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The Aging Trap: Why Aging Induces Deflation and Secular Stagnation and Constrains Government Policy*

R. Anton Braun[†] and Daisuke Ikeda[‡]

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Abstract

Routine variation in household labor supply, consumption, saving, and portfolio choice decisions over the lifecycle influences aggregate economic activity in an aging society because the size of different age groups changes. In rapidly aging societies such as Japan, this mechanism produces an aging trap. The inflation rate is low or negative. Real interest rates and per capita output are also persistently low. Unlike inflation, they resist monetary and fiscal stimulus. Monetary policy can offset the decline in the inflation rate, but neither aggressive central bank interest rate policies nor large increases in the public debt–output ratio offset the persistent declines in real interest rates and output.

JEL classification: E52, E62, G51, D15.

Keywords: Deflation, Secular stagnation, Lifecycle, Portfolio choice, Nominal government debt, Aging, Tobin effect, Fiscal policy, Monetary policy.

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1 Introduction

In the years prior to the COVID pandemic, many industrialized economies experienced secular stagnation—low per capita output growth and low real interest rates—together with inflation rates that were low and often negative. These observations are striking because they occurred in spite of significant government stimulus. Central banks reduced their policy nominal interest rates to the effective lower bound (ELB) and subsequently pursued a variety of unconventional monetary policies (UMP). Fiscal policy was also loose with debt–GDP ratios rising rapidly in Japan and other advanced economies. What are the forces that were driving secular stagnation? Why did government policy fail to stimulate economic activity? Will these forces continue to exert downward pressure on the inflation rate, real interest rates and output growth in future years?

This paper shows that population aging in Japan produces an aging trap: rapid changes in the fraction of different age groups making their routine lifecycle labor supply, consumption, saving and asset allocation choices depress the inflation rate and produce persistent declines in per capita output and real interest rates that resist conventional government demand-side stimulus policies. Our aging trap differs in two ways from a liquidity trap. First, large reductions in the central bank policy rate fail to offset the persistent declines in real interest rates and per capita output even when the nominal interest rate is not constrained by the effective lower bound. Second, fiscal policies that seek to stimulate aggregate demand by allowing the government debt–output ratio to rise also fail to offset them.

Japan is ideal for our purposes because it has experienced a protracted spell of low inflation, low real interest rates and low output growth and is in the midst of a large and rapid demographic transition that started earlier than those in other advanced economies.¹ Japan experienced a large increase in fertility rates in the period following World War II and these cohorts are now transitioning into retirement. Japan has also experienced large declines in the total fertility rate, which has fallen from 2.14 in 1970 to 1.26 in 2015. Finally, life expectancies have increased from 60 years for Japanese individuals born in 1950 to 84 years for individuals born in 2014. Japan’s population is already falling and we project that between the years 2015 and 2055 the 21+ year old population will decline from 102 million to 80 million and that the share of the population aged 70+ in the 21+

¹See Section 2 for specific details.

population will increase from 23 percent to 38 percent.² Japan is not unique. Fertility rates are falling in both advanced and emerging countries and other industrialized countries are now embarking on demographic transitions that are of a similar or even larger scale than Japan.

To isolate the macroeconomic consequences of aging we combine Japanese historical data with government projections of fertility rates and cohort-specific mortality rate profiles to determine the age distribution in each year of a demographic transition. Under the assumption that fertility and mortality rates are exogenous, the age distribution varies over time and creates exogenous variation in the relative size of different age groups.

We use a quantitative structural lifecycle model to characterize routine variation in labor supply, consumption and asset allocation decisions of Japanese households over the lifecycle. In Japanese data and in our lifecycle model of household portfolio choice, young households borrow liquid assets and use them to purchase illiquid assets like homes and durable goods. Older households, in contrast, hold positive amounts of both assets because mortality risk increases with age and because their pension income does not fully replace their previous labor earnings. Our lifecycle model also reproduces Japanese empirical impulse responses of macroeconomic indicators to an identified monetary policy shock.

We isolate how aging influences aggregate asset demand by allowing the age distribution to change in the model while holding prices and government policy fixed at their steady state levels. We find that aging produces large increases in the demand for illiquid and liquid assets and that the magnitude of the increase in aggregate demand for liquid assets is particularly large.

We next allow markets to clear and government policy to respond to the aging shock and find that it produces large, persistent, declines in inflation, real interest rates and output. Between the years 2015 and 2040 the real interest rate falls from 3.41 percent to 1.20 percent, the inflation rate declines from -0.32 percent to -1.32 percent, and (detrended) output per capita declines at an average rate of 0.26 percent per year.

We find that autonomous declines in the number of workers and their average skill levels play a central role in depressing labor input and output and propose a way to decompose the responses of aggregate consumption, household asset holdings, net worth, and disposable income into two components. The *demographic factor* reflects changes in the relative size of different age groups and the *behavioral factor* reflects the combined influences that general

²Our population projections are based on projections from the National Institute of Population and Social Security Research. See also Table 1 for more details.

equilibrium price responses and government policy reactions have on decisions of each age group.

Aging in Japan has been accompanied by nominal and real secular stagnation. The inflation rate, real interest rates and the growth rate of GDP per capita fell during the 1990s. Government policy sought to counteract these macroeconomic outcomes in several ways. The policy nominal interest rate (overnight call rate) was close to zero between the year 1997 and the onset of the COVID pandemic. Japan was also the architect of a range of unconventional monetary policies starting with quantitative easing in the year 2001. Fiscal stimulus has also been significant in Japan as measured by the government net debt–GDP ratio which increased from 0.2 in the year 1990 to 1.5 in 2019. Yet, prior to the onset of COVID, output growth, real interest rates and the inflation rate remained stubbornly low.³

According to our model, these macroeconomic outcomes are to be expected because changes in the fraction of households making their routine lifecycle decisions and the resulting changes in the price system induced by market clearing exert powerful downward pressure on aggregate demand that overwhelms even aggressive demand-side government stimulus. We establish this result by considering counterfactuals that posit alternative monetary and fiscal policy responses to aging. Monetary policy has persistent effects on the composition of household asset demand, the inflation rate and aggregate investment but only has a small impact on aggregate consumption in the medium term. Thus, output continues to fall persistently regardless of how the central bank responds to population aging. Similarly, issuing substantially more government debt crowds out private investment but has only a small positive effect on aggregate consumption, and output continues to fall in the medium term.

Finally, we find that changes in the relative size of different age groups during the transition mask the economic incidence of aging on households. For instance, consumption of households aged 46–67 persistently declines in response to the aging shock. However, because the size of this group is temporarily large and because they routinely consume more than young working households, this group has a big positive contribution to aggregate consumption.

This masking result is the microeconomic counterpart of our aggregate result that government efforts to combat aging by stimulating aggregate demand are largely ineffective at arresting the declines in real interest rates and output. Because the demographic factor is large enough to reverse the sign of an age group’s measured contribution to aggregate

³See Section 2 for more details.

consumption, and because monetary and fiscal policy only affect the behavioral factor, government stimulus that succeeds in influencing household behavior can still leave aggregate consumption and output largely unchanged.

Our result that demographic change is putting downward pressure on output, real interest rates and inflation is consistent with the views of policy makers (see [Nishimura, 2011](#); [Fischer, 2016](#); [Shirakawa, 2021](#)), but is controversial among academic economists. On the one hand, [Acemoglu and Restrepo \(2017\)](#) provide empirical evidence that aging is positively correlated with per capita output growth and [Mian et al. \(2021\)](#) provide empirical evidence that higher inequality is the main source of the secular decline in the U.S. natural interest rate.

On the other hand, our result that aging depresses output per capita is consistent with evidence by [Hayashi \(2026\)](#), who finds that aging depresses the growth rate of output per capita in Japan and other advanced economies, [Eggertsson, Lancastre, and Summers \(2019\)](#), who provide empirical evidence that aging depresses the growth rate of output per capita in periods of low nominal interest rates, and [Rachel and Summers \(2019\)](#), who provide evidence that per capita output and real interest rates decline together. In addition, a number of papers have used structural models to show that aging makes labor scarce and that this exerts downward pressure on real interest rates, including [Braun et al. \(2009\)](#), [Braun and Joines \(2015\)](#), [Carvalho et al. \(2016\)](#), [Sudo and Takizuka \(2020\)](#), [Gagnon et al. \(2021\)](#) and [Auclert et al. \(2021\)](#). However, none of these papers show that population aging produces joint downward pressure on output, real interest rates and the inflation rate. Consequently, none of them have documented our mechanism whereby exogenous changes in the fraction of different age groups produce deflation and secular stagnation and reduce the efficacy of monetary and fiscal stimulus.

In fact, our model result that inflation and real interest rates can decline together in an aging society is at odds with the predictions of standard economic theory. According to the modified golden rule, a persistently lower population growth rate is associated with a lower real return on capital. Then the Fisher equation implies that if the nominal interest rate is held fixed, the inflation rate must increase to equate the real return on nominal government liabilities with the lower real return on capital (see [Bullard et al., 2012](#)). In our model, capital and government debt are imperfect substitutes and the preceding argument fails.⁴

⁴Our model also has the property that a surprise reduction in the policy nominal interest rate increases the inflation rate and stimulates economic activity. It is thus consistent with the narrative of Japanese monetary policy makers that their intent in the period prior to COVID was to ease policy to raise the inflation rate and lower real interest rates, and not to tighten policy to lower the inflation rate and raise

Another property of our lifecycle framework is that government debt is part of household net worth and is a nominal asset. An increase in the central bank’s policy nominal interest rate produces heterogeneous capital gains/losses on real asset portfolios of different age groups and narrows the equilibrium interest rate spread between government debt and other assets. This mechanism can be traced back to [Tobin \(1969\)](#), arises in the flexible price models of [Wallace \(1980\)](#) and [Sargent and Wallace \(1982\)](#), and has recently been analyzed in [Hu et al. \(2023\)](#). An important distinction between our work and this previous literature is that capital and other illiquid assets are imperfect substitutes for government debt and other liquid assets. Thus, the reaction of the central bank to low inflation induced by aging influences the dynamics of the inflation rate, real government debt and asset market spreads at medium-term horizons via the asset substitution transmission channel of monetary policy. These results, when combined with results in [Braun and Ikeda \(2025\)](#) about the short-term effects of monetary policy, imply that our lifecycle framework provides a unified theory of monetary policy in the short run and medium term with nominal rigidities being more important in the short term and asset substitution being more important in the medium term.

Some recent research has found that fiscal policy is a potent tool for macroeconomic stabilization in settings where government debt is net worth. [Angeletos et al. \(2024\)](#) find that deficit spending can create a consumption boom large enough to finance most of the deficit in a perpetual-youth model with fixed real interest rates. We find that in a rapidly aging society, aggregate demand has a large autonomous component that government borrowing cannot influence. In addition, real interest rates are endogenous in our model and higher government borrowing crowds out private investment, which weakens the pass through of deficit spending to aggregate demand.

[Eggertsson, Mehrotra, and Robbins \(2019\)](#) analyze aging as a source of a persistent liquidity trap in a lifecycle model. The hypothesis investigated in their paper is that the economy finds itself in a steady state with a liquidity trap: the natural real interest rate is low or negative, monetary policy is constrained by the ELB, and the slope of the aggregate demand schedule for goods is positive. In this situation, deficit spending is an effective way to stimulate aggregate demand. We analyze the dynamic effects of monetary and fiscal stimulus during a demographic transition instead of across steady states. Our model produces an aging trap instead of a liquidity trap. Monetary policy is not constrained by the ELB and influences the inflation rate and real economic activity. However, aggressive

real interest rates.

monetary and fiscal reactions to aging do not prevent persistent declines in real interest rates and output. Our results are consequently consistent with the observation of [Summers \(2020\)](#) that a central puzzle raised by secular stagnation is why easy government policies failed to end it.⁵

[Goodhart and Pradhan \(2017\)](#) and [Juselius and Takáts \(2018\)](#) argue that aging can put significant upward pressure on the inflation rate. According to our results the recent increase in the Japanese inflation rate since 2021 is not due to aging.

The remainder of our paper proceeds as follows. Section 2 motivates why we analyze the macroeconomic consequences of aging in Japan. Section 3 describes the quantitative model and provides an overview of the model calibration. Our main results are reported in Section 4. Section 4.1 describes the partial equilibrium responses of asset demand by type of asset and age group to the aging shock. Section 4.2 reports our GE results, Section 4.3 discusses the distributional consequences of aging, and Section 4.4 discusses robustness. Finally, Section 5 contains our concluding remarks.

2 Motivation

A number of industrialized and large emerging economies are embarking on a transition to a much older population age distribution. Japan is interesting because the demographic transition started earlier than other countries and has been rapid and large. Finally, Japan’s demographic transition has been associated with deflation, low real interest rates, and slow GDP growth in spite of significant monetary and fiscal stimulus—the pattern we call an aging trap.

Aging reflects three factors: aging of the baby-boomers, increases in life expectancy, and reductions in the fertility rate. The old-age dependency ratio, which we define as the ratio of the population aged 65+ to the population aged 20–64, provides a simple way to summarize the joint impact of these three factors on the age distribution. Panel A of Figure 1 shows that old-age dependency ratios have been steadily rising since 1986 in all members of the Group of Seven. Japan is noteworthy because it is in the midst of a particularly rapid demographic transition. Japan had the lowest old-age dependency ratio in this peer

⁵We report a scenario where monetary policy is constrained by the ELB and it is hard to reconcile that specification with Japan’s experience of persistently low inflation, real interest rates, per capita output, and a rapidly increasing government debt–output ratio. Our interpretation of this result is that quantitative easing was effective in relaxing the ELB but that monetary policy was not able to offset the persistent negative effects of aging on aggregate demand.

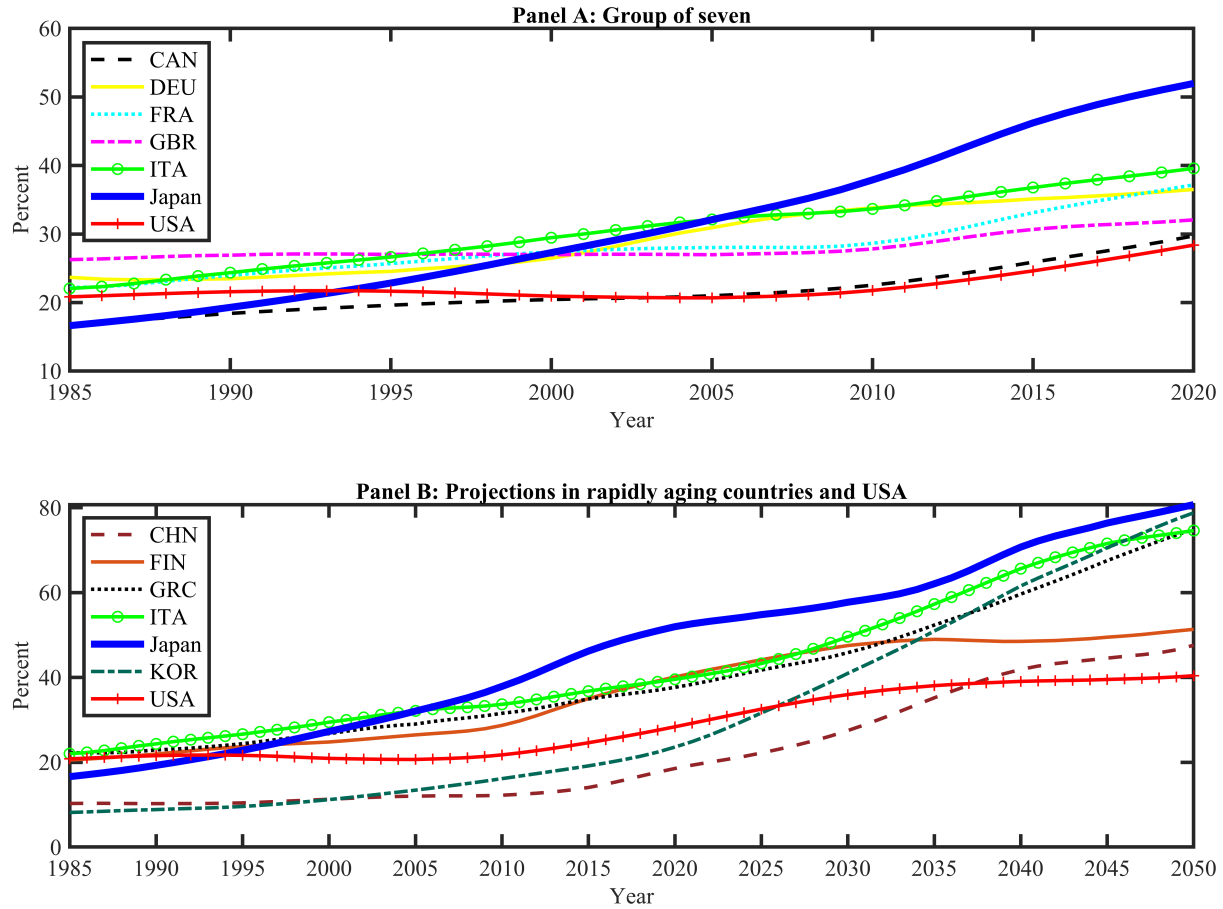


Figure 1: Old-age dependency ratios

Notes: World Bank Population Division. World Population Prospects: 2019.

group in the year 1986, but had the highest old-age dependency ratio in the year 2005.

Japan's old-age dependency ratio is projected to continue to increase rapidly until the year 2050 as shown in panel B of Figure 1. The World Bank projects that South Korea, Greece, and Italy will also experience large increases in their old-age dependency ratios with peaks exceeding 70 percent by 2050. Japan, however, stands out even in this group of rapidly aging societies. Finland shows that Northern European countries are also projected to experience rapid aging. China is starting from a much lower base, but will also experience rapid aging in future years. The old-age dependency ratio in China is projected to increase by nearly 40 percentage points between 2005 and 2050. Aging is also occurring in the U.S. albeit at a more moderate pace. The U.S. is benefiting from large immigration flows and, if these flows stop, the projected U.S. old-age dependency ratio rises to the level of Finland in 2050.⁶

⁶The U.S. Census Bureau projects that the U.S. old-age dependency ratio will rise to 49 percent by

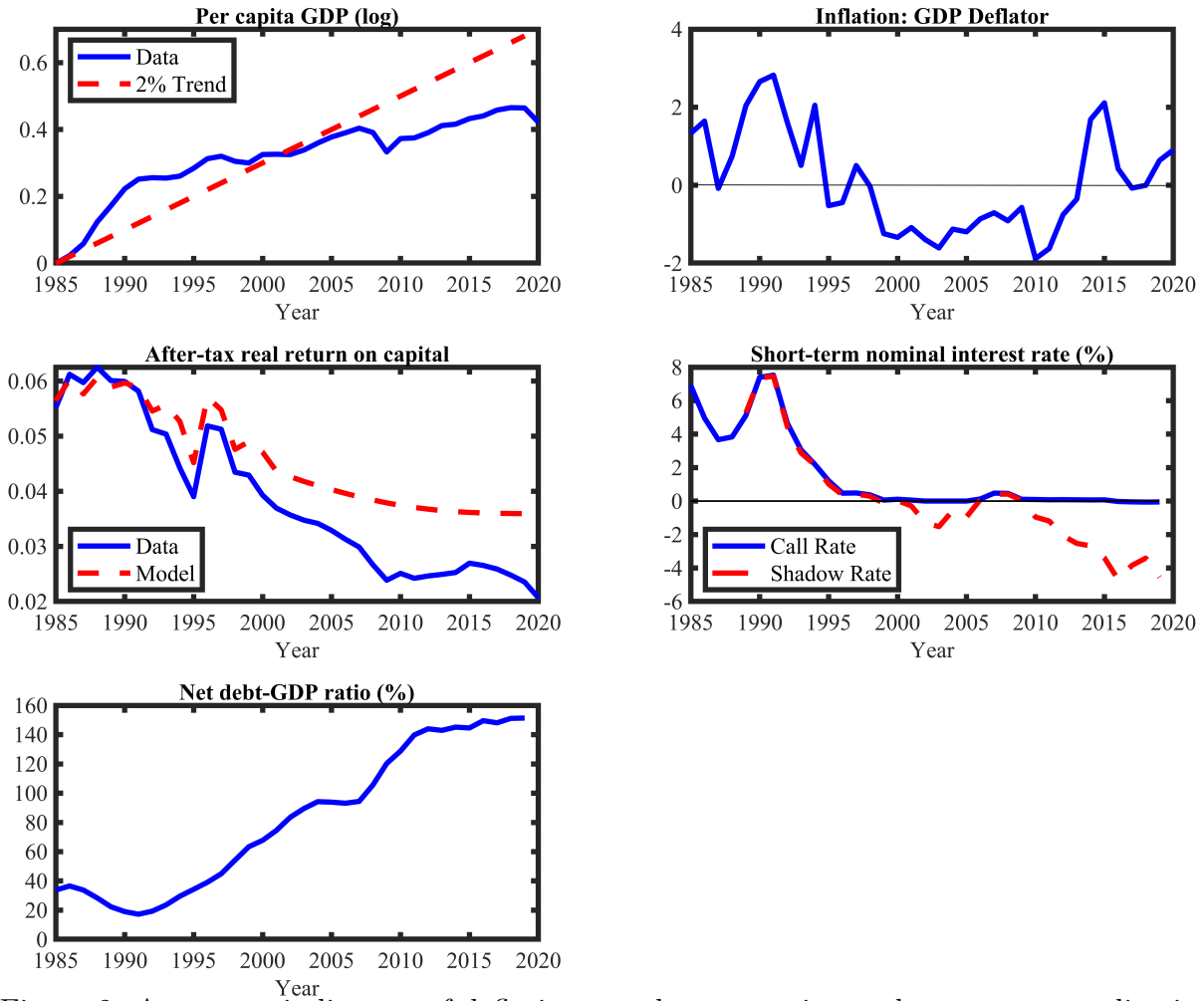


Figure 2: Aggregate indicators of deflation, secular stagnation and government policy in Japan

Notes: GDP and GDP Deflator – Cabinet Office; After-tax real return on capital – authors’ calculations using [Hayashi and Prescott \(2002\)](#) methodology; Call rate – Bank of Japan; Shadow rate – [Ueno \(2017\)](#); Net debt-GDP ratio – IMF.

