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JAPANESE MACROECONOMIC
PERFORMANCE**

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Abstract

The world is in the midst of a significant demographic transition with important implications for the macroeconomic performance of the global economy. This paper summarizes the key features of the current and projected future demographic change that are likely to have macroeconomic effects. It then develops and applies a new ten region DSGE model (the MSG3 model) incorporating demographic dynamics, to examine the impacts of projected global demographic change on the world economy from 2005 to 2100. The focus in this paper is on Japan and the effects of demographic change on recent Japanese macroeconomic performance as well as projected performance over the remainder of this century. A distinction is made between the effects on Japan of demographic change that occurs in Japan and the effects on Japan of the equally large demographic changes occurring in the rest of the world.

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1 Introduction

The world is undergoing a demographic transition from high to low population growth rates at different rates in different regions. What will be the impacts of this global demographic change on macroeconomic outcomes in major regions? How much of our current macroeconomic experience is caused by demographic change already under way? This paper explores these issues with a focus on Japan; a country currently experiencing the most dramatic demographic adjustments.

Figure 1 shows the growth of population by major region from 1950 to 2050 as projected by the United Nations World Population Prospects report (the 2004 Revision) ¹. The broad patterns in Figure 1 are by now well known. After a period of strong population growth up to the 1970s population growth in developed economies began to decline due to falling fertility rates. This phenomenon, although delayed in the developing world, also began to emerge in developing countries in the 1980s². Projections from 2005 clearly indicate that not only is the global population growth rate projected to fall over the coming half century but also that the phenomena is spread across all regions shown. It is not only the trend in growth rates in Figure 1 that are interesting. Also important are the levels of growth rates and their differential across regions and across time. Note that for the former Soviet Union (FSU) the growth rate is negative on average beginning during 1990-95 and this is also projected to occur in Japan by 2010-15. Thus in some regions although the population growth rates are falling, the population levels are projected to continue rising for some time but in other regions with negative growth rates, the absolute population levels will decline. Both the size of populations and their growth rates should have impacts on overall macroeconomic performance and its composition throughout the global economy.

Another important aspect of global demographic change is the change in dependency ratios. That is the ratio of dependent age groups on the working population. It is well known that old age dependency ratios are increasing both as a result of falling fertility rates as well as

¹ It should be stressed that there is a great deal of uncertainty about these projections. See Lee (2003) for a discussion.

² See the papers in Birdsall et al (2001) for an overview of the impacts of demographic change on developing countries.

increasing life expectancy. Figure 2 shows the elderly dependency ratio across the main regions, defined as the ratio of adults aged 65 and above to the working age population of adults aged 15 to 65. These projections from the UN mid case scenario out to 2050 are dramatic. Most obvious in Figure 2 is the rise in the Japanese dependency ratio from one elderly person to ten working age adult in 1970 to 7 to every 10 working age adults by 2050 (i.e. the ratio rises from 0.1 to 0.7). Similar but not quite as dramatic trends are projected throughout the regions indicated.

At the other end of the demographic transition is a change in the child dependency ratios. This is the ratio of children below 15 to the working age population. Figure 3 shows that this ratio falls significantly from now until 2050. While the number of elderly that need to be supported by working adults increases over time, the number of dependent children falls.

An analysis of the impact of the global and regional differences in demographic change needs to take into account the effects of changing growth rates as well as the numbers of adults and children. The goal of this paper is to incorporate these projections into a general equilibrium model that allows for the changing composition of the population and captures its affect on labour supply, investment, growth potential, asset markets and international trade and financial flows. Although extremely difficult, with a general equilibrium approach it is possible given recent analytical development, to determine the overall impact of the observed and projected global demographic adjustment.

There is already a large literature on the impact of demographic change³ particularly in Japan⁴. However the Japanese literature, as with most country specific studies has focussed only on what is happening in Japan without taking into account the global demographic picture. Exceptions are the recent work by Faruqee (2000a, 2003b). A variety of General equilibrium approaches are also emerging ranging from the multi-country OLG model of Auerbach and Kotlikoff (1997)⁵ to an extension of the GTAP model in Chan et al (2005) and broad

³ See IMF World Economic Outlook September 2004, Bloom and Williamson (1997), Borsch Supan et al (2003), Bosworth and Burtless (1998), Brooks (1998), Faruqee (2002a, 2002b, 2003a,2003b), Higgins and Williamson (1997); Higgins (1998), Cutler et al (1990) and recent papers by Bryant (2004b) and Helliwell (2004).

⁴ See for example Endo and Katayama (1998), Horioka (1991), Meredith (1995), Ogawa and Retherford (1993), Takayama and Kitamura (1999), Takayama (1998), Takayama, Kitamura and Yoshida (1998), Yashiro and Oishi (1997), Yashiro (1998), Yashiro, Oshio, and Matsuya (1997).

⁵ Examples of this approach include the INGENUE (2001) model.

macroeconomic models⁶, however none of these approaches deal adequately with both the macroeconomic and financial issues that are the focus of this paper.

Section 2 summarizes the theoretical methodology for capturing key aspects of the macroeconomics of demographic change set out in McKibbin and Nguyen (2004) in an intertemporal general equilibrium 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), Faruqee, Laxton, and Symansky (1997) and Faruqee (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). Section 3 outlines how the theoretical approach is incorporate in a new ten region model of the global economy consisting of: USA; Japan; Europe; Rest of OECD; Eastern Europe and Former Soviet Union; China; India; Other Asia; Latin America; and other Developing Countries. In section 4 the methodology for calculating the impact of demographic change from 1985 to 2100 is outlined. Section 5 presents results for the contribution of current and projected demographic change to the macroeconomic outcomes in Japan, distinguishing between the effects of Japanese demographic change in Japan from the impacts of demographic change in the rest of the world on Japan. A summary, conclusion and future research directions are set out in section 6.

2 A Theoretical Framework for Incorporating Demographic Change in a Multi-Country Model

The theoretical framework used in this paper is based on that of Bryant and McKibbin (2001) as extended in McKibbin and Nguyen (2004). For the purposes of this paper, the MSG3 model (McKibbin and Wilcoxon (1998)) has been extended to include demographic considerations. Important changes include the finite lives of individuals and that their incomes

⁶ See Borsch-Supan et al (2003) and Guest and McDonald (2004)

vary with age. Specifically, economic agents progress from being financially dependent children to eventually being adults who are financially responsible for their own children. The approach 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 is 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 age⁷. In summarizing the approach followed we first illustrate how adult and child populations evolve and then outline how the consumption decision of adults is affected. Finally we summarize the impacts of cohort transitions on the aggregate labour supply over time.

a. 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 agents in the economy face the same mortality rate⁸, 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:

$$(1) \quad n(s, t) = b(s)N(s)e^{-p(t-s)}$$

⁷ 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.

⁸ 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 adult population size can then be determined for any time t by summing the number of living adults from all of the cohorts that have ever matured:

$$(2) \quad \begin{aligned} N(t) &= \int_{-\infty}^t n(s, t) ds \\ &= \int_{-\infty}^t b(s)N(s)e^{-p(t-s)} ds \end{aligned}$$

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:

$$(3) \quad \frac{\dot{N}(t)}{N(t)} = b(t) - p$$

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

b. 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 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:

$$(4) \quad m(s, t) = b_m(s)N(s)e^{-p(t-s)}$$

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 Δ

represent the fixed number of years from when a child is born to when it reaches adulthood, i.e. the period of childhood⁹, then:

$$(5) \quad M(t) = \int_{t-\Delta}^t m(s,t) ds$$

$$(6) \quad M(t) = \int_{t-\Delta}^t b_m(s) N(s) e^{-(t-s)p} ds$$

Differentiating with respect to time:

$$(7) \quad \dot{M}(t) = -pM(t) + b_m(t)N(t) - b_m(t-\Delta)N(t-\Delta)e^{-p\Delta}$$

(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).

c. 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 Δ years past; as well as the mortality rate.

$$(8) \quad b(t)N(t) = b_m(t-\Delta)N(t-\Delta)e^{-p\Delta}$$

Now, we know that:

$$(9) \quad \begin{aligned} N(t-\Delta) &= N(t) e^{-\int_{t-\Delta}^t b(s)-p ds} \\ &= N(t) e^{p\Delta - \int_{t-\Delta}^t b(s) ds} \end{aligned}$$

9. 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 16th birthday, the agent becomes classified as an adult.

so given the birth rate of Δ years ago, and the maturity rates over the last Δ years, we can determine the current maturity rate:

$$(10) \quad b(t) = b_m(t - \Delta) e^{-\int_{t-\Delta}^t b(s) ds}$$

Since the maturity rates over the last Δ 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.

d. 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:

$$(11) \quad \max \int_t^{\infty} \ln c(s, v) e^{-(\theta+p)v} dv$$

subject to the budget constraint:

$$(12) \quad \dot{w}(s, t) = [r(t) + p]w(s, t) + y(s, t) - c(s, t)$$

where $c(s, t)$ is the consumption, at time t , of an adult who matured at time s , θ 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:

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

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:

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

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:

$$(18) \quad C_N(t) = (\theta + p(t))[W(t) + H(t)]$$

e. Labour Supply, and Demographic Considerations

Empirically, one of the key economic characteristics that changes with age is the income that a person receives. This is usually summarized in an age-earning profile of a country. An example of the age-earnings profile for Japan are given in Figure 4. This shows the income of a

cohort as they move through time relative to their initial earning as the 15-24 cohort. This is remarkably stable over 30 years and is similar (although not identical across countries). It shows that as new workers enter the workforce their income gradually rises over time presumably reflecting productivity improvements over time. From the 50-55 cohort income begins to fall over time but there is still positive income after age 65. We introduce this age-earnings profile into the model, such that an agent's income is determined by his or her age. We then aggregate over cohorts over time. Further, we assume that only adults earn labour income, and that children are completely dependent upon adults. Faruquee (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:

$$(19) \quad l(s, t) = e^{ut} [a_1 e^{-\alpha_1(t-s)} + a_2 e^{-\alpha_2(t-s)} + (1 - a_1 - a_2) e^{-\alpha_3(t-s)}] ; \quad (a_i > 0, \alpha_i > 0 \text{ for } i=1 \text{ to } 3)$$

The $e^{\mu t}$ component (where μ 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 α_i parameters are estimated, based on empirical data, using NLS¹⁰. 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:

$$(20) \quad l(s,t) = \sum_{i=1}^3 l_i(s,t)$$

where:

$$(21) \quad l_i(s,t) = e^{\mu t} a_i e^{-\alpha_i(t-s)}; \quad (a_i > 0, \alpha_i > 0)$$

and:

$$(22) \quad a_3 = (1 - a_1 - a_2)$$

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

$$(23) \quad \dot{l}(s,t) = \sum_{i=1}^3 (\mu - \alpha_i) l_i(s,t)$$

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:

$$(24) \quad \begin{aligned} L(t) &= \int_{-\infty}^t n(s,t) l(s,t) ds \\ &= \sum_{i=1}^3 L_i(t) \end{aligned}$$

¹⁰ Values used in this paper for Japan are as estimated by Faruqee for Japan: $\alpha_1 = 0.073$, $\alpha_2 = 0.096$, $\alpha_3 = 0.085$ and $a_1 = a_2 = 200$. In the theoretical model, to be consistent with Bryant (2004) we use the US parameters for

where:

$$(25) \quad L_i(t) = \int_{-\infty}^t n(s,t)l_i(s,t) ds$$

It can then be shown that:

$$(26) \quad \begin{aligned} \dot{L}(t) &= L_1(t) + L_2(t) + L_3(t) \\ &= (\mu - \alpha_1 - p)L_1(t) + (\mu - \alpha_2 - p)L_2(t) + (\mu - \alpha_{3i} - p)L_3(t) + e^{\mu t} b(t)N(t) \end{aligned}$$

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.

