future consumption (i.e. lower real interest rates). Per capita GDP also rises since there is a realization that future output will need more capital per worker to sustain production, which stimulates investment. Figure 4 shows that the capital output ratio in sector 2 (non energy) rises significantly for the first 8 decades. The rise in investment stimulates the economy and raises per capita GDP for 5 decades.

An important aspect of the shock is the effect on real interest rates. Real interest rates fall over time to be 0.9 percentage points (90 basis points) less than otherwise. The global nature of the shock means that there is now an imbalance between saving and investment as households attempt to push their current consumption into the future. Investment rises but by less than savings and thus real interest rates fall. Another way to interpret this result is that with fewer workers over time the marginal product of capital must fall. This is reflected through the real arbitrage in the model between the marginal product of capital and the real interest rate which drives real interest rates lower until the capital stock can adjust.
In terms of quantitative outcomes, the result for real interest rates is a key difference to Bryant (2004). The reason for this difference is the assumption in the MSG3 model that the intertemporal elasticity of substitution is unity (i.e. log utility) where Bryant (2004) assumes an intertemporal elasticity of substitution of 0.5\(^{13}\). Thus interest rates move by a little more than twice more in the results in Bryant (2004) compared with the results in this paper. This is a critical parameter in both studies and is the subject of a wide ranging debate in the literature.

### 4.2 Asymmetric Shock

Results for the shock that only occurs in the foreign country are also shown in figures 4 through 6. It is clear that in the country experiencing the shock, results are very similar to those for the global shock. The key lesson is that the availability of other countries not experiencing the demographic shock enables some capacity through the balance of payments, to reduce the impact of the shock in the foreign country. The aggregate effects are less for both GDP consumption. The rise in savings as a result of the action of individual households in the ZZ country now translates into a current account surplus for many decades at the beginning of the shock. This saving finds a higher rate of return outside the ZZ country. This shows up initially as a current account surplus and a trade surplus. Over time however the return on the savings are repatriated back to the ZZ economy and this shows up as a swing into trade balance deficit. Note that one country’s deficit must be another’s surplus.

The ability of households and firms in the ZZ country to use the US to help smooth the shock implies that there is less of a need for capital deepening in the ZZ country. Equity market values rise and fall by less (as shown by Tobin’s q in figure 5). This smoothing is shown even more clearly in the per capita outcome for consumption and GDP in figure 5. As expected the real interest rate outcomes are also less extreme.

One interesting aspect of the adjustment is the path of the real exchange rate shown in Figure 6. The outflow of capital in the short run as households and firms intertemporally adjust

---

\(^{13}\) See Appendix 2 page 47 of Bryant et al (2003) for a clear exposition of the role and empirical importance of the value of the intertemporal elasticity of substitution of consumption.
causes a depreciation of the real exchange rate for the US. Over time the real exchange rate appreciates as this capital is repatriated to the ZZ country to finance future consumption. On top of this asset allocation effect, there is also a real fundamental adjustment in the real exchange rate. The utility function of households in both countries consists of a CES function of all goods. Thus the facts that there are fewer goods produced by the ZZ country (both energy and non-energy) available over time as production rises less quickly, implies that the relative price of these goods will rise. Thus a key driver of the long term real exchange rate outcome is the appreciation of the real exchange rate of the ZZ country (or the rise in the relative price of its production). This effect is quite large as would be expected given the shift in relative economic weight of the two countries. After a century the real exchange rate appreciates by more than 40 percent. This is the same story as in Bryant (2004) although the magnitudes are different for the same reason as for the interest rate outcomes. There is less adjustment of asset prices when the intertemporal elasticity of substitution is higher, as in this paper.