Figure 2 shows that aging in Japan has been associated with a protracted episode of deflation, low real interest rates, and low growth in per capita GDP. These aggregate outcomes emerge in the 1990s, which is when Japan’s old-age dependency ratio begins its rapid ascent. The Japanese inflation rate is not only low, but it is also negative for protracted periods of time. The real interest rate, which we measure as the after-tax real return on capital, is also persistently low and declines over time. We also report model based projections for this measure of the real interest rate taken from [Braun et al. \(2009\)](#). Their projections start in the year 2000 and are derived from a computable OLG

2060, if immigration flows drop to zero ([Johnson, 2020](#)).

model that uses demographic projections from the National Institute of Population and Social Security Research (IPSS). Interestingly, the model projections are consistent with the subsequent declines in the real interest rate in the Japanese data, because aging induces capital deepening in the first stage of the demographic transition.⁷ Alternative measures of the real interest rate have a similar pattern (see [Han, 2019](#)). Finally, per capita GDP growth exhibits a persistent decline after 1995.

Figure 2 also reports summary statistics about the evolution of monetary and fiscal policy between 1985 and 2020. The call rate, which is the Bank of Japan’s policy nominal interest rate, falls steadily to zero in the 1990s and has been close to zero since 1997. The shadow interest rate of [Ueno \(2017\)](#) is reported; it uses (imperfect) arbitrage relationships to express the extent of quantitative easing and other UMP in call rate equivalent terms. According to this estimate from 2001, the year that quantitative easing was introduced, UMP measures have exerted steady and, in recent years, large downward pressure on the shadow call rate. The net debt–GDP ratio, which is based on data from the IMF, rises from about 20 percent of GDP in 1990 to about 150 percent in 2020.

3 Quantitative Model

We conduct our quantitative analysis using essentially the same model as [Braun and Ikeda \(2025\)](#). That paper compares the model’s steady state age profiles of asset holdings with Japanese data and provides a detailed empirical analysis of the short-run dynamic microeconomic and macroeconomic properties of the model to a tightening in monetary policy. One of our objectives here is to show that monetary policy in our model also has sensible empirical properties at medium-term frequencies for a more persistent shock and thus provides a unified theory of monetary policy in the short and medium run. We will see that the model produces persistent concurrent declines in the inflation rate and real interest rates in response to aging when using the same monetary policy feedback rule, the same transmission mechanisms of money and the same parameter settings as our previous paper and that monetary policy matters. Changing the values of the parameters that govern the monetary policy reaction function influences the impulse responses of, most notably, the inflation rate and real aggregate investment.

We consider an OLG economy with representative cohorts. Households can save and/or

⁷The scenario reported in Figure 2 assumes that total factor productivity (TFP) growth is constant at its average growth rate for the 1990s.

borrow two assets that differ in their liquidity services. Illiquid assets are costly to acquire and sell while liquid assets are costless to adjust. These assumptions result in an endogenous steady state spread between the two assets' returns due to age-specific survival risk. Depending on where households are in their lifecycle, they will choose to borrow liquid assets to purchase illiquid assets or hold positive amounts of both assets.

3.1 Demographic structure

The economy has an OLG structure that evolves in discrete time with a period length of one year. Let j denote the age of the individual as $j = 1, \dots, J$. We start keeping track of individuals at age 21 and individuals survive until at most age 120. Thus, model age of $j = 1$ corresponds to age 21, model age $J = 100$ corresponds to age 120, and $J = 100$ cohorts are active in a given year. Let $N_{j,t}$ be the number of individuals of age j in period t , then the population age distribution in period t is given by the $J \times 1$ vector $\mathbf{N}_t \equiv [N_{1,t}, \dots, N_{J,t}]'$.

The dynamics of population are governed by

$$\mathbf{N}_{t+1} = \begin{bmatrix} n_{1,t} & 0 & 0 & \dots & 0 & 0 \\ \psi_{1,t} & 0 & 0 & \dots & 0 & 0 \\ 0 & \psi_{2,t} & 0 & \dots & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & 0 & 0 \\ 0 & 0 & 0 & \dots & \psi_{J-1,t} & 0 \end{bmatrix} \mathbf{N}_t \equiv \mathbf{\Gamma}_t \mathbf{N}_t,$$

where $n_{1,t}$ is the gross population growth rate of age-1 households between periods t and $t + 1$, which we will henceforth refer to as the fertility rate⁸, and $\psi_{j,t}$ is the conditional probability that a household of age j in period t survives to period $t + 1$. It follows that the aggregate population in period t is given by $N_t = \sum_{j=1}^J N_{j,t}$ and that the population growth rate is given by $n_t = N_{t+1}/N_t$. Finally, the unconditional probability of surviving from birth in period $t - j + 1$ to age $j = 2, \dots, J$ in period t is

$$\Psi_{j,t} = \psi_{j-1,t-1} \Psi_{j-1,t-1}$$

where $\Psi_{1,t} = 1$ for all t .

⁸Note that this usage differs from other common definitions of the fertility rate and that the fertility rate, as we have defined it, can be less than unity, indicating a decline in the size of the youngest cohort from one period to the next.

3.2 Households

Individuals are organized into households. Each household consists of one individual (adult) and children. The number of children varies with the age of the adult and the age of the household is indexed by the age of the adult. Adults face mortality risk and have no bequest motives. At the beginning of each period the adult learns whether she will die at the end of the current period and this rules out accidental bequests. Let $z_{j,t}^i \in \{0, 1\}$ index the survival state for the i^{th} household where a value of zero denotes the death state. Death is the only source of idiosyncratic risk faced by households and there are only two types of households in any cohort: surviving households ($z_{j,t}^i = 1$) and non-surviving households ($z_{j,t}^i = 0$).

Households work, consume, and save for retirement. A household of age j in period t earns an after-tax wage rate of $(1 - \tau^w)w_t\epsilon_j$, where τ^w denotes a labor-income tax rate and ϵ_j is the efficiency of labor of an age- j household.⁹ All cohorts face the same age-efficiency profile and the efficiency index ϵ_j is assumed to drop to zero for all $j \geq J_r$, where J_r is the mandatory retirement age.

Households provision for retirement by acquiring liquid and illiquid assets. They may save and/or borrow using either asset and the liquid asset is nominally denominated because monetary policy directly controls the nominal interest rate on liquid assets in this economy. The liquid asset earns the nominal interest rate R_{t-1} from period $t-1$ to t and its after-tax real return is given by $\tilde{R}_{t-1}/\pi_t$ with $\tilde{R}_{t-1} = 1 + (1 - \tau^a)(R_{t-1} - 1)$, where π_t is the gross inflation rate and τ^a is the personal tax rate on asset income. The real return on illiquid assets in period t is denoted as R_t^a and its after-tax return is $\tilde{R}_t^a = 1 + (1 - \tau^a)(R_t^a - 1)$.

From the perspective of the household the only distinction between liquid and illiquid assets is that households face costs of adjusting their holdings of illiquid assets as in [Aiyagari and Gertler \(1991\)](#) and [Kaplan and Violante \(2014\)](#). When we parameterize our model, we follow [Kaplan et al. \(2018\)](#) and include physical assets such as homes and durable goods and illiquid financial assets such as equities in our measure of illiquid assets. So the adjustment costs can be interpreted as representing service flows to the financial service sector when, for instance, a household purchases or sells a home. Following [Kaplan et al. \(2018\)](#), we also abstract from the service flow of utility services provided by physical assets. Thus, the benefit from holding illiquid assets is entirely pecuniary in our model.

⁹Given that there is only one type of heterogeneity in a cohort, to conserve on notation we do not explicitly index the identity of each household of age j in period t in the ensuing discussion unless it is required to avoid confusion.

Adjustment costs on holdings of illiquid assets are given by

$$\chi(a_{j,t}, a_{j-1,t-1}, z) = \begin{cases} \frac{\gamma_a(z)}{2}(a_{j,t} - a_{j-1,t-1})^2, & a_{j-1,t-1} > 0 \\ \frac{\gamma_a(z)}{2}a_{j,t}^2, & a_{j-1,t-1} = 0 \end{cases} \quad (1)$$

where $a_{j,t}$ denotes the holdings of illiquid assets at the end of period t and $\gamma_a(z) \geq 0$ is a parameter that governs the size of the adjustment costs for $z = z_{j,t}^i \in \{0, 1\}$. These costs have two main features. First, they vary with the level of the change in assets. Second, they depend on whether the household experiences the death event in the current period. In [Braun and Ikeda \(2025\)](#) we show that this two parameter model of financial frictions allows us to match the main features of the age profiles of liquid asset holdings and illiquid asset holdings in Japanese data.

Given these definitions, the decisions of a surviving household of age- j in period t (i.e., a household with $z_{j,t}^i = 1$) are constrained by

$$\begin{aligned} (1 + \tau^c)c_{j,t} + a_{j,t} + \chi(a_{j,t}, a_{j-1,t-1}, 1) + d_{j,t} \\ \leq \tilde{R}_t^a a_{j-1,t-1} + \frac{\tilde{R}_{t-1}}{\pi_t} d_{j-1,t-1} + (1 - \tau^w)w_t \epsilon_j h_{j,t} + b_{j,t} + \xi_t, \end{aligned} \quad (2)$$

where $c_{j,t}$ is total household consumption for a household of age j in period t , τ^c is a consumption tax rate, $d_{j,t}$ denotes holdings of the liquid asset, expressed in terms of the final good, at the end of period t , $h_{j,t}$ denotes hours worked, $b_{j,t}$ denotes public pension (social security) benefits, ξ_t is a lump-sum government transfer, and $\chi(\cdot)$ is the transaction cost of adjusting individual holdings of the illiquid asset, given by equation (1).¹⁰ There are no ad hoc restrictions on borrowing of surviving households. They are free to borrow against their future earnings and they are also free to take leveraged long positions on illiquid assets, which have a higher return in equilibrium. The only constraint on borrowing of surviving households is the natural borrowing constraint.

If instead the household is in its final period of life ($z_{j,t}^i = 0$), the event is publicly observed by lenders and borrowing is not possible. Thus, the optimal strategy for the

¹⁰We are omitting here the dependence of individual choices on the survival event to save on notation. Formally, we have for $z_{j,t}^i \in \{0, 1\}$: $c_{j,t}(z_{j,t}^i)$, $a_{j,t}(z_{j,t}^i)$, $d_{j,t}(z_{j,t}^i)$, and $h_{j,t}(z_{j,t}^i)$. In what follows this dependence is only made explicit when required.

household is to consume all of its income and wealth during the current period

$$(1 + \tau^c)c_{j,t} = \tilde{R}_t^a a_{j-1,t-1} + \frac{\tilde{R}_{t-1}}{\pi_t} d_{j-1,t-1} + (1 - \tau^w)w_t \epsilon_j h_{j,t} + b_{j,t} + \xi_t - \chi(0, a_{j-1,t-1}, 0). \quad (3)$$

The period utility function for a household of age j in period t is given by

$$u(c_{j,t}, h_{j,t}; \eta_j) = \frac{\eta_j (c_{j,t}/\eta_j)^{1-\sigma}}{1-\sigma} - \frac{\omega}{1+1/\nu} h_{j,t}^{1+1/\nu}, \quad (4)$$

where $\sigma > 0$ is the inverse of the elasticity of intertemporal substitution, $\nu > 0$ governs the Frisch elasticity of labor supply, $\omega > 0$ is the labor disutility parameter, and η_j is the age-family scale profile, which is assumed to be time-invariant. In our model, children are essentially age-specific deterministic demand shocks to household consumption.

We assume that working-age households belong to a labor union.¹¹ The union respects their marginal utilities and wages are flexible. We analyze the symmetric equilibrium. Thus, hours worked are identical for all workers in period t , $h_{j,t} = \bar{h}_t$ for all $j < J_r$ with $\bar{h}_t$ given by

$$(1 - \tau^w)\bar{\epsilon}_t w_t = \omega \bar{\lambda}_t^{-1} \bar{h}_t^{\frac{1}{\nu}} \quad (5)$$

where $\bar{\lambda}_t$ is the weighted average of the marginal utilities of working households and $\bar{\epsilon}_t$ is the weighted average of the efficiency of labor. This specification implies that workers who experience an aggregate or idiosyncratic shock are unable to self-insure by adjusting their hours worked differently from the average worker. Household earnings vary by age because the efficiency of a worker's labor depends on the worker's age. The interested reader is referred to [Braun and Ikeda \(2025\)](#) for more details.

The household's optimal choices are given by the solution to

$$U_j(a_{j-1,t-1}, d_{j-1,t-1}, z_{j,t}) = \max_{\{c_{j,t}, a_{j,t}, d_{j,t}\}} \left\{ u(c_{j,t}, \bar{h}_t; \eta_j) + \beta z_{j,t} [(1 - \psi_{j+1,t+1})U_{j+1}(a_{j,t}, d_{j,t}, 0) + \psi_{j+1,t+1}U_{j+1}(a_{j,t}, d_{j,t}, 1)] \right\}, \quad (6)$$

subject to equations (2) and (3) for $z_{j,t} \in \{0, 1\}$ and for $j = 1, \dots, J-1$, and $z_{J,t} = 0$, where

¹¹This is one strategy used in the heterogeneous-agent New Keynesian (HANK) literature for reducing the impact of wealth on labor supply (see e.g. [Hagedorn et al., 2019](#)). If we were to allow households to choose their own labor supply, high wealth households work much less than poor households. The specification we adopt has the properties that households do respond to changes in aggregate wealth, earnings increase with age, but that the length of the workweek is the same for young and older working-age households.

$\beta > 0$ is the preference discount factor and $\psi_{j+1,t+1}$ is the conditional probability that a household of age $j + 1$ in year $t + 1$ survives to the next period.¹²

3.3 Production of goods and services

The production of goods and services is organized into four sectors.

Final good sector. Firms in this sector are perfectly competitive and combine a continuum of intermediate goods, $\{Y_t(i)\}_{i \in (0,1)}$, to produce a homogeneous final good Y_t , using the production technology: $Y_t = \left[\int_0^1 Y_t(i)^{\frac{1}{\theta}} di \right]^\theta$ with $\theta > 1$. Let $P_t(i)$ denote the price of intermediate good i , and P_t denote the price of the final good. Final good firms are price takers in input markets and it follows that demand for intermediate good i is

$$Y_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\frac{\theta}{\theta-1}} Y_t. \quad (7)$$

The final good is either consumed by households or used as an input in the capital good sector.

Intermediate goods sector. Firms in this sector are monopolistically competitive and each firm produces a unique good indexed by $i \in (0, 1)$. Intermediate goods firm i produces $Y_t(i)$ by combining capital $K_t(i)$ and effective labor $H_t(i)$ with a Cobb-Douglas production function

$$Y_t(i) = K_t(i)^\alpha H_t(i)^{1-\alpha}, \quad 0 < \alpha < 1. \quad (8)$$

Intermediate goods firm i faces demand curve (7), and sets its price $P_t(i)$ to maximize profits subject to a quadratic price adjustment cost function. In a symmetric equilibrium, the condition can be expressed as

$$(\pi_t - 1)\pi_t = \frac{1}{\gamma} \frac{\theta}{\theta - 1} (mc_t - 1) + \Lambda_{t,t+1} \frac{Y_{t+1}}{Y_t} (\pi_{t+1} - 1)\pi_{t+1}, \quad (9)$$

¹²There is a theoretical possibility that adjustment costs on illiquid assets could exceed the size of beginning of period illiquid assets. Our strategy for parameterizing the adjustment costs on illiquid assets rules this possibility out. We also impose no restrictions on the sign or magnitude of asset holdings beyond the natural borrowing constraint. In a steady state equilibrium, the return on illiquid assets exceeds the return on liquid assets and all private borrowing is in the form of liquid assets. However, off the steady state depending on the relative returns of the two assets households may choose to borrow illiquid assets, to purchase liquid assets, or to borrow both types of assets.

where $\pi_t = P_t/P_{t-1}$ is the gross inflation rate. Equation (9) is the New Keynesian Phillips curve that relates the current inflation rate π_t to the real marginal cost mc_t and the future inflation rate π_{t+1} . In a symmetric equilibrium the aggregate output is

$$Y_t = K_t^\alpha H_t^{1-\alpha}, \quad (10)$$

where K_t denotes the aggregate capital and H_t denotes the aggregate effective labor. The aggregate total profits of intermediate goods firms in period t , $\Omega_t \equiv \int_{i \in (0,1)} \Omega_t(i) di$, are given by

$$\Omega_t = \left[\theta - mc_t - \frac{\gamma}{2} (\pi_t - 1)^2 \right] Y_t. \quad (11)$$

Capital good sector. Capital good firms are perfectly competitive and use a linearly homogeneous production technology to produce capital. The representative firm purchases $(1 - \delta)K_t$ units of old (depreciated) capital from the mutual fund and I_t units of the final good from the final good firms, and uses the two inputs to produce K_{t+1} units of new capital that is sold back to the mutual fund. Then, the conventional investment identity obtains

$$K_{t+1} = (1 - \delta)K_t + I_t. \quad (12)$$

Mutual fund sector. Our economy has two types of illiquid assets – capital and shares in intermediate goods firms – and there is no aggregate uncertainty in the model after time zero. Thus, a no arbitrage argument implies that the return on the two illiquid assets is the same in all periods except possibly time zero when their returns will differ if an aggregate time-zero shock occurs. We allocate ownership and the potential time-zero capital gains and losses among households by assuming that households invest in a mutual fund produced by perfectly competitive financial service firms. Each firm holds the market portfolio of the two illiquid assets and pays households the market return on illiquid assets.

To derive the market return on illiquid assets note that the return on capital in period t is given by

$$R_t^k = r_t^k + 1 - \delta. \quad (13)$$

The one period return from investing one unit of the period $t - 1$ final good into shares is

$$R_t^v = \frac{\Omega_t + V_t}{V_{t-1}}, \quad (14)$$

where V_t is the share price in period t . We assume that the return on capital and equity is subject to a corporate tax as well as an asset income tax paid by households. Liquid assets, in contrast, will consist primarily of government debt in equilibrium and are taxed once at the household level. To reduce the notational burden, we assume that corporate taxes are paid by the mutual fund. Let τ^k denote the corporate tax rate. Then, perfect competition leads to the arbitrage conditions

$$R_t^a - 1 = (1 - \tau^k)(R_t^k - 1) = (1 - \tau^k)(R_t^v - 1). \quad (15)$$

for all $t > 0$. From this no-arbitrage restriction the share price is given by

$$V_t = \sum_{i=1}^{\infty} \left(\prod_{j=1}^i \frac{1}{R_{t+j}^k} \right) \Omega_{t+i}. \quad (16)$$

Hence, the discount factor $\Lambda_{t,t+1}$ in equation (9) is given by $\Lambda_{t,t+1} = 1/R_{t+1}^k$.