In the application in this paper we use the estimate age earnings profile for Japan and the estimate US age earnings profile for all other regions. This is a crude approximation in lieu of getting sufficient data to estimate a more extensive set of age earnings profiles.

f. Intergenerational Transfers

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, μ —as the economy becomes more efficient in production, children benefit.

$$(27) \quad c(t) = c_0 e^{\mu t}$$

The simplest specification¹¹ for adult transfer payments is to assume that adults share the burden of supporting children equally, i.e.

$$(28) \quad j(s,t) = j(t)$$

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:

$$(29) \quad c(t)M(t) = \int_{-\infty}^t j(t)n(s,t) ds$$

Thus:

$$(30) \quad j(t) = \frac{c(t)M(t)}{\int_{-\infty}^t n(s,t) ds}$$

$$(31) \quad j(t) = c(t)\delta(t)$$

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

$$C(t) = (\theta + p)[A(t) + H(t)] + c(t)M(t) \quad (1)$$

g. 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:

11. 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.

$$(32) \quad y(s, t) = [1 - \tau(t)]w(t)l(s, t) + tr(t) - tx(t) - j(t)$$

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:

$$(33) \quad Y(t) = \int_{-\infty}^t y(s, t)n(s, t) ds$$

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

$$(34) \quad \dot{h}(s, t) = [r(t) + p]h(s, t) - [1 - \tau(t)]w(t)l(s, t) - [tr(t) - tx(t) - j(t)]$$

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.

Further details on the approach followed in this paper and the implications of various simplifying assumptions can be found in Bryant (2004), Bryant and McKibbin (2004), Bryant and Velculescu (2001,2002), Bryant et al (2004) and McKibbin and Nguyen (2004).

3 The modified 10 region MSG3 Multi-Country Model

We embed the demographic approach outlined in Section 2 into a 10 region version of the MSG3 model. The country and region aggregation is summarized in Table 1.

The MSG3 multi-country model is based on the theoretical structure of the G-Cubed model outlined in McKibbin and Wilcoxon (1998)¹². 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.¹³ Some of the principal features of the model are as follows:

¹² Full details of the model including a list of equations and parameters can be found online at: www.gucubed.com

¹³ 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.

- The model is based on explicit *intertemporal* optimization by the agents (consumers and firms) in each economy¹⁴. In contrast to static CGE models, time and dynamics are of fundamental importance in the G-Cubed model. The MSG3 model is known as a DSGE (Dynamic Stochastic General Equilibrium) model in the macroeconomics literature and a Dynamic Intertemporal General Equilibrium (DSGE) model in the computable general equilibrium literature.
- In order to track the macro time series, 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 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 (following Campbell and Mankiw (1987). 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 (following Hayashi (1979, 1982)).
- 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

¹⁴ See Blanchard and Fischer (1989) and Obstfeld and Rogoff (1996).

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.

The theoretical approach to modelling demographics outlined in Section 2 is embedded into the large scale MSG3 model in the key areas of labour supply and consumption and saving

decisions. The rest of the model endogenizes the response of investment, asset prices and international trade and capital flows adjustment to changes in demographic inputs.

4 Calculating the Impacts of Demographic Change

The demographic changes projected over coming decades are large, but are they likely to have an important effect on the economies of advanced and developing countries? This section uses simulations from the MSG3 model to investigate this issue. This is a difficult issue to untangle from the historical data as well as from future projections. It necessarily requires the use of a model. In an earlier paper (Batini, Callen and McKibbin (2005)) we explored this in 4 region model. The same technique is used in this paper.

The approach is to first project the world economy from 1985 to 2200 assuming the UN (2002) mid range demographic projection. The projections from the UN data have to be modified to fit into our simplified analytical framework. In particular we have to modify the birth rates of children and maturity rates of adults to adjust for the fact that we assume a constant probability of death which is not consistent with the UN projections. We try as much as possible to match the population numbers from the UN projections. In addition we make assumptions about productivity growth by sector and country using the approach outlined in Bagnoli et al (1996) extended in McKibbin et al (2004). We build a baseline projection with the expected demographic transition.

We then want to ask the question “what is the impact of the demographic projections in this baseline projection”? There are a number of ways this could be addressed. One is to modify the demographic assumptions as in Bryant et al (2004) and Bryant and McKibbin (2004) to test the sensitivity of projections to different demographic assumptions. In this paper we want to calculate the entire impact of demographic change. In other words we want to see what would be happening over the next century if there had not been any demographic transition. We explore this question by effectively removing the demographic change from our projections. How this is done is styled in Figure 5. Our baseline projections for population for example are indicated in Figure 5. We then redo the projections assuming that the demographic variables in the model such as child birth rate and adult maturity rates for each country are set equal to the long run

steady state rates. These are assumed to be the rates, equal in all countries where the population growth is zero in all countries. The assumptions are that the child birth rate is 1.9 percent (importantly defined differently to a population growth rate) and an adult maturity rate of 1.5 percent plus a constant probability of death of 1 percent. It should be stressed that in the intertemporal modelling approach in this paper there needs to be a well defined long run steady state with all countries growing at the same rate. This is forced by having productivity growth by country eventually converging and demographic variables eventually converging. It is assumed that all countries will eventually have the same demographics (in terms of growth rates) in the steady state. In the counterfactual experiment we assume these demographic rates apply from 1985 onwards. The difference between the baseline with demographics built in and the counterfactual experiment with demographic growth rates at steady state values gives a measure of the contribution of the demographic transition in the current economies of the world. The steady state we assume will affect the results presented below. The results should be interpreted as indicative of the current contribution of demographic change the economies and more usefully, how these changes projected to occur over time will lead to changes in economies over time. Even if the reader is sceptical about the steady state assumptions imposed in this study, the **change** in variables over time are less dependent on this assumption in the near term and primarily reflect the demographic consequences of the UN projections.

The process of removing a large shock of this nature is not a conceptually easy exercise because the model assumes rational expectations in a variety of markets. Thus the initial conditions for 1985 (i.e. the actual data) in the baseline have expectations about the future demographic transition already embodied in stock variables such as physical capital stocks, net asset positions (both domestic and foreign) and human capital. We thus have a problem in the counterfactual exercise that in 1985 when we remove the demographic shock, because we are capturing both the impact of the underlying demographic change as well as the impact of the change in expectations about future demographic change. For a period after the new information is announced there will be a large adjustment in asset stocks which reflects the revision in expectations. In an admittedly imperfect attempt to separate out the expectations revision from the underlying demographic change, we let the model run for 20 years to 2005 so that much of this initial asset adjustment is completed and we believe we are capturing more of the pure demographic effect and less of the revision to expectations from 2005 onwards. Thus in the

following analysis all results are presented from 2005 to 2100, after the asset stock adjustment and asset price volatility to the change in information in 1985 have washed through the economy.

We convert the 2002 UN population projections (mid case scenario) into the parameters of the model given the assumption in the model of a constant probability of death for adults and a different but constant probability of death for children. This conversion is done in a way which gives us as close as possible the aggregate adult and child populations over time for each country as projected by the United Nations. It is not an exact representation of the UN projections because the probability of death is changing over time in the UN projections and at this stage of the research we are unable to incorporate this feature into the model. Thus the results should be interpreted as illustrative rather than as precise predictions about the future.

Figures 6 and 7 present the deviation of the child birth rate and adult maturity rates from the long run steady state rates in each year commencing from 1985. These are the basic shocks that are removed from the baseline in the counterfactual simulation and which are interpreted as the demographic shocks in the baseline projection. Several important points can be seen in Figures 6 and 7. In each region from 1985 to 2020, child birth rates and adult maturity rates are falling. For Japan the fall in the growth rates are actually smaller than the fall in the growth rates for developing countries but this is a starting from a rate below the steady state rate. Thus the population is falling in Japan but still rising in developing countries despite a large projected fall in growth rates in developing countries. The difference between growth rates of the population and the level of the population will be shown to be important in the results. In an important sense the prospective demographic transition in developing countries is larger than the prospective demographic transition in Japan. Much of Japan's demographic transition has already occurred in the second part of the twentieth century.

5 The Impact of Global Demographic Change on Japan

Results for the contribution of demographic change to the Japanese economy from 2005 to 2100 are contained in figures 8 through 13. Each figure contains two graphs. The top graph is the estimated impact on the Japanese variable in question, from the demographic change in

Japan (labelled 'Japan') and the contribution to the Japanese variable from the demographic change occurring in all countries including Japan (labelled 'all countries'). The difference between the two lines shows the impacts of the demographic change in the rest of the world on Japan. The lower graph in each figure decomposes the relative contribution of each region apart from Japan, to the Japanese macroeconomic outcomes. Thus for example in Figure 8 we estimate that Japanese GDP growth in 2005 is 0.2 percentage points higher as a result of Japanese demographic change, considered in isolation, than it would have been if the steady state demographics applied in 2005. Furthermore when we estimate the contribution of global demographic change, we find that Japanese GDP growth is 0.4 percent higher (than otherwise) in 2005 because of demographic change occurring in Japan and in the rest of the world. The lower graph in Figure 8 shows the contribution of demographic change in each region to the Japanese growth outcome. We find that the largest foreign contributor to this result is the demographic change in other East Asia (contributing 0.06 percent points to Japanese growth in 2005). The spill-over of demographic change occurs both through changes in trade flows and capital flows. With more workers in developing countries, the marginal product of capital is higher than it otherwise would be and this raises incomes in the rest of the world and increases the demand for Japanese goods. It also gives a higher rate of return to Japanese investments in these economies, which also raises the income of Japanese citizens and raises the rate of economic growth in Japan.

The impacts of demographics on the Japanese current account and trade account are shown in Figures 9 and 10. Figure 9 shows that demographic change in Japan is contributing close to 3.2% of GDP of Japan's current account surplus in 2005. When the rest of the world demographic change is incorporate the surplus is 3.8 percent of GDP higher relative to what it would be without demographic factors taken into account. This is most of the Japanese current account surplus in 2005. The mechanism through which the demographic change in Japan impacts on the current account is outlined in the detailed papers containing simple theoretical models such as Bryant and McKibbin (2004) and McKibbin and Nguyen (2004). Whether the current account rises or falls depends on the relative shifts in savings and investment¹⁵. In our

¹⁵ See the discussion on the ambiguity of this in practice in Bryant (2004) and Helliwell (2004).

model, private and aggregate savings rates rise relative to investment rates in Japan as the demographic transition occurs. In other countries following after Japan, strong demand for capital to cope with a rising labour force attracts capital from Japan where the rate of return on capital is falling. The flow of capital attracted into these developing regions further increases the Japanese current account surplus.

