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**BONFATTI, Andrea**
University of Padua

**İMROHOROĞLU, Selahattin**
University of Southern California

**KITAO, Sagiri**
RIETI

Research Institute of Economy, Trade & Industry, IAA

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# Aging, Factor Prices and Capital Flows*

Andrea BONFATTI†, Selahattin İMROHOROĞLU‡, Sagiri KITAO§

Abstract

Although populations are aging in all economies, projections for coming decades describe differential timing and extent of aging. Advanced economies are aging earlier and faster than the developing and emerging economies, with Japan leading the way. In a world with integrated capital markets, these differences in demographic trends, with different social security environments, will have differential implications on national or regional capital accumulation, investment, factor prices and capital flows across borders. This paper develops a general equilibrium model of the world economy under imperfect capital mobility, populated by overlapping generations of individuals in three regions: the High-income (HI) and Middle-income (MI) regions and Japan. We compute equilibrium transitions from the 1990s toward a future balanced growth path and numerically characterize the first few decades. Our findings highlight the quantitative importance of the differential aging mechanism in studying capital flows across regions. In particular, we find that the projected decline in national saving in Japan, not matched with a similar decline in domestic investment, will lead to a reversal of capital flows into Japan, which will become a net borrower before 2050. The reason for Japan's attractiveness for foreign capital from the MI region is the initially rising but soon flattening path of its capital labor ratio while the MI region experiences a monotonically increasing capital labor ratio. This projection, coupled with the slow speed with which the MI region's TFP catches up with that of Japan, necessitates an outflow of capital from the MI region to the HI region and Japan in order for the world capital market to clear.

**Keywords:** Capital Flows, Demographic Trends, Factor Prices, Japan.
**JEL Classification:** F21, F41, J11, H55.



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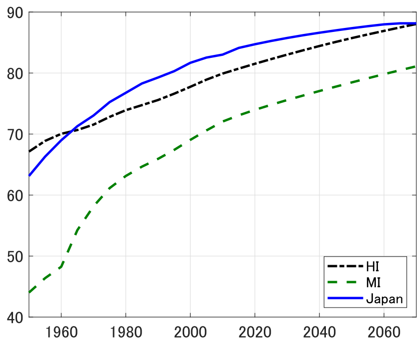
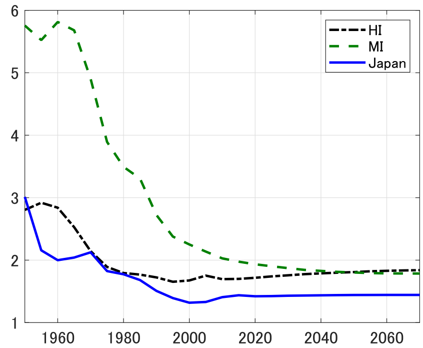
†University of Padua, andrea.bonfatti@unipd.it
‡Marshall School of Business, University of Southern California, selo@marshall.usc.edu.
§The University of Tokyo and RIETI, sagiri.kitao@gmail.com.

# 1 Introduction

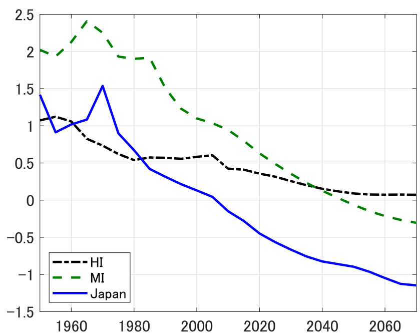
One of the major challenges facing all economies is the aging of the populations. In virtually all countries, fertility rates and death rates have fallen and this demographic trend has been accompanied by a secular decline in real interest rates and slow economic growth. However, the timing and the severity of these demographic trends are quite different across countries and regions of the world. Advanced economies such as United States, Japan, and those in the Eurozone have started aging much earlier and more significantly than emerging and developing countries. In order to see the differential demographic trends in the world, Figure 1 shows various aspects of the aging process and its implications in three 'regions', 1) 'high-income' (HI) region, 2) 'middle-income' (MI) region, and 3) Japan.[1]



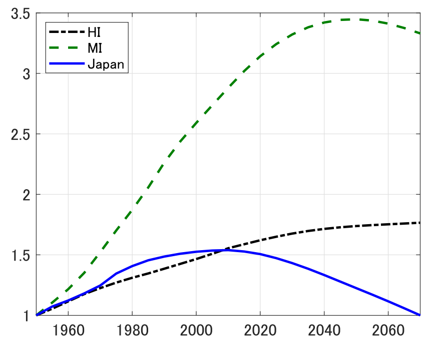

(a) Life Expectancy




(b) Total Fertility Rate




(c) Population Growth Rates




(d) Normalized Populations

Figure 1: Demographic Trends in the Three Regions

[1]The main source of demographic data is United Nation's *World Population Prospects: The 2017 Edition Revision* (2017), which provides harmonized data on population, fertility and life table projections for all countries from 1950 to 2100. The division of the first two regions is mainly based on the stages of overall economic growth and timing of demographic transition. The choice of countries included in these regions is based on the size of the economy, as well as the degree of investment and financial exposure to Japan. More details are provided in section 4.

The first frame in Figure 1 shows life expectancy at birth over time in the three regions. Longevity is rising in all regions but significant differences are projected to persist well into the second half of the 21st century. Furthermore, Japan has and will continue to have higher longevity relative to the highly advanced economies during the next several decades. The second frame in Figure 1 plots total fertility rates which have all come down from their earlier levels in 1960. In particular, fertility rates in HI and MI regions are projected to approximately converge (just below 2) whereas that in Japan is predicted to be significantly lower at around 1.5 for several more decades.

Given the significant fall in fertility rates, it is not surprising that population growth rates have fallen significantly since 1960 as the third frame in Figure 1 shows. What stands out in this frame is that Japan's population growth has already turned negative in the late 2000s and the decline in the Japanese population is projected to accelerate over the next decades. According to the last frame in Figure 1, the Japanese population in 2070 will be about the same size as that in 1950. The populations in HI and MI regions will continue to rise, at least until the 2040s.

Combined, the fall in fertility and the rise in longevity imply significant increases in the old-age dependency ratio, defined as the ratio of individuals 65 or older to those between the ages of 20 and 64, shown in Figure 2. The dependency ratios show a gradual increase in all regions since 1950. In HI and MI regions, the main part of the increase is very recent and the projections put these ratios at about 55% and 42%, respectively, by 2070. In Japan, however, the sharp rise in the dependency ratio has started in the 1990s and it is projected to increase to 80% by 2050. In other words, the rise in the old-age dependency ratio in Japan has started much earlier and is predicted to reach unprecedented levels in a few decades.

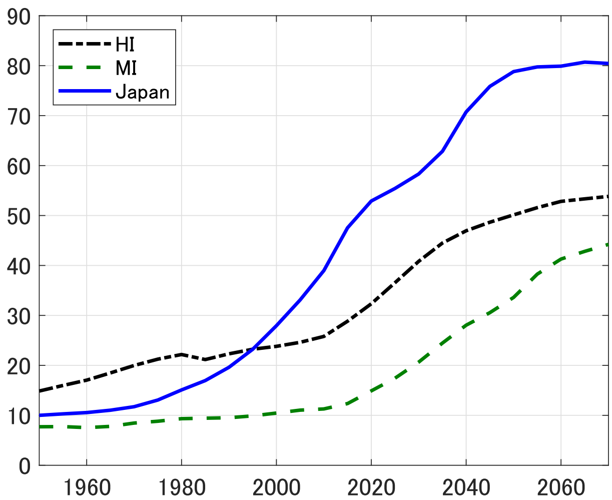



Figure 2: Dependency Ratios

These large demographic shocks and the accompanying policy adjustments have already started to affect capital accummulation, labor supply and economic growth in all economies and will continue to do so in the next few decades. To the extent that capital markets are integrated across regions, different demographic trends and different fiscal responses to them will have differential implications on capital accumulation, labor supplies, and capital movements across regions. When viewed through the lens of a general equilibrium model of the world, these capital movements will have effects on the time paths of factor prices. The impact of demographic shocks and fiscal responses is maximized in a closed economy, general equilibrium setting, with a direct link between the domestic capital labor ratio and factor rental rates. This mechanism is totally absent in a small, open economy, partial equilibrium model. Actual economies, however, are neither closed nor small, open, and depending on bilateral trade and capital flows, they may be closer to one extreme or the other.

This paper develops a general equilibrium model of the world in which overlapping generations of individuals populate three regions that are connected through capital mobility. As mentioned earlier, our idea is to view our world economy as consisting of three regions that have very different demographic trends. The HI region is aging earlier and faster than the MI region, and, Japan has been aging even earlier and faster than the HI region. By isolating Japan as a separate region, our framework aims to highlight the quantitative importance of the differential aging mechanism in shaping capital flows and fiscal sustainability.

Each region in our model consists of overlapping generations of individuals who face complete markets except for missing annuity markets. Labor is immobile but we assume that capital can move across regions in the open economy version of our model. In addition, we assume that labor is exogenous in order to focus on the role of demographics in determining capital flows. Governments in the three regions have exogenous government purchases and transfer payments which increase over time as the populations get older. We also incorporate differences in the fiscal institutions across regions, captured by different degrees of generosity in the social security systems as well as taxes that support the programs. We assume that government debt to output ratios are held constant and lump sum taxes are used to achieve fiscal sustainability.

We calibrate the model under the assumption of an open economy using data from the World Bank, IMF, United Nations, and in the case of Japan, the Institute for Population Studies. We first compute equilibrium transitions in the three regions assuming that the economy is open and characterize the paths of equilibrium quantities such as output, capital, wages and factor prices. Second, under the same institutional settings we compute an equilibrium transition of the closed-economy version of the model, shutting down capital flows across regions. We find that the return to capital in the world capital market falls from about 4% in 2015 to about 2% by 2070. The capital-labor ratio rises significantly in the HI region and Japan until the 2040s but starts to stabilize thereafter. The increases, however, continue in the MI region well into the second half of the century. This difference drives the reversal of the net foreign asset position of Japan. In particular, Japan starts running current account deficits, its net foreign asset position worsens, and eventually becomes a net foreign borrower.

In our theory, it is unclear whether Japan's openness and capital flows will improve or worsen the fiscal projections. On the one hand, capital inflows in the long-run driven by the fast rising capital-labor ratio in the MI region would raise output and wage rates, and therefore tax revenues. On the other hand, returns on savings paid to the Japanese would be lower and higher pension benefits due to higher earnings would raise transfer payments. Our quantitative results suggest that the fiscal cost of demographic projection would be slightly lower in the open economy, although the effect is relatively small. We conclude that openness alone cannot be counted on to achieve fiscal sustainability in Japan.

The paper is organized as follows. Section 2 describes the related literature and summarizes the contributions of the paper. Section 3 describes the model and the economic environment. Section 4 summarizes our calibration with the details described in the Appendix. Section 5 discusses our main quantitative findings, Section 6 provides a sensitivity analysis and explores the effects of alternative policy and longevity outcomes, and Section 7 provides concluding remarks.

# 2 Related Literature

Our paper follows the tradition of Auerbach and Kotlikoff (1987) by using a quantitative general equilibrium model populated by overlapping generations, and incorporates life cycle institutions and demographic projections in detail to tease out the implications of aging on capital flows across borders.[2]

Our paper is related to the recent 'secular stagnation' papers such as Ikeda and Saito (2014), Gagnon, Johnson, and Lopez-Salido (2016), Carvalho, Ferrero, and Nechio (2016) and Eggertsson, Mehrotra, and Robbins (2017). Most of this research restricts attention to closed economy models and focus on understanding the mechanisms, including demographics, that contribute to the low real interest rates and economic growth in advanced economies.[3]

This paper is more closely related to the work by Attanasio, Kitao, and Violante (2006), Domeij and Floden (2006), Börsch-Supan, Ludwig, and Winter (2006), Attanasio, Kitao, and Violante (2007), Krueger and Ludwig (2007), Backus, Cooley, and Henriksen (2014) and Lisack, Sajedi, and Thwaites (2017) that analyze the effects of demographic changes in open economies. This research exploits the differential timing and nature

[2]Earlier papers that studied the effects of aging on the economy focused on the effects arising from the social security budget in closed economy models. See, for example, Huang, İmrohoroğlu, and Sargent (1997), De Nardi, İmrohoroğlu, and Sargent (1999).

[3]For example, Eggertsson, Mehrotra, and Robbins (2017) build a three-period New Keynesian model to highlight the various mechanisms of their model (shocks to collateral constraints, demographics, zero lower bound, debt to output ratio, relative price of investment goods, labor share, nominal rigidities, productivity growth, hysteresis) to create secular stagnation and negative natural interest rates for the United States between 1970 and 2015, with projections to 2030. For Japan, their numerical example using a 3-period OLG model under a closed economy setup delivers persistent low growth, low inflation and low real interest rates in the 1970-2013 period.

of aging and different ways of dealing with pension programs in large, open economy models. The general finding is that capital flows from the 'North' to the 'South' as aging occurs earlier and more severely in high income countries relative to that in less developed economies.[4]

When an economy ages faster than others, then the rise in capital labor ratio will be larger than others and as a result the fall in the return to capital will be bigger. If capital is allowed to flow between economies, the fall in the return to capital in an aging economy will be accompanied by an outflow of capital seeking higher returns elsewhere. This is the simple mechanism that determines capital flows in this quantitative literature.