We analyze the evolution of our economy during a demographic transition by solving a two point boundary problem. The terminal condition is determined by a steady state and the initial condition is an initial age distribution and an initial age-asset distribution. Equation (15) does not obtain in period $t = 0$ because the response of the price system generally induces distinct capital gains and losses on shares in intermediate goods firms and capital.

3.4 Government

The government consists of a central bank and a fiscal authority.

Central bank. The central bank sets the nominal interest rate R_t following a simple rule that depends on the current inflation rate and the past nominal interest rate

$$\log \left(\frac{R_t}{R} \right) = \rho_r \log \left(\frac{R_{t-1}}{R} \right) + (1 - \rho_r) \phi_\pi \log(\pi_t), \quad (17)$$

where R is a constant. The parameter ρ_r governs the inertia of the nominal interest rate, and the parameter $\phi_\pi > 1$ captures the central bank's stance on inflation. A high ϕ_π implies a strong anti-inflation stance and vice versa.

Fiscal authority. The fiscal authority raises revenue by taxing consumption, labor income,

and asset income, with corporate taxes collected from the mutual fund. The total tax revenue is

$$T_t = \sum_{j=1}^J \left[\tau^c \bar{c}_{j,t} + \tau^{ka} (R_t^k - 1) a_{j-1,t-1} + \tau^a \frac{(R_{t-1} - 1)}{\pi_t} d_{j-1,t-1} + \tau^w w_t \epsilon_j \bar{h}_t \right] N_{j,t}, \quad (18)$$

where $\bar{c}_{j,t} = \psi_{j,t} c_{j,t}(1) + (1 - \psi_{j,t}) c_{j,t}(0)$ is the average consumption by surviving and non-surviving households and $\tau^{ka} = \tau^a + \tau^k - \tau^a \tau^k$ is the total tax rate on illiquid assets.

Let D_t^n denote the face value of nominal government debt issued in period t . Then aggregate government expenditures consist of government purchases G_t , nominal interest payments on its debt, net of new issuance, $(R_{t-1} D_{t-1}^n - D_t^n)/P_t$, subsidies to intermediate goods firms, $\tau^f Y_t = (\theta - 1) Y_t$, public pension benefits $B_t \equiv \sum_{j=J_r}^J b_{j,t} N_{j,t}$, and lump-sum transfers to households, $\Xi_t \equiv \sum_{j=1}^J \xi_t N_{j,t}$. It follows that the government flow budget constraint is given by

$$G_t + \frac{R_{t-1} D_{t-1}^n - D_t^n}{P_t} + \tau^f Y_t + B_t + \Xi_t = T_t \quad (19)$$

and the government bond market clearing condition is given by

$$\frac{D_t^n}{P_t} = D_t \equiv \sum_{j=1}^J \bar{d}_{j,t} N_{j,t}, \quad (20)$$

where $\bar{d}_{j,t} = \psi_{j,t} d_{j,t}(1) + (1 - \psi_{j,t}) d_{j,t}(0)$ is the average government bond holdings by surviving and non-surviving households.¹³

We consider two scenarios for the time path of government debt. It is easier to understand the contribution of monetary policy to our results if we fix the supply of per capita nominal government debt as in [Bewley \(1980\)](#) and [Hu et al. \(2023\)](#). We also consider scenarios where the supply of nominal government debt varies over the transition.

For a given time path of nominal government debt, we close the government budget constraint by varying the size of the lump-sum transfer, ξ_t . Benefits from the public pension program are modeled in the same way as [Braun et al. \(2009\)](#). A household starts receiving

¹³Because $d_{j,t}(0) = 0$, the aggregate bond can be arranged as

$$D_t \equiv \sum_{j=1}^J [\psi_{j,t} d_{j,t}(1) + (1 - \psi_{j,t}) d_{j,t}(0)] N_{j,t} = \sum_{j=1}^J \psi_{j,t} d_{j,t}(1) N_{j,t} = \sum_{j=1}^J d_{j,t}(1) N_{j+1,t+1}.$$

a public pension benefit at the mandatory retirement age of J_r . The real size of the benefit during the household's retirement is constant at a level that is proportional to its average real wage income before retirement

$$b_{j,s+j-1} = \begin{cases} 0 & \text{for } j = 1, \dots, J_r - 1 \\ \kappa \left(\frac{1}{J_r - 1} \sum_{j=1}^{J_r-1} w_{s+j-1} \epsilon_j \bar{h}_{s+j-1} \right) & \text{for } j = J_r, \dots, J, \end{cases} \quad (21)$$

where κ is the replacement ratio of the pension benefit and s is the household's birth year. Thus, the public pension system implicitly assumes perfect inflation indexation of pension benefits.

3.5 Competitive equilibrium

Our aim here is to understand the quantitative significance of demographic change for the deflation and secular stagnation observations that motivate our analysis, which is easiest to identify if we conduct an impulse response analysis to a demographic shock. In the analysis that follows, we assume that at the beginning of time zero, households observe the future evolution of the demographic distribution and have perfect foresight about the subsequent evolution of prices and government policy reactions.¹⁴ Consequently, our definition of equilibrium is a perfect foresight competitive equilibrium. Additional details on the definition of equilibrium can be found in Online appendix A.1.

3.6 Model parameterization

Demographic transition We assume that new households are formed at age 21 and the size of the household is parameterized in the same way as Braun et al. (2009). In the model individuals face mandatory retirement at age 68 ($J_r = 48$). Age 68 is older than the statutory age to qualify for full public pension benefits of 65 and is chosen to be consistent with the effective labor-market exit age in 2014 for Japan estimated by the OECD.¹⁵ Finally, the maximum lifespan is set to 120 years ($J = 100$). Our methodology for computing the demographic transition follows Braun and Joines (2015) but uses updated data from the IPSS. Given an initial age distribution in 1983, we allow fertility rates and cohort-specific survival rates to evolve as in Japanese data between 1983 and 2019 and then according to

¹⁴Boppart et al. (2017) provide a justification for using this approach in heterogeneous agent economies.

¹⁵See Pensions at a Glance OECD, 2015.

Table 1: Age distribution and 21+ population by decade and terminal steady state asset holdings

	Age/pop 21+					Steady state		
	2015	2025	2035	2045	2055	Net worth	Liquid assets	Illiquid assets
Under 30	0.11	0.11	0.10	0.09	0.09	0.10	-0.65	0.74
30–39	0.15	0.12	0.12	0.12	0.11	1.11	-0.88	1.99
40–49	0.18	0.16	0.13	0.13	0.13	3.16	0.13	3.03
50–59	0.15	0.17	0.17	0.14	0.14	5.81	2.07	3.74
60–69	0.18	0.14	0.18	0.17	0.15	7.61	3.54	4.07
70+	0.23	0.29	0.31	0.35	0.38	4.43	0.98	3.44
Pop 21+ (millions)	102	100	95	88	80			

Notes: The figures on demographics are our estimates using data from the IPSS. Net worth and asset holdings are reported as ratios relative to income of households aged 50–59.

projections made by the IPSS until 2060. The fertility rate is based on the IPSS medium scenario. After 2060, survival rates are held fixed at their 2060 levels. Between 2060 and 2163 the fertility rate increases linearly from its IPSS projected level for 2060 to a value that is consistent with a terminal steady state distribution with a constant population, and remains at that value thereafter. We allow a total of 300 years, through 2314, for the economy to reach its terminal steady state equilibrium with a constant population and constant price system.

Table 1 reports summary statistics for Japan’s age distribution and population at 10 year intervals. We limit attention to the 21+ population to make the data consistent with the workings of our model. The combined impact of aging of the baby-boom cohorts, lower fertility rates and longer life expectancies is already putting downward pressure on the age 21+ population and this pressure will increase in future years. During this transition the percentage share of the 70+ population in the total 21+ population will increase from 23 percent to 38 percent according to our estimates, which are based on data from the IPSS.

Steady-state age profiles of net worth and assets The right panel of Table 1 reports age profiles for net worth and holdings of liquid and illiquid assets in the *terminal* steady state. The terminal steady state is based on survival profiles from 2060, a fertility rate consistent with a constant population, and a consumption tax rate of 10 percent, which was implemented in Japan in 2019. Other parameters that determine aggregate steady state allocations are calibrated to match targets from 2014 because we do not have good

information to guide us on their values at such a distant point in the future. In particular, the public debt–GDP ratio target of 1.23 is estimated from Japanese NIPA and flow of funds data for the year 2014 and the preference discount factor is set to 0.99623 to reproduce a data target capital–output ratio of 3.5 for the same year in a steady state that assumes survival rates for 2014. This results in a capital–output ratio of 2.3 in the terminal steady state.¹⁶

Finally, two parameters govern the extent of imperfect substitutability of liquid and illiquid assets and we calibrate them so that the maximum cost over the life cycle of liquidating illiquid asset holdings in a death year is 20 percent of illiquid assets, and the maximum cost otherwise is 2 percent of illiquid assets in the steady state that uses the 2014 survival probabilities. The first target is slightly higher than that in [Braun and Ikeda \(2025\)](#), who use 15 and 2 percent.¹⁷

The qualitative properties of the age profiles of net worth and asset holdings reported in [Table 1](#) capture the main feature of net worth accumulation and asset holdings over the lifecycle described in [Braun and Ikeda \(2025\)](#). Net worth increases with age up until retirement, which occurs at age 68 and declines thereafter. The variation in holdings of liquid assets over the lifecycle is particularly large. Liquid asset holdings are negative for younger age groups, who borrow liquid assets to purchase illiquid assets. Then they turn positive and become large for households as they approach retirement. After retirement households draw down their liquid assets. Illiquid asset holdings are positive for young households and grow steadily until retirement at age 68, at which point they also decline but more gradually than liquid asset holdings.

Two differences between our model here and [Braun and Ikeda \(2025\)](#) are, first, that they impose ad hoc borrowing constraints on households between the ages of 21 and 23 to improve the model’s fit with Japanese data in the year 2014 for the under 30 year old age group. Here we impose the weaker natural borrowing constraint on all age groups. Second, we do not model warm glow bequest preferences here, deliberately. Japan provides universal public insurance for long-term care risk so precautionary asset demand of the elderly is falling. Fertility rates are well below the replacement rate in Japan so the number of potential recipients will fall in the future. Bequest taxes in Japan are among the highest of any advanced economy, ranging from 30 to 50 percent of the bequest and many potential

¹⁶In the dynamic simulations the initial age-asset distribution is set to reproduce the empirical age-distribution in Japanese data in 2014.

¹⁷This choice slightly improves the age profile of net worth in the model under our assumption here of no warm-glow bequests.

inheritors refuse to declare themselves as inheritors. Over 10 percent of Japanese residential real estate is abandoned and many of these properties have no owner of record. Japan lacks probate laws that net out liabilities, and potential inheritors may be refusing to declare themselves because of uncertainty about whether the total estate has positive net expected value after they pay bequest taxes.¹⁸

Other model parameters and model assessment The remaining model parameters are set as in [Braun and Ikeda \(2025\)](#). That paper provides an extensive discussion of our calibration strategy and also reports a range of data and model statistics that are designed to assess the empirical fit of our model to a shock in monetary policy. The complete parameterization of our model is reported in Table A.1 in Online appendix A.3.

An open question is whether the differences in the two specifications and calibration targets that we just discussed lead to a deterioration in the aggregate dynamics of the model that are the focus of our analysis here. Appendix Figure A.1 shows that the answer to the question is no. The model analyzed here is in good accord with empirical evidence on responses to monetary policy shocks in Japan based on alternative structural vector autoregression (SVAR) and high-frequency identification (HFI) schemes. A noteworthy feature of the figure is that the SVAR nominal interest rate response is smaller than the responses using the HFI scheme and the model. As we explain in [Braun and Ikeda \(2025\)](#) this difference arises because the SVAR scheme imposes an ELB while neither the model nor the HFI scheme impose this restriction. A direct comparison of the model responses to a monetary policy shock here with those in [Braun and Ikeda \(2025\)](#) also reveals only small differences. Consumption falls by slightly less and investment by more here due to a slightly stronger monetary policy reaction to the shock.

Using essentially the same model as in [Braun and Ikeda \(2025\)](#) adds force to our claim that our model provides a unified theory of monetary policy in the short run and medium run. The transmission models of money are the same, and the extent of nominal rigidities and financial frictions are the same because the parameterizations are the same. However, the shock here is a persistent shock to the age distribution.

¹⁸Absent warm glow bequests, the oldest households in the model choose to leverage up on illiquid assets. This allows them to smooth consumption without incurring the costs of liquidating their higher return illiquid asset positions. A similar strategy is used by affluent Americans to avoid paying transactions costs and capital gains ([UBS, 2021](#)). With the warm glow bequest specification in [Braun and Ikeda \(2025\)](#) the eldest households prefer to hold positive amounts of both assets.

Table 2: Partial equilibrium scenario: maximum increases in liquid and illiquid assets

Demographic Scenario	Liquid assets		Illiquid assets	
	Maximum	Peak year	Maximum	Peak year
Aging of baby-boom cohorts	19.83	2038	2.32	2029
Longer life expectancy	0.63	2045	0.07	2044
Lower fertility rates	24.12	2065	6.18	2067
Baseline	27.10	2043	5.24	2053

Notes: The table reports the maximum increase in each type of asset expressed as a percentage of initial assets and the year where the maximum increase occurs. “Aging of baby-boom cohorts” reflects changes in the population distribution due to aging of the baby-boom cohorts only. “Longer life expectancy” reflects changes in the age distribution due to higher survival rates only. “Lower fertility rates” reflects changes in the birth rate of 21 year olds only and “Baseline” incorporates all three channels.

4 Results

4.1 Partial Equilibrium: Population aging produces an asset demand glut

Changes in the age distribution associated with aging in Japan produce an aggregate asset demand glut in our lifecycle model. We document this result by allowing the age distribution to change while holding prices and government policy fixed and restricting households to follow their steady-state asset allocation plans.

In this partial equilibrium simulation, we hold fixed age-specific savings and asset allocation decisions at their values as reported in the right hand panel of Table 1 and allow the age distribution to vary in each year of the transition as summarized in the left panel of Table 1. Thus, the only reason why aggregate asset demand changes in this simulation is that the fraction of households with the reported age-specific net worth and asset portfolios changes. Observe that the changes in population shares of different age groups are large. For instance, between the years 2015 and 2035, the fraction of households aged 50–69 increases from 0.33 to 0.35, while the fraction of households under age 40 declines from 0.26 to 0.22. Since the former group has much larger net worth than the latter group, these changes in the age distribution can have a large influence on aggregate asset demand.

Table 2 reports the maximum increase in aggregate demand for liquid and illiquid assets, and the year in which it occurs, for the baseline (time-varying) population distribution and three counterfactuals. The “Aging of baby-boom cohorts” scenario holds fertility rates and survival probabilities fixed in all years at their terminal values and uses the initial

2014 age distribution as the initial condition. In the “Longer life expectancy” scenario, survival probabilities vary by birth cohort and gradually increase over time, but the age distribution and fertility rates are fixed in all periods. The “Lower fertility rate” scenario considers the case where fertility rates gradually decline and the initial age distribution and survival probability age profiles are set to their terminal values. Finally, the “Baseline” demographic scenario incorporates all three factors.

Table 2 shows that the three demographic factors individually and collectively induce large and persistent increases in liquid and illiquid asset demand. Moreover, because the determinants of the population distribution are exogenous, these changes in aggregate asset demand reflect no GE effects due to the imposition of market clearing and/or the reaction of government policy. For these reasons, we refer to these changes in asset demand as autonomous because they are due entirely to exogenous changes in the age distribution. Lower fertility rates are the largest factor. They produce a peak increase in liquid assets of 24.1 percent in 2065. This result is important because fertility rates are falling in most countries ([Fernandez-Villaverde and Norick, 2026](#)) and the autonomous changes in asset demand are likely to be important in other advanced and emerging economies in future years. Aging of the baby-boom cohorts is also important, producing a peak increase in liquid asset demand of 19.8 percent in 2038. The second main result is that aging has a much larger influence on aggregate demand for liquid assets than for illiquid assets. Illiquid assets also increase in the baseline but peak at 5.24 percent in 2053, which is less than one-fifth of the size of the peak increase in aggregate demand for liquid assets. As households enter retirement, they prefer to hold a larger share of their portfolios in liquid assets because the replacement rate provided by pension income is less than one. Moreover, they face an elevated mortality risk and can avoid some of the costs of liquidating their holdings of illiquid assets in their death year if they tilt their portfolio holdings toward liquid assets.

4.2 General equilibrium results

We now report results for general equilibrium simulations. We are not attempting to make forecasts about the future course of the Japanese economy. Instead our objective is to show that aging is putting significant and persistent downward pressure on interest rates, per capita output, and the inflation rate, to understand why this is occurring, and to understand why government demand-side policy measures have not been more effective in stimulating aggregate demand for goods.

We conduct a nonlinear impulse response analysis to a demographic shock. In the year 2014, households discover that the population distribution is going to evolve over time and they adjust their consumption, savings and labor supply plans accordingly. When making these adjustments, they fully understand government policy reaction functions and anticipate the future evolution of prices. These assumptions allow us to use global sequence methods to compute an equilibrium.^{19, 20} When computing the transition, we assume that the economy reaches its terminal steady state in the year 2314.

The baseline specification assumes that the central bank follows the nominal interest rate rule given in equation (17) with a serial correlation coefficient ρ_r set to 0.35 and an inflation elasticity, $\phi_\pi = 2$. Nominal per capita debt is held fixed and lump-sum taxes adjust to satisfy the government budget constraint in each period. These assumptions help us to isolate the contribution of the monetary policy reaction function to our results. In Section 4.2.3 we relax this assumption and allow the fiscal authority to issue more nominal debt in response to the aging shock.

4.2.1 Baseline results

Figure 3 reports results for the baseline scenario. These results show that the aging shock reproduces the deflation and secular stagnation observations that motivate our analysis. Aging puts steady downward pressure on the real interest rate, the nominal interest rate, the inflation rate, and per capita output between 2015 and 2034 and all of these variables are well below their 2015 levels in 2040. The real interest rate on illiquid assets declines from 3.41 percent in 2015 to 1.20 percent in 2040, and the inflation rate falls from -0.32 percent in 2015 to a low of -1.41 percent in 2034 and is -1.32 percent in 2040. Responding to the decline in the inflation rate, the nominal interest rate also falls. The model also produces a large increase in the government debt–output ratio. It rises from 1.16 in 2015 to 1.64 in 2040. Finally, the model produces a gradual but steady decline in per capita output at the average rate of 0.26 percent per year between 2015 and 2040.²¹

Consider first per capita output. Output is initially 6.4 percent above the terminal steady state (see Figure 3) and steadily falls over time. One mechanism responsible for its

¹⁹Chen et al. (2006) find that their results are robust to the model of expectations formation for a demographic shock in a representative agent model.

²⁰Computing an equilibrium for a given parameterization of the model takes multiple days to converge on a 2024 vintage Mac Studio with 192GB of main memory and an M2 Pro CPU using Matlab’s parallel toolbox.

²¹As a reference point, the output gap – the deviation of output from the potential output, estimated by the Bank of Japan – is -0.21 percent on average between 1990–2020.