The long run dynamics of this saving and investment story as it plays out through the balance of payments can be seen in the trade balance adjustment in Figure 10. Although the Japanese current account remains in surplus for a substantial period, the trade balance is seen to gradually move from surplus to deficit (relative to that which would occur without demographic change). By 2028 Japanese demographic change is exerting a negative impact on the trade balance as incomes from abroad are increasing repatriated to Japan to support Japanese consumption. The long run sustainability condition that foreign debts globally must be serviced is clearly shown in the trade dynamics in Figure 10.

Figure 11 shows the long swing in the Japanese real exchange rate estimate in the model. The pattern can be explained in terms of goods demand or in terms of international capital flows. As Japan becomes smaller relative to the rest of the world, the relative price of Japanese goods should rise as long as consumers follow an Armington assumption of regarding goods by place of origin as different goods¹⁶. In addition as capital is repatriated to Japan from foreign investments made in earlier years, the inflow of revenue also appreciate the yen. Figure 11 shows that in 2005, demographics in Japan were still exerting a negative 8% impact on the real exchange rate since Japanese savings is still being channelled overseas chasing higher returns relative to those in Japan. Taking into account the global demographic change, the real exchange rate appreciates even more over time. By 2030 world demographic adjustment raises the yen by 35% relative to otherwise whereas the contribution of the demographic adjustment in Japan is only 8%.

¹⁶ Bryant and de Fleurieu (2005) contains a comprehensive evaluation of this assumption.

Figure 12 contains results for short real interest rates in Japan. This is a very similar adjustment to that found in the symmetric two country models in Bryant and McKibbin (2004) and McKibbin and Nguyen (2004). In Japan, the fall in effective labour supply reduces the marginal product of capital and this is reflected in lower real interest rates. By 2035 real interest rates are more than 1 percentage point (100 basis points) lower than base. When the global demographic shock is also included, the strong demand for capital globally from a rising labor force in growing economies drives up global real interest rates, including in Japan. Thus in 2005 the demographic transition is causing the real interest rate to be 30 basis points higher in Japan than otherwise, whereas the Japanese contribution is to hold down real interest rates by 22 basis points. In other words if there was only demographic change in Japan the real interest rate would be lower in Japan but because there is a demographic transition in the entire world, real interest rates in Japan are actually higher than they otherwise would have been in 2005. The outcome that global demographic change is holding up Japanese real interest rates is reversed by the middle of the century when the global demographic transition is driving down global returns to capital.

Figure 13 contains the contribution of demographic change to investment in Japan. Investment has already been identified as an important part of the adjustment outlined above. As in the theoretical models using this approach in McKibbin and Nguyen(2004) there are two offsetting impacts of the Japanese demographic adjustment on private investment. On the one hand the labor force is expected to fall which encourages a fall in overall investment, but there is also a substitution effect by which capital will be substituted for labour and the capital labour ratio should rise. In this model the substitution effect initially dominates the overall shrinkage of the Japanese economy and investment rises for a number of years. In the results in figure 13, by 2005 investment is higher than would have been the case because the economy is adjusting to a new higher capital labor ratio but over time the aggregate investment rate eventually falls although it is delayed when the global demographic transition is taken into account.

6 Summary and Conclusion

This paper has developed a ten region global economic model with demographic dynamics to explore the impact of current and projected future global demographic change on the Japanese

economy. The paper illustrates that it is possible to use new theoretical developments in modelling overlapping generations in large scale quantitative models with ten key countries and two sectors. More research is now needed in incorporating the new theoretical results of the US based Brookings team lead by Bryant into the more realistic large scale 10 region model. In particular, in this paper it is assumed that social security systems function reasonably well in each economy in order to capture the pure macroeconomic effects of demographic change. Although challenging to incorporate the features of social security systems in each of the ten regions, Bryant and his team have shown how important this can be in a small scale theoretical model¹⁷. In addition greater work is required in the modelling of developing countries which make up a majority of the countries in this new model and where important demographic changes are projected to occur. A number of key issues such as the impact of surplus labour, infrastructure needs etc could be added in interesting ways to the new model and may change the spill-over to Japan of demographic change in developing countries.

There are at least two most important policy implications from this new research. The first is that the projected demographic transition in Japan will likely have important macroeconomic impacts on growth, trade flows, asset prices (real interest rate and real exchange rates) and investment rates. The second results which is just as important for Japanese policymakers, is that demographic change in the rest of the world is also likely to have important impacts on Japanese macroeconomic performance. The fact that the demographic transition is at different stages across countries, particularly in industrialized countries relative to developing countries, implies that the global nature of demographic change cannot be ignored. As well as now having a framework for exploring a range of possible policy responses directly related to

¹⁷ See Bryant (2004)

demographics, future work will use this new model to explore how other policies apparently unrelated to demographics might impact on the macro economy to offset any negative consequences or reinforce any positive consequences of global demographic change. A first attempt at this is contained in recent paper using a four region version of the model in this project by Batini, Callen and McKibbin (2005). That paper explored the impact of economic reform induced productivity improvements and lowering barriers to international capital flows in developing countries. Other issues to which this new framework can be applied include the ability to use trade reform as a way of allowing labour intensive goods to flow into rapidly aging societies such as Japan, and enable domestic labour to be reallocated into activities that more directly support an ageing society. There is no reason why policies in other parts of the economy might not have a more substantial positive contribution to dealing with demographic change than the more direct policies that are usually proposed, such as increased migration, subsidies to child birth or changes in retirement ages. The ability offered by the model developed in this paper to assess a wide range of alternative policies aimed at dealing with the global demographic transition suggests an exciting new area of policy evaluation.

References

- Auerbach, A and L J. Kotlikoff, (1987) *Dynamic Fiscal Policy* (Cambridge: Cambridge University Press).
- Batini, N., Callen T. and W. McKibbin (2005) "Global Impact of Demographic Change" background paper prepared for the IMF World Economic Outlook, September 2004.
- Birdsall, N., Kelley, A. and S. Sinding (2001) *Population Matters: Demographic Change, Economic Growth and Poverty in the Developing World*, (Oxford University Press: Oxford)
- Blanchard, O. (1985), 'Debt, Deficits, and Finite Horizons', *Journal of Political Economy*, vol. 93, pp. 223-247.
- Blanchard O. and S. Fischer (1989) *Lectures on Macroeconomics* MIT Press, Cambridge MA.
- Bloom, D, and J. G. Williamson. (1997) "Demographic Transitions, Human Resource Development, and Economic Miracles in Emerging Asia," in Jeffrey Sachs and David Bloom, (eds.), *Emerging Asia* (Manila: Asian Development Bank) 1997.
- Börsch-Supan, Axel, Alexander Ludwig, and Joachim (2003), "Aging, Pension Reform, and Capital Flows: A Multi-Country Simulation Model," MEA Discussion Paper No. 28–30 (Mannheim, Germany:Mannheim Research Institute for the Economics of Aging).
- Bosworth, B. and G. Burtless (eds) (1998) *Aging Societies: The Global Dimension*. Washington, DC: Brookings Institution, 1998. (Introduction: "Population Aging and Its Impact on Economic Performance: Overview."
- Brooks, R. (1998), "Asset Market and Saving Effects of Demographic Transitions" (Ph.D. dissertation; New Haven, Connecticut: Yale University, Department of Economics).
- Bryant R. (2004a) "Demographic Pressures on Public Pension Systems and Government Budgets in Open Economies" paper prepared for the February 2004 *International Forum of Collaboration Projects*, Tokyo.
- Bryant R. (2004b) "Cross Border Macroeconomic Implications of Demographic Change" in "Global Demographic Change: Economic Impacts and Policy Challenges" Federal Reserve Bank of Kansas City Conference Proceedings.
- Bryant R. and M. de Fleurieu (2005) "Exchange Rate and External Balance Consequences of Asymmetric Demographic Transitions: Key Determinants of Cross-Border

Substitutability” paper prepared for the Spring 2005 meeting of the *International Forum of Collaboration Projects*, Tokyo.

- Bryant, R and W.J. McKibbin (1998) "Issues in Modeling the Global Dimensions of Demographic Change." Brookings Discussion Paper in International Economics No. 141. Washington, DC: Brookings Institution, December 1998.
- Bryant R. and W. McKibbin (2004) "Incorporating Demographic Change in Multi-Country Macroeconomic Models" in P. Onofri (ed) *The Economics of an Ageing Population: Macroeconomic Issues*, Edward Elgar.
- Bryant, R. and D.Velculescu (2001), 'Introducing Youth Dependency and Elderly Dependency into the Demographic Components of Multi-Country Macroeconomic Models: Illustrative Results" paper prepared for the Fall 2001 *International Forum of Collaboration Projects*, Tokyo.
- Bryant, R. H. Faruqee, D.Velculescu, and E. Arbatli (2004) "Fertility Declines and Youth Dependency: Implications for the Global Economy." Working paper first circulated in February 2003. Revised version March 2004. Washington, DC: Brookings Institution, March 2004.
- Bryant, R. , D. Velculescu (2002) "Population Aging and Public Pension Systems: A First Look at the Cross Border and Global Effects" presented at the Spring 2002 *International Forum of Collaboration Projects*, Tokyo.
- Callen T. and W. McKibbin (2001) "Policies and Prospects in Japan and the Implications for the Asia Pacific Region" IMF Working Paper (forthcoming).
- Campbell J. And N.G. Mankiw (1987) "Permanent Income, Current Income and Consumption" NBER Working Paper 2436.
- Chan M., Q Shi and R. Tyers (2005) "Global Demographic Change and Economic Performance: Implications for Agricultural Markets" paper prepared for the 49th annual Conference of the Australian Agricultural and Resource Economics Society, Coffs Harbour.
- Cutler D.M. Poterba J. Sheiner L. and L. Summers (1990) "An Ageing Society: Opportunity or Challenge?" *Brookings Papers on Economic Activity* no 1, p 2-74.
- Endo, Y. and Katayama, E. (1998), 'Population Aging and Japanese Economic Performance', in Bosworth, B. and Burtless, G. (eds), *Ageing Societies: The Global Dimension*, Washington, DC, The Brookings Institute Press, ch. 5, pp.240-265.