In addition to this mechanism, there is also differential growth rates in total factor productivity that lead to differences in returns to capital among economies. It is also possible that tax treatment of capital income is different or pension institutions have different sustainability issues that may influence the return to capital in these economies. With these and other 'moving parts' in large scale, quantitative general equilibrium models populated with overlapping generations, it becomes necessary to conduct numerical experiments to isolate some of these effects in an attempt to quantify their contributions to the overall results. We address these issues in section 6 on Alternative Computations.

Also, this paper extends the literature that studies fiscal sustainability issues and macroeconomic effects of aging population in Japan. Hansen and İmrohoroğlu (2016) uses a neoclassical growth model to quantify costs of aging demographics, showing a very large fiscal adjustment needed to stabilize the government debt. Braun and Joines (2015) and Kitao (2015) build a life-cycle model with details of the social insurance system in Japan and study effects of alternative policies including reforms of social security and health insurance programs. Kitao and Mikoshiba (2019) studies effects of changes in the labor market on fiscal projections, focusing on participation of females and the elderly in Japan. All of these models assume a closed economy and factor prices are determined solely by domestic factors. Our model allows for capital mobility into and out of Japan and quantifies how unsynchronized demographic aging in different parts of the world and different fiscal institutions could affect future paths of the Japanese macroeconomy.

Finally, this paper adds to the literature on the Lucas Paradox by highlighting the quantitative importance of the key mechanisms that determine capital flows. In a seminal paper, Lucas (1990) uses the standard Cobb-Douglas production function in the workhorse macro models to illustrate a paradox. These models predict that capital ought to flow to poor economies with higher rates of return such as developing economies with much lower capital labor ratios and total factor productivities but capital flows in the data seem to go in the other direction. Lucas (1990) suggests measuring and incorporating human capital in these calculations and also mentions the possibility of political risk as potential factors

[4]Chen, İmrohoroğlu, and İmrohoroğlu (2006) develop a two-country open economy, representative agent model and study the effects of productivity, tax, and population growth rate differences on capital flows between the U.S. and the rest of the world (RoW). They argue that the factor that seems to have driven the capital to flow into the U.S. in the 1960-2004 period is faster productivity growth in the U.S.

that may reconcile theory and data.[5]

Using a large international panel data set, Alfaro, Kalemli-Özcan, and Volosovych (2008) conduct an empirical analysis to study what factors seem to explain capital flows across borders. They consider measures of fundamentals that raise productivity and an index of institutional quality in their panel regressions of fifty-eight countries during 1970-2000. They find evidence that institutional quality explains the variation in net capital flows.

In order to check whether a typical neoclassical model may be consistent with data from the fifty U.S. states, Kalemli-Özcan, Reshef, Sørensen, and Yosha (2010) develop a neoclassical model and use data from the states in the U.S. Their model predicts that capital flows to fast-growing states from slow-growing states, and therefore, high-growth states pay capital income to other states, and eventually become net debtors with persistent productivity shocks. Using data, they find evidence that suggests that the net capital flows and patterns of ownership seem consistent with their frictionless neoclassical model. They argue that the limited size and the 'wrong' direction of international capital flows may be due to frictions associated with national borders.

Alfaro, Kalemli-Özcan, and Volosovych (2014) construct measures of net private and public capital flows for a large cross-section of developing economies and using these constructs they find that net international private capital flows are positively correlated with productivity growth, consistent with neoclassical macro models.

Our model's mechanism for capital flows consists of fundamentals such as regional capital labor ratios and total factor productivities; the former is affected by demographics. In addition, we introduce a 'transaction cost' in investing abroad in our calibration which is intended to represent frictions across regional borders and this allows us to match the net foreign asset position of Japan over 1990-2015. Our simulation results indicate that capital flows beyond 2015 are primarily driven by fundamentals. In section 6 we show that our quantitative model suggests that the timing and direction of capital flows are entirely driven by fundamentals and demographics but the magnitude does depend on the size of the frictions across regional borders.

# 3 The Model

## 3.1 Economic Environment

**Preliminaries:** Our model consists of Japan ($J$) and two regions; High-income ($HI$) and Middle-income ($MI$) regions. The two regions and Japan differ in their realized and projected demographic trends, total factor productivity levels and growth rates, and fiscal institutions. Our approach is to calculate a perfect foresight equilibrium transition path

[5]Caselli and Feyrer (2007) argue that a more comprehensive production function incorporating land and other resources may matter. In addition, they suggest that the use of a multi-sector model in which the price of capital is higher in poor countries, and even with higher physical capital in rich countries, the return to capital may be close in these countries.

for the world economy from 2015 to a distant future steady state and characterize the transition path under the baseline and alternative economic settings. Let $t$ denote time, $j$ a household's age, and $r$ the regions, with $r = HI, MI, J$.

**Technology:** In each region $r$, a constant returns to scale, aggregate production function $F(Z_t^r, K_t^r, N_t^r)$ produces output of a final good $Y_t^r$ which can be used for consumption $C_t^r$ or investment $I_t^r$. Among the arguments of the production function, $Z_t^r$ denotes the total factor productivity level in region $r$ at time $t$, $N_t^r$ is the aggregate labor supply in efficiency units, and $K_t^r$ is the aggregate stock of physical capital used in production. Physical capital depreciates at the same rate $\delta$ each period in all regions. The level of technology in region $r$ grows exogenously at rate $\lambda_t^r$ between $t$ and $t+1$. The growth rates differ across regions during the transition, but in the long-run all regions grow at the same constant rate $\lambda$.

**Demographics:** Each region is populated by overlapping generations of ex-ante identical households who become active economically at age $j = 1$ and may live for a maximum of $J$ periods. For households born in region $r$, $s_{j,t}^r$ denotes the probability of survival until age $j$ at time $t$, conditional on being alive at time $t-1$. Hence, in region $r$, the unconditional probability of surviving $j$ periods up to time $t$ is given by

$$S_{j,t}^r = \prod_{k=1}^{j} s_{k,t+(k-j)}^r,$$

where $S_{1,t}^r = s_{1,t}^r \equiv 1$ for all $t$ by definition. We denote by $\mu_{j,t}^r$ the size of the population of age $j$ at time $t$ in region $r$.

**Household Preferences:** Households of age $j$ at time $t$ in region $r$ make consumption allocation decisions based on the instantaneous utility function

$$u(c_{j,t}) = \frac{\left(c_{j,t}^r\right)^{1-\theta}}{1-\theta}, \tag{1}$$

where $c_{j,t}^r$ denotes consumption of a household of age $j$ at time $t$. The intertemporal preference ordering for households born at adult-age $j = 1$ at time $t$ is given by

$$U^r = \sum_{j=1}^{J} \beta^{j-1} S_{j,t+j-1}^r \frac{\left(c_{j,t+j-1}^r\right)^{1-\theta}}{1-\theta}, \tag{2}$$

where $\beta$ is the subjective discount factor. There is no explicit bequest motive driven by altruism. Accidental bequests left by the deceased are distributed as a lump-sum transfer, denoted as $b_t^r$.

**Household Endowments:** Households exogenously supply labor and derive no utility from leisure.[6] At age $J_R^r$, households are subject to compulsory retirement from market

[6]We abstract from a labor-leisure choice in order to focus on the effects of saving and investment responses and capital flows across borders coming from exogenous demographic changes and saving/investment behavior.

work. Households of age $j$ at time $t$ in region $r$ are endowed with $\varepsilon^r_{j,t}$ efficiency units of labor for each unit of time worked in the market. Finally, we assume that the initial asset holdings of each household is zero, i.e. $a^r_{1,t} = 0$ for any $t$ in all regions.

**Household Budget Constraint:** Let $a^r_{j,t}$ be the net asset holding of a household of age $j$ at time $t$ in region $r$.

$$\left(1+\tau^r_{c,t}\right)c^r_{j,t} + a^r_{j+1,t+1} = y^r_{j,t} + \left[1+\left(1-\tau^r_{a,t}\right)r^r_t\right]\left(a^r_{j,t}+b^r_t\right) + p^r_{j,t} - \tau^r_{ls,t}. \tag{3}$$

We require households to die with non-negative wealth once they reach age $J$, but otherwise impose no borrowing constraint during their life. Net earnings $y^r_{j,t}$ accruing to households of age $j$ in region $r$ at time $t$ are defined as

$$y^r_{j,t} = \begin{cases} \left(1-\tau^r_{w,t}\right)w^r_t\varepsilon^r_{j,t} = \left(1-\tau^r_{w,t}\right)\tilde{y}^r_{j,t} & \text{if } j < J^r_R, \\ 0 & \text{if } j \geq J^r_R, \end{cases} \tag{4}$$

where $w^r_t$ is the market wage rate, $\varepsilon^r_{j,t}$ is the efficiency units of labor of a household of age $j$, and $\tilde{y}^r_{j,t}$ is the before-tax labor income. $p^r_{j,t}$ is pension income and takes a positive value for eligible individuals at and above social security's retirement age $j \geq j^r_{SS}$ and zero otherwise. $r^r_t$ denotes the interest rate households in region $r$ earn on their saving.

Households pay proportional taxes at the rate of $\tau^r_{c,t}$ on consumption, $\tau^r_{a,t}$ on capital income, and $\tau^r_{w,t}$ on labor income and a lump-sum tax $\tau^r_{ls,t}$. Residents of region $r$ pay capital income taxes in region $r$, independently of where capital was invested. Social security benefits are given by the formula

$$p^r_{j,t} = \kappa^r_t \frac{W^r_{j,t}}{J^r_{SS}-1},$$

where $\kappa^r_t$ is the replacement ratio of average past earnings. Cumulated past gross earnings $W^r_{j,t}$ are defined recursively as

$$W^r_{j,t} = \begin{cases} \tilde{y}^r_{1,t} & \text{if } j = 1 \\ \tilde{y}^r_{j,t} + W^r_{j-1,t-1} & \text{if } 1 < j < J^r_{SS} \\ W^r_{j-1,t-1} & \text{if } j \geq J^r_{SS}. \end{cases} \tag{5}$$

**Government Budget Constraint:** In each region $r$, public expenditures and social security program are administered by the government under a unique consolidated intertemporal budget constraint. The government can raise revenues by taxes on consumption, labor income, interest and capital income, and lump-sum taxes and can issue one-period risk-free debt, $B^r_{t+1}$. Government borrowing and tax revenues finance a stream of expenditures $G^r_t$ and the PAYG social-security program described above. The consolidated government budget constraint reads as

$$\begin{aligned} &G^r_t + (1+r^r_t)B^r_t + \textstyle\sum_{j=J^r_{SS}}^J p^r_{j,t}\mu^r_{j,t} = \\ &\tau^r_{w,t}w^r_t \textstyle\sum_{j=1}^{J^r_R-1}\mu^r_{j,t}\varepsilon^r_{j,t} + \sum_{j=1}^J \mu^r_{j,t}\tau^r_{a,t}r^r_t\left(a^r_{j,t}+b^r_t\right) + \sum_{j=1}^J \mu^r_{j,t}\tau^r_{c,t}c^r_{j,t} + \sum_{j=1}^J \mu^r_{j,t}\tau^r_{ls,t} + B^r_{t+1}. \end{aligned} \tag{6}$$

**Market Structure:** There are three goods in the world economy: a final good which can be used either for consumption or investment, the services of labor and the services of capital. The price of the final good (homogeneous across the three regions) is used as the world numeraire. Labor is immobile, thus wages are determined independently in regional labor markets.

In the open economy, we assume that physical capital is mobile across the three regions, so there is one world market for capital where the world return to capital is determined. Let $X_t^r$ denote the external wealth of region $r$ at time $t$, that is, the stock of capital used in production in other regions and owned by households of region $r$. A negative value indicates ownership of capital used for production in the region but owned by households of other regions. The sum of positive and negative external wealth across regions is zero in equilibrium, satisfying the condition $\sum_r X_t^r = 0$ at any time $t$. The markets where these goods and assets are traded are perfectly competitive. An intuitive no-arbitrage condition between assets and the absence of aggregate uncertainty imply that the return on the three regional bonds is equal to the return on physical capital, as we have already implicitly assumed when we wrote the budget constraints of the government and households.

In equilibrium, firms in each region maximize profits

$$\begin{aligned} w_t^r &= F_N(Z_t^r, K_t^r, N_t^r), \text{ for all } r \\ r_t^r &= F_K(Z_t^r, K_t^r, N_t^r) - \delta. \end{aligned}$$

If capital were perfectly mobile across regions, we would have the world interest rate $r^*$ equal the interest rates of all regions, that is, $r_t^* = r_t^{HI} = r_t^{MI} = r_t^J$. In our baseline economy, however, we assume that there is an exogenous transaction cost that reduces the return that foreign $(HI, J)$ savers earn on capital in $MI$. We include this transaction cost as a simple reduced form to capture region-specific expropriation risk typical of less developed financial markets. In addition, when MI households lend abroad, the differential captures the extra benefit for savers in MI to invest in safe assets abroad: $r_t^* = r_t^{HI} = r_t^J$ and $r_t^{MI} = r_t^*/(1-\phi)$, where $\phi \in (0,1)$ captures the transaction cost. We will calibrate this parameter to match the average net external wealth of Japan in the 1996-2015 period.