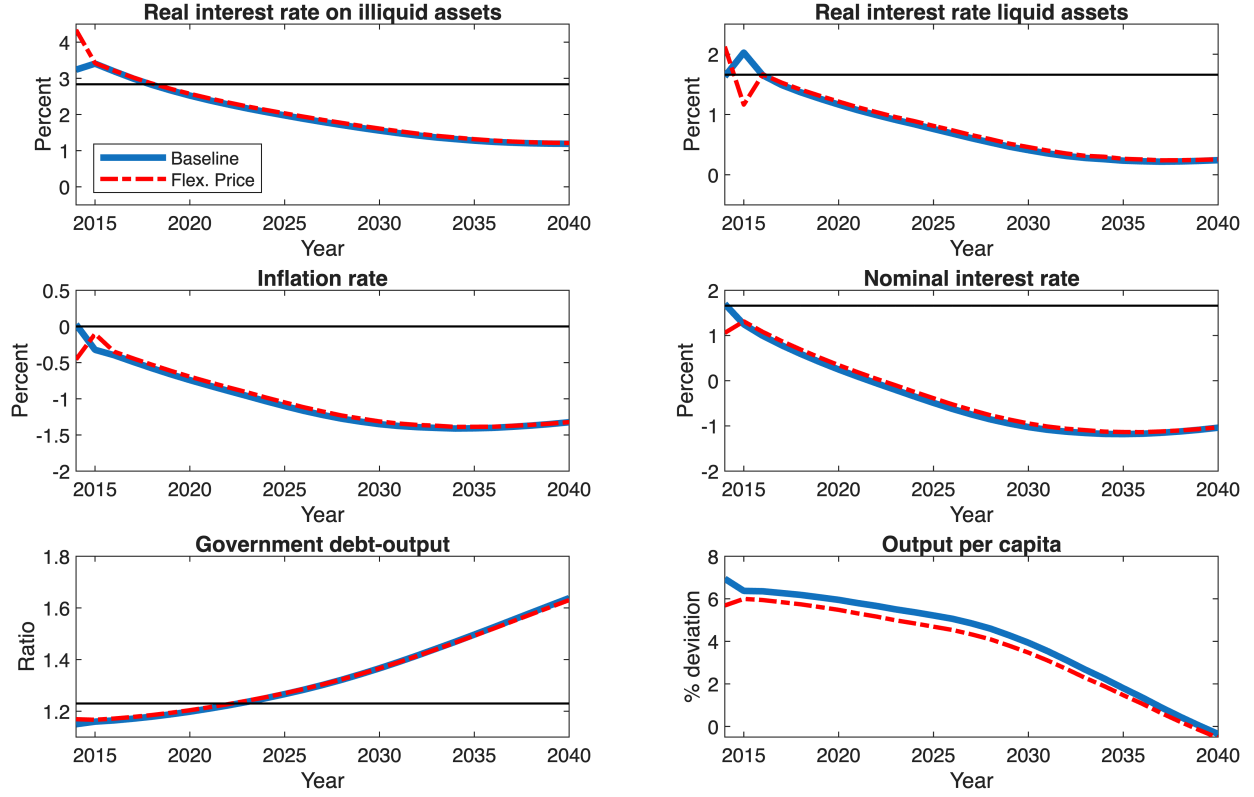


Figure 3: Baseline and flexible price responses to aging

Notes: The flexible price specification sets $\gamma = 0$. The two real interest rates are the ex post real returns on liquid and illiquid assets. Interest rates and the inflation rate are annual rates and the solid lines are their steady state values. Output per capita is the percentage deviation from the terminal steady state. The complete transition including terminal steady state values are reported in Figure A.8.

response is that labor input becomes scarce over time. This effect can be readily discerned in Figure 4. Labor input in efficiency units declines steadily, but hours per worker is essentially flat. The movements in hours per worker reflect behavioral responses to changes in the economic environment but the changes in average efficiency units are due entirely to changes in the age distribution. Efficiency units of workers vary by age and the 68+ age group does not work at all but age–efficiency unit profiles are exogenous. Thus, the labor input is falling in the model because the fraction of workers in the total population and their average skill levels are declining over time.

Consider next the responses of factor prices. Initially labor is relatively abundant compared to capital and it follows that the wage rate is initially low (Figure 4) and the return on illiquid assets is relatively high (Figure 3). Then as labor becomes increasingly scarce the wage rate increases and the real interest rate declines.

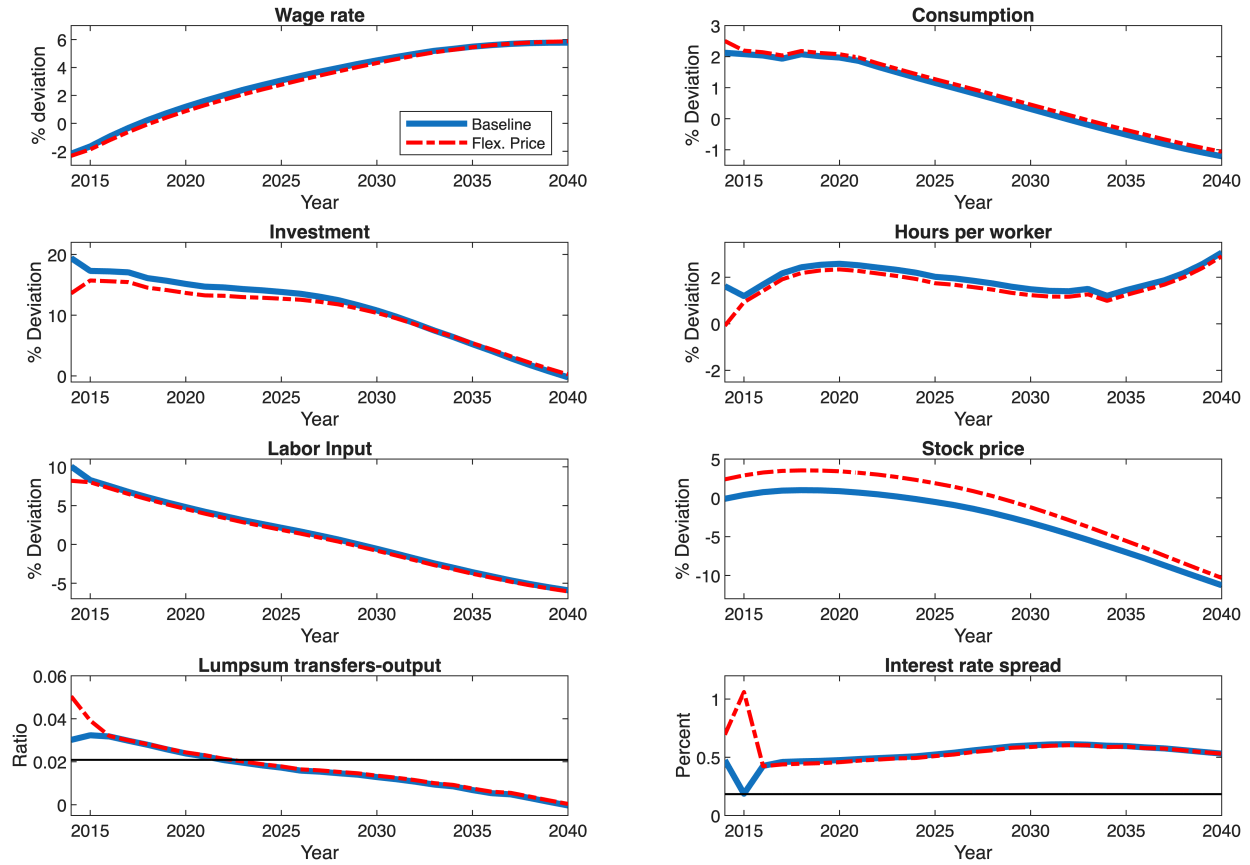


Figure 4: Additional baseline and flexible price responses to aging

Notes: All variables are percentage deviations from the terminal steady state except the interest rate spread which is reported in levels. The thin black line is its terminal steady state value.

A second factor contributing to the steady decline in real interest rates is an increase in aggregate household asset holdings. Government debt and illiquid assets are imperfect substitutes and the returns and spread on these two assets are now equilibrium objects. So it is hard to ascertain the relative magnitude of GE effects versus the PE effects due to changes in the age distribution reported in Table 2 but the GE effects are magnifying the aggregate asset demand glut. Private holdings of liquid assets peak later and both assets peak at a higher level here compared to the partial equilibrium (PE) results. The peak increase in private holdings of liquid assets is 68.9 percent in the baseline GE simulation as compared to 27.1 percent in the baseline PE scenario and the peak occurs in 2074 in the GE scenario as compared to 2043 in the PE scenario. Holdings of illiquid assets peak in 2027 in the GE simulation as compared to 2053 in the PE simulation. The peak increase in holdings of illiquid assets is also higher at 7.3 percent in the GE scenario as compared

to 5.2 percent for the PE scenario. Thus, modeling the responses in GE has a particularly strong and persistent impact on liquid asset holdings.

Higher aggregate holdings of liquid assets depress the price level and the inflation rate in our model. This mechanism is transparent in the baseline simulation because per capita nominal government debt is fixed. Under this assumption the asset market clearing condition (20) is

$$\frac{d^n}{P_t} = \frac{\sum_{j=1}^J \bar{d}_{j,t} N_{j,t}}{N_t}. \quad (22)$$

where d^n is the constant per capita supply of nominal government debt; P_t is the price level; and the right hand side is per capita aggregate household demand for liquid assets.

One reason the price level falls is that the decline in the Japanese fertility rate is assumed to be permanent. Nominal per capita debt is constant, so the price level has to eventually drop to clear the asset market for liquid assets. Still, this does not explain the timing, that is, how and why the baseline specification produces concurrent declines in both real interest rates and the inflation rate between the years 2014 and 2040.

To identify the economic mechanisms producing the aggregate responses during the transition we decompose household level responses into demographic and GE or behavioral components. Then we discuss how the aggregate responses are related to the household level responses of different age groups, and conduct counterfactuals where we allow the reaction functions of monetary and fiscal policy to change.

Figure 5 decomposes the aggregate baseline responses of consumption, liquid and illiquid asset holdings, net worth, disposable income, and asset income into a demographic and a behavioral factor for three age groups: 21–45, 46–67 and 68+. The total contribution of an age group to the aggregate response is the first bar in a given year and the solid ticked line is the aggregate response of the variable. The total contribution of an age group is decomposed into a demographic factor: the contribution of the reported age group’s population share deviation to the aggregate response, and a behavioral factor: the contribution of the given age group’s endogenous responses to the aggregate response. Summing over age groups for a single factor gives the total contribution of the factor. Summing across the two factors gives an age group’s contribution to the total response and summing over age groups’ total responses, yields the aggregate response.

For instance, the decomposition for aggregate per capita consumption reported in the

figure is given by

$$\begin{aligned}
\frac{c_t - c_{ss}}{c_{ss}} &= \sum_g \frac{c_t^g - c_{ss}^g}{c_{ss}} = \sum_g \sum_{j \in g} \frac{(\mu_{j,t} c_{j,t} - \mu_{j,ss} c_{j,ss})}{c_{ss}} \\
&= \underbrace{\sum_g \sum_{j \in g} \frac{(\mu_{j,t} - \mu_{j,ss}) c_{j,t}}{c_{ss}}}_{\text{Demographic factor}} + \underbrace{\sum_g \sum_{j \in g} \frac{(c_{j,t} - c_{j,ss}) \mu_{j,ss}}{c_{ss}}}_{\text{Behavioral factor}} \tag{23}
\end{aligned}$$

where, $\mu_{j,t}$ is the population share of age group j in period t , ss is the terminal steady state value of the variable, g denotes age group, and $c_t^g = \sum_{j \in g} \mu_{j,t} c_{j,t}$ is the consumption of households in age group g . The demographic factor is large in absolute value for age groups that have large deviations from their terminal steady state population shares, and it is weighted by the consumption share of the age group. Thus, middle-aged groups that have relatively large consumption receive more weight than young groups who have small consumption. The behavioral factor is large in absolute value when consumption of the age group is far from its steady state level, and it is weighted by the steady-state population share. This decomposition scheme aggregates exactly to the total response when we sum across age groups and sum across behavioral and demographic responses and provides a reasonably accurate decomposition into demographic and behavioral factors.²² One way to test this claim is to compare the size of the demographic factors in each of the different policy counterfactuals. Under an ideal decomposition the difference would be zero. Under our decomposition the differences are indiscernible (compare Figure 5 with Figures A.2, A.4, A.5, and A.7).²³

Figure 5 shows that the total response of liquid asset demand rapidly increases from -0.03 percent in 2014 to 23.9 percent in 2035, which acts to depress the price level (equation 22). Because liquid asset demand accelerates, the inflation rate declines over time (Figure 3). The decomposition shows that older working-age households become more important over time. In later years the demographic factor of the 46–67 age group is large and positive. In addition, its behavioral factor also changes substantially from 2014 to 2035 as it turns from a large negative value to positive values in later years. Behavioral responses of the 68+

²²We first experimented with linear and log-linear decompositions but the approximation errors when summing across age groups were unacceptably large.

²³For instance, the maximum difference in the consumption demographic factor across policy counterfactuals compared to the baseline is 0.16 percentage points for the 21–45 and 46–67 age groups and 0.22 percentage points for the 68+ age group. The maximum difference in aggregate consumption is 0.21 percentage points with one exception. In the high debt simulation presented in Section 4.2.3 it is 0.35 percentage points in 2035 and 0.21 percentage points or less in the other years.

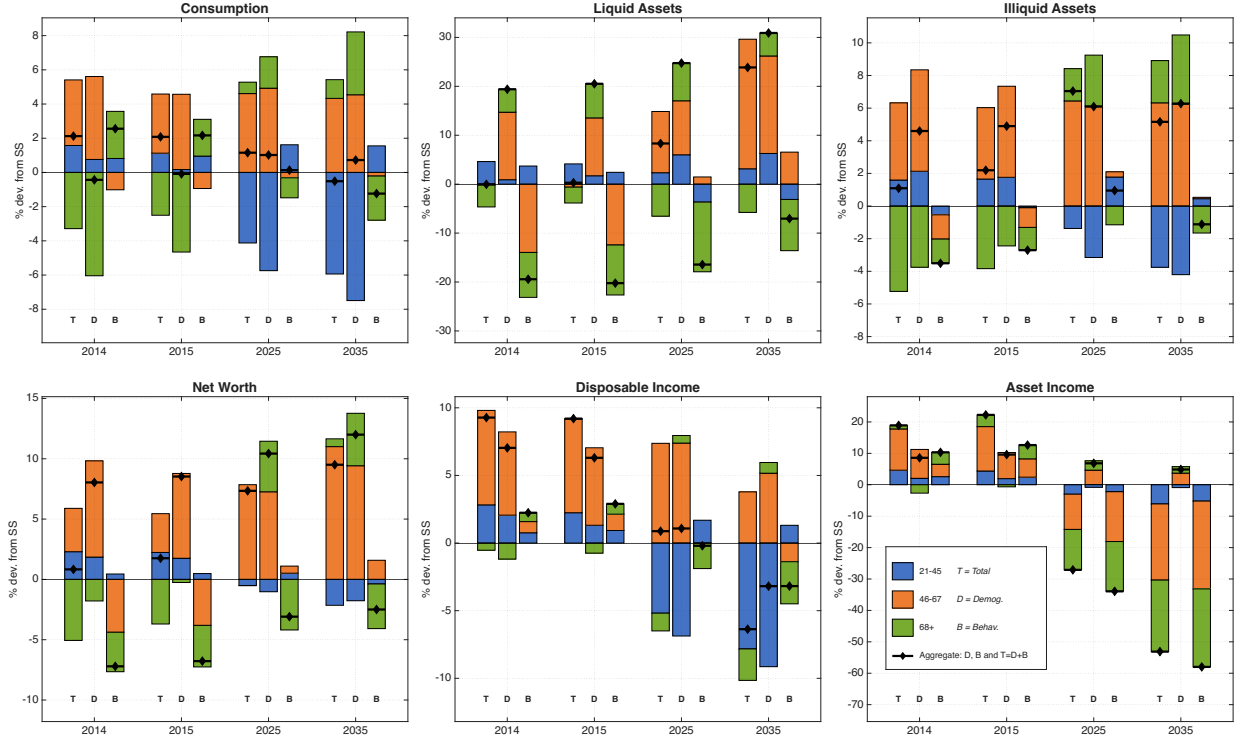


Figure 5: Decomposition of aggregate household responses by age group in assorted years

Notes: All variables are percentage deviations from the terminal steady state. The first bar (T) in a given year is the total contribution to the aggregate response of the 21–45, 46–67 and 68+ age groups. The center bar in a given year is the contribution of demographics (D) to the total age group deviation (the weighted deviation of the population share of a given age group from its terminal steady state). The third bar is the contribution of behavioral (B) responses by households (weighted deviation of the response of households choices in the given age group). The total response of an age group is the sum of its demographic and behavioral factors. The black ticked lines denote the total contribution of each factor to the total aggregate response ($T=D+B$).

age group are the biggest drag on liquid asset demand. This age group is experiencing much lower income on their asset portfolios, which is depressing their net worth and allocations to both assets. Behavioral responses of net worth for this group are -4.2 percentage points in 2025 and -3.7 percentage points in 2035.

More generally, Figure 5 shows that the demographic factor is offsetting and attenuating the behavioral responses for asset holdings and that the prominence of the demographic factor grows over time. The demographic factor is larger than the behavioral factor for both liquid and illiquid asset holdings in 2014 and 2015. The in 2025, liquid assets are up by 8.3 percent with the demographic factor up by 24.7 percentage points, and the behavioral factor down by 16.4 percentage points. Illiquid assets in 2025 are up 7.0 percent primarily

because the demographic factor is up 6.1 percentage points, while the behavioral response is positive too but only 0.95 percentage points.

Figure 5 also indicates that the behavioral factor has a particularly strong contribution to total asset income. Figure 3 indicates that real returns on liquid and illiquid assets are above their steady state levels in the first several years of the transition then they fall below their terminal steady-state levels after 2018 and decline persistently. In 2014 and 2015, the demographic and behavioral responses of asset income increase by similar magnitudes (Figure 5). However, in 2025 and 2035, positive responses in the demographic factor are overwhelmed by the effects of low real interest rates on household portfolios. For instance, in 2025 the total contribution of the demographic factor to the 27.1 percent decline in average per capita asset income is 6.8 percentage points and the behavioral contribution is -33.9 percentage points. Behavioral effects are particularly pronounced in the two oldest age groups because they have large net worth (Table 1).

Figure 5 shows that the two factors influence aggregate per capita consumption in opposing ways. The total demographic factor depresses aggregate consumption by 0.43 percentage points in 2014 and by 0.09 percentage points in 2015 and then turns positive contributing 1.0 percentage points in 2025 and 0.72 percentage points in 2035 as the population share of older and thus more affluent consumers increases. The behavioral factor, in contrast, is strong and positive in the first two years of the transition contributing 2.6 percentage points in 2014 and 2.2 percentage points in 2015. Its contribution then falls to 0.13 percentage points in 2025 and then turns negative depressing aggregate consumption by 1.2 percentage points in 2035. Thus, the behavioral factor is the main contributing factor to the increases in aggregate consumption of 2.1 percent in 2014 and 2.1 percent in 2015. The demographic factor is the largest contributing factor in 2025 and both factors are large in 2035.

Figure 5 also has the property that cross-sectional heterogeneity in the demographic factor is larger than cross-sectional heterogeneity in the behavioral factor and the difference increases over time. This result is troubling because it implies that the total consumption response of an age group misrepresents the true incidence of the shock on the age group. For instance, each member of the oldest age group has higher consumption in 2014 and 2015 and each member of the middle age group has lower consumption in the same two years. However, a (naive) decomposition of total aggregate consumption by age group would indicate that aging depresses consumption of the oldest age group and increases consumption of the middle age group.

We now discuss two outstanding issues. First, we have posited a particular nominal interest rate targeting rule and assumed that nominal per capita public debt is constant. We next document the sensitivity of our conclusion that aging is persistently depressing real interest rates, output and inflation to the choice of the monetary policy (MP) rule and show that our conclusion also obtains when we allow the nominal supply of government debt to increase.

Second, we have found that the two factors have offsetting effects on aggregate consumption and that the influence of the demographic factor increases over time. This raises the possibility that conventional government policies for stimulating aggregate demand are less effective in rapidly aging societies. We now analyze this possibility by modeling stronger reaction functions of monetary and fiscal policy.

4.2.2 The reaction of monetary policy to aging

Our analysis of monetary policy proceeds in three steps. First, we analyze the transmission channels of monetary policy in an aging society. Second, we show that the reaction function of monetary policy to aging plays a central role in producing concurrent declines in the real interest rate and the inflation rate. Third, we show that a more aggressive focus of the central bank on price stability has a large impact on equilibrium asset holdings and aggregate investment but a negligible effect on aggregate consumption.

[Braun and Ikeda \(2025\)](#) consider a shock to MP in this model and find that nominal price rigidities play a central role in the model’s ability to reproduce local projection evidence on the signs and magnitudes of a variety of Japanese aggregate variables to monetary policy shocks. They reach this conclusion by showing that the fit of the model deteriorates sharply when price adjustment costs (γ) are set to zero. We use the same strategy to show that nominal rigidities are not essential for understanding how and why the reaction of monetary policy matters in an aging society in the medium term.