- Faruqee, H. (2000a), 'Population Aging and its Macroeconomic Implications', in *Japan: Selected Issues*, IMF Staff Country Report No.00/144, International Monetary Fund, Washington, DC.
- Faruqee, H. (2000b), 'Population Aging and its Macroeconomic Implications: a Framework for Analysis', Draft Manuscript, International Monetary Fund, Washington DC.
- Faruqee, H. (2003a) "Debt, Deficits, and Age-Specific Mortality." *Review of Economic Dynamics*, 6 (2003), 300-312.
- Faruqee, H. (2003b) "Population Aging in Japan: Demographic Shock and Fiscal Sustainability." *Japan and the World Economy*, 15 (2003), 185-210.
- Faruqee, H. and D. Laxton (2000) "Life Cycles, Dynasties, Saving: Implications for Closed and Small Open Economies." IMF Working Paper No. WP/00/126. Washington, DC: International Monetary Fund, July 2000.
- Faruqee, H, D. Laxton, and S. Symansky (1997) "Government Debt, Life-Cycle Income and Liquidity Constraints: Beyond Approximate Ricardian Equivalence." *IMF Staff Papers*, 44 (September 1997), 374-82.
- Guest R. and I. McDonald (2003) "The Effect of World Fertility Scenarios on International Living Standards" *The Economic Record Special Issue* vol 80, ppS1-, S12.
- Hayashi, F. (1979) "Tobins Marginal q and Average q: A Neoclassical Interpretation." *Econometrica* 50, pp.213-224.
- Hayashi, F. (1982) "The Permanent Income Hypothesis: Estimation and Testing by Instrumental Variables." *Journal of Political Economy* 90(4) pp 895-916
- Helliwell, J. (2004) "Demographic Change and International Factor Mobility" Federal Reserve Bank of Kansas City Conference Proceedings.
- Higgins, M. and J. G. Williamson (1997) "Age Structure Dynamics in Asia and Dependence on Foreign Capital." *Population and Development Review*, 23 (June 1997), 261-93. (See also NBER Working Paper 5560, May 1996.)
- Higgins, M. (1998) "The Demographic Determinants of Savings, Investment, and International Capital Flows." *International Economic Review*, 39 (1998), 343-69.
- Horioka, C.Y. (1991), 'The Determinants of Japan's Saving Rate: The Impact of Age Structure and Other Factors', *Economic Studies Quarterly*, Vol. 42, No. 3., pp.237-253.
- INGENUE Team, 2001, "INGENUE: Une Modélisation Intergénérationnelle et Universelle" (Paris: Banque de France).No. 3, pp. 393-41.

- Lee, R. D. (2003) "The Demographic Transition: Three Centuries of Fundamental Change." *Journal of Economic Perspectives*, 17 (Fall 2003), 167-190.
- McKibbin W. and J Nguyen (2004) Modelling Global Demographic Change: results for Japan. Lowy Institute for International Policy Working paper 3.04; Brookings Discussion Papers in International Economics no162; paper presented at the Conference on the International Collaborations Project , Tokyo Japan
- McKibbin W., D. Pearce and A. Stegman (2004) "Long Run Projections for Climate Change Scenarios" Lowy Institute for International Policy Working paper 1.04; Brookings Discussion Papers in International Economics no160;
- McKibbin W.J. and D. Vines (2000) "Modelling Reality: The Need for Both Intertemporal Optimization and Stickiness in Models for Policymaking" *Oxford Review of Economic Policy* vol 16, no 4. (ISSN 0266903X)
- McKibbin W. and P. Wilcoxon (1998) "The Theoretical and Empirical Structure of the G-Cubed Model" *Economic Modelling* , 16, 1, pp 123-148, also Brookings Discussion Paper in International Economics #118.
- McKibbin W. and Wilcoxon (2005) 'Economics for an Integrated World' forthcoming. The Brookings Institution.
- Meredith, G. (1995), 'Alternative Long-Run Scenarios', in U. Baumgartner and G. Meredith, eds., *Saving Behaviour and the Asset Price 'Bubble' in Japan*, IMF Occasional Paper No. 124, Washington D.C., International Monetary Fund.
- Miles D. (1999) :Modeling the Impact of Demographic Change on the Economy" *Economic Journal* 109, p 1-36.
- Obstfeld M. and K. Rogoff (1996) *Foundations of International Macroeconomics* MIT Press, Cambridge MA.
- Ogawa, N. and Retherford, R. D. (1993), 'The Resumption of Fertility Decline in Japan, 1973-1992', *Population Development Review*, Vol. 19, No. 4, pp. 703-741.
- Takayama, N., and Y. Kitamura (1999), 'Lessons From Generational Accounting in Japan', *American Economic Review*, 89:2, 171-180.
- Takayama, N. (1998), *The Morning After in Japan: Its Declining Population, Too Generous Pensions and a Weakened Economy*, Maruzen Co Ltd, Tokyo.
- Takayama, N., Y. Kitamura and H. Yoshida (1998), *Generational Accounting in Japan*, Institute for Monetary and Economic Studies, Bank of Japan, Discussion Paper 98-E-1.
- Weil, P. (1989) "Overlapping Families of Infinitely-Lived Agents." *Journal of Public Economics* 38 (1989), 183-98.

Yaari, M. E. (1965) "Uncertain Lifetime, Life Insurance, and the Theory of the Consumer." *Review of Economic Studies*, Vol. 32 (April 1965), pp. 137-50.

Yashiro, N, and A.S. Oishi (1997), 'Population Aging and the Savings-Investment Balance in Japan', in: M.D. Hurd and N.Yashiro (eds.), *The Economic Effects of Aging in The United States and Japan*, University of Chicago Press, Chicago and London.

Yashiro, N. (1998) 'The Economic Factors For the Declining Birthrate', *Review of Population and Social Policy*, No. 7, pp.129-144.

Yashiro, N., and T. Oshio, and M. Matsuya (1997), *Macroeconomic and Fiscal Impacts of Japan's Aging Population with a Specific Reference to Pension Reforms*, Discussion Paper No.78, Economic Research Institute, Economic Planning Agency, Tokyo.

Table 1: The MSG3 10 Region Demographic Model (version 58T)

Countries:

United States

Japan

Europe

Rest of OECD

Eastern Europe and Former Soviet Union

China

India

Other Asia

Latin America

Other Developing Countries

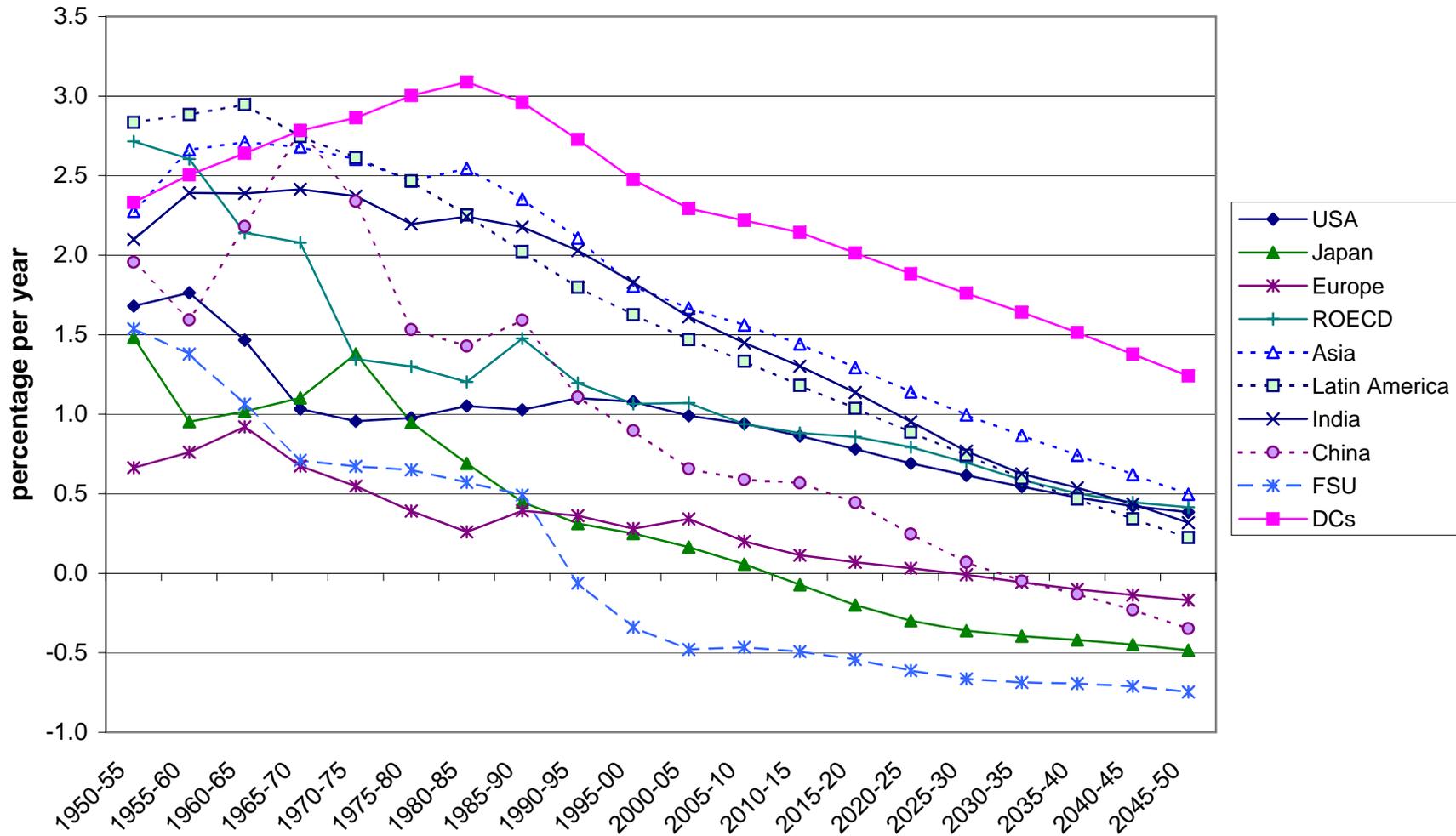
Sectors:

Energy

Non-Energy

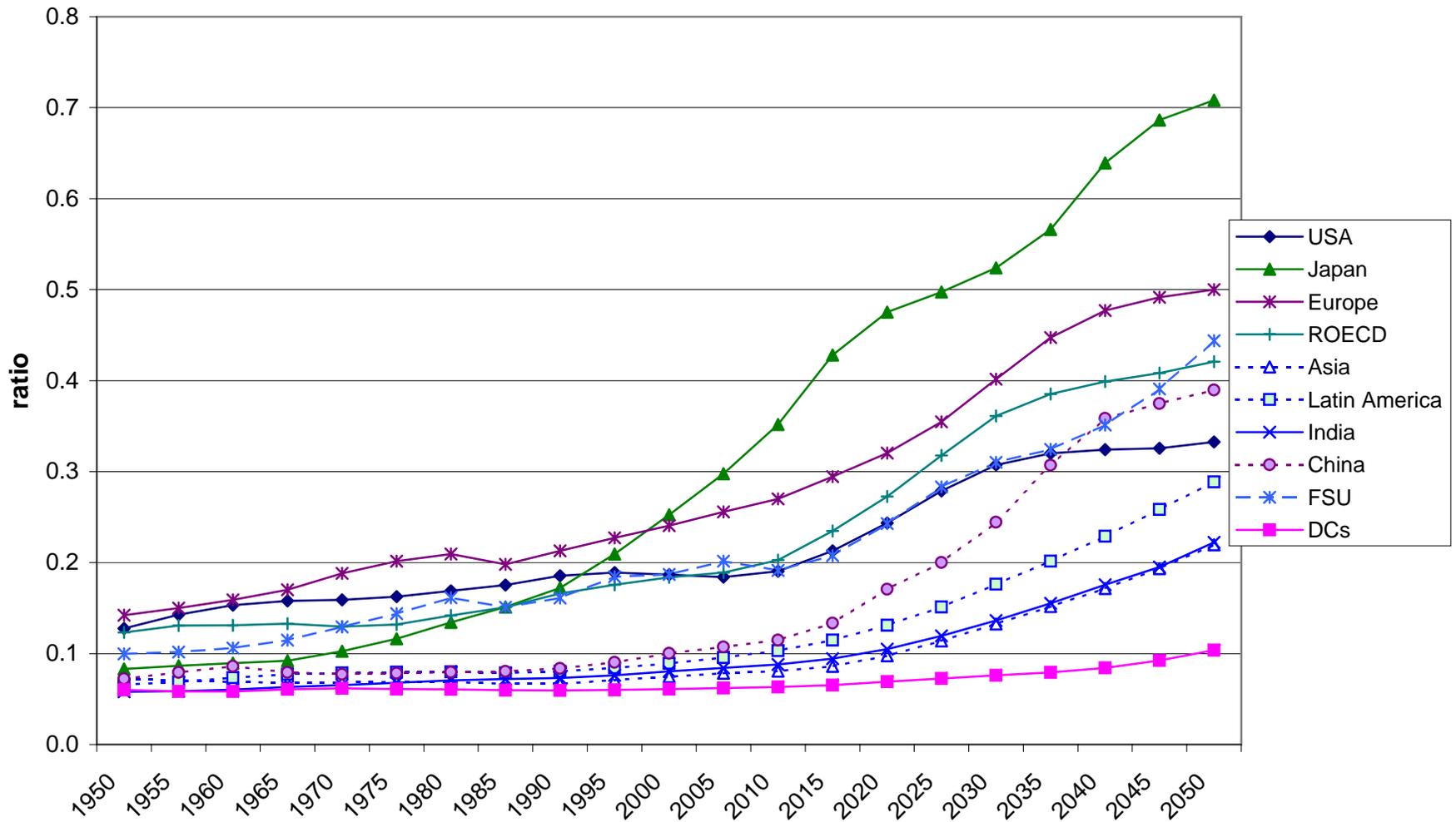
Capital goods producing sector.