The nominal exchange rate path is driven by the assumption about monetary policy. In this paper, in contrast to Bryant (2004) and earlier papers using this model, we now assume that monetary authorities follow a modified Henderson McKibbin Rule in which they adjust the nominal short term interest rates based on the lagged nominal interest rate and the gap between actual and desired inflation and the gap between actual and potential growth rates of real output. Clearly from Figure 6, the ZZ price level rises relative to the domestic price levels and monetary authorities are slow to offset the effects of rising inflation due to a decline in the growth of capacity output.

Another aspect of the adjustment through the balance of payments is the accumulation of foreign assets (figure 6) which is the counterpart of the current account surpluses. Within the trade balance the share of imports in GDP rises more for the ZZ country for the asymmetric shock than for the global shock as agents attempt to adjust their relative consumption baskets. As a result of the demographic shock in the ZZ country, there are relatively less ZZ goods and relative more US goods available.
This stylized model has many useful insights that parallel those in Bryant (2004). It is interesting to add further complexity to this framework to see how robust the basic insights are. This is done in the following sections.

5. Simplest Model versus a stylized MSG3 Model

In Section 4 we used the simplest benchmark theoretical model that is consistent with the approach of the MSG3 model. We now introduce some rigidities in agent’s behaviour that is found in the larger MSG3 model. In particular we assume that 70% of households do not re-optimize continually but follow an optimal rule of thumb where their consumption is a proportion of current income (both from labour and returns on financial assets). Similarly we assume that 70% of firms are using an error correction model for Tobin’s Q in which the Q determining their investment gradually adjusts to the true underlying Tobin’s Q.

We continue to maintain the assumption that countries are symmetric and of equal size. The question of country size and structure will be shown to matter once we move to more realistic models of Japan.

The results for this Symmetric MSG3 model are shown in figures 7 through 9. The main result is that the movement away from complete intertemporal optimization does not change the qualitative story very much within the countries but does change the interactions between countries. The main difference from introducing less forward looking behaviour is that there is less smoothing of consumption. Thos shows in Figure 7 where there is a smaller current account surplus for the first two decades. This contrasts which much larger swings in the current account deficits in later years. A similar difference can be found in the adjustment of the trade balance between the two countries. The lack of smoothing through the balance of payments also shows up in a larger fall in consumption after a century in the MSG3 model compared to the theoretical model.

Overall it seems that reducing the extent of optimization by agents seems to have significant quantitative but not qualitative impacts on the basic story about adjustments to demographic shocks. The overall story is dominated by the large demographic swings and how these feed into change in labour supply and output on the supply side and consumption and investment behaviour on the demand side. Perhaps the apparently small impact of reducing the extent of forward looking behaviour is not surprising, given that the introduction of finite lifetimes already reduces the forward looking-ness of households in the model.

6. Results in the 4 Region MSG3 Model

We now move away from the largely theoretical world of the small models used in sections 4 and 5, to try and capture the actual characteristics of the world economy. We now incorporate the same theoretical demographic assumptions used in the smaller models above, into the MSG3 model aggregated so that there are four main regions: Japan, The United States, the rest of the OECD (ROECD) and the rest of the world (ROW). As well as incorporating the key differences between these economies as captured in the structure of the full MSG3 model, we also change the demographic characteristics to suit each of the countries actual demographic features. This involves using actual estimated age earnings profiles for the United States, Japan and the rest of the OECD. For the ROW region we use the ROECD estimates.

We also start with exactly the same demographic shock as in the theoretical models above so as to have a benchmark for comparison. The current results will illustrate how different our theoretical insights might be when we allow for a number of key differences such as asymmetries in country production structures, consumption baskets, composition of trade flows, net asset positions etc. However we do not at this stage calculate individually what each difference makes but only what the entire group of differences make as a whole for the stylized shock.

Results are contained in figures 10 through 12 for a demographic shock that only occurs in Japan. It is assumed to occur today as a benchmark for the theoretical models. In this case the results for Japan can be compared to the “foreign country” in the theoretical models. We also truncate the results to focus on the first 80 years of the shock given the numerical problems of solving large model over several hundred years. It is important when comparing the results in
figures 10 through 12 with figure 7 through 9 to remember the difference in time periods between the simulations.