Figures 3–4 report responses for the baseline and flexible price specifications. The aggregate responses for the two specifications are different in the impact year, as is to be expected. Inflation declines by more on impact when prices are flexible and the ex post real return on liquid assets rises to 2 percent. Because government debt is a nominal asset, its real value in 2014 is also higher than the baseline.

Higher ex post returns on both assets translate into higher asset income in 2014 for the two older age groups. A comparison of Figure A.2, which is reported in Online appendix

A.2, with Figure 5 reveals that the total response of portfolio income rises from 18.9 percent in the baseline to 60.3 percent under flexible prices and that this increase is due to a large increase in the behavioral factor for the two older age groups. However, this benefit is short lived. Total portfolio income responds more in the baseline in 2015, (22.2 percent versus 11.6 percent with flexible prices) and in subsequent years asset income responses by age group are essentially the same in the two simulations.

Consumption increases slightly more in 2014 (2.5 percent versus 2.1 percent in the baseline) and the investment response is slightly smaller. From 2015 on the only discernible differences in the aggregate responses are that investment and output are slightly lower when prices are flexible.

Figures 5 and A.2 show that the moderately larger response in aggregate per capita consumption in 2014 reflects higher asset income received by the two older age groups. In subsequent years, the response of total consumption by age group and the incidence of the aging shock on consumption of different age groups is similar to the baseline. Finally, changes in the relative sizes of different age groups continue to mask the true incidence of the shock on household consumption when prices are flexible.

We next show that the reaction of monetary policy to aging plays a central role in our baseline finding that the inflation rate gradually falls over time. The nominal interest rate targeting rule in the baseline specification assumes that $\phi_\pi = 2$ and that the smoothing parameter is $\rho_r = 0.35$. This is the same parameterization used in Braun and Ikeda (2025).²⁴

Figure 6 and Figure A.3 report results for a scenario with a higher persistence parameter in the interest rate targeting rule: ρ_r is set to 0.9. This specification exhibits different dynamics from the baseline in the first two years of the transition, but it continues to have the property that real interest rates are falling over time from 2016 onward. However, the inflation rate now falls to -3.8 percent in the impact period and then increases over time. In addition, output increases and then is essentially flat in the first 10 years of the transition. These final two observations are inconsistent with the secular stagnation observations that

²⁴We are considering an environment here where the real return on liquid assets falls persistently over time and this raises the question about whether the natural interest rate in the nominal interest rate targeting rule should include a term with the natural real interest rate on liquid assets. In the experiment we are considering, the inflation rate and the real interest rate on liquid assets are moving in the same direction so introducing such a term would not over turn our main result. Instead it would result in a stronger response of monetary policy to the combined effects of a lower natural real interest rate and a lower inflation rate. We will entertain this possibility by considering a higher value of $\phi_\pi = 10$ in the analysis that follows.

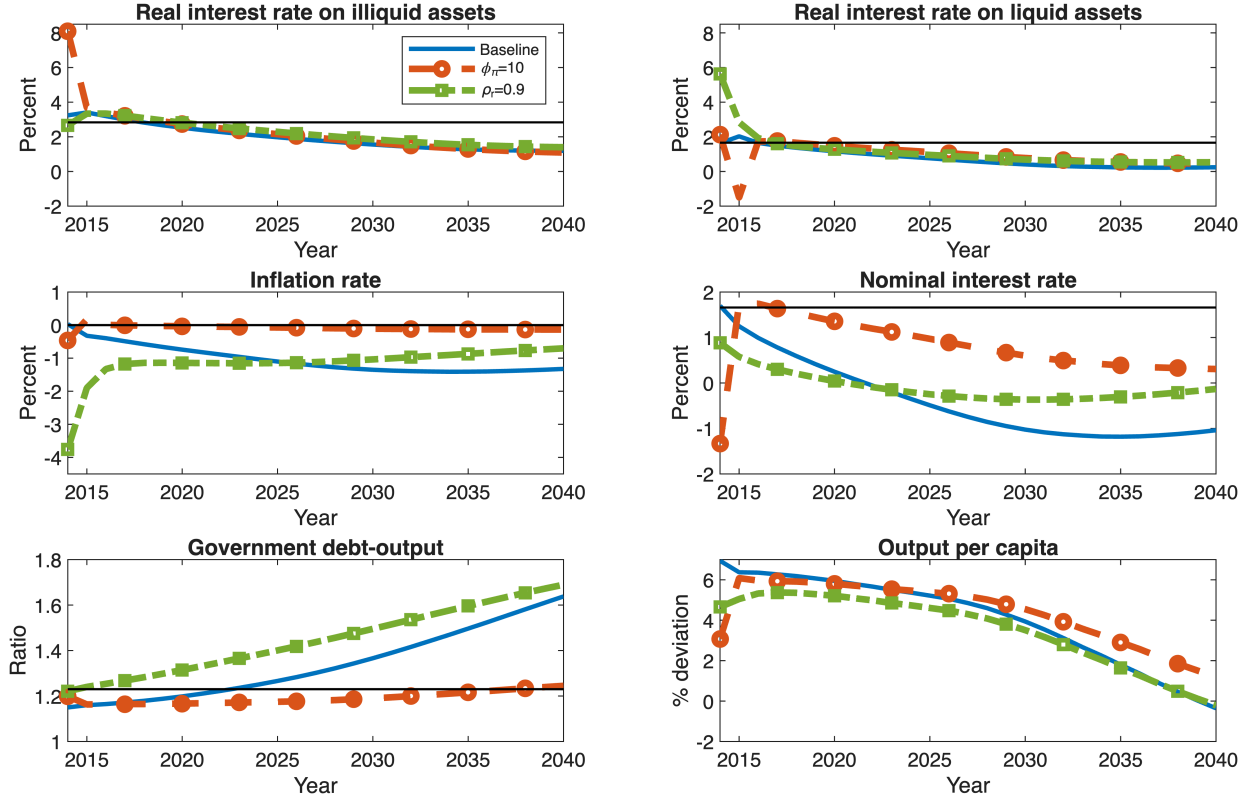


Figure 6: Responses to aging under alternative monetary policy feedback rules

Notes: “Baseline” denotes the baseline shown in Figure 3 with $\phi_\pi = 2$ and $\rho_r = 0.35$. The $\rho_r = 0.9$ uses this higher value of interest rate smoothing instead and the $\phi_\pi = 10$ scenario uses this higher value of the inflation elasticity instead. See the notes to Figure 3 for definitions of the variables. See the Online appendix A.2 for responses of other macroeconomic variables.

inflation, real interest rates, and output fell concurrently and were persistently low.

The stronger focus on smoothing the nominal interest rate has two main effects on the nominal interest rate in Figure 6. First, the nominal interest rate only falls moderately in response to the large decline in the price level in 2014. Second, the response of the nominal interest rate to the persistent deflation in subsequent periods is gradual and small in magnitude. The nominal interest rate is higher than the baseline after 2023 and never falls below -0.37 percent.

The interest rate smoothing monetary policy rule produces very different patterns of capital gains and future returns than the baseline, as indicated by a comparison of Figure A.4 with Figure 5. In 2014 asset income increases by 80.9 percent here but by only 18.9 percent in the baseline and the beneficiaries are older working households and retired households. The behavioral factor in 2014 is up by 47.7 percentage points for older workers

and up 29.1 percentage points for retired households. Conversely, young working households experience capital losses and their asset income falls by 18 percentage points. The two older groups still face lower expected returns on their savings but the trajectory of spreads helps them to mitigate their future losses in asset income. For instance, the baseline behavioral factor for asset income is down 15.9 percentage points for both groups in 2025. In this scenario, the decline is only 10.1 percentage points for older working households and 11.2 percentage points for retired households. Younger working households also partially hedge their future losses in asset income. Their asset income in 2025 is down 2.2 percentage points in the baseline and only 1.0 percentage points here.

Compared to the baseline, this monetary policy increases aggregate holdings of liquid assets and crowds out illiquid assets (Figure A.4). Aggregate holdings of liquid assets in 2025 are up 19.1 percent here compared to 8.3 percent in the baseline while aggregate holdings of illiquid assets are up only 5.5 percent here and 7.0 percent in the baseline. By tolerating more deflation, the central bank not only creates capital gains for the two older age groups but also increases the real aggregate supply of liquid assets. Monetary policy is having fiscal effects. Nominal per capita debt is fixed, but the debt–output ratio increases more rapidly in this scenario than the baseline (Figure 6) and private investment is crowded out (Figure A.3).

Under this MP, aggregate consumption is lower than the baseline in the impact year and marginally higher in subsequent years. In 2014, the $\rho_r = 0.9$ MP redistributes wealth across households in a way that depresses aggregate consumption from 2.1 percent in the baseline to 1.9 percent. However, aggregate per capita consumption responses are close to the baseline responses after 2014 and the contributions of the two factors are about the same. In 2025, the behavioral factor contributes 0.51 percentage points to the total consumption response of 1.7 percent here while in the baseline it contributes 0.13 percentage points to a total consumption response of 1.2 percent. In 2035, the total consumption response is marginally larger here (0.068 versus -0.51 percent) because the behavioral factor decline is marginally smaller.

On net, a strong focus on interest rate smoothing has mild positive effects on consumption in most years but depresses investment more, and output is lower than the baseline in all years between 2014 and 2035.

Stabilizing the price level is the optimal policy in the standard New Keynesian framework, and setting the inflation elasticity to a large number is one way to implement it (see Gali, 2008). This rule also has attractive welfare properties in some HANK models. Braun

and Nakajima (2012) find that stabilizing the price level is essentially the optimal monetary policy in a tractable HANK model with countercyclical idiosyncratic risk in earnings and assets.²⁵ Our model has nominal rigidities so we now consider a MP rule that aggressively penalizes deviations of the inflation rate from its steady state value of zero and refer to this scenario as the strict inflation stabilization rule.

Figures 6 and A.3 report the aggregate responses and Figure A.5 reports the responses of different age groups for a scenario where $\phi_\pi = 10$. Under this policy, the nominal interest rate responds aggressively to the deflationary pressure created by the aging shock. The nominal rate falls to -1.3 percent in the impact period, rises back to its steady state level in 2015 and then gradually declines over time. In subsequent years, the nominal rate declines gradually but never falls below zero. This aggressive response of MP is successful in stabilizing the inflation rate, which declines slightly in the impact year but is close to its terminal steady state of zero in all subsequent years. In contrast, the baseline, which uses the same parameterization of the nominal interest rate targeting rule as Braun and Ikeda (2025), is more consistent with Japan’s experience with deflation than the $\phi_\pi = 10$ scenario. Thus, our model implies that the persistent downward pressure on the price level associated with population aging could have been avoided with a more aggressive reaction of monetary policy, but not the declines in real interest rates and output. The output declines are somewhat smaller in this scenario than the baseline, but the real interest rate declines are larger here, falling by 2.59 percentage points between 2015 and 2040 compared to a 2.22 percentage point decline in the baseline.

Debt and liquid asset holdings also respond less in 2014 in this scenario compared to the $\rho_r = 0.9$ scenario (Figure A.5). In that scenario liquid asset holdings increase by 3.9 percent in 2014 due to the large decline in the price level and the ex post real return on liquid assets is large and positive. In the strict inflation stabilization scenario, the price level response is small in 2014 and aggregate liquid asset holdings only increase by 0.46 percent. The ex post return on liquid assets is close to its steady-state level and the ex post real interest rate on illiquid assets and the price of equity both increase.

Wealth effects are large and positive in this scenario in 2014 (Figure A.5), which increase consumption and depress hours worked (Figure A.3). Total asset income increases by 166 percent in 2014 and the contribution of the behavioral factor is positive for all age groups.

Strict inflation stabilization also has a big impact on the size and composition of ag-

²⁵Acharya et al. (2020), in contrast, document a welfare enhancing role for integrating distributional considerations into the central bank’s MP rule in their HANK specification.

gregate asset holdings in subsequent periods. Aggregate supply of liquid assets is lower here compared to the baseline (real government debt does not increase much). In fact, the behavioral contribution of liquid asset holdings is negative, offsetting the positive contribution of the demographic factor, and aggregate holdings of liquid assets are close to their steady state level from 2015 onward. Instead, households accumulate more illiquid assets. In 2025 and 2035, the contribution of the behavioral factor is strong and positive. It reinforces the positive contribution of the demographic factor, and aggregate holdings of illiquid assets increase by 13.7 percent in 2025 and by 14.7 percent in 2035.

These adjustments result in much smaller increases in the debt–output ratio than the baseline in all periods (Figure 6) and eventually higher aggregate investment (Figure A.3). Aggregate investment is lower than the baseline in 2014 and 2015 but higher than the baseline after 2025.

This monetary policy reallocates wealth across different age groups in a way that boosts aggregate consumption demand in 2014 (Figure A.5). Aggregate consumption increases by 3.6 percent here and by only 2.1 percent in the baseline. However, the aggregate consumption responses are similar to the baseline in subsequent years. In 2025, the behavioral factor contributes 0.4 percentage points to the total increase in consumption of 1.5 percent compared to a contribution of 0.1 percentage points to a total increase of 1.2 percent in the baseline. In 2035 the aggregate consumption response is -0.34 percent here and -0.51 percent in the baseline and the contributions of the two factors are also close to their baseline values.

The household portfolio and consumption responses produced under the strict inflation stabilization rule also fail to offset the effects of aging on output and real interest rates. Output declines over the medium term in both the baseline and the $\phi_\pi = 10$ scenarios. The timing of the decline, however, is different. Strict inflation stabilization also produces a deep recession on impact, and output remains below the baseline in all years prior to 2025. Output then rises above the baseline and is 1.11 percentage points higher in 2035 due to the cumulative effect of higher private investment on the capital stock. However, these results indicate that strict inflation stabilization is reallocating output over time rather than arresting the secular decline induced by aging.

Taken together, our results indicate that monetary policy influences the inflation rate and real allocations. MP has persistent and distinct effects on the price level and the time path of real government debt in the three scenarios. MP also influences the cross-sectional distribution of capital gains and losses and aggregate consumption in the impact period.

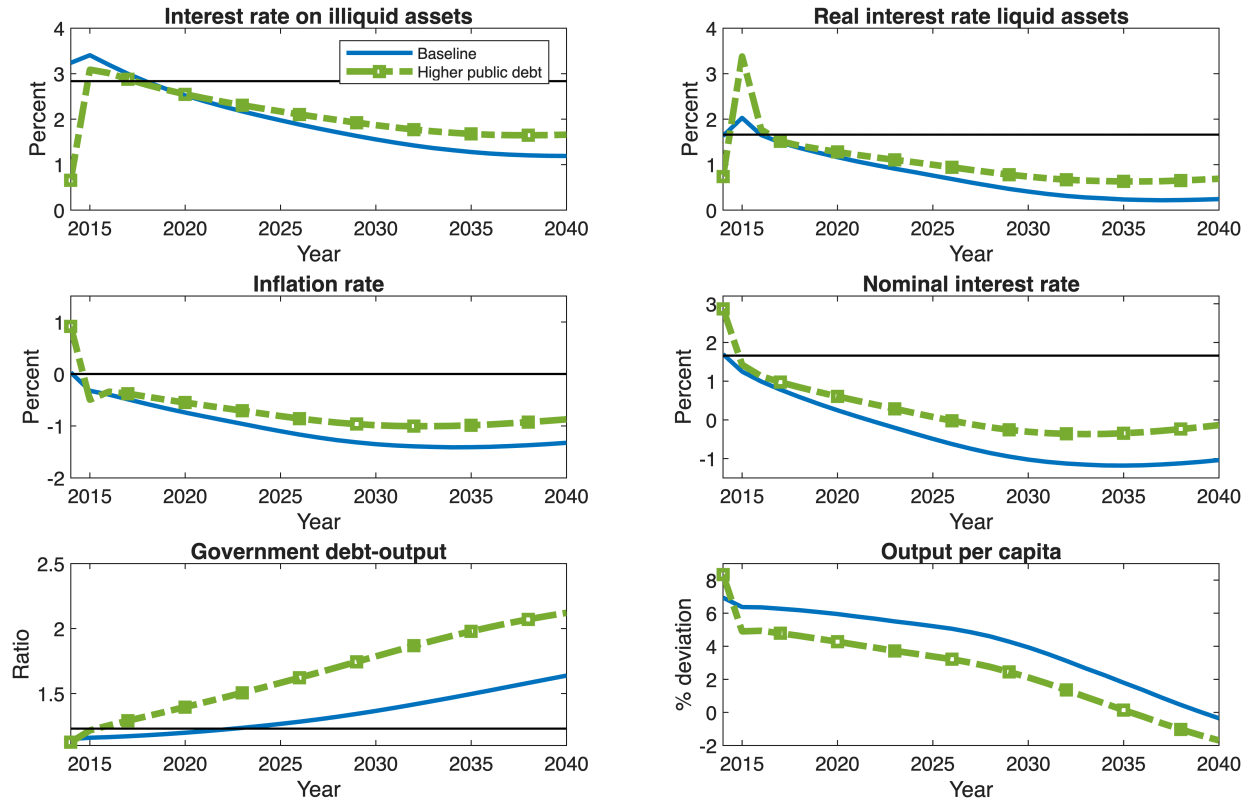


Figure 7: Responses to aging with higher nominal government borrowing

Notes: “Higher govt debt” denotes the case of higher nominal government borrowing, “ $\rho_r = 0.9$ ” is the scenario with a higher smoothing parameter in the interest rate targeting rule and “Baseline” denotes the baseline shown in Figure 3. See the notes to Figure 3 for definitions of the variables. See Online appendix A.2 for responses of other macroeconomic variables.

Monetary policy has a persistent impact on aggregate holdings of liquid and illiquid assets, and the interest rate spread. However, these non-neutralities only have a small impact on aggregate consumption demand in 2015 and beyond. Aggregate consumption in these years is close to the baseline and the demographic factor continues to damp and offset the behavioral consumption responses in a way that masks the incidence of the shock on different age groups. MP can also influence aggregate investment and how the declines in output are distributed over time. However, output and real interest rates decline in the medium term in all three scenarios. Thus, even aggressive MP reactions are not able to offset the persistent negative effects of aging even though monetary policy is unconstrained by the ELB. This establishes the first half of our policy ineffectiveness claim in an aging trap.

4.2.3 Higher government borrowing in an aging society

Up to this point, we have held the supply of per capita nominal government debt fixed. This was a deliberate choice because it made it easier to inspect the mechanisms that allow our model to account for the deflation and secular stagnation facts and to ascertain the magnitudes of endogenous revaluation effects on real government debt under alternative MP regimes. Still, the increases in the real debt–output ratio documented so far are entirely due to changes in the real value of the constant per capita stock of nominal debt. Our aging trap claim asserts that the persistent declines in real interest rates and output are also resistant to fiscal stimulus. In reality the nominal stock of government debt has been increasing over time in Japan. We now show that large increases in nominal government debt have a small but positive influence on the inflation rate, but also fail to offset the persistent declines in real interest rates and per capita output in our model.

Our economy is dynamically efficient. This property of the model matters when analyzing the macroeconomic effects of higher government borrowing for the reasons discussed in [Blanchard \(2023\)](#). In our baseline specification, the demographic shock is not large enough to push the real return on government debt below the growth rate of output even temporarily. Thus, a temporary increase in government borrowing has real effects, but higher government debt must eventually be offset by other government policies to prevent the debt–output ratio from exploding.

Figures 7 and A.6 report aggregate responses to a scenario where the fiscal authority accommodates the increase in real aggregate private demand for liquid assets by gradually increasing the supply of nominal government debt. Figure A.7 reports responses of the three age groups for the high government debt scenario.²⁶ The debt–output ratio in 2015 is 1.22, somewhat higher than its baseline response of 1.16. The debt–output ratio also increases more rapidly over time in this simulation, reaching a level of 2.12 in the year 2040, while the corresponding value is 1.64 in the baseline. Thus, the increase of the ratio ($0.90 = 2.12 - 1.22$) in this simulation is nearly twice as large as the increase in the baseline ($0.48 = 1.64 - 1.16$) over the same horizon. Of the increase in the real stock of government debt over this time period, 59 percent is due to higher nominal debt issuance and 41 percent is due to revaluation effects.