Figure 1: Population Growth Rate 1950-2050



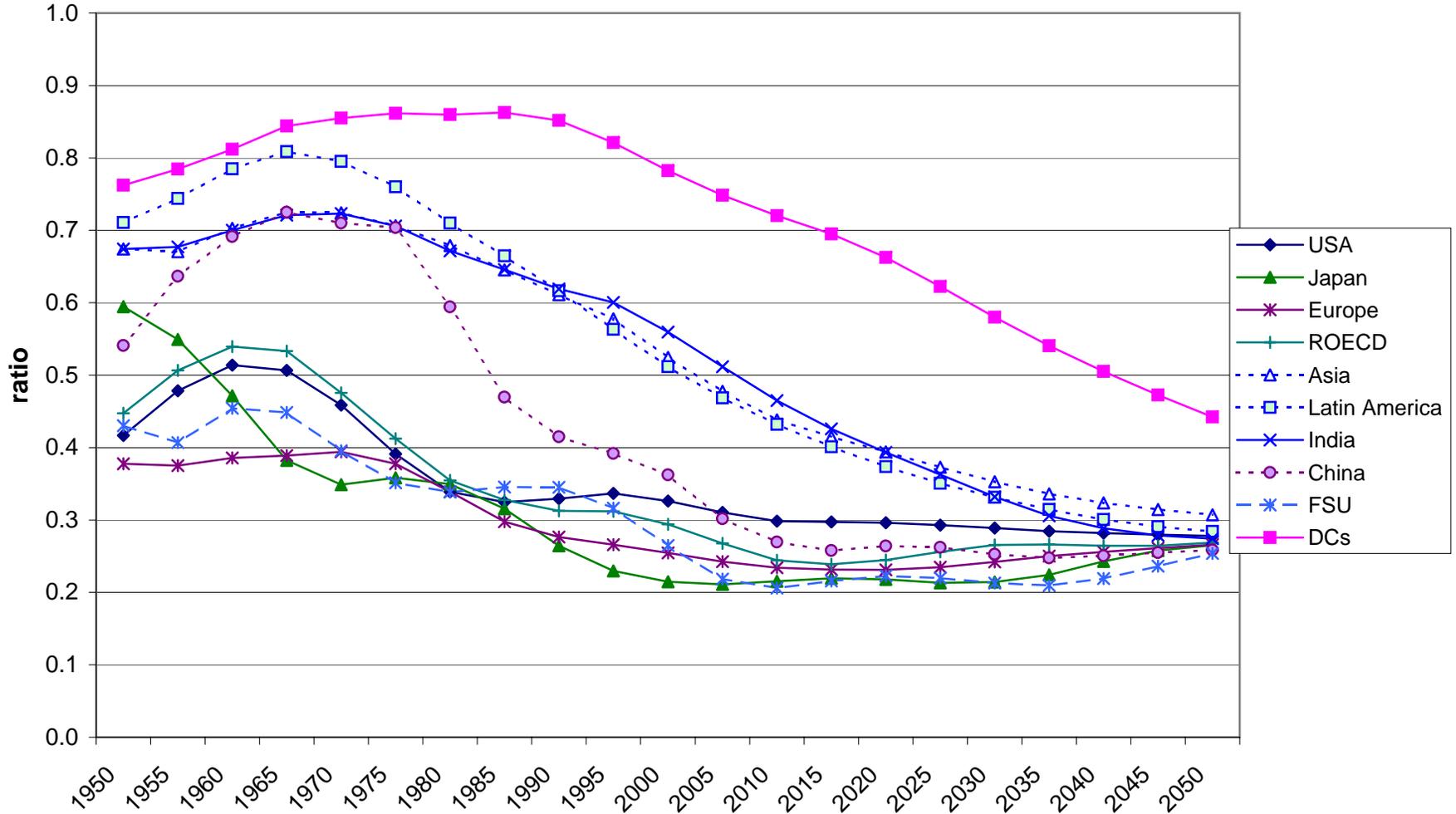
Source: UN, World Population Prospects: The 2004 Revision

Figure 2: Elderly Dependency Ratio 1950-2050
 (ratio of adults 65+ to adults 15-65)



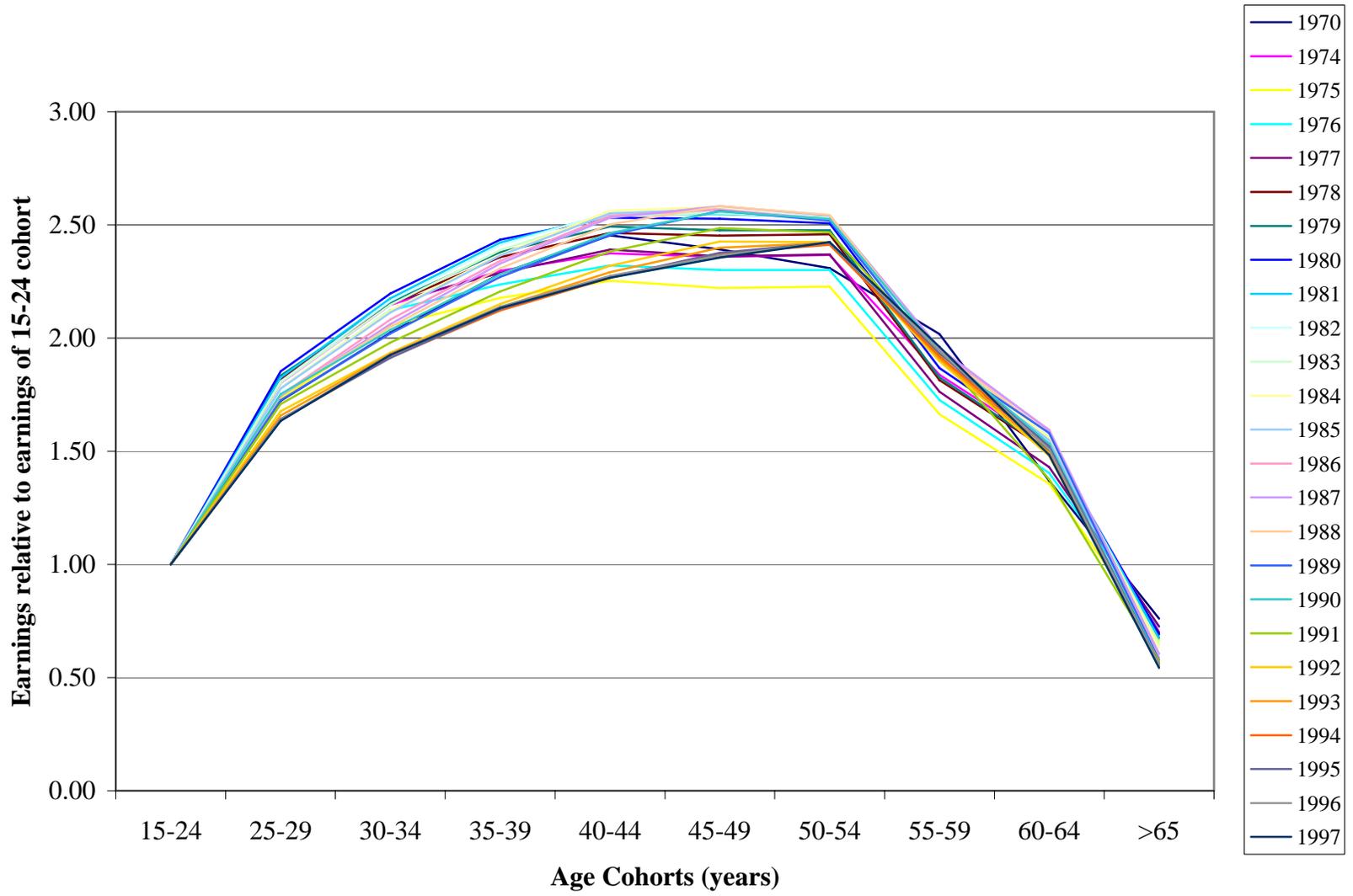
Source: UN, World Population Prospects: The 2004 Revision

Figure 3: Child Dependency Ratio 1950-2050
 (ratio of children 0-14 to adults 15-65)



Source: UN, World Population Prospects: The 2004 Revision

Figure 4. Age Earnings Profiles, Japanese Data 1970-1997



source: Bryant and McKibbin (2004)

Figure 5: Removing the Demographics
(A stylized Representation)