## 3.2 Equilibrium

Before stating the definition of equilibrium, it is useful to point out that, without further restrictions, the equilibrium path of the fiscal variables $\left\{G_t^r, \kappa_t^r, \tau_{w,t}^r, \tau_{a,t}^r, \tau_{c,t}^r, \tau_{ls,t}^r, B_t^r\right\}_{t=1}^{\infty}$ is indeterminate, as there is only one budget constraint we can operate on. In what follows, we define an equilibrium for the case where the paths of all fiscal variables are given, except for $\left\{\tau_{ls,t}^r\right\}_{t=1}^{\infty}$. It is straightforward to extend this definition to the case where the path of a different set of government policies is given exogenously. Finally, for brevity we omit the definition of the closed-economy equilibrium and state directly the equilibrium conditions for the open economy.

A *Competitive Equilibrium of the Multi-Region Economy*, for a given sequence of region-specific demographics, TFP levels $\{Z_t^r\}_{t=1}^{\infty}$, and fiscal variables $\left\{G_t^r, \kappa_t^r, \tau_{a,t}^r, \tau_{c,t}^r, \tau_{w,t}^r, B_t^r\right\}_{t=1}^{\infty}$, is a sequence of: (i) households' choices $\left\{\left\{c_{j,t}^r, a_{j,t}^r\right\}_{j=1}^{J}\right\}_{t=1}^{\infty}$, (ii) lump-sum taxes $\left\{\tau_{ls,t}^r\right\}_{t=1}^{\infty}$, (iii) wage rates $\{w_t^r\}_{t=1}^{\infty}$, (iv) aggregate variables $\{K_t^r, N_t^r, I_t^r, C_t^r\}_{t=1}^{\infty}$ in each region $r$, (v) world interest rates $\{r_t^*\}_{t=1}^{\infty}$, and (vi) external wealth positions $\{X_t^r\}_{t=1}^{\infty}$ such that:

1. Households choose optimally consumption and wealth sequences $\left\{\left\{c_{j,t}^r, a_{j,t}^r\right\}_{j=1}^{J}\right\}_{t=1}^{\infty}$, maximizing the objective function in (2) subject to the budget constraint (3), and the income process (4), and the time allocation constraint.

2. Firms in each region maximize profits by setting the marginal product of each input equal to its price, i.e.

$$\begin{aligned} w_t^r &= F_N(Z_t^r, K_t^r, N_t^r), \text{ for all } r, && (7) \\ r_t^r + \delta &= F_K(Z_t^r, K_t^r, N_t^r). && (8) \end{aligned}$$

3. The lump-sum transfer of accidental bequests equals the amount of assets left by the deceased, distributed equally to all households of the region.

$$b_t^r = \frac{\sum_{j=1}^{J-1} a_{j,t}^r (1 - s_{j+1,t}^r) \mu_{j,t-1}^r}{\sum_{j=1}^{J} \mu_{j,t}^r}$$

4. The regional labor markets clear at wage $w_t^r$ and aggregate labor supply in each region is given by

$$N_t^r = \sum_{j=1}^{J_R^r - 1} \mu_{j,t}^r \varepsilon_{j,t}^r. \tag{9}$$

5. The regional bond markets and the world capital market clear at the world interest rate $r_t^*$, and the aggregate stocks of capital in the two regions satisfy

$$K_t^r + X_t^r + B_t^r = \sum_{j=2}^{J} \mu_{j-1,t-1}^r a_{j,t}^r, \tag{10}$$

where

$$K_t^r = \sum_{j=1}^{J} \mu_{j,t}^r (a_{j,t}^r + b_t^r). \tag{11}$$

The world interest rate and regional interest rates satisfy the relationships $r_t^* = r_t^{HI} = r_t^J$ and $r_t^{MI} = r_t^*/(1-\phi)$, with the transaction cost $\phi \in (0, 1)$.

6. The lump-sum taxes $\left\{\tau_{ls,t}^r\right\}_{t=1}^{\infty}$ satisfy the consolidated budget constraint (6) in each region.

7. The allocations are feasible in each region, i.e., they satisfy the regional aggregate resource constraints

$$K_{t+1}^r - (1-\delta)\,K_t^r + X_{t+1}^r - (1+r_t^r)\,X_t^r = F(Z_t^r, K_t^r, N_t^r) - C_t^r - G_t^r. \tag{12}$$

Before concluding, it is useful to recall that aggregate gross investments in region $r$ are given by

$$I_t^r = K_{t+1}^r - (1-\delta)\,K_t^r, \tag{13}$$

whereas aggregate or national (private plus public) savings in the three regions are,

$$S_t^r = F(Z_t^r, K_t^r, N_t^r) + r_t^r X_t^r - C_t^r - G_t^r. \tag{14}$$

As a result, the current account balances of the three regions equal their respective changes in net asset positions, and, are given by,

$$S_t^r - I_t^r = CA_t^r = X_{t+1}^r - X_t^r. \tag{15}$$

The sum of these current account balances is zero.

# 4 Calibration

We calibrate the initial steady-state using demographic and economic variables for the period 1990-2015 in the three regions. We assume that demographic parameters stabilize in 2100 and TFP growth rates in the three regions converge to the same values in the long run, and all regions eventually reach a balanced growth path some time after 2200. We then let our world economy transition between the two steady-states. The model's period is annual. Our calibration strategy is to match a set of moments in the data with the model's counterparts in the *open economy.* Appendix B provides more details of the calibration, including description of various database used to compute statistics across regions. Calibrated parameters are summarized in Tables 1 to 4.

**The Three Regions:** As discussed above, there are three regions in the model, Japan, High-income and Middle-income regions. For High-income region, we include North America (United States and Canada), Europe, Australia, and New Zealand. For Europe, we include 28 countries that are members of European Union.

Middle-income region includes countries in Asia (China, Hong Kong, Taiwan, South-Korea, Singapore, Thailand, Indonesia, Malaysia, Philippines, Vietnam, India, Saudi Arabia, U.A.E., and Turkey), Mexico, Brazil, Russia, and South Africa.[7]

[7]We selected countries that have at least 100 billion yen (about $1 billion U.S.) of either foreign direct investment or portfolio investment according to the breakdown of Japanese foreign assets as of 2015 reported by the Bank of Japan. We exclude Cayman Islands from the list and also add Turkey to Middle-income region.

**Technological Parameters:** We assume a constant returns to scale production function

$$F(Z_t^r, K_t^r, N_t^r) = Z_t^r (K_t^r)^{\alpha} (N_t^r)^{1-\alpha},$$

with capital share $\alpha = 0.35$ in three regions, following Holmes, McGrattan, and Prescott (2015). Based on the World Bank's *World Development Indicators* (WDI), we obtain growth rates of output per capita in the three regions from 1990-2015, which stand at 1.1% in Japan, 1.4% in High-income region and 3.9% in Middle-income region. The growth rate of TFP $\lambda_t^r$ in each region is set so that the region achieves the target average per-capita output growth rate during the same period. Values of the calibrated parameters are indicated in Table 4.

After 2015, we let $\lambda_t^r$ of all regions converge smoothly to the common long-run growth rate of TFP, which we set to 1%.[8] We set the initial value of the Japanese TFP, $Z_0^J$, in order to normalize income per capita in Japan to 1 in 2015. Based upon the WDI, income per capita in High-income and Middle-income region in 2015 were 1.11 (\$45,373) and 0.31 (\$12,696) of that of Japan (\$40,763), respectively, and we set $Z_0^H$ and $Z_0^M$ to match these ratios. The depreciation rate of capital is set to 6% per year.

**Demographic Parameters:** The population data is based on the estimates of the United Nations (2017) for the High-income and Middle-income regions and on the data and projections of the National Institute of Population and Social Security Research (IPSS) (2017) for Japan. The population in 1990, the initial year of the transition, is 122 million in Japan, 778 million in High-income region, 2,976 million in Middle-income regions. The survival probabilities are computed based on the population data and projections by age for each region. The population dynamics thereafter follow the projections of the United Nations and the IPSS.

Each model-period corresponds to one year and we let households enter the economy at age $j = 1$, which corresponds to 20 years old, and live up to the maximum age of $J = 80$, up to 99 years old. We set the age to exit the labor force $J_R^r$ at 46, which corresponds to 65 years old.[9]

**Preferences and Endowments Parameters:** Preferences are common across regions. We set $\theta = 2$ based on the estimates in the literature (for a survey, see Attanasio, 1999). We set the subjective discount factor $\beta$ =1.0296 to match the target world rate of return on capital of 4% in 2015.

The calibration of the age profile of efficiency units is done separately for each region. The age-efficiency profile for Japan is based on the earnings data from the Basic Survey of

[8]We assume that the growth rate of Middle-income region converges over the next 30 years, by 2045, and those of Japan and High-income region by 2100. The TFP level in the long-run will differ across regions and the levels of Japan and Middle-income region will be around 0.75 of that of the High-income region. We simulate the model under alternative assumptions about the future growth of TFP across regions in section 5.

[9]Note that the age to exit the labor force $J_R^r$, which is assumed to be exogenous in the model, can be different from the retirement age for the purpose of the social system. The latter is a policy parameter as discussed below.

the Wage Structure (BSWS) in 2010. For High-income region, we use weekly wage data from the Consumer Expenditure Survey (CEX) for the period 1982-1999. For Middle-income region, we use estimates used in Attanasio, Kitao, and Violante (2007), an age-efficiency profile on Mexican data—precisely from the Encuesta Nacional de Ingreso y Gasto de los Hogares (ENIGH), which is the equivalent of the U.S. CEX, using 1989-2000 waves. For all data sources average earnings of male and female workers are used in the calibration.

**Transaction cost in the World Capital Market:** The transaction cost $\phi$ is calibrated to match the external wealth to output ratio in Japan during the 1996-2015 period, which stands at 40%. We assume a fixed value until 2020 and let it decline gradually to reach zero over a 80-year period and by the end of the century. In section 6, we simulate the transition under alternative assumptions about the transaction cost, including the case of zero cost and compare results to those of the benchmark transition.

**Government Debt to Output Ratios:** Government debt and expenditures as a fraction of output for High and Middle-income regions are computed from the IMF's World Economic Outlook database (WEO, 2017) as time-averages over the period 1990-2015.

The WEO data yield a ratio of government expenditures to output at 35%, 41% and 25% for Japan, High-income and Middle-income regions, respectively, in 1990-2015. These expenditures contain all expenditures including interest payments on the government debt and transfers such as social security benefits. We calibrate the ratio of the government expenditures in our model, $G_t^r$, to output to match these data and they turn out to be 25% in Japan, 34% in High-income and 20% in Middle-income region. The ratio of government debt $B_t^r$ to output in 1990-2015 was 51% and 31% in High-income and Middle-income regions, respectively, based on the WEO database. The debt level of the Japanese government, based on data from the Ministry of Finance, greatly fluctuated during the period and rose from 14% of output in 1990-1995 to approximately 120% in 2010-2015 and we set the ratio to 100%.

**Public Pension Replacement Rates:** Pension replacement rates for the three regions are calculated using OECD Pensions at a Glance (2014). In particular, we compute 'coverage adjusted' net replacement rates (NRRs) by multiplying NRRs by active coverage (defined as total number of contributors divided by labor force), available from the World Bank Pensions database (2014). The GDP (current PPP) weighted, coverage adjusted NRRs are 47.8%, 26.8%, and 38.5% for High and Middle-income regions and Japan, respectively.

The statutory retirement age is 65, 66 and 56 in Japan, High-income and Middle-income regions, respectively, based on the population-weighted average of the World Bank's database and we set the retirement age $J_{SS}^r$ in the model to these ages.

**Tax Rates:** Tax rates on consumption and assets are computed using the revenue data from the OECD Revenue Statistics, OECD National Accounts Statistics and UN National Account Statistics, following the method of Mendoza, Razin, and Tesar (1994). $\tau_a^r$ is set at 34.7%, 34.1% and 18.8% in Japan, High-income and Middle-income regions, respectively. Consumption tax rates are 10.9% and 12.7% for High-income and Middle income regions. The Japanese consumption tax rate had been zero until 1989, when it was set to 3% and increased to 5% in 1997, 8% in 2014 and 10% in 2019. We let $\tau^J_{c,t}$ increase accordingly and assume that it stays constant after 2019. Labor income tax rates $\tau^r_w$ are set to 32.8%, 17.0% and 29.8% for High-income, Middle-income and Japan, respectively. We adjust lump-sum tax $\tau^r_{ls,t}$ to satisfy the government budget constraint in each year and region. The paths of endogenously determined lump-sum taxes are reported in section 5.

Table 1: Demographic Parameters

| Parameter and description | | Value, source |
|---|---|---|
| $s^r_{j,t}$ | Survival rates | United Nations (2017) and IPSS |
| $n^r_t$ | Cohort growth rates | United Nations (2017) and IPSS |
| $J^r_R$ | Age to retire from the labor force | 46 (65 yrs) |
| $J$ | Maximum age | 80 (99 yrs) |

Table 2: Calibrated Parameters: Preferences, Technology and Endowment

| Parameter and description | | Value | Target, source |
|---|---|---|---|
| $\beta$ | Subj. discount factor | 1.0296 | Interest rate in 2015 |
| $\theta$ | Risk aversion | 2.0 | Attanasio (1999) |
| $\varepsilon^r_j$ | Wage profile | – | see text |
| $\alpha$ | Capital share | 0.35 | Holmes, McGrattan, and Prescott (2015) |
| $\delta$ | Depreciation rate | 0.06 | Holmes, McGrattan, and Prescott (2015) |
| $\phi$ | Transaction cost | 0.41 | External wealth of Japan in 1996-2015 |

Note: values are on an annual basis.