Figure 10 shows that the aggregate results for GDP and consumption follow a similar profile to those for the theoretical MSG3 model, although the initial rise in GDP is more pronounced and the subsequent fall in GDP is larger for Japan in the 4 country model than for the generic ZZ country in the smaller models. The demographic shock is the same but the age earnings profiles in Japan are quite different to those in the small model (where we use age earnings profiles for the US in both the US and ZZ models to preserve symmetry). This larger effective shock results in a large fall in effective workers in Japan relative to the theoretical model which was based on the US age earnings profile. There is also a large rise in the current account surplus for Japan for the 8 decades shown which peaks at 1.5% of GDP after 25 years. This outcome reflects a range of issues but in particular the larger initial holding of net foreign assets in Japan compared to the zero holdings in the theoretical models.

It is interesting that although the Japan in the large model is a much smaller share of the global economy than the ZZ country is in the small models (i.e. it was 50% of the world), the effects on asset markets of the Japanese demographic shock within Japan are still large. Real interest rates in Japan fall by over 2% after 80 years compared to 0.5% the theory models. The appreciation of the nominal exchange rate is also twice as large in the Japan model after 80 years (60% versus 25%). The Yen also appreciates in nominal terms as a result of a combination of factors.

Introducing a more realistic representation of the Japanese economy including it’s relative economic size, trade structure, initial asset balances, structure of production and consumption and Japanese age earnings profiles quantitatively change the results we found in the simple two country stylized model. However, the qualitative story from the theoretical models remains robust to the more realistic representation on the Japanese economy. This is an important result because it means that the theoretical advances in other research such as Bryant (2004) do give useful insights for policymakers on the likely qualitative story behind a large global demographic transition. It is perhaps not surprising that although the basic story from the theoretical models remains robust, the quantitative magnitudes of effects are sensitive to the quantitative specification of the model.
7. The Impact of Demographic Change in Japan Since 1970

The earlier sections examined the impact of a stylized demographic shock within increasingly complex models of the world economy. In this section we present results for a demographic shock in Japan that corresponds to the actual changes since 1970 and projected changes from 2000. The goal is to see what contribution demographic change might have made to the Japanese macroeconomic experience since 1970 and what might be expected over coming decades.

Before proceeding, we need to raise a difficult problem with simulating demographic shocks in a model with rational expectations. In the four country model we have assumed that children become adults after 16 years. Thus a surprise change in the birth rate today will be a perfectly predicted change in the adult population 17 years hence. In most papers that ignore children, changes in birth rates are assumed to be the arrival of new adults into the work force. The simulation we undertake is a realisation that there is a change in the birth rate of children from 1970 onwards (based on UN actual birth rates and projected rates past 2000). This implies in 1970 there is also a known shock to the adult population from 1986 onwards. In comparing this simulation with the results from our earlier study without children, it should be kept in mind that in the model with children, we are assuming that in 1970 people expect the adult birth rate to change from 1986 onwards and have a good idea of the macroeconomic implications of this. For a strict comparison we could assume that the change in the adult birth rate occurs in 1986 by complete surprise, even though it was the result of a change in the birth of children from 1970 onwards. This latter assumption corresponds to the simulation in McKibbin and Nguyen (2001) in which there were no children. Although we remain uneasy about the assumptions behind the simulations presented and how much people realised there was a demographic transition in 19970 to impact on 1986, these results are illustrative of the likely consequences for Japan of the demographic change currently under way.