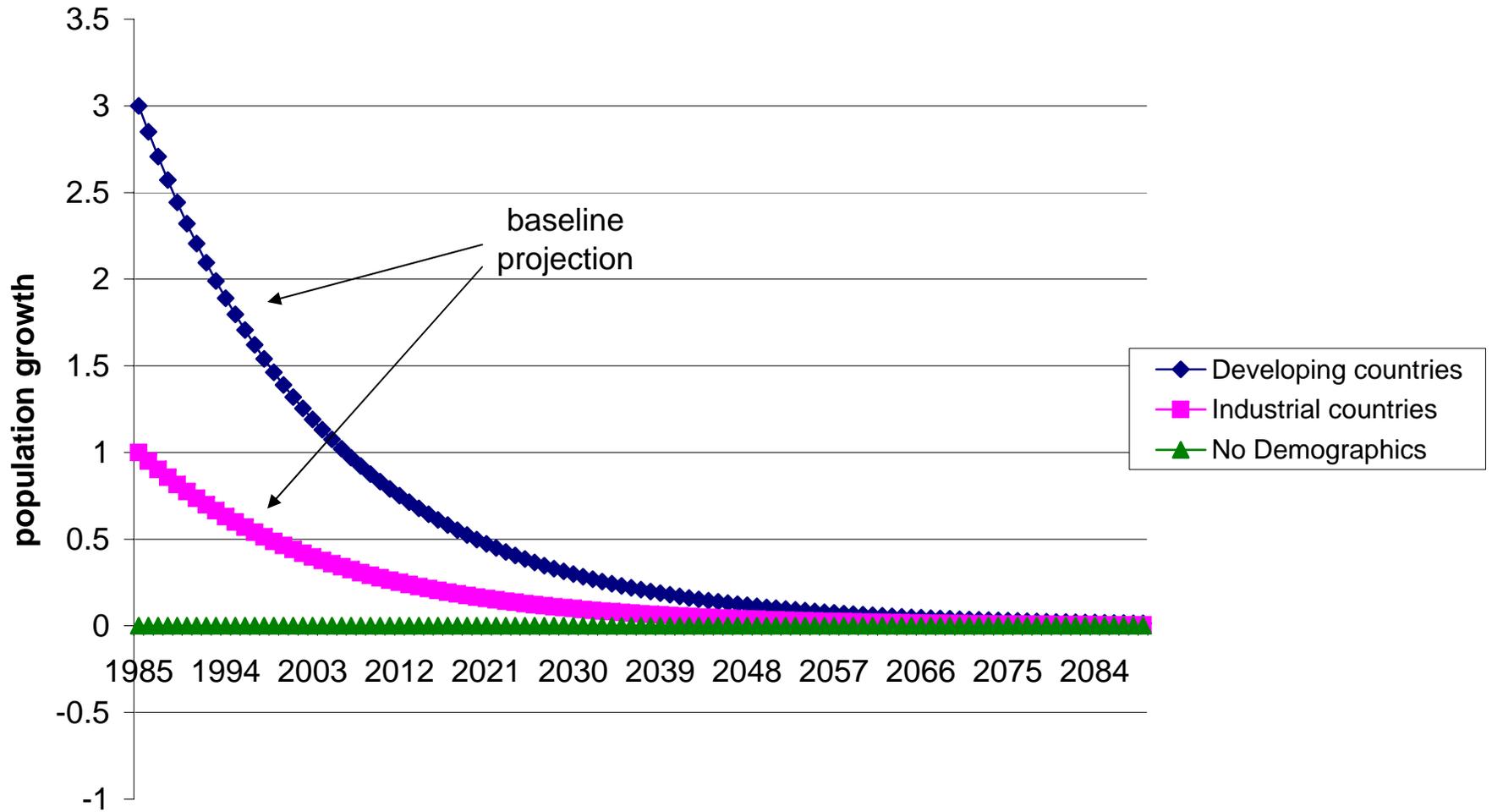


Figure 7: Change in Adult Maturity Rate (relative to steady state)

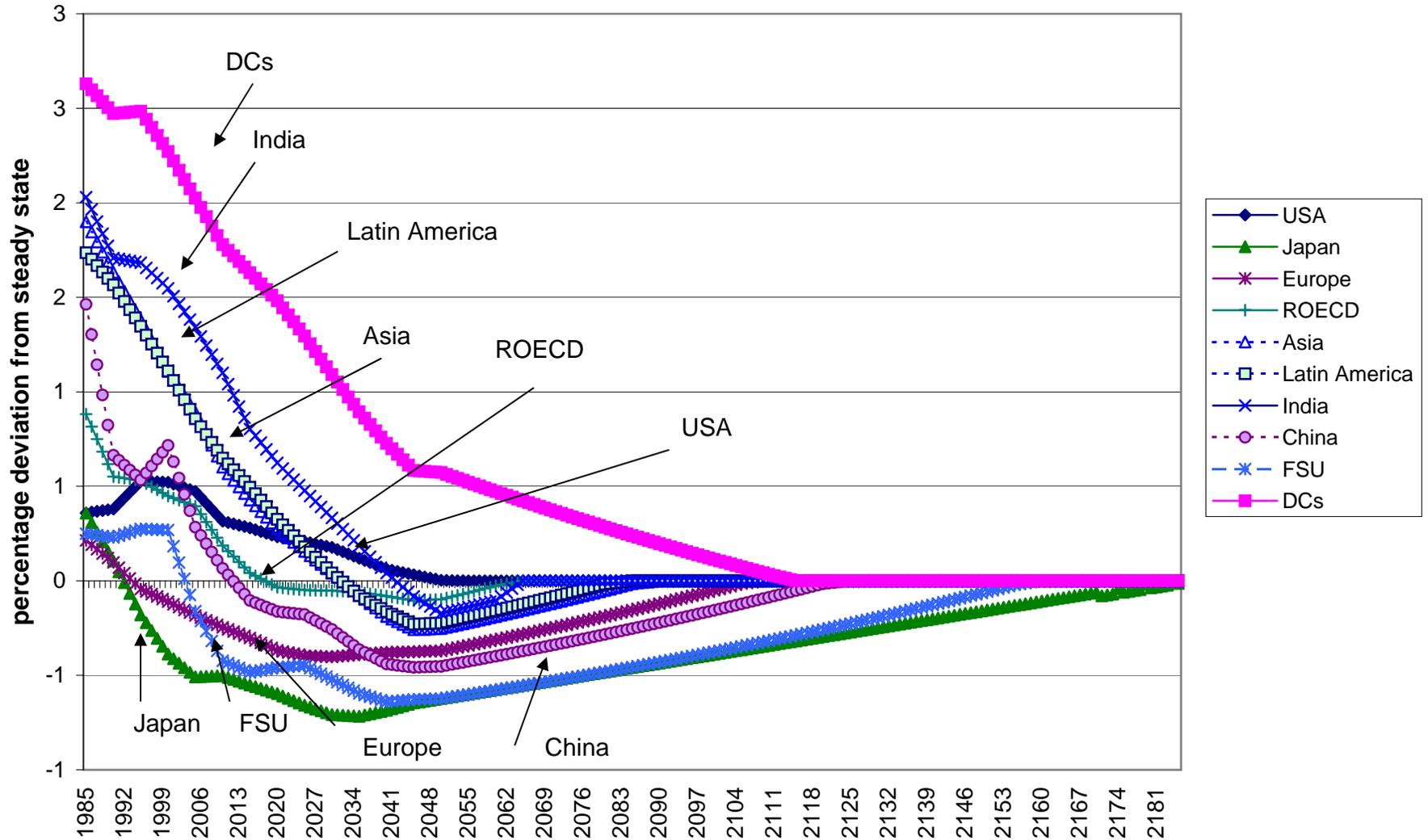


Figure 8: Contribution of Demographic Change in All Countries to Japanese Growth Rate

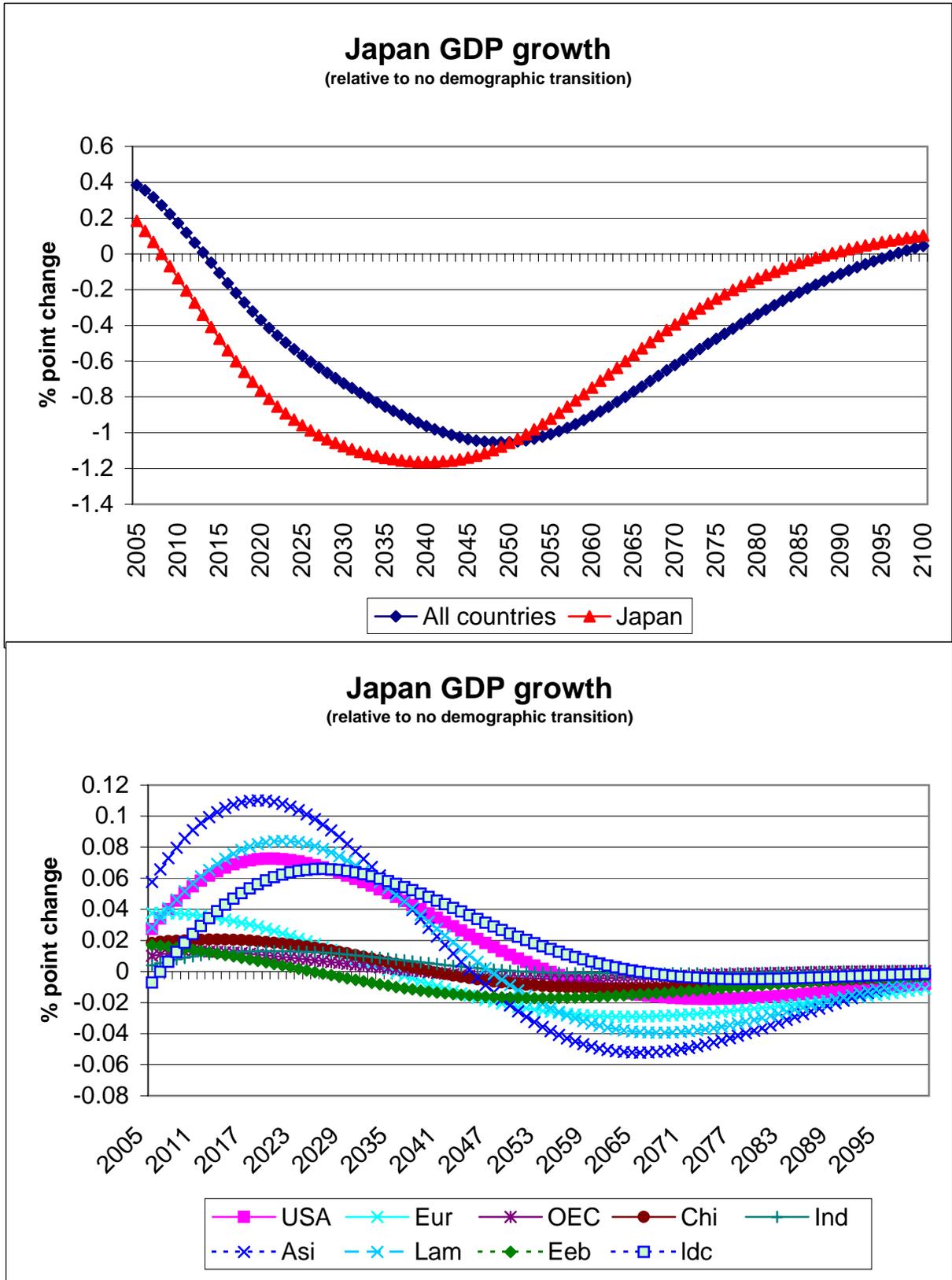


Figure 9: Contribution of Demographic Change in All Countries to Japanese Current Account