Table 3: Calibrated Parameters: Government

| Parameter and description | | Target, source |
|---|---|---|
| $D_t/Y_t$ | Debt to output ratio | IMF World Economic Outlook (2017) |
| $G_t/Y_t$ | Gov. purch. to output ratio | IMF World Economic Outlook (2017) |
| $\kappa_t^r$ | Pension replacement rate | OECD Pension at a Glance (2014) |
| $J_{ss}^r$ | Pension retirement age | 66 (HI), 56 (MI) and 65 (Japan) World Bank Pensions database |
| $\tau_{c,t}^r$ | Consumption tax | OECD Revenue Stat., OECD/National Acct. Stat., Mendoza, et al (1994) |
| $\tau_{a,t}^r$ | Capital income tax | OECD Revenue Stat., OECD/National Acct. Stat., Mendoza, et al (1994) |
| $\tau_{w,t}^r$ | Labor income tax | OECD Revenue Stat., OECD/National Acct. Stat., Mendoza, et al (1994) |

Table 4: Growth rate and level of TFP

| Region | GDP per capita growth, WDI (1990-2015), target | TFP growth rate $\lambda_t^r$(1990-2015) calibrated | GDP per capita level, WDI 2015, target | Initial TFP level $Z_0^r$ calibrated |
|---|---|---|---|---|
| Japan | 1.1% | 0.99% | \$40,763 (1.00) | 0.60 |
| High Income | 1.4% | 0.90% | \$45,373 (1.11) | 0.76 |
| Middle Income | 3.9% | 1.98% | \$12,696 (0.31) | 0.31 |

# 5 Quantitative Findings

In this section, we present our numerical findings that characterize equilibrium transition paths from the initial steady state that represents the economy in 1990 to a final steady state in the distant future.[10]

These equilibrium paths are computed under the 'perfect foresight' assumption and are therefore deterministic. All households and firms have perfect information on factor prices and fiscal policy parameters (tax rates, benefits, etc.) and make optimal decisions under new demographic variables and fiscal parameters and associated (endogenous) factor prices, given their asset holdings in the initial steady state. In other words, cohorts that are alive in 1990 re-optimize given their new demographic and policy environments. Along the transition, like in the initial and final steady states, it is assumed that a lump-sum

[10]In the program, we compute transitions of about 400 periods (from 1990 to 2400), long enough to guarantee a smooth convergence of all variables to the final steady state.

tax adjusts in each time period to satisfy the government's budget. These computations form our baseline results below.

In most of the figures below, we will show the equilibrium transition paths under two separate assumptions on the closeness of the economies. First, we compute the transitions under the assumption that each region has been operating in a world economy in the initial steady state and will remain open forever. Alternatively, in the closed economy computations, we assume that there are three segmented regions in the initial steady state and the transition path such that labor and capital are both immobile with segmented equilibria in three regions.

## 5.1 Baseline Transitions

**Capital Labor Ratios in the Three Regions:** We begin with the actual and projected labor supply in the three regions in Figure 3, normalized to unity in 1990. In the High-income region, the labor force is predicted to decline gradually and then stabilize around 2050. In the middle income region, there is a significant increase from 2015 to 2035 but then an equally significant drop after 2045. In Japan, however, there is a monotonic decline throughout and by 2070 the labor supply is projected to drop by approximately 45%.

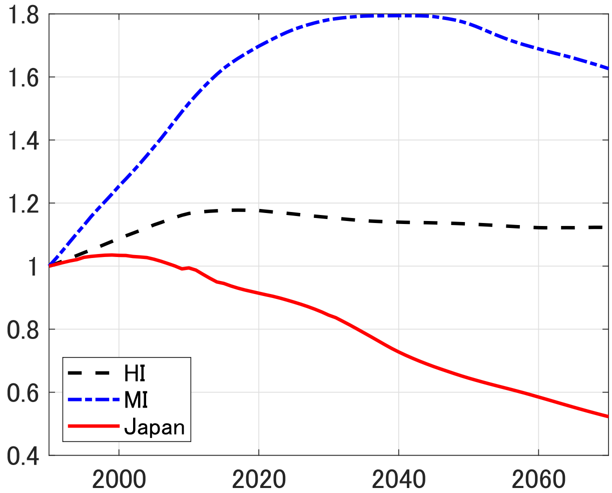


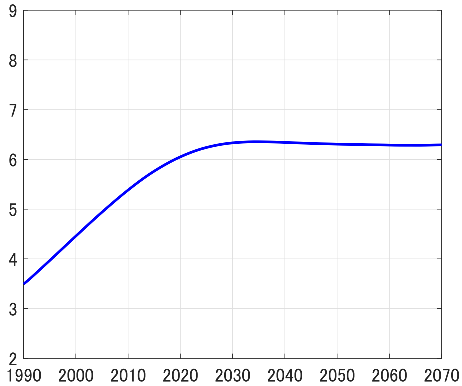

Figure 3: Labor Supply

Given these exogenous demographic effects on labor supply, the paths for capital labor ratios will be determined by what happens to saving behavior and capital accumulation in the three regions.

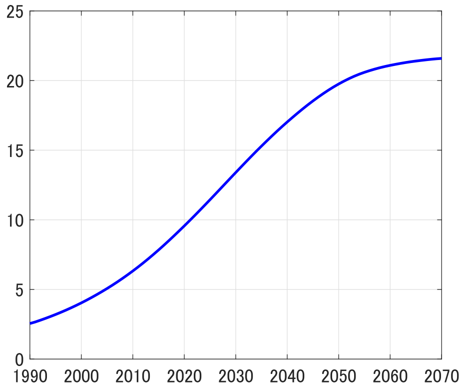
Figure 4 depicts endogenous capital accumulation behavior in response to demographics and also the particular fiscal policy of raising lump-sum taxes in the three regions to satisfy the respective governments' budget constraints. Paths of capital in the closed economy help us understand the roles of aging demographics on saving behavior in isolation from capital flows across regions.

Under the closed economy case, capital would rise rapidly in the Middle-income region, which will experience a rapid and significant demographic aging during the next several decades. Their less comprehensive social security systems give additional incentives to save for retirement compared to the HI region and Japan.

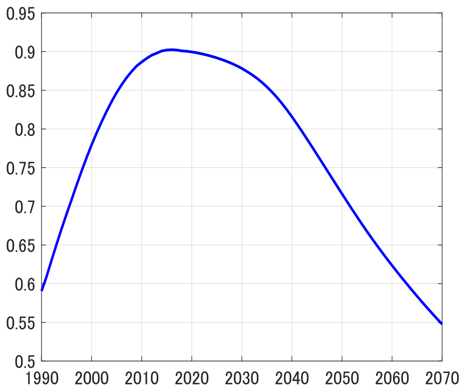
In the High-income region, the capital stock rises until about 2025 but stays flat through 2070. In Japan, capital initially increases with demographic aging but starts to fall after the mid 2010s. A rise in longevity strengthens the life cycle saving motive to provide old age consumption for a longer period of retirement. The sharp decline in the fraction of working age population, on the other hand, decreases the relative share of 'savers' and as a result capital decumulates throughout the 2015-2070 period under the closed economy.




(a) High Income




(b) Middle Income




(c) Japan

Figure 4: Capital Stock in the Closed Economy

Figure 5 shows the paths of capital-labor ratios in the closed economy equilibrium of the three regions. Capital labor ratios monotonically rise in the MI region because of strong growth of capital stock as we saw above. In the HI region, the ratios rise until around 2030 and stabilize thereafter. Japan shows a similar trend, but the ratios will decline after 2040s as the capital stock falls faster than labor supply declines.

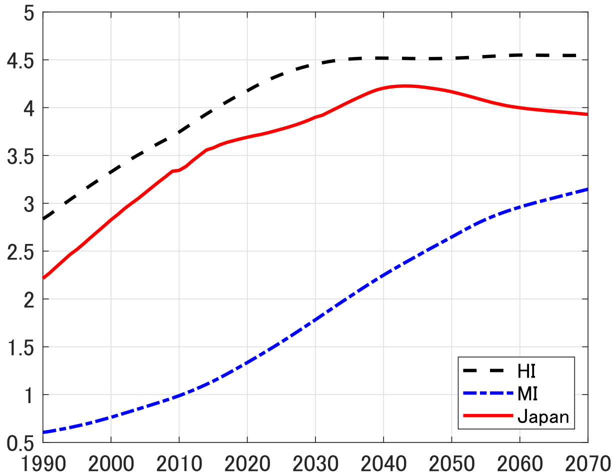



Figure 5: Capital Labor Ratios in Closed Economy

Although the capital labor ratios generally rise in all three regions until about 2040s, the gap between them shrinks. Figure 6 displays the capital labor ratios in the HI and Japan regions relative to those in the MI region. After about 1995, there is larger capital deepening in the MI region compared to the HI region and Japan, suggesting that the return to capital would be higher but would fall faster in the MI region in the closed economy version of the model.

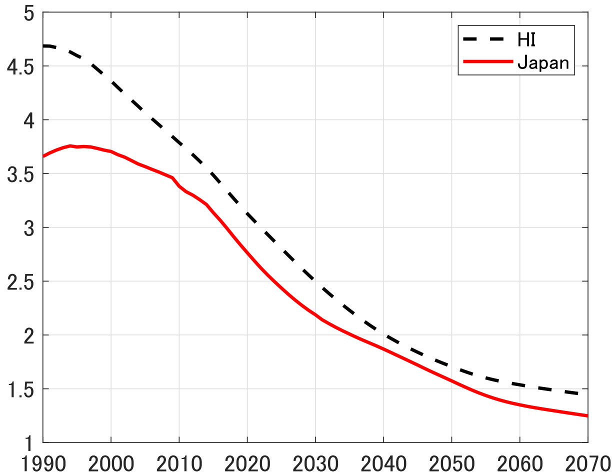



Figure 6: Relative Capital Labor Ratios in Closed Economy (HI and Japan relative to MI)

**TFPs and Interest Rates in the Closed Economy:** Paths of factor prices are affected by the dynamics of aggregate capital and labor examined above, as well as the trajectory of the TFP. With our GDP per capita growth rates of 0.99%, 1.98%, and 0.90% for the HI and MI regions and Japan, respectively, for the 1990-2015 period, and the growth rate assumptions beyond 2015, the time paths of TFP levels are shown in Figure 7. Even though the TFP levels are increasing in all regions, while the growth rates converge to a common value in the long-run, the rate of increase is higher in the MI region.

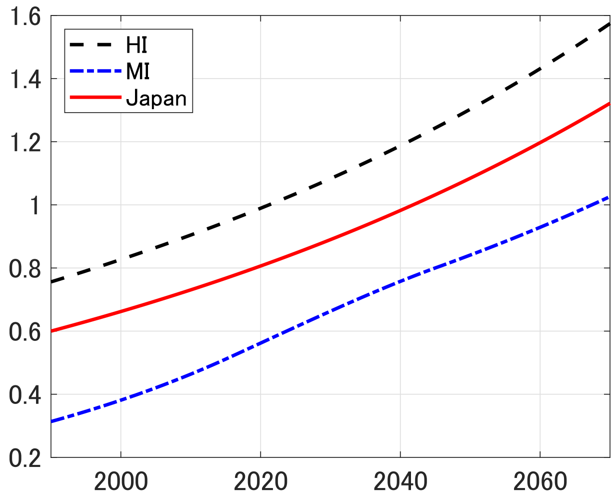



Figure 7: Total Factor Productivity in the Three Regions

Figure 8 indicates how the gaps between the TFP levels in the HI region and Japan relative to that in the MI region shrink over time in the model. The relative TFPs move more slowly after 2040. The decline in the relative TFPs counter the incentive to move foreign capital out of the MI region that a rising capital labor ratios would imply.