The large increase in the real debt–output ratio associated with higher nominal govern-

²⁶We calibrate the size of the increase in nominal government debt to produce a -1 percent floor in the inflation rate during the transition. For purposes of comparison, the minimum inflation rate in the baseline is -1.41 percent.

ment borrowing has a relatively small impact on the inflation rate between 2015 and 2030. There is less downward pressure on the price level, but the model continues to predict that aging is deflationary. The lowest value of the inflation rate in the baseline scenario is -1.41 percent. In this scenario its minimum value is -1 percent and it hits this floor in the year 2032. An inflation rate of -1 percent is not exceptionally low. For instance, the Japanese GDP deflator experienced year over year declines of -0.9 percent on average between 1995–2013. Real interest rates, output, and the nominal interest rate are also declining between 2015 and 2040. Thus, our main result that aging induces deflationary pressure continues to obtain when we allow for considerably more fiscal stimulus in response to the aging shock. One reason for this result is the response of monetary policy to the new trajectory of the inflation rate. Higher government borrowing is reducing the downward pressure on the price level, and less deflationary pressure means less monetary stimulus. The nominal interest rate still falls over time but is always higher than the baseline value. For instance, the minimum value of the nominal interest rate is -0.37 percent per annum here as compared to -1.18 percent in the baseline scenario.

This combination of fiscal and monetary policies affects households in new ways. In 2014, for instance, ex post returns on both assets are negative and the asset income behavioral factor is negative and large in absolute value for all three age groups (Figure A.7). These losses are so large that the disposable income behavioral factor also falls for all three age groups with a total behavioral decline of 11.4 percentage points. The baseline has the opposite properties. The behavioral factors of asset and disposable income increase for all three groups in 2014 (Figure 5).

Despite these capital losses, the nominal supply of government debt is increasing over time, and the level of real interest rates and the spread adjust to induce households to increase their real holdings of liquid assets. Their responses are particularly strong later in the transition. The behavioral factor contributes 8.5 percentage points to total aggregate demand for liquid assets in 2025 and 30.4 percentage points in 2035 (Figure A.7). The larger contribution of the behavioral factor reflects higher liquid asset demand of young and middle-aged workers. Demand by the oldest age group falls in both years. In the baseline (Figure 5), the behavioral factor acts to depress aggregate liquid asset holdings in 2025 and 2035 and the positive total responses reflect increases in the demographic factor.

This surge in demand for liquid assets crowds out demand for illiquid assets. The declines in the behavioral factor of illiquid asset holdings are large relative to the baseline responses in all years, and the crowding out effect of higher government debt on illiquid

asset demand is also particularly pronounced at longer horizons. The high government debt scenario has the property that all age groups choose to reduce their illiquid asset holdings in 2025 and 2035. The behavioral component of illiquid asset demand declines by a total of 4.6 percentage points in 2025 and by 7.3 percentage points in 2035 (Figure A.7). In the baseline, both younger and older workers choose to increase their holdings of illiquid assets, and retired households reduce their holdings and the total behavioral responses are 0.95 percentage points in 2025 and -1.1 percentage points in 2035 (Figure 5). These differences in household choices can be readily observed in aggregate investment, which is depressed in the high government debt scenario relative to the baseline in all years between 2015 and 2040 (Figure A.6).

Aggregate consumption gradually declines over time in this scenario too. In 2014, total consumption is 1.9 percent above its terminal steady state here and 2.1 percent in the baseline. In 2025, total consumption is 1.5 percent above steady state here and 1.2 percent in the baseline and in 2035 responses are 0.14 percent here and -0.51 percent in the baseline.

Overall, higher government debt gradually boosts consumption but at the cost of crowding out private investment and output is lower relative to the baseline in all years between 2015 and 2040 as shown in Figure A.6. This establishes the second half of our policy ineffectiveness claim in an aging trap.

4.3 The distributional consequences of aging

We have seen that aging has heterogeneous effects on young, middle-aged, and old households and that government policy influences the incidence of aging. We now analyze how government policies influence the incidence of the aging shock on different cohorts by reporting their consumption responses at assorted dates.²⁷

Table 3 reports age profiles of the behavioral component of consumption responses to the aging shock at alternative horizons.²⁸ We report the behavioral component because the demographic factor is large but nearly identical across the policy counterfactuals. Total consumption responses by age group therefore obscure the effects of different government policies on individual household consumption. The top panel reports results for the baseline

²⁷We report consumption at different dates instead of expected present value utility to make it easier for the reader to distinguish between the large impact responses that alternative government policies have on consumption in the impact year (2014) from the responses in subsequent periods.

²⁸In the ensuing discussion the reader may find it helpful to refer back to Table 1, to see how holdings of liquid and illiquid assets vary over the lifecycle in our model.

Table 3: Behavioral Component of Consumption (percentage point deviation from steady state)

Scenario	Age Group	2014	2015	2025	2035
Baseline	21–45	0.82	0.96	1.62	1.55
	46–67	-1.01	-0.94	-0.31	-0.21
	68+	2.76	2.15	-1.17	-2.58
	Total	2.56	2.17	0.13	-1.24
Strict inflation stabilization ($\phi_\pi = 10$)	21–45	0.86	0.64	1.41	1.61
	46–67	-0.56	-0.84	-0.35	-0.35
	68+	3.82	2.82	-0.66	-2.31
	Total	4.11	2.63	0.40	-1.05
Interest rate smoothing ($\phi_\pi = 2$, $\rho_r = 0.9$)	21–45	0.16	0.40	1.19	1.27
	46–67	-0.86	-0.73	-0.28	-0.28
	68+	2.83	2.41	-0.40	-1.82
	Total	2.13	2.08	0.51	-0.83
Higher government debt	21–45	0.54	0.77	1.14	0.86
	46–67	-0.71	-0.51	0.02	0.04
	68+	2.32	1.89	-0.90	-1.82
	Total	2.14	2.15	0.26	-0.93

simulation. In our model the aging shock has persistent positive implications for consumption of households in the 21–45 year old age group. They benefit from an increasing wage profile as labor becomes more scarce. In addition, young households borrow liquid assets to purchase illiquid assets, and aging increases the profitability of their preferred asset allocation strategy because the interest rate spread is persistently high during the demographic transition (see Figure 3). Households in the 46–67 age group, in contrast, experience consumption declines at all three horizons. The main reason for this difference is that members of this age group hold positive amounts of both types of assets, and the returns on both assets fall persistently during the transition. When the aging shock arrives, they realize that they will accumulate less wealth in their remaining lifetime and reduce their consumption persistently. Average consumption in the 68+ age group increases in 2015 due to portfolio revaluation effects associated with the shock. After-tax returns on illiquid assets are above their terminal steady-state level until 2017. However, their average consumption declines in the years 2025 and 2035 due to persistently low returns on their portfolios.

Our main objective in this paper is to understand the quantitative significance of aging for secular stagnation and deflation. Still, it is also interesting to understand the individual

roles of monetary and fiscal policy in redistributing resources across households during the demographic transition. Consider first monetary policy. The top panel of Table 3 reports behavioral consumption responses by age group and in total for the baseline. The second panel reports results for the strict inflation stabilization MP scenario, and the third panel reports results for the interest rate smoothing MP scenario. The 21–45 age group has uniformly lower consumption in the interest rate smoothing scenario compared to the baseline. They experience smaller capital gains in the impact period and face persistently lower wages than in the baseline (Figures 6 and A.3). The differences between the baseline and the strict inflation stabilization scenario are much smaller for the 21–45 age group but they strictly prefer the baseline or strict inflation stabilization monetary policies to interest rate smoothing.

Individuals in the 46–67 age group experience persistent consumption losses in all three monetary policy scenarios. The two alternative monetary policies deliver somewhat higher consumption than the baseline in the years 2014 and 2015 but lower consumption at longer horizons.

The 68+ age group strictly prefers either of the two alternative monetary policy scenarios over the baseline. These households are retired and both alternative monetary policies offer them higher portfolio income at medium horizons compared to the baseline.

Issuing more government debt redistributes wealth from young workers to middle-aged workers. Young workers have higher consumption in the baseline in all four periods compared to the high government debt simulation. This group faces a flatter time profile of wages and a smaller interest rate spread, which reduces the returns on their preferred investment strategy of borrowing liquid assets to purchase illiquid assets (Figure A.6).

Middle-aged workers, in contrast, like the higher government debt scenario. They experience larger behavioral losses on their asset portfolios in the impact period compared to the baseline but benefit from higher interest rates on their asset portfolio in subsequent years and have higher consumption in all four periods in the high debt scenario.

Higher government borrowing changes the timing of consumption for the 68+ age group. This group experiences larger negative losses on its portfolio in the impact period and has low asset income in 2014 and 2015 in the high government debt scenario and its consumption is lower than the baseline in 2014 and 2015. However, at medium-term horizons it benefits from higher asset income and higher consumption compared to baseline.

Overall, our results suggest that younger workers benefit from aging, that older working-age households are the only group that loses at every horizon, and that the largest medium-

term losses fall on the retired.

4.4 Robustness

We have found that aging puts persistent upward pressure on aggregate demand for liquid assets and downward pressure on the inflation rate. Eventually this pressure reverses and demand for liquid assets falls and the price level rises in our model. This result is similar in spirit to arguments made in [Sargent and Wallace \(1981\)](#) that monetary policy influences the time profile of asset demand and inflation. It also has a bearing on [Goodhart and Pradhan \(2017\)](#) who argue that aging will produce inflation in future years, and [Juselius and Takáts \(2018\)](#) who provide empirical evidence that the combination of a lower share of younger population cohorts and a higher share of older cohorts will create inflationary pressure in future years.

Figure [A.8](#) (see Online appendix [A.2](#)) displays the entire demographic transition. The inflation rate falls persistently then rises above its steady state level before returning to the terminal steady state from above. The reason for this result is that private asset demand peaks during the transition and after this peak it declines. Table [2](#) shows that the date of the peak for the partial equilibrium baseline scenario is 2043. The period of peak asset demand for the baseline general equilibrium specification occurs in the year 2074, which is the same year that the inflation rate changes sign. The inflation rate does not peak until 2100 and the peak inflation rate is only 0.79 percent.

The baseline specification holds government debt fixed. But the conclusion is the same if we consider the higher nominal public debt scenario instead. In that scenario the peak inflation rate is even smaller, 0.53 percent, and the peak occurs in 2097. Thus, the subsequent rise in the inflation rate is small, and one cannot attribute the recent increase in inflation and real interest rates since COVID to aging.

We have also performed simulations that investigate the robustness of our main conclusions. The first set of simulations asks whether our results depend on the preference parameters that govern the size of the behavioral factor. Online appendix [A.3](#) reports results for a lower value of the inverse elasticity of intertemporal substitution and a higher Frisch labor supply elasticity, chosen to make the behavioral factor as large as the model will support, with the discount factor, the labor disutility parameter and the illiquid asset adjustment costs recalibrated to match the same steady-state targets. Aging continues to depress real interest rates, inflation and output per capita. Stronger monetary and fiscal

reactions have smaller medium-term effects on aggregate demand under these parameters than under our baseline, not larger.

Our baseline specification starts the transition in 2014 and allows the nominal interest rate to go negative, which is a simple way to capture the view that quantitative easing and other balance sheet policies were equivalent to pushing the shadow nominal interest rate below zero. We have also explored how the dating of the demographic shock and imposing a zero lower bound (ZLB) on the nominal interest rate impacts our conclusions by considering a scenario where households learn about the demographic transition in 1983 instead of 2014. The results are shown in Figures A.10 – A.11 (see Online appendix A.2). This scenario abstracts from other shocks as in the baseline, but still manages to produce a boom period with rising real interest rates, high inflation, and above trend output growth. These outcomes are consistent, at a qualitative level, with Japan’s experience in the 1980s. The model then produces a protracted episode of falling real interest rates, deflation and declining output. These latter outcomes are consistent with Japan’s experience between 1991 and the onset of the COVID pandemic in 2020.

Imposing the ZLB on the nominal interest rate deteriorates the fit of the model once it binds. The inflation rate turns positive in 1992, one year before the ZLB constraint on the nominal interest rate binds, whereas real interest rates continue to decline in subsequent years. Thus, imposing the ZLB constraint is inconsistent with the observation that the inflation rate and real interest rates fall concurrently.²⁹ We interpret this result to mean that unconventional monetary policy such as quantitative easing was successful in steering the effective nominal interest rate into negative territory. Empirical evidence in favor of our interpretation is reported in Ikeda et al. (2024) who estimate structural non-linear vector autoregressions that embed the ELB for Japan and find that unconventional monetary policy has been, if anything, a more effective stabilization tool than conventional monetary policy at horizons of one year and beyond.

5 Conclusion

In this paper we have shown that a demographic transition to an older age distribution along the lines that Japan is experiencing creates an aging trap: changes in the size of different age groups of households making routine lifecycle labor supply, consumption, saving and

²⁹This negative correlation between the inflation rate and real interest rates at the ZLB also occurs if the transition starts in 2014.

asset allocation decisions depress the inflation rate and produce persistent declines in real interest rates and output. Conventional monetary and fiscal policy responses influence the path of the inflation rate but cannot prevent the persistent declines in real interest rates and output because they only influence the behavioral response of households, which is small relative to the autonomous effects of aging on aggregate demand. Even strong reactions of monetary and/or fiscal policy to aging fail to offset the negative impact of aging on output and real interest rates. Finally, the demographic factor masks the true heterogeneous effects of aging on different age groups and the effects of government efforts to combat the negative macroeconomic consequences of aging.

According to our results, older working-age households have been the losers from aging in Japan and higher government borrowing improves their situation. However, this policy has negative consequences for younger working-age households and crowds out private investment.

The pace of aging is increasing in many advanced economies and a topic for future research is whether policies that directly change the age distribution—higher immigration flows, higher female labor force participation rates and higher fertility rates—or policies that boost labor productivity are more effective ways to stabilize macroeconomic activity than demand-side stimulus.

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Online Appendix

A Quantitative Model

A.1 Competitive equilibrium

The competitive equilibrium of the quantitative model studied in Section 3 is defined in the following way. Given prices, government policies and demographic variables, all firms maximize their profits, all households maximize their utility, and all markets clear. Here we simply state the two market clearing conditions that have not yet been reported in the main text. First, the aggregate household illiquid assets, denoted by $A_t \equiv \sum_{j=1}^J \bar{a}_{j,t} N_{j,t}$ with $\bar{a}_{j,t} = \psi_{j,t} a_{j,t}(1) + (1 - \psi_{j,t}) a_{j,t}(0)$, are equal to the sum of capital and the value of all ownership shares of intermediate goods firms:

$$A_t = K_{t+1} + V_t.$$

Second, Walras' Law implies the market clearing condition for the final good

$$C_t + I_t + G_t = Y_t - \frac{\gamma}{2} (\pi_t - 1)^2 Y_t - X_t,$$

where $X_t = \sum_{j=1}^J \bar{\chi}_{j,t} N_{j,t}$, with $\bar{\chi}_{j,t} = \psi_{j,t} \chi_{j,t}(1) + (1 - \psi_{j,t}) \chi_{j,t}(0)$, is the aggregate cost of adjusting illiquid assets. Observe that the aggregate costs of price adjustments and illiquid asset adjustments are modeled as explicit resource costs and consequently subtracted from the aggregate output.

A.2 Additional impulse responses and decompositions

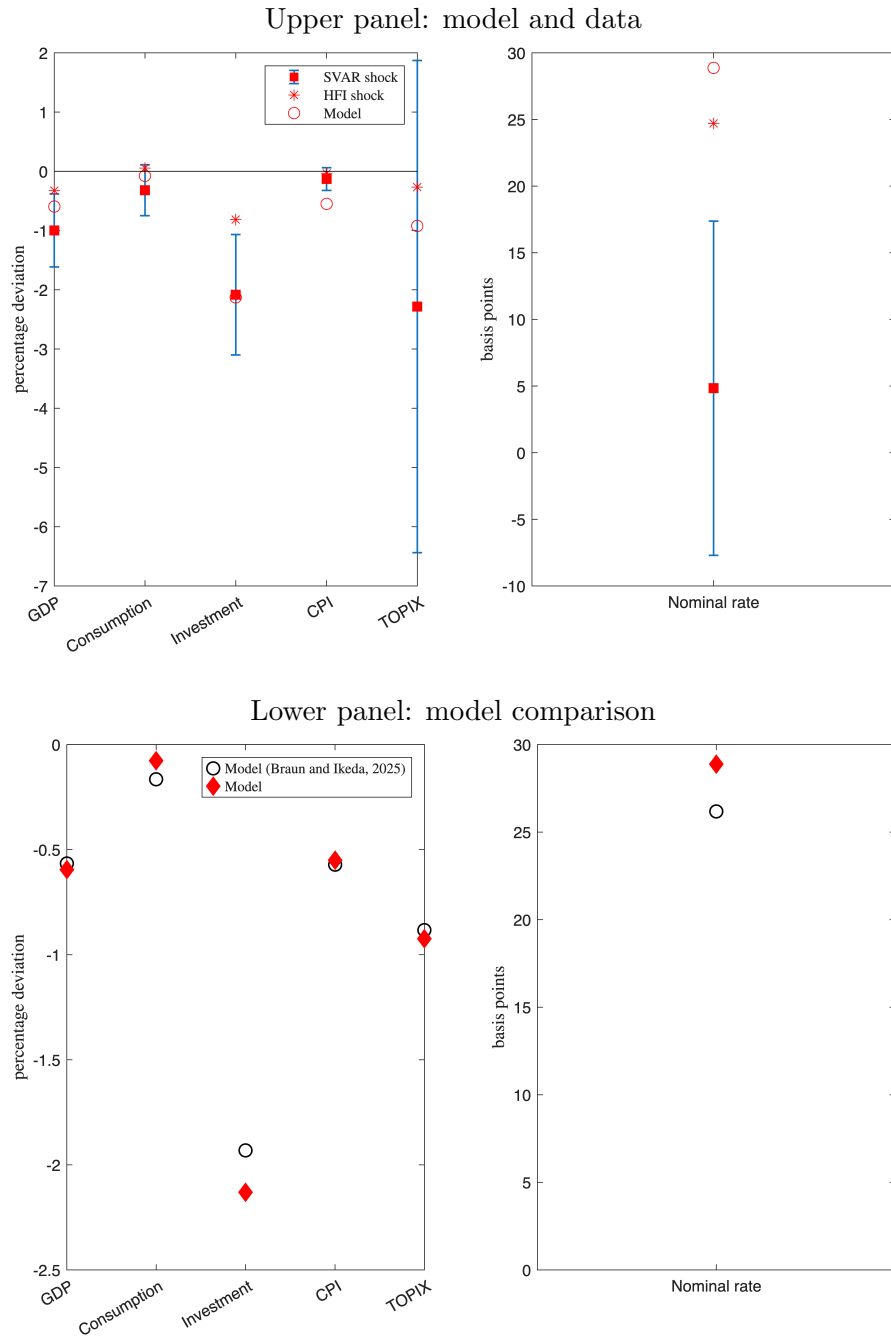


Figure A.1: Model and data impact responses to a surprise tightening in monetary policy

Notes: The figure reports impact responses to a 1 percent surprise tightening in monetary policy. GDP, consumption, investment, the CPI, and TOPIX are reported as percentage deviations and the nominal rate, which is the one-year nominal government bond yield, is reported in basis points. The upper panel reproduces Figure 3 of [Braun and Ikeda \(2025\)](#), where “Model” refers to the model analyzed in this paper. The empirical responses are local projections estimated on quarterly Japanese data for 1992–2019 using the monetary policy shocks of [Ikeda et al. \(2024\)](#) (“SVAR shock”) and [Kubota and Shintani \(2022\)](#) (“HFI shock”). The vertical bars are 95 percent confidence intervals for the local projections with the SVAR shocks. The lower panel compares model results reported in [Braun and Ikeda \(2025\)](#) with results from the model used here; see [Braun and Ikeda \(2025\)](#) for details.