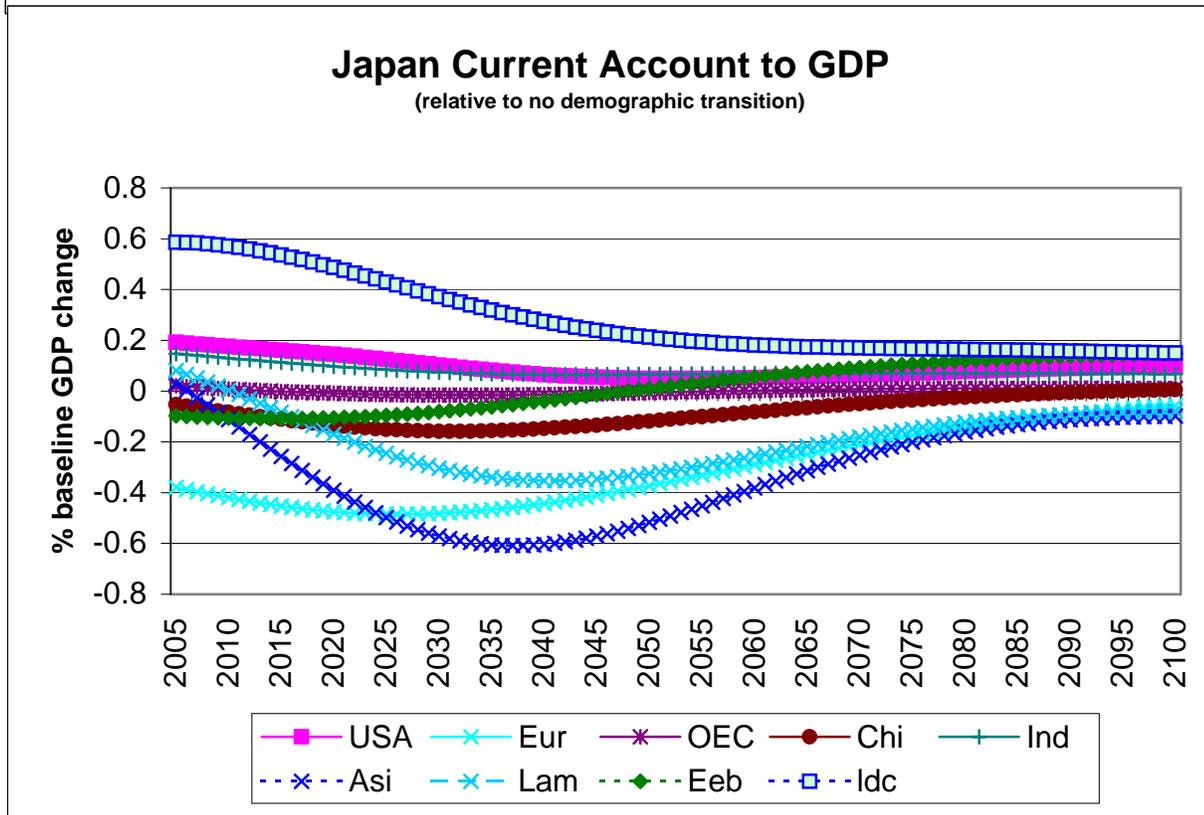
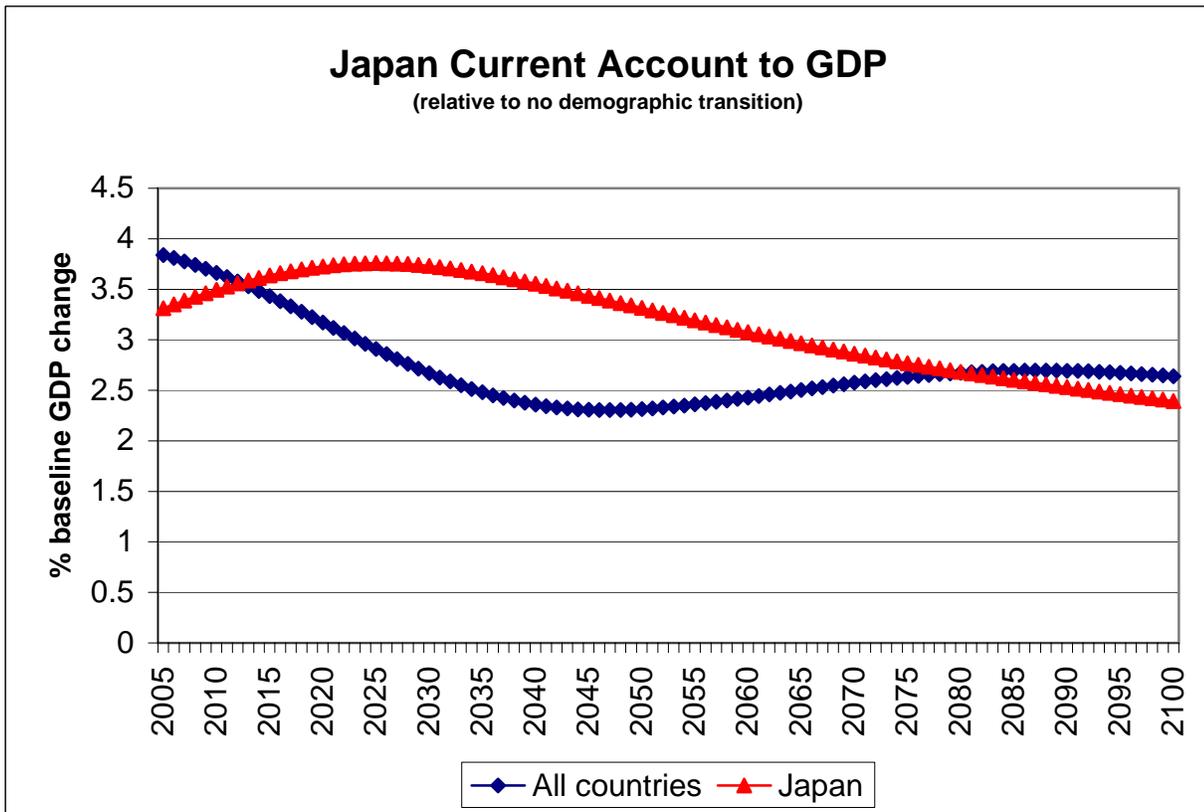


Figure 10: Contribution of Demographic Change in All Countries to Japanese Trade Account

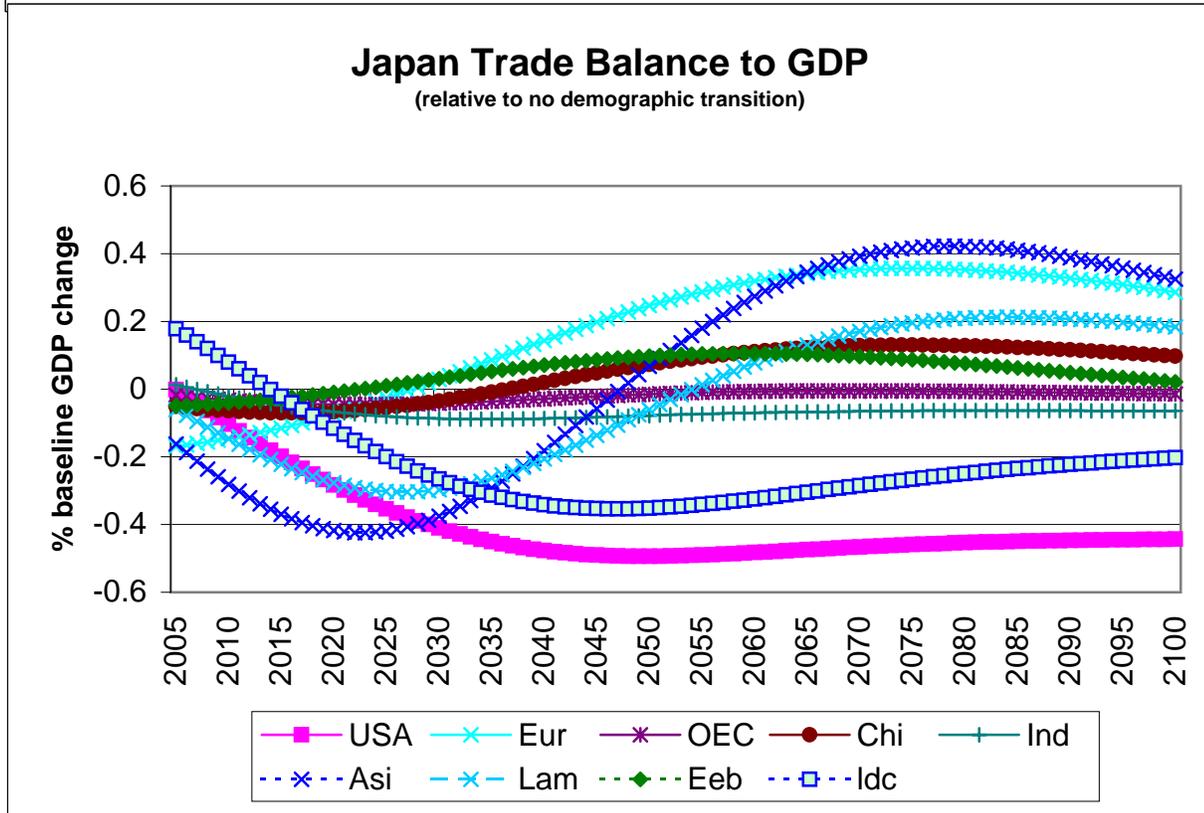
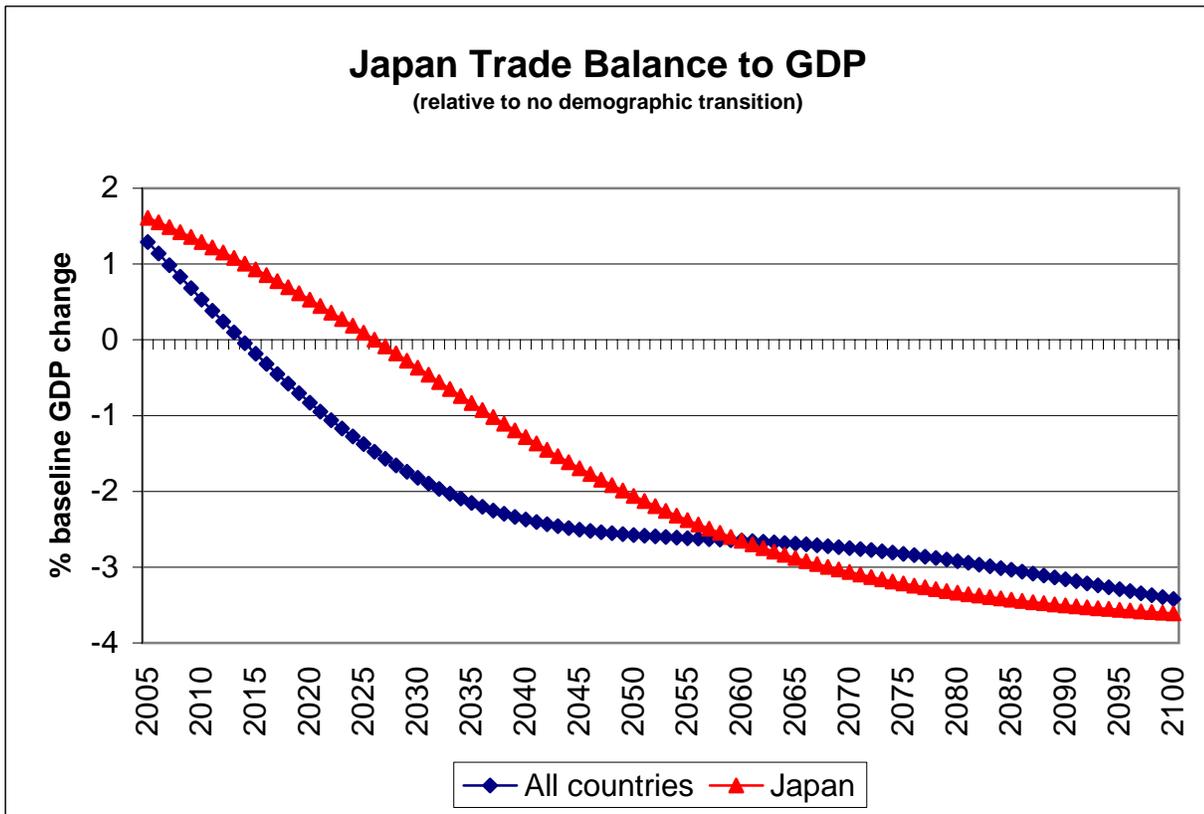