In simulating the model from 1970, we re-bench the demographic model of age structure etc to be at the 1970 structure and change the net asset positions of countries but we keep the other data calibration as for the standard MSG3 model. Thus this is not a complete recalibration of the entire model based on 1970 but a partial recalibration of key initial conditions. We first solve the model from 1970 to 2100 in order to get a baseline in which no further demographic
shocks are present. We then commence the counterfactual simulation in 1970 on the assumption that the demographic shock becomes news in that year. The assumption that the demographic shock is unanticipated until 1970 might be regarded as problematic for a number of reasons. In a model with rational expectations we have little choice than to make that assumption. The main consequence is that the results for 1970 and years around that date are likely to be less accurate than results by the time the model reaches 2000 and beyond. Given we are interested in what is likely to happen from now for the next several decades, this assumption may not be such a problem for the analysis. However, the reader is cautioned to interpret the results from 1970 to 2000 with great care. Nonetheless they give some insight into the likely impact of the demographic transition already occurring in Japan.

A second important qualification is that we are not imposing a demographic transition in the other countries outside Japan in these results. This could be important and will be undertaken in future research. As shown in the results above with the simpler models, this is unlikely to have a major impact on the results for Japanese variables but might be important for the scale of the results for bilateral variables such as exchange rates and current account adjustment.

Table 3 contains projections from the United Nations Population Division World Population Prospects: The 2002 Revision (Medium Variant Projections). These are converted into adult population growth rates (defined as the growth in the adult population) and the maturity rate, which is the rate at which children become adults as a proportion of the adult population. Think of this as the adult birth rate (in terms of our earlier). It is clear that to fit the actual experience into the assumption of our modelling framework requires some simplifying assumptions. In the actual data, the mortality rate varies over time as does the mortality rate by cohort. We have to convert these numbers into rates consistent with the assumption of a constant mortality rate over time and over cohorts. The key variable that is tied down is the adult population growth rate so that we capture the changes in the labour force over time. The child birth rate is then calculated to give this aggregate outcome.

Figure 13 shows the maturity rate and adult population growth rate in the UN projections out to 2050. Figure 14 shows the birth rate, maturity rate and adult mortality rate over the entire period. This figure contains three lines. The mortality rate is the death rate for adults. We assume that the death rate for children is 0.75%. The birth rate is the birth rate of children (expressed a
percent of the adult population) and the maturity rate is the rate at which children become adults in terms of the adult population (simply thought of as the “adult birth rate”). To get the child birth rate, we take the maturity rate from the UN projections and our assumption about the mortality rate and back out the implied birth rate of children in terms of the adult population. None of the figures contain the more conventional notation of a population growth rate since we express everything in terms of adults not totals for reasons outlined in section 3.

Another feature of Figure 14 is that it reflects the UN projections out to 2050 and then an arbitrary assumption that the rates return to the baseline rates gradually after 2050. This assumption will clearly matter for results past 2050 and for the expectations of earlier periods about the future. For our purposes it is numerically simpler to assume reversion and this assumption has little impact on the results from 1970 to 2020, which is our main focus. In summary this shock can be characterized as a sharp fall in the birth rate of children from 1970 followed from 1986 by a fall in the maturity rate (i.e. rate of emergence of new adults into the working adult population). After 2050, the birth rate gradually returns to baseline. This is similar in many ways to the stylized shock used in sections 4 to 6 and in Bryant (2004).

Figure 15 shows the impact of the assumptions on the child population, the adult working population and the effective labour supply, shown as percent deviation from what would have been the case in the baseline, without the change in the birth rate. The overshooting of effective labour supply, relative to the population decline, reflects the aging of the population and the movement of the current working population along the age earnings profile with declining effectiveness as they move past the peak earning years of 40-45 year of age. The profile of the effective labour force (relative to the baseline) seems rather large but reflects the size of the estimated coefficients of the age earnings profile from Japanese data (based on Faruqee (2000a)). Future work will explore the sensitivity of the results to these parameters.