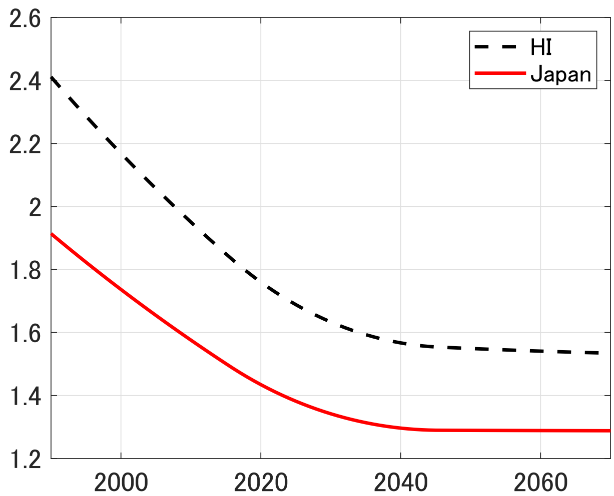
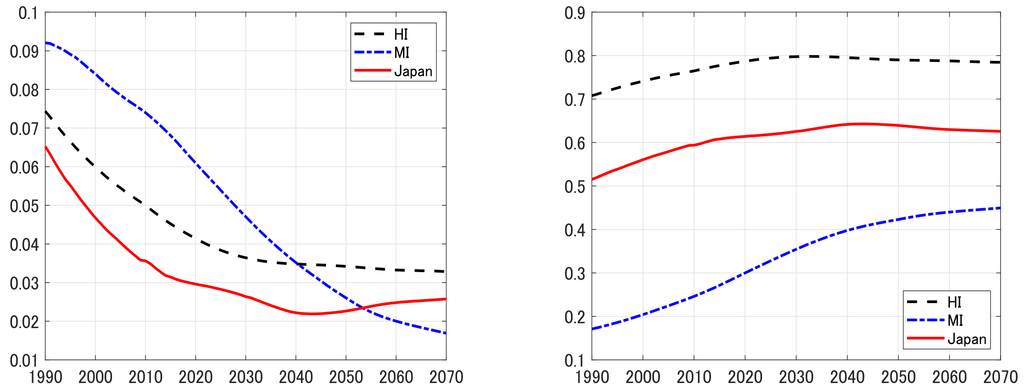



Figure 8: Relative TFPs (HI and Japan relative to MI)

Figure 9 shows the returns to capital and labor under the closed economy of the three regions. In the HI region, the interest rate falls until 2030, stays fairly flat thereafter and stays almost unchanged until 2070. In the MI region, the interest rate monotonically falls from 6.7% in 2015 to 1.7% in 2070. In Japan, the closed economy interest rate is rather flat, similar to that in the HI region, but at a much lower level. These differences in the interest rate in the closed economy, as driven by the dynamics of capital labor ratios and TFP, are what will drive the flow of capital across regions in the open economy.

The only region that enjoys continuously rising wages is the MI region. Wages are flat for most part of the period in the HI region. In Japan, wages rise initially but declines slightly after 2040 following the trajectory of capital labor ratios.




(a) Interest Rate (b) Wage

Figure 9: Factor Prices in Closed Economy

**Fiscal Adjustments in the Three Regions:** We now look at the magnitude of adjustments undertaken in these three regions to maintain fiscal sustainability in the future. In our baseline results, we assumed that the lump-sum tax is used to satisfy government budgets, holding the initial debt to output ratios and other tax rates constant. Figure 10 shows the time paths of lump-sum taxes that maintain fiscal sustainability in these regions in the closed economy transitions.

Aging demographics will raise expenditures for old-age transfers and by more in economies that have more generous benefits. At the same time, a decline in the labor force would reduce tax revenues. As shown in the figure, Japan will experience a rapid increase in the fiscal burden during the next decades. The MI region has a lower replacement rate of social security and will experience a milder increase initially but tax will continue to rise as dependency ratios increase rapidly.

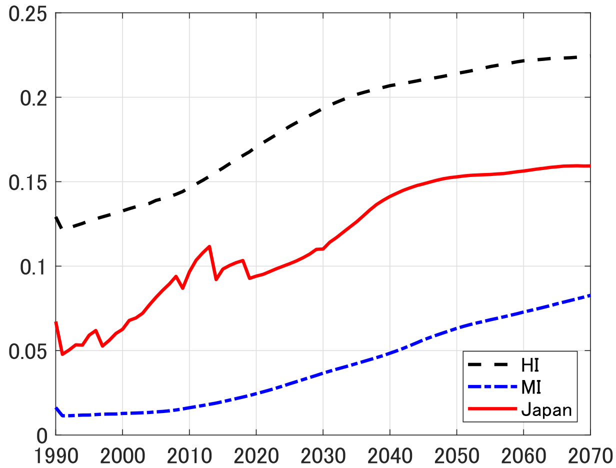



Figure 10: Lump-sum Tax in Closed Economy

**External Wealth and Factor Prices in the Open Economy:** Now we will turn our attention to our open economy and study how flows of capital across the three regions affect the transition paths. Our focus of the analysis is on the comparison of transition paths under closed and open economies in Japan.

As discussed in section 4, the transaction cost $\phi$ associated with the return to capital from the HI region and Japan to the MI region is calibrated to match the net external wealth to output ratios in Japan, for which we use the Bank of Japan data available during the 1996-2015 period. Figure 11 shows the ratios of net external wealth in the data and model during the calibration period. A rise in net external wealth occurs in Japan because of a decline in the interest rate that occurs faster than in other regions during the period, as we saw in figure 9a, and incentives to allocate more wealth abroad are strengthened.

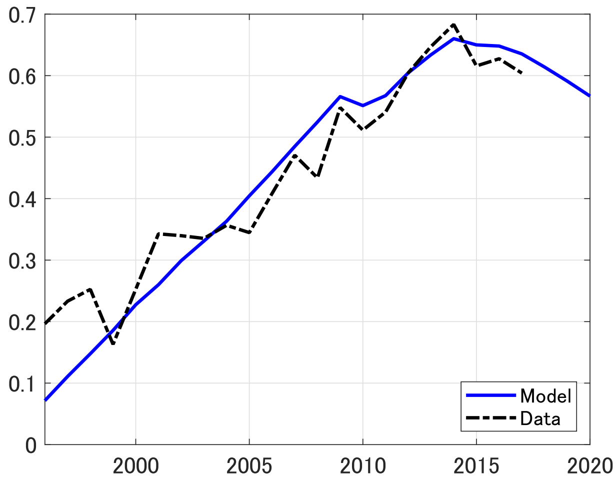
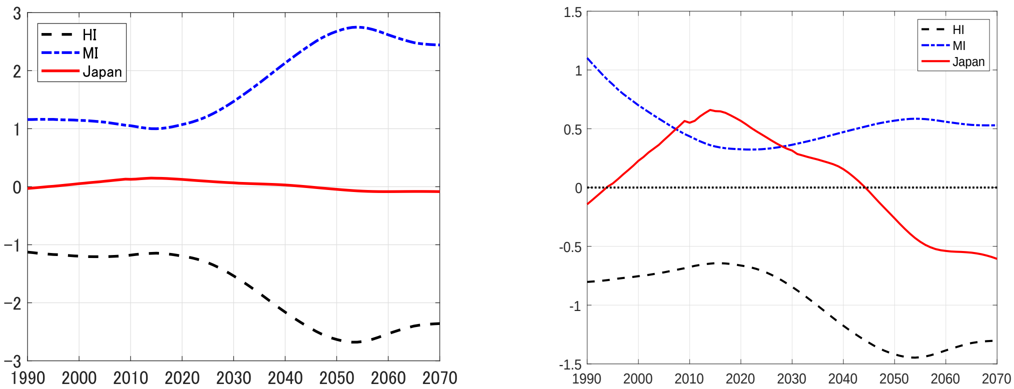



Figure 11: External Wealth to GDP Ratio in Japan: Model and Data

Figure 12 shows the path of net external wealth held by households in the three regions. The MI region will hold external wealth and claims in the HI region and Japan throughout the transition, while the HI region will remain a recipient of external wealth from the rest of the regions. Japan and the HI region do not start as lenders to the MI region due to the transaction cost associated with the capital flow to the MI region. The MI region, despite its high return to capital in the domestic market, is willing to lend abroad due to the symmetric transaction "returns," which as we discussed above can be interpreted as gains they enjoy by investing in safe assets in more developed financial markets.[11] To show the size of the external wealth within each region, the right panel of Figure 12 shows the net external wealth to output ratios in the three regions.

In Japan, the external wealth to output ratios increase until the mid-2010s and start to fall thereafter, as the gap in closed economy interest rate between Japan and other regions starts to shrink. This is also seen in figure 13a, which shows the paths of interest rates in closed and open economies faced by Japan. The paths intersect in the mid 2040s, after which the open economy interest rates are lower and Japan turns from a net lender to a net borrower from abroad.

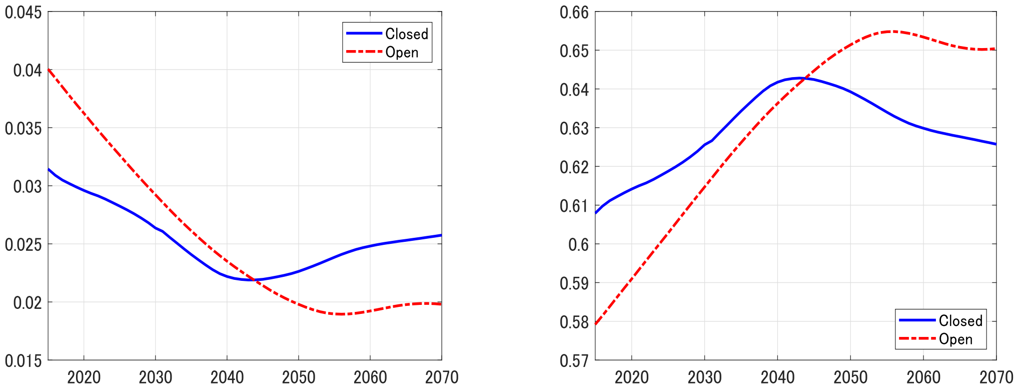



(a) Level

(b) Ratio to Output

Figure 12: External Wealth in Open Economy

[11]For example, the interest rate of the MI region in the closed economy is above 9% in 1990, as shown in Figure 9a, while those of the HI region and Japan are around 7.3% and 6.5%, respectively. The MI interest rate is not high enough for the other regions of the world to be a lender due to the transaction cost; they would not find it an attractive investment unless $r^{MI}(1-\phi)$ is above their local interest rates. For agents in the MI, rates are lower abroad but they are high enough for them to willingly lend because of the "gains" due to the symmetric transaction cost. If, for example, $r^{HI}/(1-\phi)$ is above their local interest rate, then the MI region is willing to lend to the HI region.




(a) Interest Rate

(b) Wage

Figure 13: Factor Prices in Japan: Closed and Open Economy

Figure 14 shows that capital stock will be higher in the open economy transition path than in the closed economy after the mid 2040s. The additional capital comes from the MI region, that faces monotonically decreasing returns from domestic capital. The decline of capital stock in the closed economy is accompanied by an even larger shrinkage of the labor force, which makes the capital-labor ratio rising until the mid 2040s, when eventually it levels off (see figure 5). This path shapes the pattern of wage rate which rises until the mid 2040s and then starts to decline, as shown in figure 13b. The wage peak in open economy is instead reached later, at about mid 2050s, due to capital inflows.

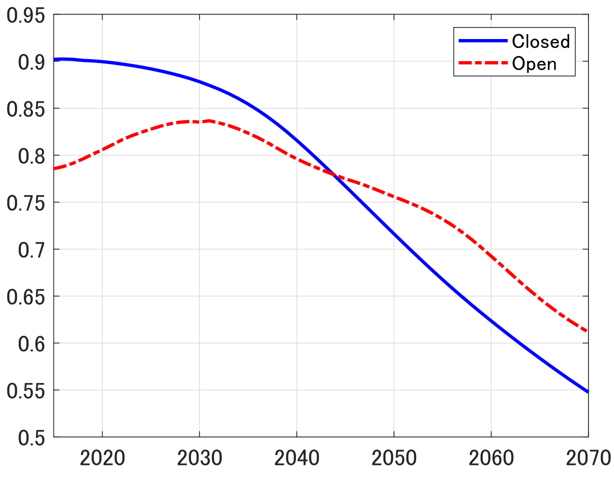



Figure 14: Capital in Japan: Closed and Open Economy

**Fiscal Effects of Capital Flows:** An interesting question is whether the effects of aging demographics on fiscal sustainability would be different under the open economy market setting where we allow for capital mobility. Figure 15 shows the transition paths of equilibrium lump-sum taxes that are needed to satisfy the government's budget in Japan and maintain a constant debt to GDP ratio, under the two scenarios.

There are opposing effects on the fiscal burden in the open economy version of the model. Output and wages are eventually higher due to capital inflows which imply higher tax revenues, while capital income is lower (with a lower world return to capital) and social security expenditures are also higher in the long run due to larger contributions that are linked to higher wages. As shown in figure 15, it turns out that taxes are slightly lower in the open economy, but the magnitude of the increase, for example from 2020 to 2070, is very similar under the two cases, implying that fiscal reforms would be needed independently of the openness of the economy and future capital flows into Japan.[12]

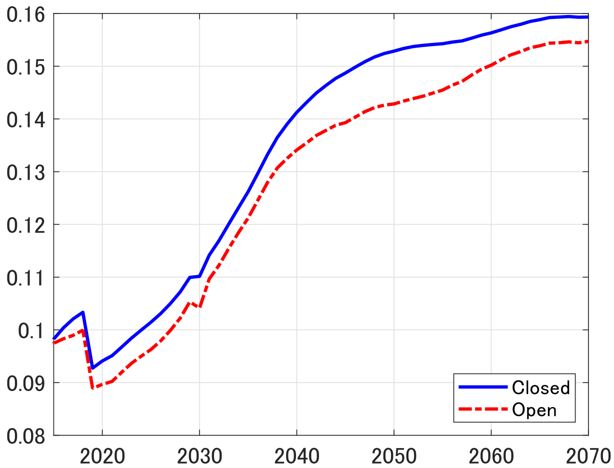



Figure 15: Lump-sum Tax in Japan: Closed and Open Economy

**National Saving, Regional Investment and Current Account Implications:** In our open economy transitions, capital is mobile across regions subject to the transaction cost and facilitates the smoothing of lifetime consumption of individuals in national economies or regions. Figure 16 shows the time paths of current account to output ratios in the three regions in the open economy. The transition is characterized with persistent current account surpluses in the middle income region whereas in the HI region and Japan there are current account deficits. Put differently, capital flows into Japan and the HI region from the economies in the MI region.