Figure 11: Contribution of Demographic Change in All Countries to Japanese Real Exchange Rate

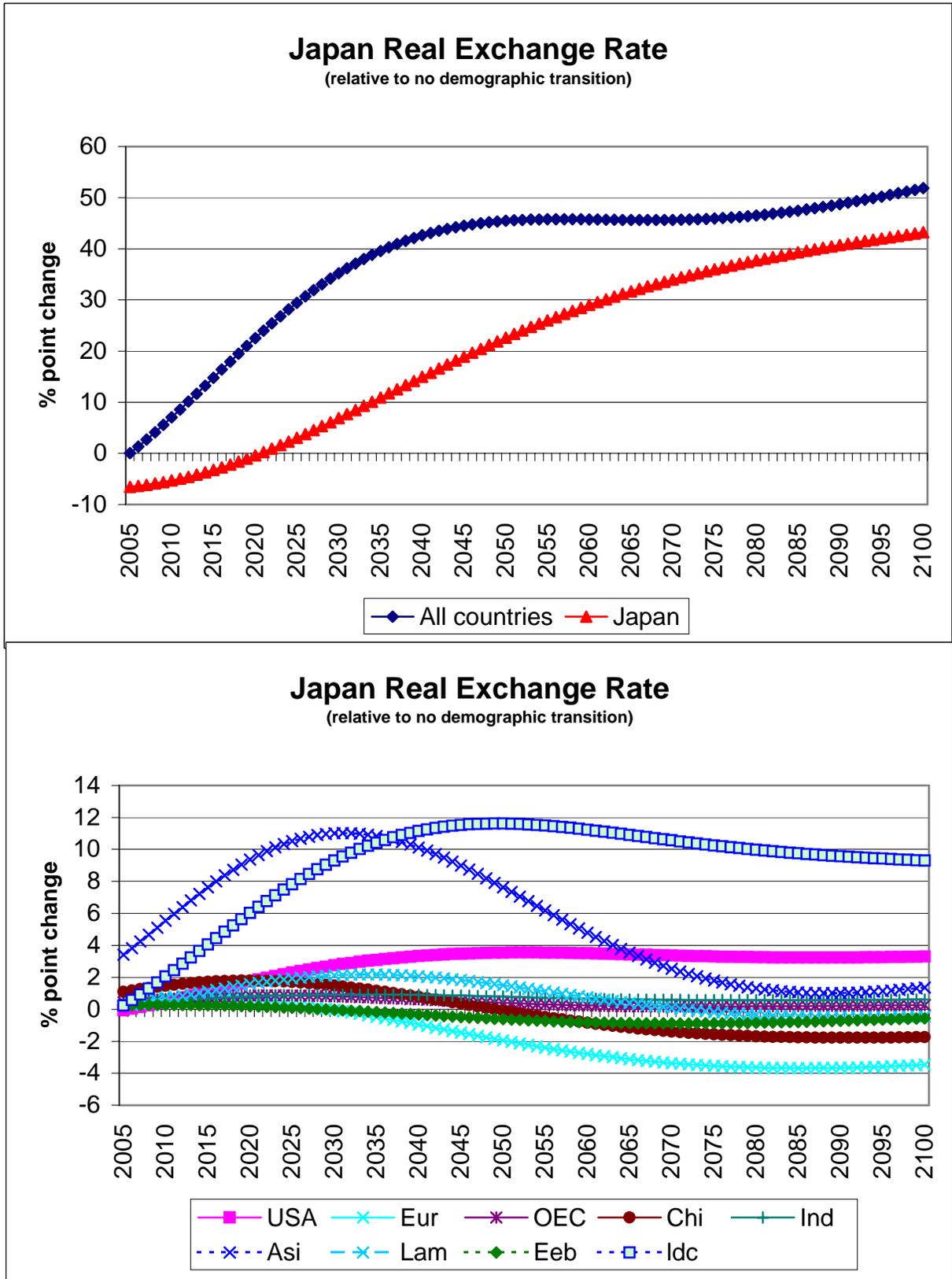


Figure 12: Contribution of Demographic Change in All Countries to Japanese Real Interest Rates

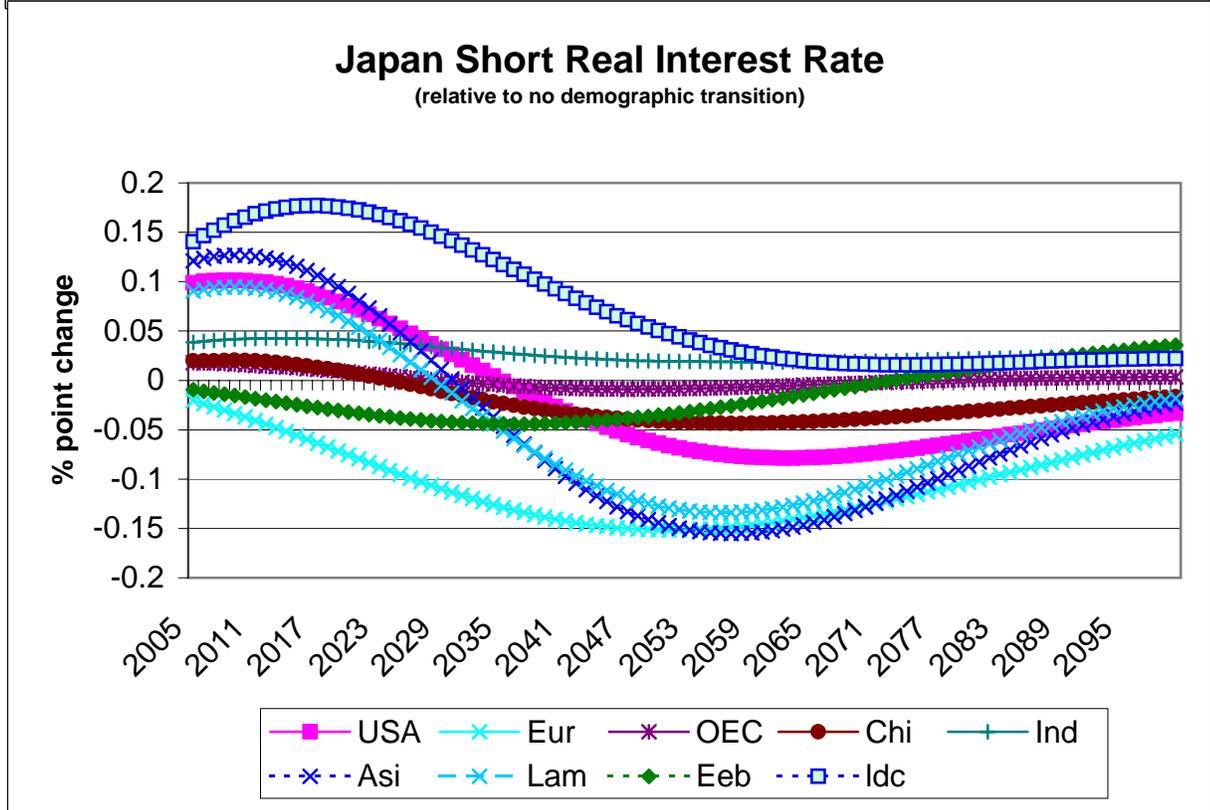
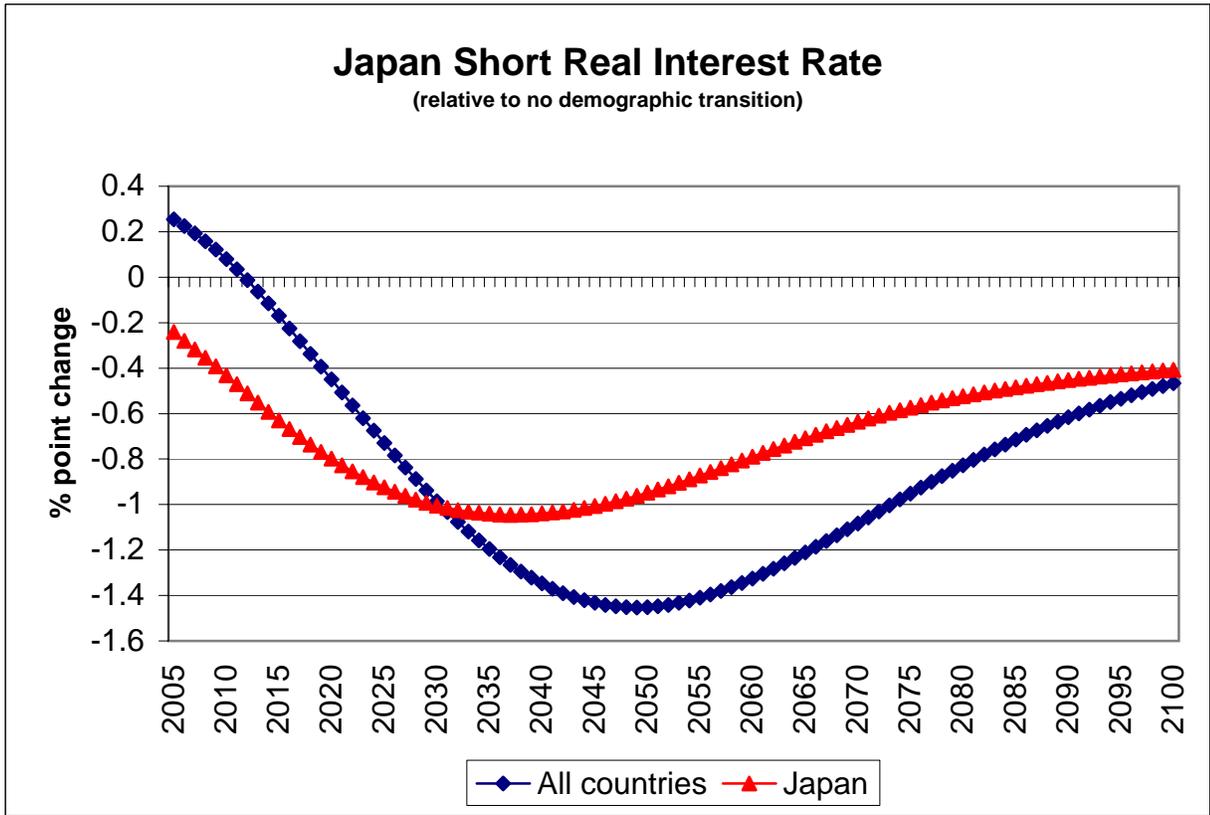


Figure 13: Contribution of Demographic Change in All Countries to Japanese Private Investment