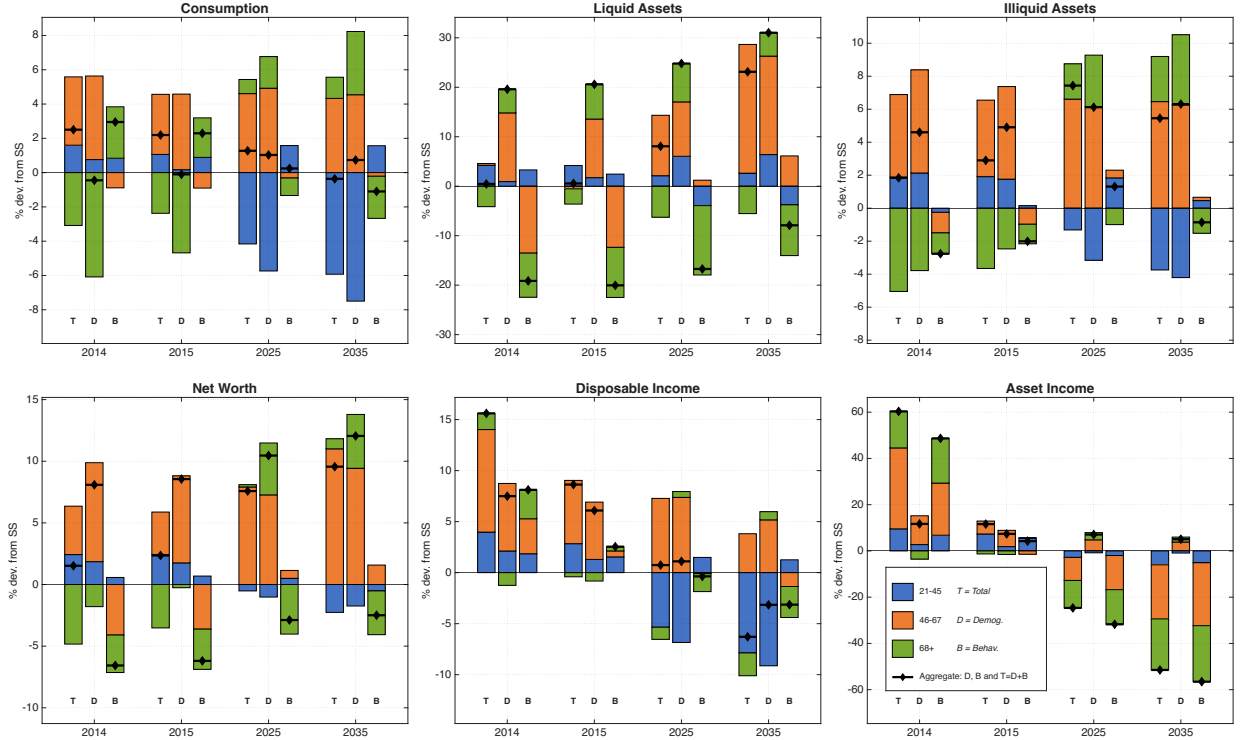


Figure A.2: The contribution of demographic and behavioral factors to aggregate responses of assorted variables in the specification with flexible prices

Notes: All variables are percentage deviations from the terminal steady state. The first bar (T) in a given year is the total contribution to the aggregate response of the 21–45, 46–67 and 68+ age groups. The center bar in a given year is the contribution of demographics (D) to the total age group deviation (the weighted deviation of the population share of a given age group from its terminal steady state). The third bar is the contribution of behavioral (B) responses by households (weighted deviation of the response of households choices in the given age group). The total response of an age group is the sum of its demographic and behavioral factors. The black ticked lines denote the total contribution of each factor to the total aggregate response ($T=D+B$).

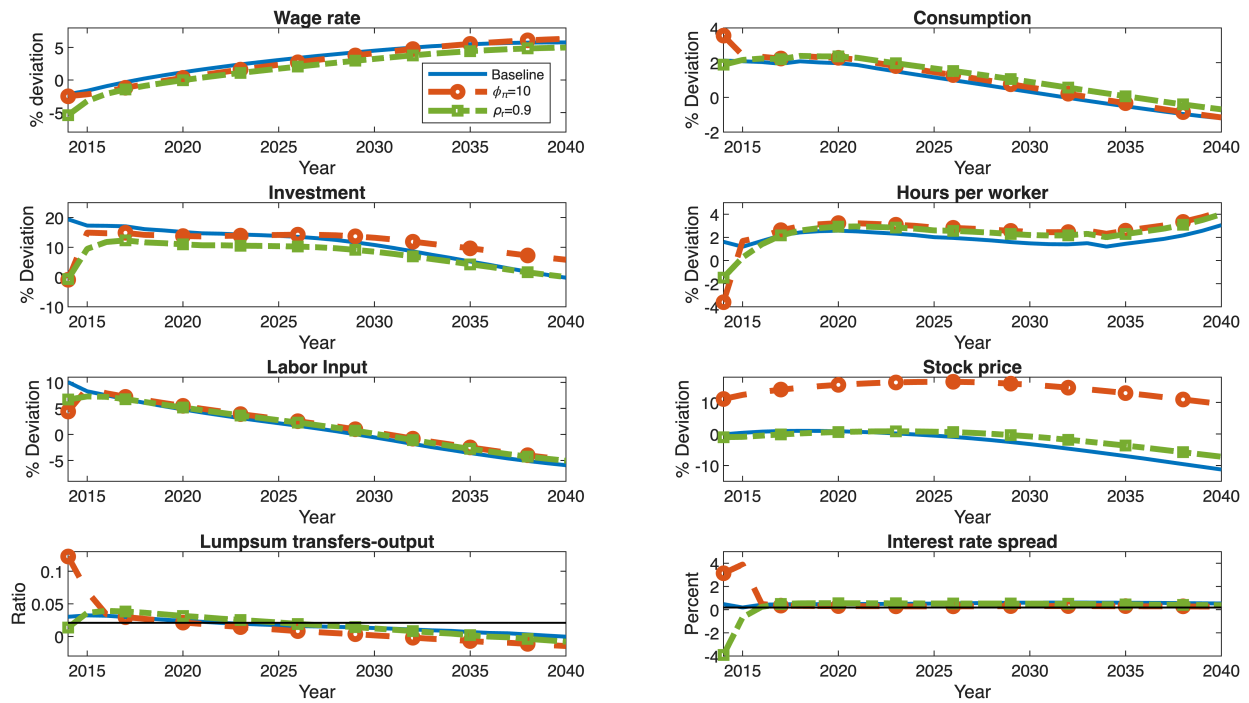


Figure A.3: Additional responses to aging under alternative monetary policies

Notes: All variables are percentage deviations from the terminal steady state except the lump-sum transfer-output ratio and interest rate spread. These two variables are in levels and the solid thin black line shows the steady state level.

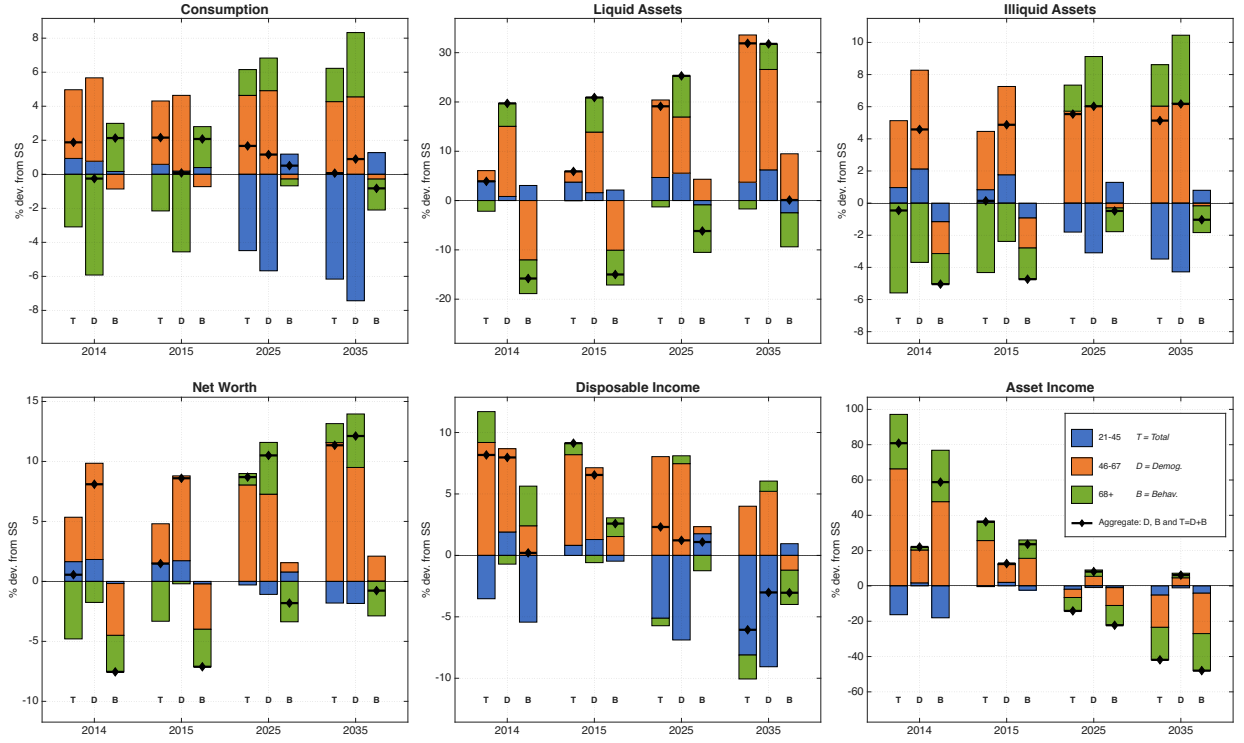


Figure A.4: The contribution of demographic and behavioral factors to aggregate responses of assorted variables in the specification with more persistence in the nominal interest rate targeting rule

Notes: In this scenario the interest rate targeting rule smoothing parameter is increased from its baseline value of $\rho_r = 0.35$ to 0.9. All variables are percentage deviations from the terminal steady state. The first bar (T) in a given year is the total contribution to the aggregate response of the 21–45, 46–67 and 68+ age groups. The center bar in a given year is the contribution of demographics (D) to the total age group deviation (the weighted deviation of the population share of a given age group from its terminal steady state). The third bar is the contribution of behavioral (B) responses by households (weighted deviation of the response of households choices in the given age group). The total response of an age group is the sum of its demographic and behavioral factors. The black ticked lines denote the total contribution of each factor to the total aggregate response (T=D+B).

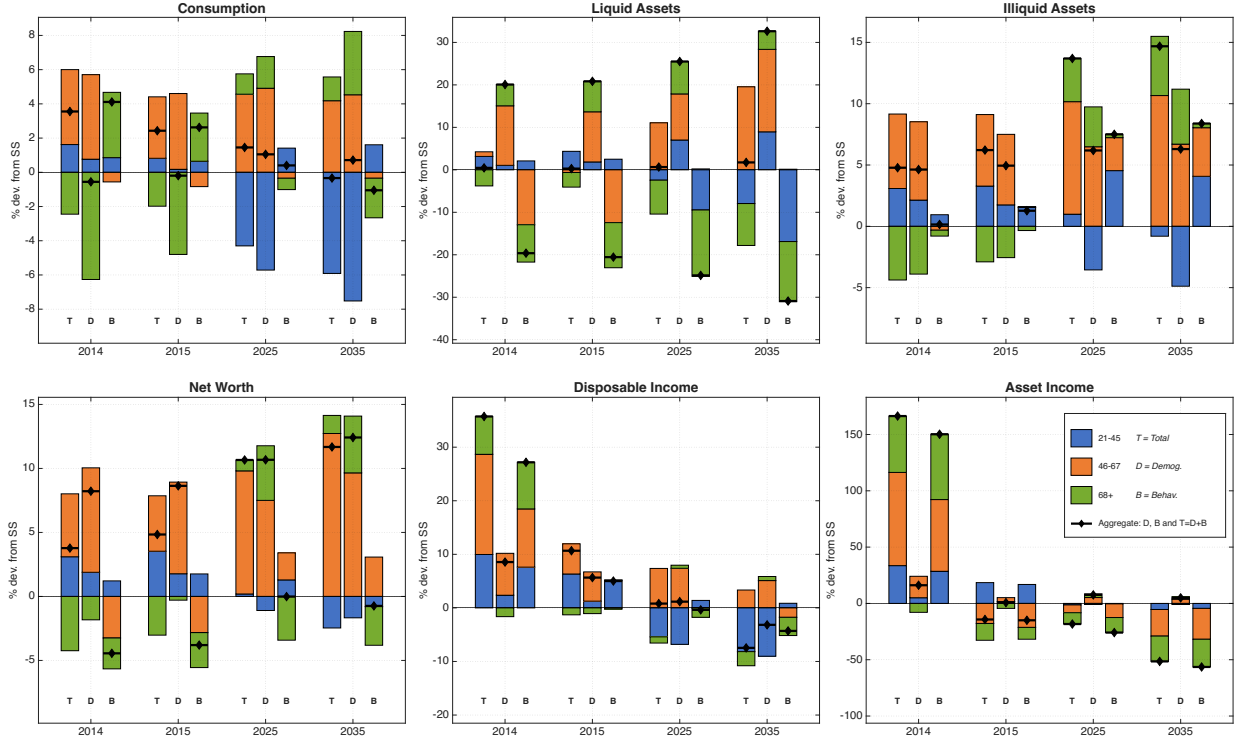


Figure A.5: The contribution of demographic and behavioral factors to aggregate responses of assorted variables in the specification under the strict inflation stabilization rule ($\phi_\pi = 10$)

Notes: This scenario increases the inflation elasticity in the interest rate targeting rule from its baseline value of $\phi_\pi = 2$ to 10. All variables are percentage deviations from the terminal steady state. The first bar (T) in a given year is the total contribution to the aggregate response of the 21–45, 46–67 and 68+ age groups. The center bar in a given year is the contribution of demographics (D) to the total age group deviation (the weighted deviation of the population share of a given age group from its terminal steady state). The third bar is the contribution of behavioral (B) responses by households (weighted deviation of the response of households choices in the given age group). The total response of an age group is the sum of its demographic and behavioral factors. The black ticked lines show the total contributions of the demographic and behavioral factors to the total aggregate response (T=D+B).

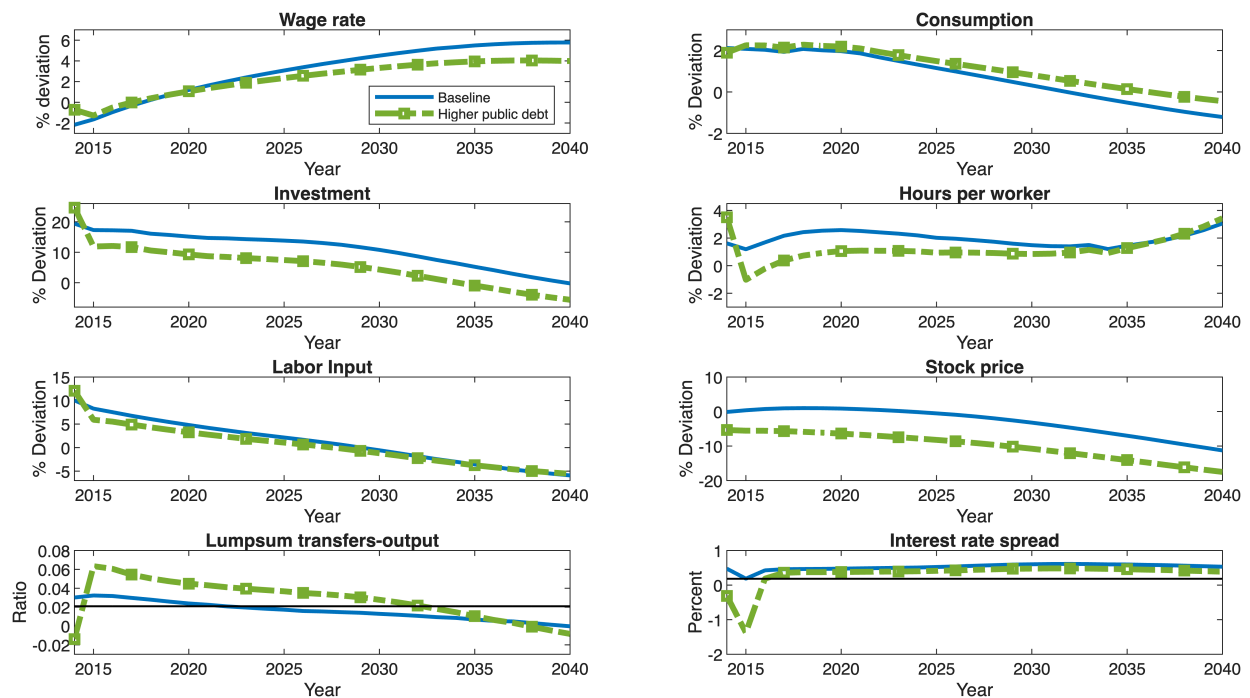


Figure A.6: Additional responses to aging with higher nominal government debt

Notes: This figure reports impulse response functions for additional aggregate variables for the baseline, the higher government debt, and $\rho_r = 0.9$ specifications. All variables are percentage deviations from the terminal steady state except the lump-sum transfer-output ratio and interest rate spread. These two variables are in levels and the solid thin black line shows the steady state level.

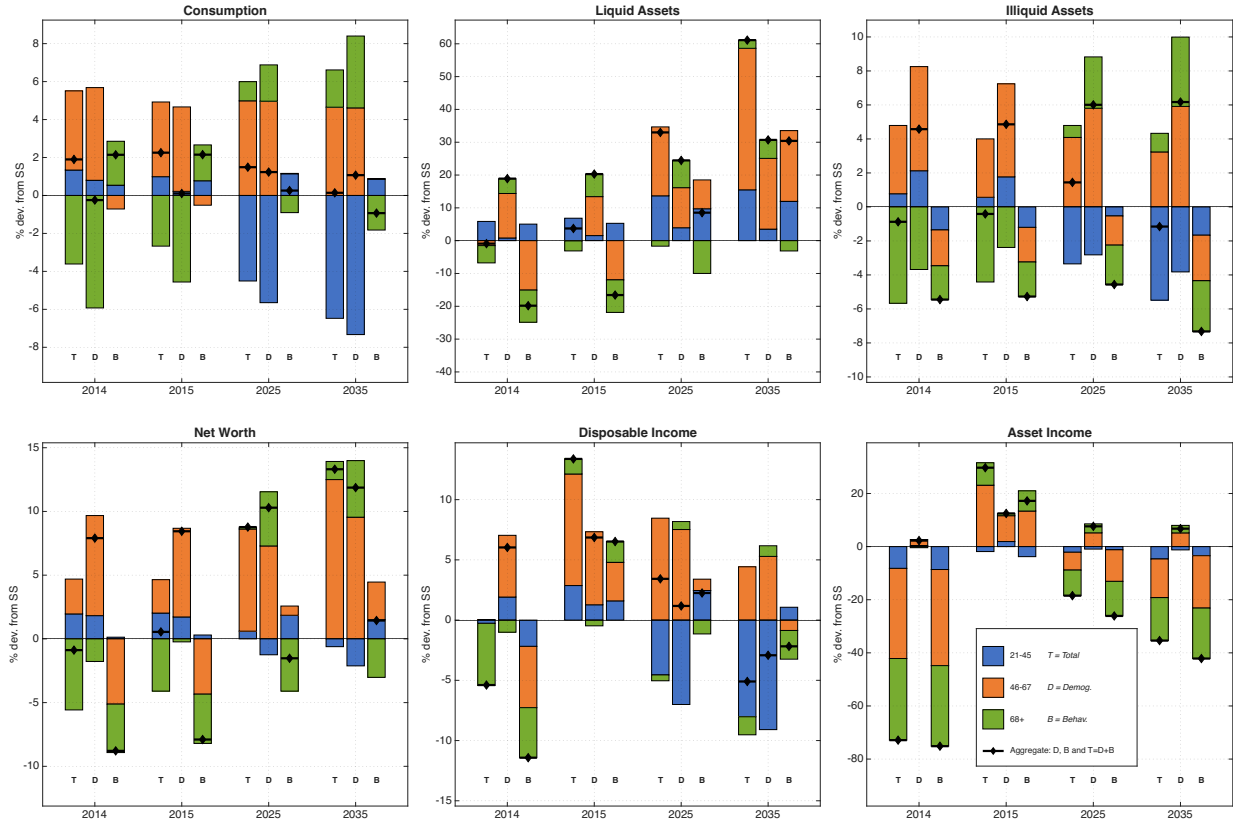


Figure A.7: The contribution of demographic and behavioral factors to aggregate responses of assorted variables in the specification with higher nominal government debt

Notes: In this scenario the fiscal authority accommodates the increase in real aggregate demand for liquid assets by increasing nominal government debt. All variables are percentage deviations from the terminal steady state. The first bar (T) in a given year is the total contribution to the aggregate response of the 21–45, 46–67 and 68+ age groups. The center bar in a given year is the contribution of demographics (D) to the total age group deviation (the weighted deviation of the population share of a given age group from its terminal steady state). The third bar is the contribution of behavioral (B) responses by households (weighted deviation of the response of households choices in the given age group). The total response of an age group is the sum of its demographic and behavioral factors. The black ticked lines denote the total contribution of each factor to the total aggregate response ($T=D+B$).