[12]Since we use non-distortionary lump-sum taxes to balance the government budget, the positive effects of openness in our simulation may well be considered as a conservative estimate of such effects. Using distortionary taxes that undermine tax base may have stronger effects and generate larger differences between open and closed economies.

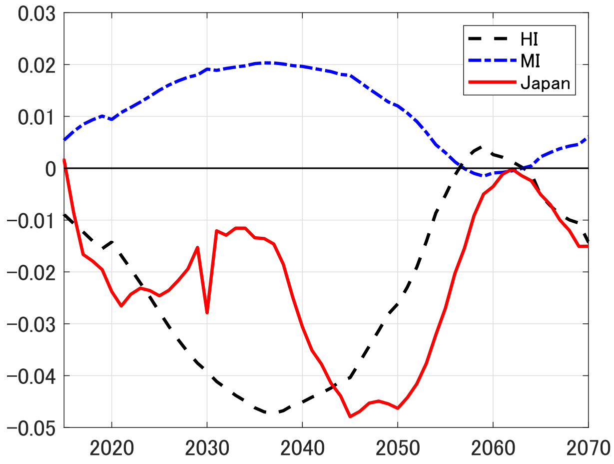
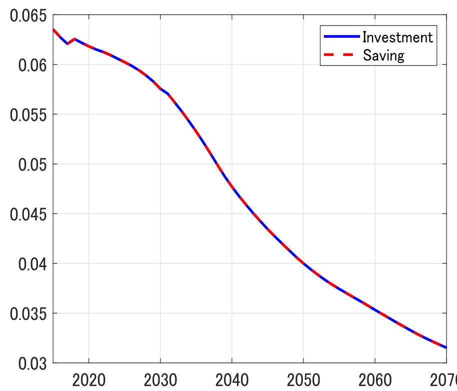
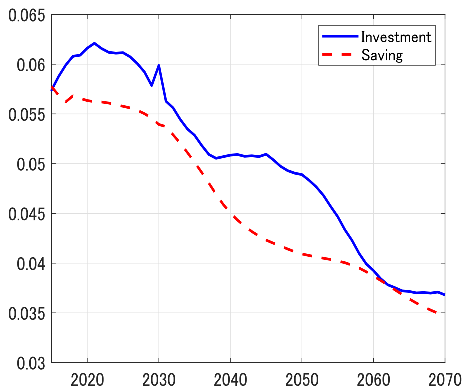



Figure 16: Current Account to GDP Ratio

In order to understand the sources of the trends in the current account balances of Japan, consider the time paths of domestic investment and national saving in closed and open economy transitions. Figure 17a shows the time path of national saving and domestic investment in Japan in the closed economy transition. As they are equal in a closed economy, the curves coincide with the current account at zero by construction. Note that national saving falls throughout the 2015-2070 period. There are two main reasons for this. First, the increase in (lump-sum) taxes to achieve fiscal sustainability forces individuals of all ages to consume and save less over time. As a result, total national saving falls over time. Second, the rapid aging of the population reduces the relative share of savers in the economy.




(a) Closed Economy




(b) Open Economy

Figure 17: Investment and Saving in Japan

Figure 17b shows the paths of national saving and investment as a share of output in the open economy transition. National saving declines similarly to the case of the closed economy but the fall in domestic investment is slower as foreign capital starts to flow in with the decline in national saving not matched with a relatively stable regional investment in Japan. This suggests that the effect of catching up of the TFP level in the MI region is dominated by the opposing effect of the catching up of the capital labor ratio in the MI region, thereby not diverting investments from Japan.

Figure 18 combines the saving and investment behavior as a percentage of GDP. According to our numerical results, Japan will soon start running current account deficits primarily due to the decline in national saving.

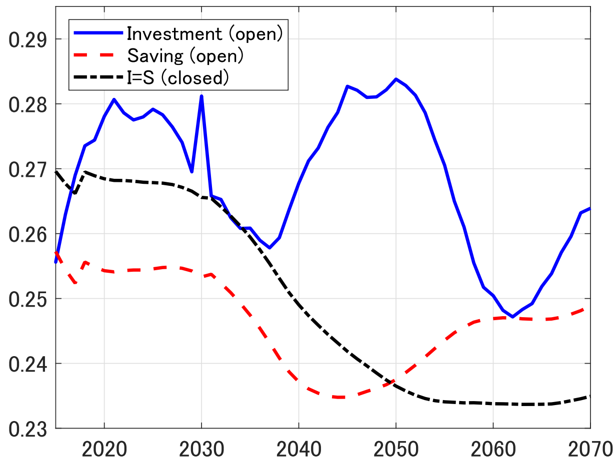



Figure 18: Investment and Saving in Japan

**GDP and Living Standards:** Figure 19 displays output in Japan in the closed and open economy transitions. Although output (measured as GDP) falls in both cases, the decrease is slower in the open economy case because capital inflows help produce more output than otherwise.

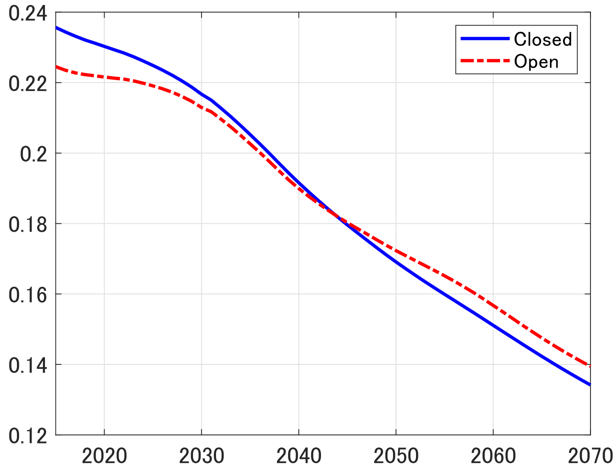



Figure 19: Output in Japan

Figure 20 shows the ratio of output to labor under the closed and open economy transitions. Typically interpreted as an indicator for living standards, the ratio starts lower in the open economy transition but it increases more rapidly than in the closed economy and continues to rise until mid 2050s, while it starts to decline in the early 2040s under the closed economy transition. The main reason for the difference is the capital inflows and the corresponding increase in output in the open economy.

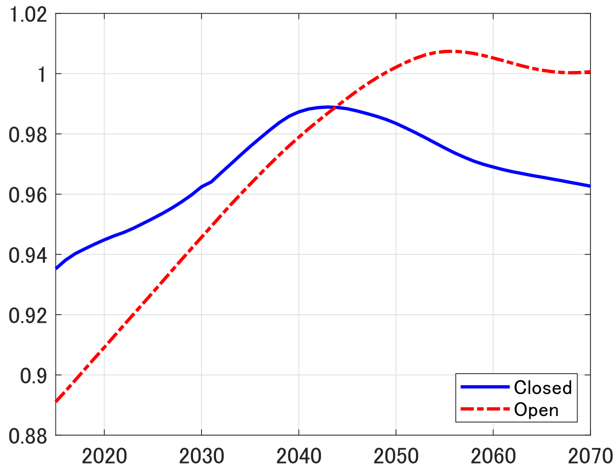



Figure 20: Output per Labor in Japan

**Current Account and Net Asset Position in Japan:** Figure 21 shows data on Japan's current account balance as a percentage of GDP based on the data from the Ministry of Finance and the model's estimates for the same period, as well as model's projections in the near future. According to our model's predictions, Japan's current account can turn negative soon and capital flows are reversed for several decades. This current account balance improves and becomes zero at the end of the century. The main reason for this behavior is the large decline in Japanese national saving while domestic investment stays substantially above national saving after 2020 through 2060 as shown in figure 17 above.

Japan is currently a significant net lender to the rest of the world, with its 2015 net foreign asset position at about 60-70% of GDP as shown in figure 11. The earlier onset of aging and the magnitude of aging in Japan lead to a large decline in national saving and our model predicts a shift in the flow of net assets. The decline in this net foreign asset position starts soon and Japan becomes a net international borrower before 2050 according to our quantitative results.

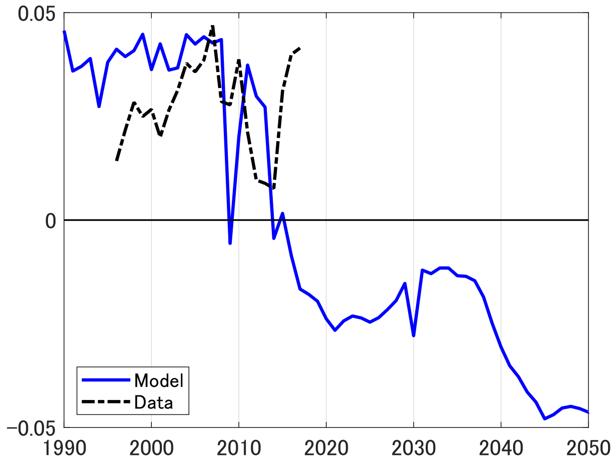


Figure 21: Current Account to Output in Japan

# 6 Alternative Scenarios and Sensitivity Analysis

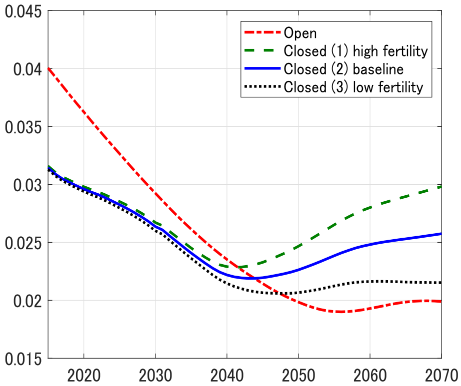
As we mentioned in section 2, capital flows are affected by various factors, including the timing and extent of projected demographics, TFP paths and fiscal policies. In this section, in order to assess the quantitative importance of these different factors in explaining capital movements affecting Japan, we discuss the sensitivity of our results to alternative assumptions of the model and study equilibrium paths with the following features:

- Alternative demographic paths
  - Lower or higher fertility rates in Japan and alternative population growth
  - Convergence of survival probabilities in the MI region to those in Japan
- Alternative fiscal policies
  - More generous social security in the MI region
  - Less generous social security in Japan
- Alternative capital adjustment costs

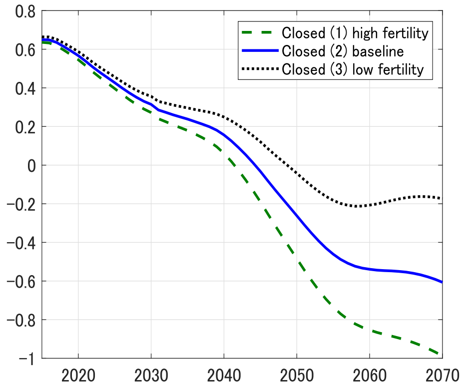
## 6.1 Demographics in Japan

Figure 22 shows the paths of closed economy interest rates in Japan under three scenarios of fertility rate projections. We use high and low variants of the IPSS projections. A higher fertility rate implies a larger labor supply in the future, reducing the capital labor ratio and generating a higher equilibrium interest rate in the closed economy. As shown in the figure, the closed economy interest rate will be higher by about 0.5 percentage points by 2070.

Although the change does not affect the open economy interest rate, the closed economy interest rate will start to lie above that of open economy earlier with the high fertility rate and stays well above in the following decades, as shown in figure 22a.[13] Hence, as shown in figure 22b, net external wealth in Japan will turn negative sooner and Japan will have a larger amount of net borrowing from the other regions under higher fertility rates in the long-run.




(a) Interest Rate in Japan




(b) External Wealth to GDP in Japan

Figure 22: Lower and Higher Fertility Rates in Japan

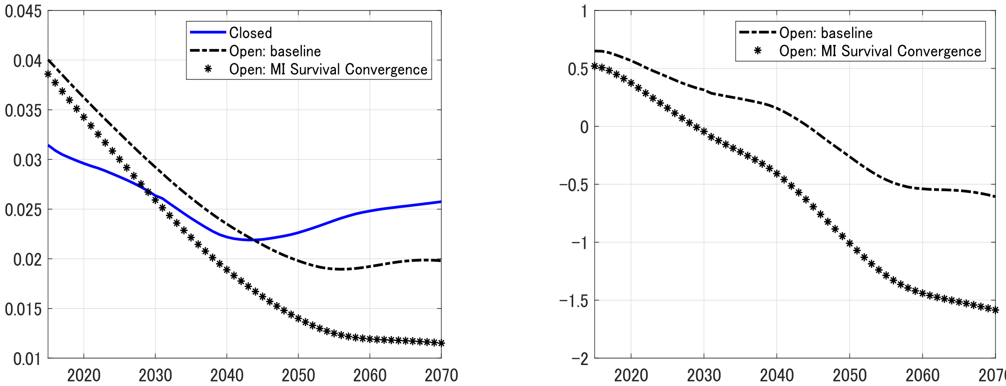
## 6.2 Demographics in the MI Region

In the baseline simulations, we use the population projections of the U.N. which indicate a large gap, even towards the end of the century, in the survival probabilities and life expectancies between the MI region and other regions. Here, we consider an alternative scenario about the demographic projections of the MI region, assuming that survival probabilities will increase more rapidly and grow fast enough to reach the level of Japan over the next 50 years.