Figures 16 through 18 shows results for Japan for the shock summarized above. These results are expressed as deviation from the baseline (which has the estimated age earnings profiles but no changes in birth rates) expressed as either percent deviation from baseline or percentage point deviation from baseline as indicated. It is important to note that the underlying baseline without the demographic transition has underlying growth in Japan of close to 3% per
year. Thus when we present results of variables falling relative to base this does not mean that they are falling in absolute terms. The slope of a curve showing percent deviation from baseline for variables is the deviation from baseline of the growth rate of that variable. Thus if GDP is falling relative to baseline by 1% per year it is still rising in absolute terms by 2% per year rather than 3% per year.

Figure 17 contained results express per adult whereas the remaining charts show results for the broader macro economy. These results can also be interpreted as the relative contribution of the demographic adjustment in Japan to the changes in Japanese variables over time.

The realization that the demographic shock is to occur leads to a rise in private saving or a fall in consumption (fig 17, top right hand chart). Once the adult population begins to change from 1987, per capita saving rises even more than aggregate because the population of adults is falling. An interesting aspect of the shock is that although real GDP growth is expected to eventually decline over time, there is a realization that the capital stock will need to rise in Japan as workers become scarce in the future. The initial rise in GDP is caused by a desire to gradually increase the capital stock through greater investment and through the improvement in the current account through a rise in net exports as Japanese saving channels overseas. The rise in investment and net exports causes a short term Keynesian style overshooting in GDP in the early years of the shock. This lasts for a number of decades until the large fall in the number of people in Japan leads to a fall in the capital stock in Japan (past 2050). The current account moves into surplus (relative to baseline) (figure 16) and stays in surplus until 2020. The trade balance gradually moves towards deficit as foreign investments made during the earlier period are repatriated from overseas.

The movement in the real exchange rate is consistent with the relative changes in saving and investment. In the long run, the consumption side of the model in which all households in all countries consume a share of Japanese goods in their consumption bundle implies that as less Japanese goods are produced, their relative value will rise. Thus as shown in the theoretical model, a long run real appreciation of the Yen is expected. In the short run, this effect partly determines the real exchange rate. The real exchange rate is also determined by the allocation of international financial capital. In the short run the saving response dominates the investment response and there is a depreciation of the yen in real terms (relative to the baseline which has an appreciating yen). The strong investment response during 2000 and onwards begins a period of
appreciation relative to baseline. In earlier papers without children in the model, the investment response dominated the short run and a net capital inflow was found. However in that earlier paper the change in the labour force occurred in the first period and new capital was urgently needed. In this more realistically simulation the change in the labour force is expected to occur 17 years into the future thus the saving response dominates the investment response in the short run.

8. Summary and Conclusion

This paper has attempted to explore the implications of changing demographic structures in Japan by starting with a simple theoretical framework and moving to a complete global model with Japan a central focus. The starting point of the paper is aligned with the theoretical work in Bryant (2004) although we both branch out into different directions. This paper demonstrates that the insights in the various papers by the Brookings team using a theoretical framework based on the Multimod model gives broadly similar insights into the key issues and key sensitivity of results as the MSG3 approach. While Bryant et al (2003) and Bryant (2004) extend the theoretical approach that can subsequently be implemented in the MSG3 model; we have tried to undertake the extremely difficult agenda of implementing the theoretical developments into empirically based models of Japan.

The results in this paper suggest some important implications of current and expected demographic adjustment in Japan. The results may be specifically driven by key assumptions in the modelling framework used and substantial more research is required to understand key sensitivities. In particular we have found that many of the differences between the earlier results from the MSG3 approach and the Multimod approach can be traced to core assumptions about initial conditions or key parameters such as the intertemporal elasticity of substitution of consumption.

The paper shows that the type of demographic shock already underway in Japan and which is expected to persist for many decades has important impacts on the Japanese economy although it is very important to distinguish between the aggregate impacts versus the per capita impacts. According to the results in this paper the big aggregate adjustments in Japan are likely to occur commencing from around 2010. These include a fall in consumption and GDP growth relative to baseline but strong investment out to at least 2040 as capital is substituted for labour. Note
that the baseline assumes GDP growth without any demographic transition of close to 3% per year so the actual growth rate in Japan with still be over 1% per year in absolute terms – the results show the deviation relative to that growth rate. Between 2010 and 2020 the slope of the deviation from base curve for GDP in figure 16 suggest a fall in the growth rate of GDP of 1% per year and 2% per year from 2020 relative to base. Also there is predicted to be a period of appreciating real exchange rates and falling real interest rates. To the extent that the investment response we currently observe in Japan may not be happening to the extent predicted by the simulation results, this points to a possible problem of the current Japanese economic difficulties for the adjustment to the demographic shocks. It may also point to a deficiency in the model. Indeed an inference that the reader might draw from the results of this paper is that because the actual response of the Japanese economy from 1990 to 2001 has been quite different to that predicted by the model, the model must be incorrect. However, an alternative inference is that the malaise in the Japanese economy in the last decade has overshadowed the underlying process captured by this model. Thus there needs to be an assessment of the range of shocks facing Japan during the 1990s, independently of the demographic shock, before a firm conclusion can be drawn\textsuperscript{15}. It is also clearly important to include the demographic adjustments in the rest of the world before a firm conclusion can be drawn.

One key difference between the results in this paper and our earlier research summarized in McKibbin and Nguyen (2001) is the pattern of current account adjustment. In the earlier paper the current account moved into deficit initially. In the current paper there is a sustained period of current account surpluses accompanied by eventual deficits in the balance of trade. The key reason for this difference is in the nature of the demographic shock. In the earlier result we assumed that the falling adult population was a surprise when it started and thus their needed to be a rise in current investment, which was larger than the rise in current saving. In this paper the shock to the future adult population is anticipated well in advance once the realization of a changing child birth rate is observed. Thus the short-run response of saving begins immediately while the investment response is delayed until the additional capital required to replace the disappearing workers is needed. We also assume a higher productivity growth rate in this new

\textsuperscript{15} See for example Callen and McKibbin (2001).
model and hence current account changes can be sustained by productivity growth. The key to the balancing of the intertemporal budget constraint can be found in the adjustment of the trade balance (i.e. there can be permanent changes in the stocks of assets). Thus the current account moves into surplus in this paper rather than into deficit as was found in that earlier paper.

We have attempted to begin the analysis in this paper in line with the basic theoretical starting point of Bryant (2004) and have found many similarities in the results across the two different frameworks. Once we move away from the simple model we find results change just as they do once the issue of pension systems are introduced as in Bryant (2004). One of the issues which appears to have an important affect on the results are the consequences of initial conditions matter for the subsequent adjustment. This was true in moving from the MSG3 model with 4 countries for the stylized shock and attempting to replicate the Japanese conditions since 1970. Some of the issues that emerge in creating the initial demographic data is outlined in Appendix 1 but there are a range of further sensitivity analysis required to fully understand key results. Another important issue is the fact that the full MSG3 model departs from the stylised model of Bryant and McKibbin (2001) by allowing imperfection in the model such as the degree of optimizing versus backward looking consumers and firms. The more inertia in the MSG3 model compared to the simple analytical models of that earlier work, the more dampened is the degree of intertemporal smoothing. Yet an equally important consideration is the intertemporal elasticity of substitution in consumption already demonstrated by Bryant et al (2003) to be important.

The results in this paper are preliminary and significantly more work is needed on the modelling the nature of the demographic shock as well as sensitivity analysis on the key determinants of the macroeconomic outcomes. However over the past years of research we have been able to refine the modelling and understand better the key issues. Also Japan is not undergoing a demographic transition in isolation from the rest of the world and once the foreign demographic changes are incorporated into the analysis the results for Japan could be quite different. Nonetheless, the results to date suggest that the approach taken in this paper using the MSG3 model and the research in the Brookings Institution Project using the Multimod approach but focussing on theoretical developments is very promising and has generated important and
robust insights. However as with most research the results of this paper raise more questions for future research.
References