Figure 23a shows the paths of open economy interest rates in the baseline and under this alternative scenario. A rise in longevity leads to stronger saving motives for retirement and a larger aggregate capital will lower interest rate in the MI region. Given the large size of the MI region in the world economy, the open economy return to capital will be lower. Figure 23b shows that capital will flow to Japan much earlier and in larger quantities relative to the benchmark. Both the timing and the magnitude are determined by the

[13]The figure shows the path of the open economy interest rate in the baseline scenario, but the paths are essentially the same under variants of fertility rates in Japan since Japanese assets make up a small fraction of the world financial markets.

new development of demographic aging in other regions of the world. In particular, the speed with which the MI region catches up with HI and Japan in terms of longevity will expedite the flow of capital to both HI and Japan.



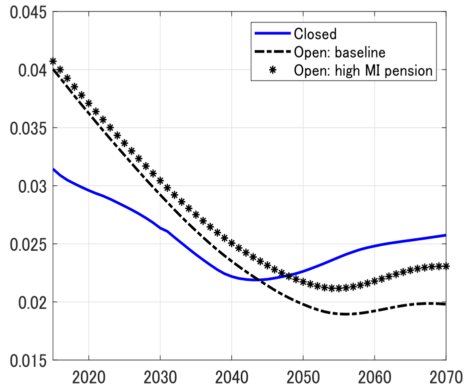

(a) Interest Rate in Japan (b) External Wealth to GDP in Japan

Figure 23: Convergence of Survival Rates of MI

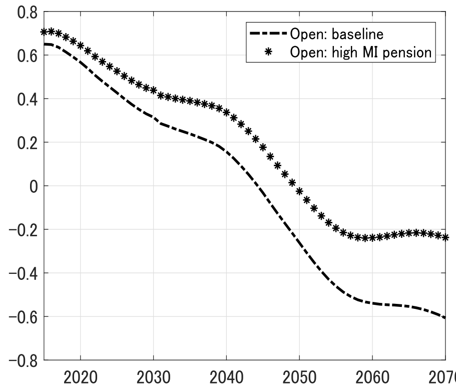
## 6.3 Social Security in the MI Region

The social security in the MI is less comprehensive than in the HI region or Japan and the replacement rate of public pensions is lower. In this subsection we simulate a transition assuming that the MI region starts to provide more generous retirement benefits. More precisely, we let the replacement rate of the MI region, which stands at 26.8% in the baseline, increase to the level of Japan, 38.5%, gradually over the next 20 years.

Under this alternative assumption, households in the MI region will have lower retirement saving motives and and the resulting decline in their capital stock raises equilibrium open economy interest rates as shown in figure 24a. Given higher interest rates within the MI region, capital will flow less towards other regions. Net external wealth in Japan will turn negative by about five years later than in the baseline model and the level of external wealth will be less negative thereafter as shown in figure 24b.




(a) Interest Rate in Japan




(b) External Wealth to GDP in Japan

Figure 24: More Generous Pension in MI

## 6.4 Social Security in Japan

In this section we study the effects of a reduction in the pension replacement rate in Japan, motivated by ongoing policy discussions concerning how to improve fiscal sustainability. We assume that the replacement rate declines by 20% over a 30 year period in Japan, a magnitude equivalent to what a successful reform under the current policy agenda implies.[14]

Figure 25 shows the path of the capital stock in the closed economy in the baseline and under the scenario of lower pensions. Lower pensions will have a sizeable effect on household savings and the capital stock will be higher by almost 10% by 2070.

[14] The policy reform implemented in 2004 included an automatic adjustment scheme of pension benefits called the "macroeconomic slide," which according to projections of the Ministry of Health, Labour and Welfare, would lower the replacement rate by approximately 20% before 2050 from the current level in 2019.

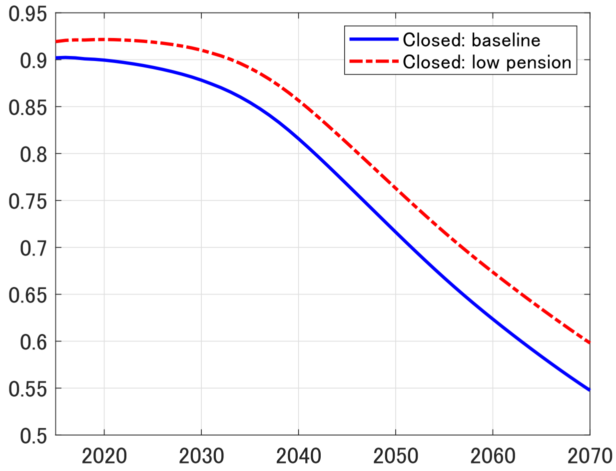
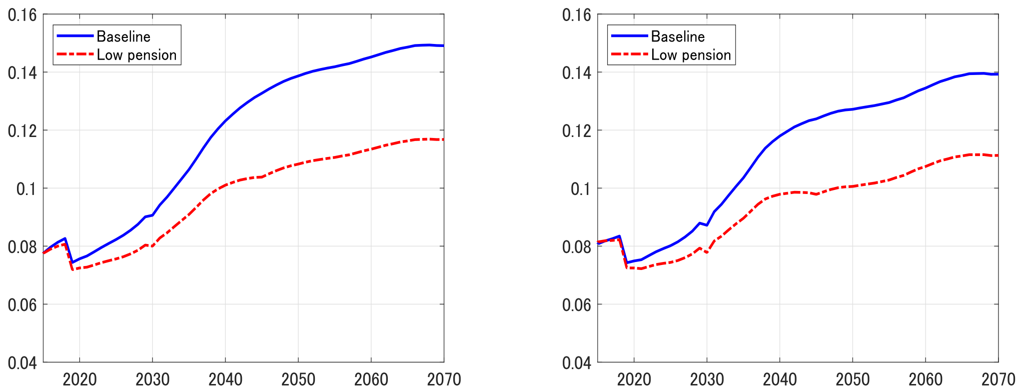



Figure 25: Less Generous Pension in Japan: Capital Stock in Closed Economy

Less generous pension will lower government expenditures and will reduce the tax burden significantly, as shown in figure 26. Comparing the two panels of the figure, the level of taxes under the baseline model is slightly lower in the open economy although the trend remains unchanged as we discussed above. The social security reform considered in this subsection will have similar quantitative effects under closed and open economies as shown in the figure.

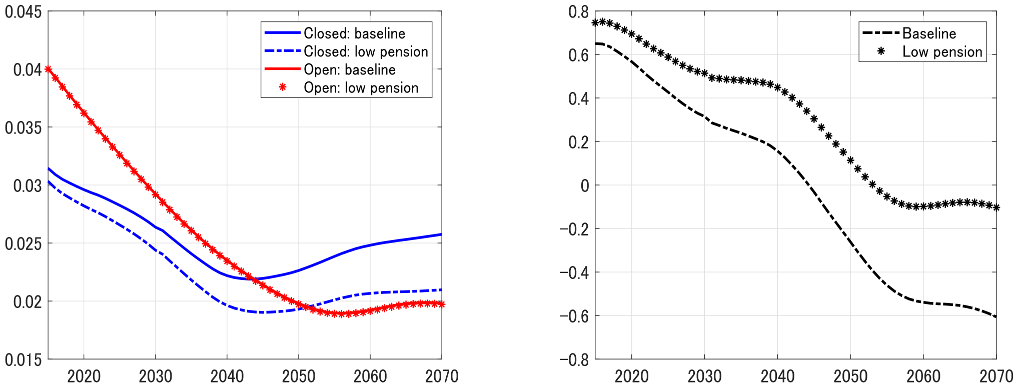



(a) Closed Economy

(b) Open Economy

Figure 26: Less Generous Pension in Japan: Lump-Sum Tax

Figure 27a shows paths of the return to capital. In the open economy version of the model, the world interest rates are not affected by the pension reform in Japan but the closed economy interest rates in Japan are lower through out the transition due to the increase in the Japanese aggregate capital stock. In the open economy case, this decline in the closed economy interest rates would lessen the quantity of capital that would need to flow into Japan to equate the regional returns and as a result, less capital flows to Japan and the net external wealth held by Japan will be much higher as shown in figure 27b.




(a) Interest Rate in Japan

(b) External Wealth to GDP in Japan

Figure 27: Less Generous Pension in Japan

## 6.5 Transaction Costs

In the baseline simulation, the parameter that represents 'transaction costs of capital' is set to 0.41 of returns and we assume that the cost will fall gradually to zero after 2020. The symmetric transaction cost is a reduced form device which approximates a cost that lenders in the international capital markets incur in investing in less developed financial markets or an extra benefit that lenders in less developed markets derive from investing in safe assets in high income economies. It is of course an open question how such costs are large or how they will evolve over time in the future. In this section we characterize an equilibrium transition under alternative scenarios about paths of transaction costs, assuming that they will fall but only by about one-half, to 0.20 in the long run, or they do not change and remain at 0.41.

In this new scenario, households in the MI region will perceive investment in Japan (and HI) as providing the additional benefit longer and continue to lend additional amounts. Hence, as shown in figure 28, Japan will receive a greater amount of capital flow, thus experiencing larger current account deficits, and will have more negative net external wealth. The magnitude of the net external wealth differs (see figure 29b) but the direction of capital flows remains unchanged under alternative scenarios. Since less capital will stay in the MI region, the world interest rate will be higher in the open economy as shown in figure 29a.

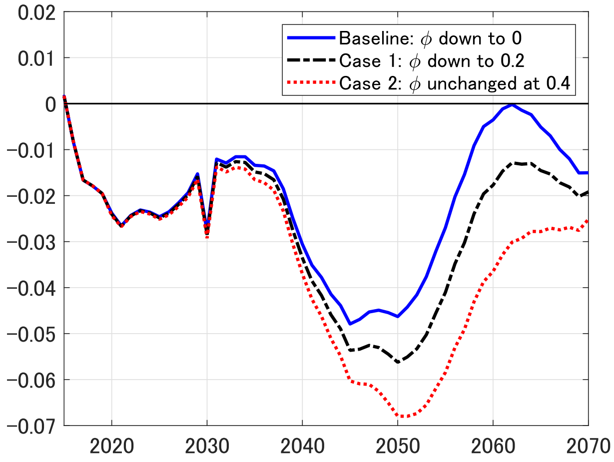
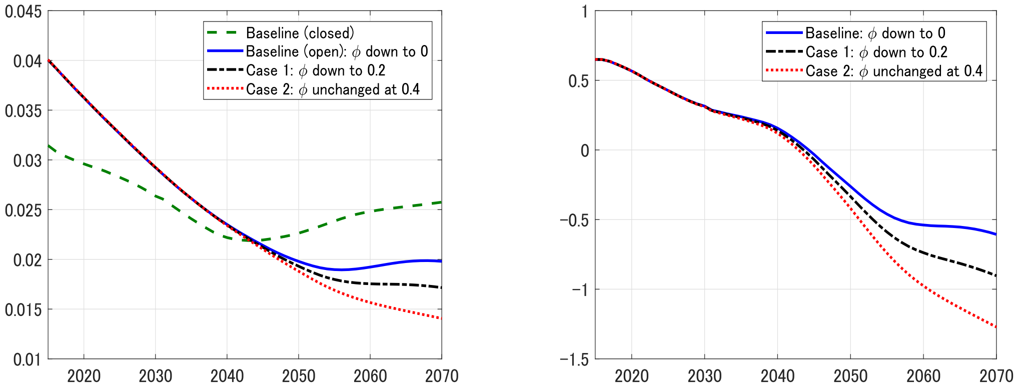



Figure 28: Alternative Capital Adjustment Cost: Current Account to GDP ratios




(a) Interest Rate in Japan

(b) External Wealth of Japan

Figure 29: Alternative Capital Adjustment Cost

# 7 Conclusion

With improvements in longevity in all countries and declines in fertility in most regions, populations have been aging. The timing and the severity of these demographic trends are different across advanced and emerging economies. With existing differences in social security programs in place, the differential aging will impact saving and investment decisions and therefore capital flows in coming decades.

This paper develops a general equilibrium model populated with overlapping generations of individuals located in three regions that demonstrate large differences in their demographic trends and pension programs. Labor is immobile and there are segmented regional labor markets with regional wage rates. Capital, on the other hand, is allowed to move across borders with the return to capital determined in an imperfect world capital market subject to a symmetric transaction cost. Two of the three regions consist of a large number of high income and middle income countries and the third region is Japan. This specification allows us to isolate a country that has experienced aging earliest among the advanced economies and where the aging is most severe. As a result, Japan serves as a laboratory case for our model's mechanisms in determining the future path of capital flows.

The demographic trends in the high and medium income region countries in the model are taken from UN's population projections whereas we rely on the Japanese government's projections for our third region. After calibrating the model to regional macroeconomic and fiscal indicators, we calculate equilibrium transition paths from the 1990s to a future balanced growth path. Our main quantitative finding is the reversal of capital flows for Japan: with the projected decline in national saving in Japan and with a much slower investment in Japan, we find that Japan will soon run current account deficits. The net foreign asset position is projected to turn Japan into a net borrower before 2050. The reason for Japan's attracting foreign capital from the MI countries is the flattening of its capital labor ratio while the MI region experiences an increasing capital labor ratio. This projection, coupled with the slow speed with which the MI region's TFP catches up with that of Japan, necessitates an outflow of capital from the MI region to the HI region and Japan in order for the world capital market to clear.

Our additional computations of transition paths under alternative demographic projections, policy reforms, and various sensitivity analyses suggest that any economic outcome which implies lower closed-economy interest rates in the MI or higher interest rates in Japan will generate larger current account deficits and a greater capital flow into Japan and HI countries. For example, if longevity in the MI region were to rise faster than the UN projections, this would lead to stronger saving motives for retirement and a larger aggregate capital would lower the return to capital in the MI region (under the closed economy case). Our numerical results show that capital would flow to Japan (and the HI region) much earlier and in larger quantities relative to the benchmark.

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# A Computation of the Equilibrium

We describe the computation of the equilibrium in an open economy, where the labor income tax rate in each period is adjusted to achieve the government budget balance. All the other policy variables either remain fixed throughout the transition or move deterministically.

**Step 1:** Compute the initial and final steady-states of the model. Let the transition between the two steady states take $T$ periods, long enough so the economy converges smoothly to the final steady state.

**Step 2:** Guess three $T$-dimensional vectors for the world interest rate, the lump-sum tax, and accidental bequests in each region. The first and last entry of these vectors are the initial and final stationary equilibrium values computed in Step 1.

Given the path for the interest rates, using the property of the constant returns to scale technology and the optimization conditions for the firm, sequences of wages in each region can be derived. the problem of the households can be solved in each region.

**Step 3:** Given prices and the sequence of tax rates and accidental bequests obtained in Step 2, solve households' problem. Recall the budget constraint of the household at time $t$:

$$\left(1+\tau^r_{c,t}\right) c^r_{j,t} + a^j_{j+1,t+1} = y^r_{j,t} + \left[1+\left(1-\tau^r_{a,t}\right) r^r_t\right] \left(a^r_{j,t}+b^r_t\right) + p^r_{j,t} - \tau^r_{ls,t}.$$

Denote net-of-tax gross interest rate as

$$R^r_t \equiv 1+\left(1-\tau^r_{a,t}\right) r^r_t.$$

From the first order condition with respect to asset holdings next period, we obtain

$$\frac{c_{j+1,t+1}}{c_{j,t}} = \left[\beta s^r_{j+1,t+1} \frac{1+\tau^r_{c,t}}{1+\tau^r_{c,t+1}} R^r_{t+1}\right]^{\frac{1}{\theta}} \equiv g^c_{j+1,t+1}, \tag{16}$$

which is the optimal growth rate of consumption between age $j$ and $j+1$ and between time $t$ and $t+1$. Iterating backward over (16), we obtain that

$$c_{j+1,t+j} = c_{1,t} \prod_{k=1}^{j} g^c_{k+1,t+k}.$$

The discounted present value of the total (gross of taxes) lifetime consumption expenditures of the household of age 1 at time $t$ is given as

$$\overline{c}_{1,t} = c_{1,t}\left[\left(1+\tau^r_{c,t}\right) + \sum_{j=1}^{J-1}\left(1+\tau^r_{c,t+j}\right)\prod_{k=1}^{j}\frac{s^r_{k+1,t+k}}{R^r_{t+k}} g^c_{k+1,t+k}\right]. \tag{17}$$

In general, the discounted present value of the total (gross of taxes) lifetime consumption expenditures of the household of age $j^*$ at time $t$ is

$$\overline{c}_{j^*,t} = c_{j^*,t}\left[\left(1+\tau^r_{c,t}\right)+\sum_{i=j^*}^{J-1}\left(1+\tau^r_{c,t+(i-j^*+1)}\right)\prod_{k=j^*}^{i}\frac{s^r_{k+1,t+(k-j^*+1)}}{R^r_{t+(k-j^*+1)}}g^c_{k+1,t+(k-j^*+1)}\right]. \tag{18}$$

Define a variable $x^r_{j,t}$, as a sum of earnings, pensions and a bequest transfer net of taxes:

$$x^r_{j,t} = y^r_{j,t} + p^r_{j,t} + R^r_t b^r_t \tag{19}$$

The discounted present value of the total (net of taxes) lifetime earnings and bequest transfers of a household of age 1 at time $t$ is:

$$\overline{x}_{1,t} = x^r_{1,t} + \sum_{j=1}^{J-1}\left(\prod_{k=1}^{j}\frac{s^r_{k+1,t+k}}{R^r_{t+k}}\right)x^r_{j+1,t+j}, \tag{20}$$

where we are implicitly imposing the initial condition $a_1 = 0$. The discounted present value of the total (net of taxes) lifetime earnings of a household of age $i^*$ at time $t$ is:

$$\overline{x}_{j^*,t} = x^r_{j^*,t} + \sum_{j=j^*}^{J-1}\left(\prod_{k=j^*}^{j}\frac{s^r_{k+1,t+(k-j^*+1)}}{R^r_{t+(k-j^*+1)}}\right)x^r_{j+1,t+(j-j^*+1)} + R^r_t a_{j^*,t}. \tag{21}$$

Since individual optimization requires $\overline{c}_{j^*,t} = \overline{x}_{j^*,t}$ for each age $j^*$ and time $t$, from (18) and (21), we obtain $c_{j^*,t}$ as

$$c_{j^*,t} = \frac{\overline{x}_{j^*,t}}{\left[\left(1+\tau^r_{c,t}\right)+\sum_{i=j^*}^{J-1}\left(1+\tau^r_{c,t+(i-j^*+1)}\right)\prod_{k=j^*}^{i}\frac{s^r_{k+1,t+(k-j^*+1)}}{R^r_{t+(k-j^*+1)}}g^c_{k+1,t+(k-j^*+1)}\right]}.$$

Note that $a_{j^*,t}$ in equation (21) is computed residually from $c_{j^*-1,t-1}$ and the budget constraint (3) :

$$a_{j^*,t} = x^r_{j^*-1,t-1} + R^r_{t-1}a_{j^*-1,t-1} - \left(1+\tau^r_{c,t-1}\right)c_{j^*-1,t-1}.$$

**Step 4:** Aggregating asset holdings of all age groups and using equation (10) for each region, we obtain the implied sequence for external wealth of the region $X^r_t$. Together with the world capital market clearing condition (8), we arrive at a new guess for the sequence of the world interest rate. We use the government budget constraints (6) in each region with price sequences to update our guess for the tax rate. From the life-cycle asset decisions, we compute the accidental bequests left by the deceased in each region to update the guess for the bequests in the next iteration. If convergence is not reached, we restart from Step 3 with the new vector of guesses.

# B Summary of calibration targets

This section provides further details on the data used in the model calibration. Table B.1 reports a summary by region of the indicators used as targets in calibrating the model. Table B.2 presents a description of the macro data used and a short explanation of how calibration targets were computed; the sample period over which the statistics are calculated is also reported.

Table B.1: Summary of calibration targets

| Parameter | Description | Target | Period | Value by region | | |
|---|---|---|---|---|---|---|
| | | | | Japan | HI[c] | MI[c] |
| *Preferences and endowments* | | | | | | |
| $\beta$ | Subj. discount factor | Interest rate, % | 2015 | | 4 | |
| *Production technology* | | | | | | |
| $Z_0^r$ | TFP level (initial) | GDP per capita level, $ PPP | 2015 | 40,763 | 45,373 | 12,696 |
| $\lambda_t^r$ | TFP growth rate | GDP per capita growth, % | 1990-2015 | 1.1 | 1.4 | 3.9 |
| *Government* | | | | | | |
| $D_t/Y_t$ | Debt to GDP ratio | General gov. net debt to GDP, % | 1990-2015 | 100[a] | 50.9 | 30.7 |
| $G_t/Y_t$ | Gov. purch. to GDP ratio | General gov. total expenditure to GDP, % | 1990-2015 | 34.9 | 41.5 | 25.2 |
| $\kappa_t^r$ | Pension replacement rate | Net replacement rate, coverage adjusted | 2014 | 38.5 | 47.8 | 26.8 |
| $\tau_w^r$ | Labor income tax | Avg. eff. labor income tax, % | 2000-2014 | 29.8 | 32.8 | 17.0 |
| $\tau_a^r$ | Capital income tax | Avg. eff. capital income tax, % | 2000-2014 | 34.7 | 34.1 | 18.8 |
| $\tau_c^r$ | Consumption tax | Avg. eff. consumption tax, % | 2000-2014 | $3-8^b$ | 10.9 | 12.7 |

Notes: [a,b] See text for details on how targets were set; [c] High Income (HI): United States, Canada, Europe (UE 28), Australia, New Zealand; Middle Income (MI): China, Hong-Kong, Taiwan, South Korea, Singapore, Thailand, Indonesia, Malaysia, Philippines, Vietnam, India, Saudi Arabia, United Arab Emirates, Turkey, Russia and South Africa.

Table B.2: Dataset description

| Indicator | Period | Description | Sources |
|---|---|---|---|
| GDP per-capita (PPP, current international $) | 2015 | Gross domestic product divided by midyear population and converted to international dollars using purchasing power parity exchange rates. The target indicator by region is computed as a cross-country weighted mean, using GDP at current PPPs for weighting. | World Bank World Development Indicators (2017) |
| GDP per-capita growth (%) | 1990-2015 | The annual growth rate of GDP per-capita is calculated from GDP per-capita measured in constant local currency. The target indicator by region is a time average of the cross-country weighted mean. GDP at constant 2010 US$ is used for weighting. | World Bank World Development Indicators (2017) |
| General government total expenditure (% GDP) | 1990-2015 | Total spending of general government includes expenditures incurred by the central, state and local government, and social security funds. Total expenditure comprises current outlays, including interest payments on government debt and social transfers, and net investment in non-financial assets. The target total expenditure to GDP ratio by region is a time average of the cross-country weighted mean. GDP at constant 2010 US$ is used for within-region weighting. | IMF World Economic Outlook (2017) |
| General government net debt (% GDP) | 1990-2015 | Net debt of general government is given by gross debt minus financial assets corresponding to debt instruments (monetary gold and SDRs, currency and deposits, etc.). The target net debt to GDP ratio by region is a time average of the cross-country weighted mean. GDP at constant 2010 US$ is used for within-region weighting. | IMF World Economic Outlook (2017); Ministry of Finance for Japan |
| Labor income tax rate (%) | 2000-2014 | Average effective tax rate computed following the method by Mendoza, Razin and Tesar (1994). Tax revenue data and national account aggregates available from various sources. The target indicator by region is a time average of the cross-country weighted mean. GDP at constant 2010 US$ is used for within-region weighting. | OECD Revenue Statistics (2017), OECD National Accounts Statistics (2017), UN National Accounts Statistics (2017) |
| Capital income tax rate (%) | 2000-2014 | Average effective tax rate computed following the method by Mendoza, Razin and Tesar (1994). Tax revenue data and national account aggregates available from various sources. The target indicator by region is a time average of the cross-country weighted mean. GDP at constant 2010 US$ is used for within-region weighting. | OECD Revenue Statistics (2017), OECD National Accounts Statistics (2017), UN National Accounts Statistics (2017) |

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| Indicator | Period | Description | Sources |
|---|---|---|---|
| Consumption tax rate (%) | 2000-2014 | Average effective tax rate computed following the method by Mendoza, Razin and Tesar (1994). Tax revenue data and national account aggregates available from various sources. The target indicator by region is a time average of the cross-country weighted mean. GDP at constant 2010 US$ is used for within-region weighting. For Japan, actual statutory tax rates are used, ranging from 3% in 1990 to 10% in 2019. | OECD Revenue Statistics (2017), OECD National Accounts Statistics (2017), UN National Accounts Statistics (2017); Ministry of Finance for Japan |
| Net replacement rate, coverage adjusted (%) | 2014 | The net replacement rate (NRR) is given by net pension entitlements divided by net preretirement lifetime earnings, thus accounting for individual income tax and social contributions (for a mean male earner). The adjustment for coverage is done by multiplying the NRR by active coverage (defined as the number of contributors to the social security system divided by labor force). GDP at current PPPs is used for within-region weighting. | OECD Pensions at a Glance (2014), World Bank Pensions Database (2014) |
| Pension retirement age | 2013 | It is the statutory retirement age (mean of females and males if they differ) at which people eligible to old-age pension start receiving benefits. Total population is used for within-region weighting. | World Bank Pensions Database (2014) |
| Total population by age groups | 1990-2100 | Historical data and projections (medium variant). Total population is used for within region weighting. | UN World Population Prospects (Rev. 2017); National Institute of Population and Social Security Research (IPSS) (2017) for Japan |
| Age-specific fertility rate | 1990-2100 | The age-specific fertility rate is the number of births to women in a particular age group divided by the number of women in that group. Historical data and projections (medium variant). Total population is used for within-region weighting. | UN World Population Prospects (Rev. 2017); National Institute of Population and Social Security Research (IPSS) (2017) for Japan |
| Current account (% GDP) | 1996-2015 | It shows the flows of goods, services, primary income, and secondary income between residents and non-residents. | Ministry of Finance, Japan |
| Net External Wealth (% GDP) | 1996-2015 | It is the net international investment position of an economy, measuring at a point in time the difference between the value of financial assets of residents that are claims on nonresidents (or are gold bullion held as reserve assets) and the liabilities of residents to nonresidents. | Bank of Japan |