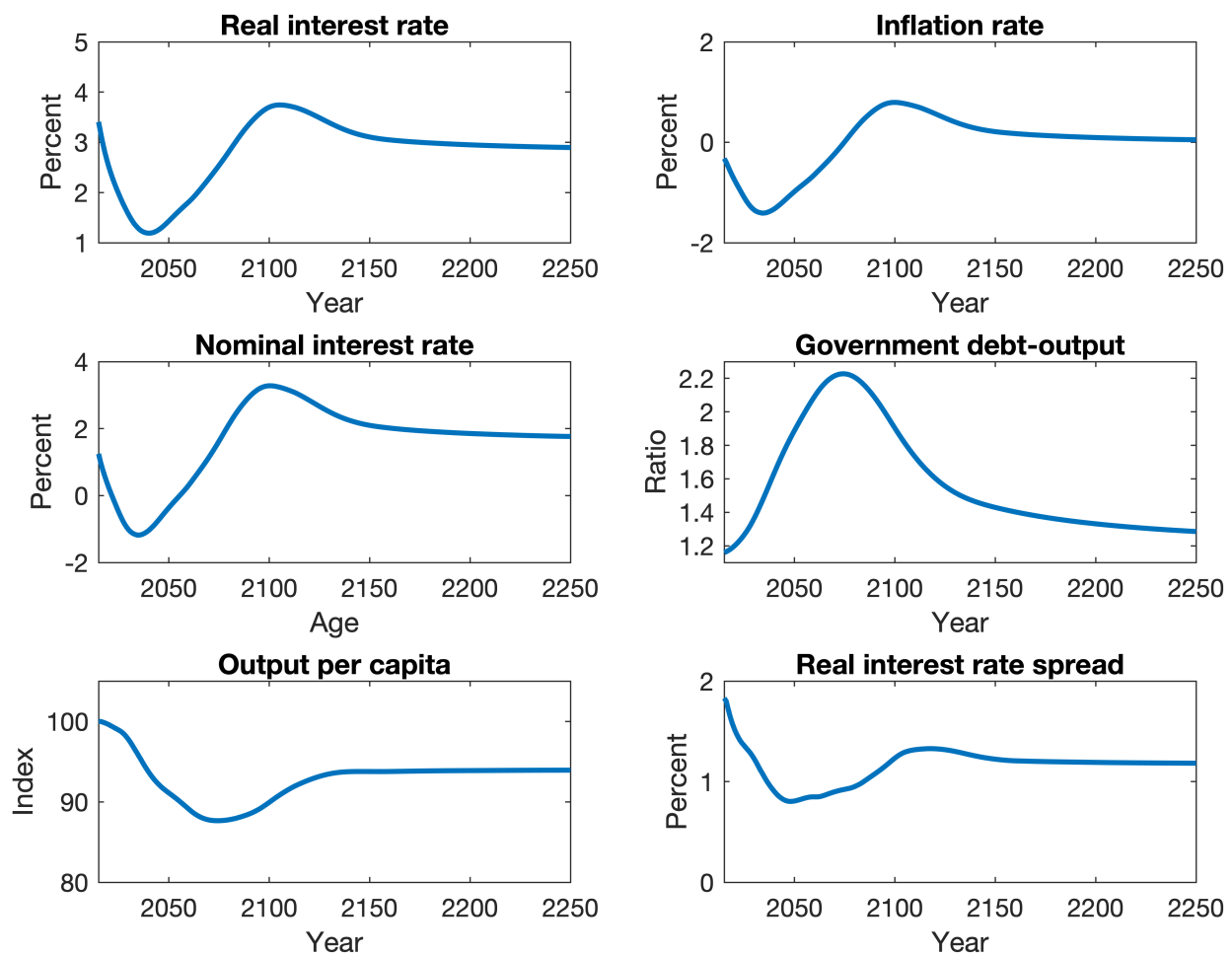


Figure A.8: Baseline responses to aging at longer horizons

Notes: See the notes to Figure 3 for definitions of the variables. See Figure A.9 for responses of other macroeconomic variables.

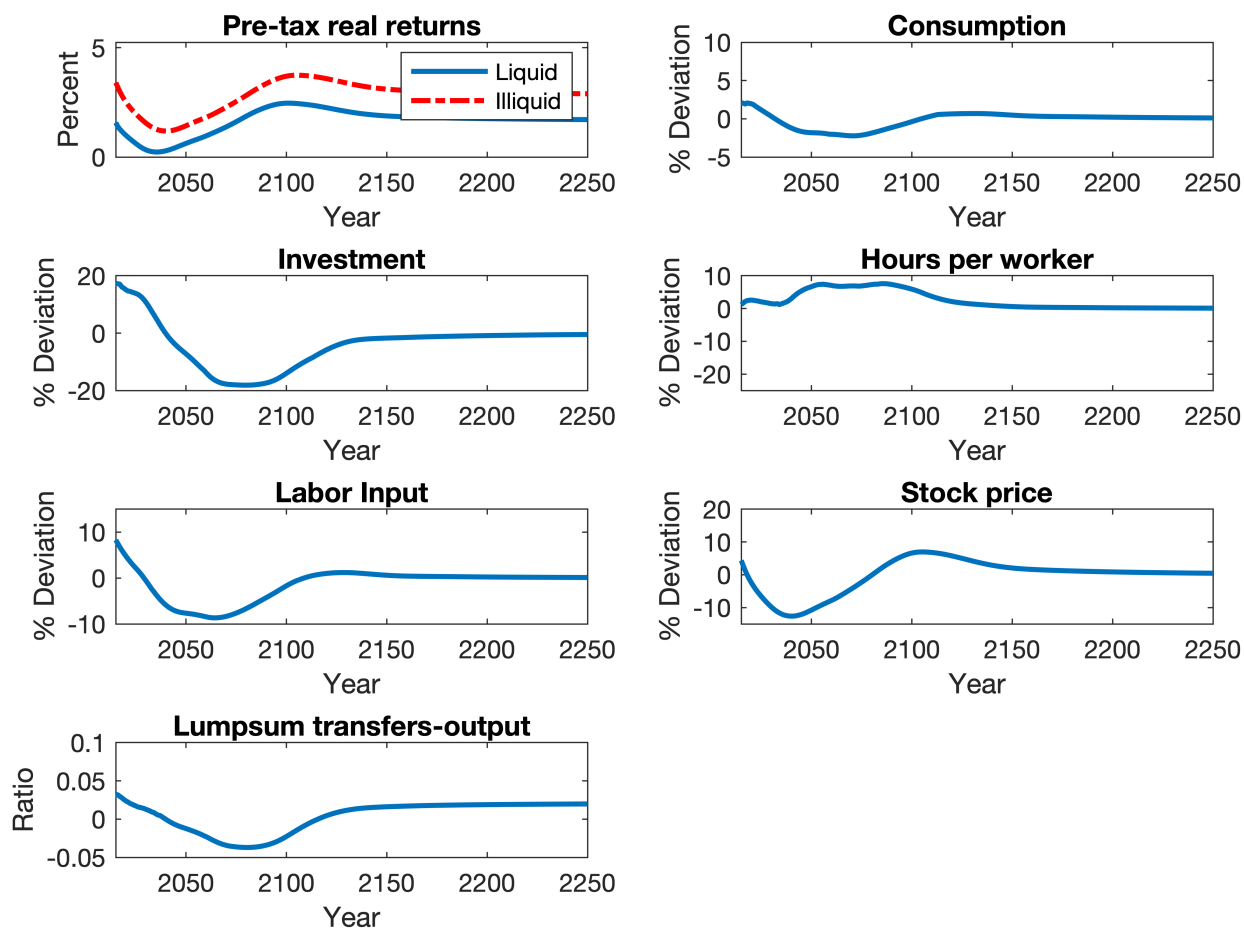


Figure A.9: Additional baseline responses to aging at longer horizons

Notes: All variables are percentage deviations from the terminal steady state except the two interest rates which are annual rates.

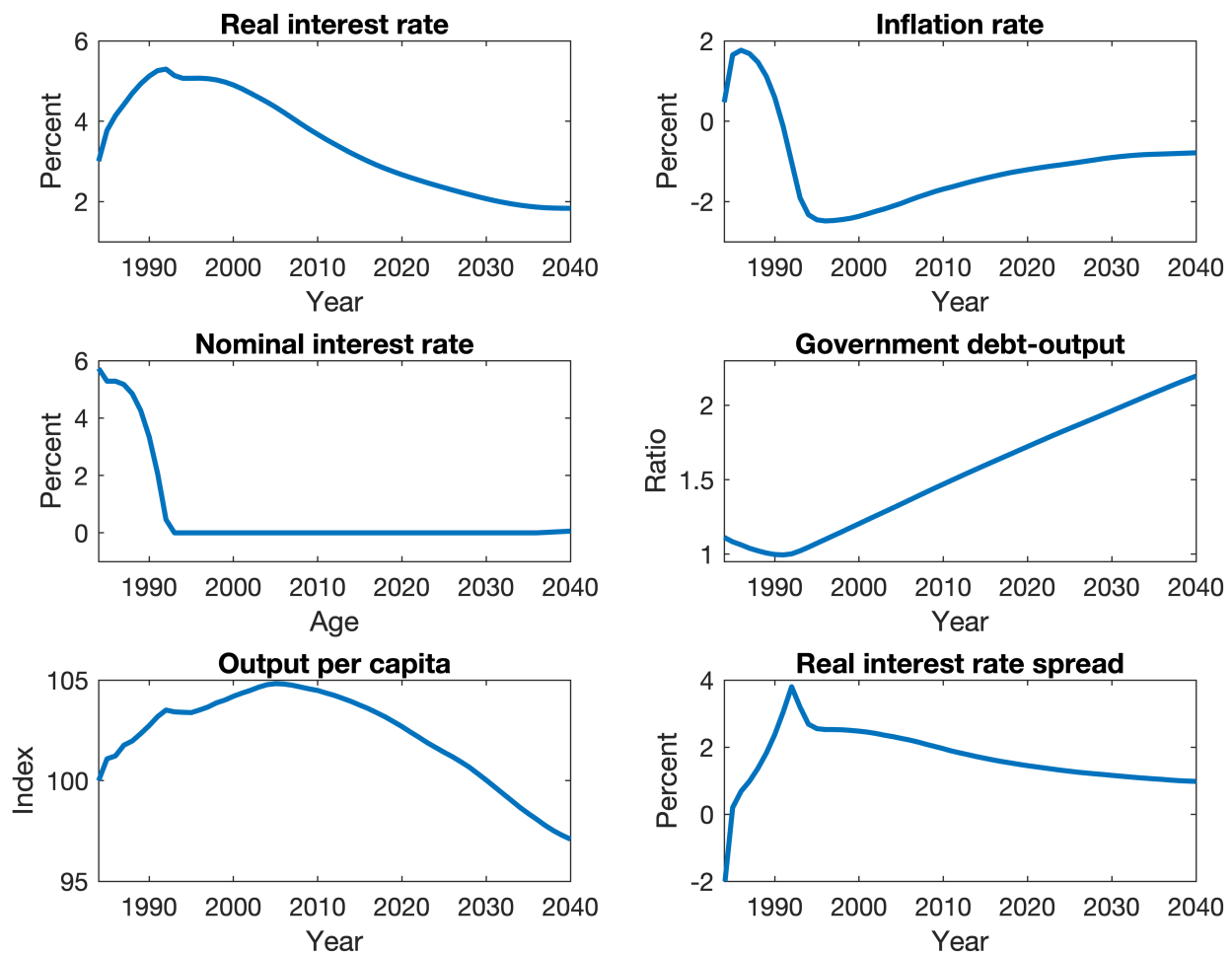


Figure A.10: Responses to aging if a demographic shock arrives in 1983

Notes: See the notes to Figure 3 for definitions of the variables. This simulation imposes the ZLB on the policy nominal interest rate.

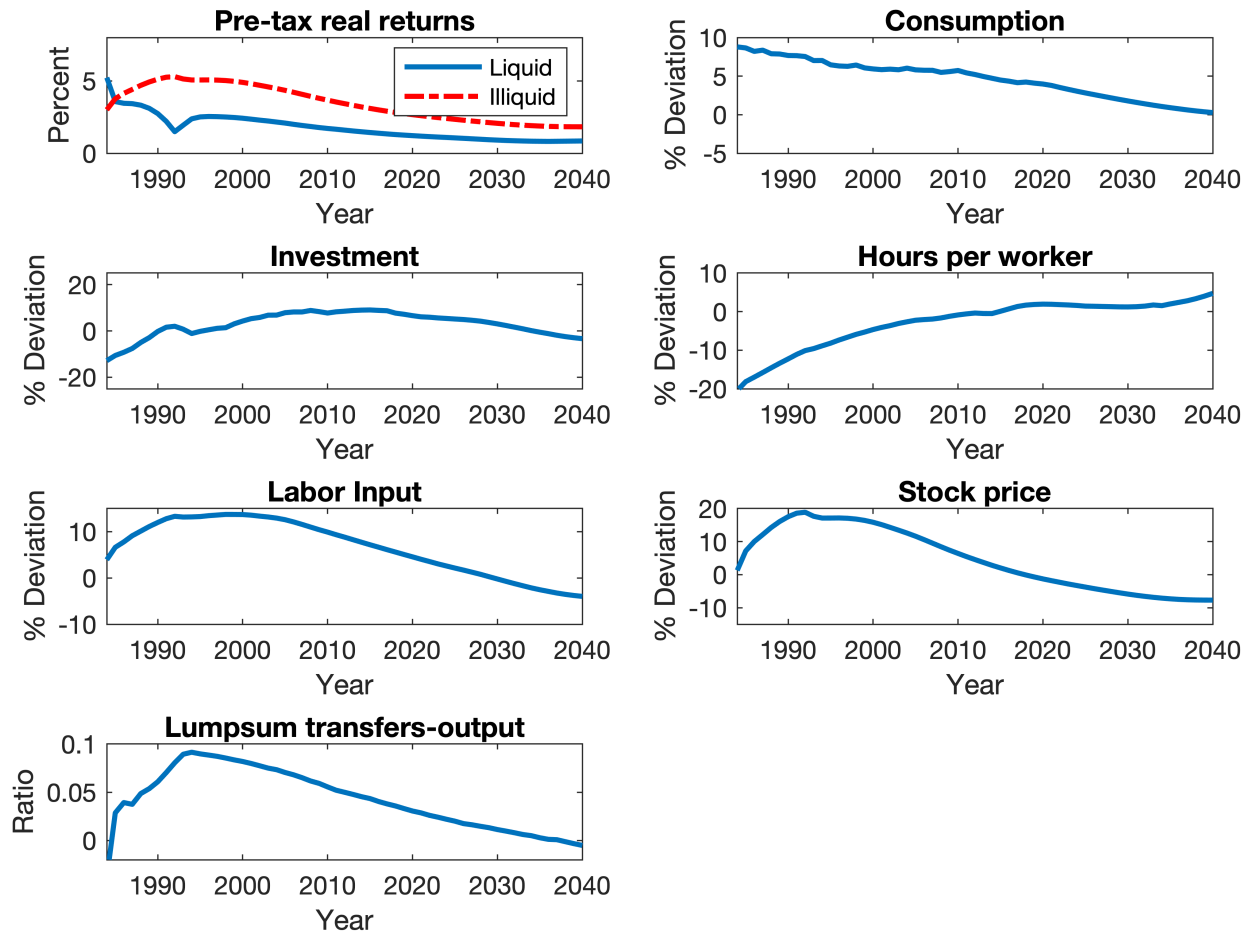


Figure A.11: Additional responses if demographic shock arrives in 1983

Notes: This simulation imposes the ZLB on the policy nominal interest rate.

A.3 Calibration and sensitivity analysis of preference parameters

Table A.1 reports the parameter values used in the baseline specification. Table A.2 reports the steady-state targets that every parameterization of the model is required to match, together with three alternative settings of the two preference parameters that govern the size of the behavioral factor.

Table A.1: Parameterization of the model

Parameter	Description	Value
Demographics		
J_r	Retirement age	48 (Age 68)
J	Maximum lifespan	100 (Age 120)
$\psi_{j,t}$	Cohort-specific survival probabilities	Braun and Joines (2015)
Technology		
θ	Gross markup	1.05
γ	Price adjustment cost	41.2
α	Capital share parameter	0.30
δ	Depreciation rate	0.102
$\gamma_a(0)$	Cost of adjusting illiquid assets in death year	0.0723
$\gamma_a(1)$	Cost of adjusting illiquid assets in non-death year	0.203
Preferences		
σ	Inverse elasticity of intertemporal substitution	3
ν	Frisch labor supply elasticity	2
ω	Labor disutility parameter	6.9
β	Preference discount factor	0.996
Monetary Policy		
ρ_r	Interest rule persistence	0.35
ϕ_π	Interest rule inflation elasticity	2
Fiscal Policy		
τ^c	Consumption tax rate	0.10
τ^k	Corporate tax rate	0.35
τ^a	Tax rate on asset income	0.2
τ^w	Tax rate on labor income	0.232
τ^f	Subsidy to intermediate goods firms	$\theta - 1$
G/Y	Government share of output	0.16
κ	Public pension replacement ratio	0.094
D/Y	Net government debt output ratio	1.23

Notes: These are the parameter values used in the baseline specification analyzed in Section 4. Table A.2 reports the steady-state calibration targets and three alternative settings of the preference parameters σ and ν .

The size of the behavioral factor in the decomposition (23) depends on how strongly household consumption and labor supply respond to the price changes that aging induces. Two preference parameters govern those responses: the inverse elasticity of intertemporal substitution, σ , and the Frisch labor supply elasticity, ν . This raises the question of whether

Table A.2: Alternative preference parameterizations

Parameter	Description	Baseline Alternatives			
Set directly					
σ	Inverse elasticity of intertemporal substitution	3	3	1.1	1.1
ν	Frisch labor supply elasticity	2	4	4	2
Recalibrated					
β	Preference discount factor	0.99623	0.99623	0.99636	0.99636
ω	Labor disutility parameter	6.872	6.504	2.321	2.470
$\gamma_a(0)$	Cost of adjusting illiquid assets in death year	0.0723	0.0723	0.0727	0.0727
$\gamma_a(1)$	Cost of adjusting illiquid assets in non-death year	0.203	0.203	0.169	0.169
Targets		<i>identical in all four columns</i>			
	Capital-output ratio (pins down β)			2.301	
	Hours-output ratio (pins down ω)			0.700	
	Adjustment cost, non-death year, percent of assets (pins down $\gamma_a(1)$)			2.54	
	Adjustment cost, death year, percent of assets (pins down $\gamma_a(0)$)			23.92	

Notes: The baseline is the parameterization of Table A.1. In each alternative, σ and ν are set directly and β , ω , $\gamma_a(0)$ and $\gamma_a(1)$ are recalibrated so that every economy matches the same four steady-state targets. The targets are met to a relative tolerance of 10^{-4} in all four cases. The last two targets are the maximum over the age profile of the adjustment cost in that year as a percentage of illiquid asset holdings. The death-year figure is the larger of the two despite the smaller value of $\gamma_a(0)$ because the death-year cost is levied on the square of the entire position while the non-death-year cost is levied on the square of the change in the position.

our finding that the demographic factor dominates the behavioral factor at medium horizons is a property of the model or an artifact of our choice of $\sigma = 3$, which implies an elasticity of intertemporal substitution of one-third. We address this question by lowering σ to 1.1, which raises the elasticity of intertemporal substitution to 0.91, and by doubling ν to 4. We choose these values because they make the behavioral factor as large as our model will support, and thus stack the deck against our conclusion. In each case we recalibrate β , ω , $\gamma_a(0)$ and $\gamma_a(1)$ so that every economy reproduces the same four steady-state targets.³⁰ Table A.2 reports the resulting parameterizations.

The Frisch elasticity has almost no bearing on our results. Doubling ν from 2 to 4 changes the average annual decline in output per capita between 2015 and 2040 by 0.004 percentage points when $\sigma = 3$ and by 0.006 percentage points when $\sigma = 1.1$. Figure A.12 shows why this is hard to see: the four scenarios trace out only two distinct paths, one for each value of σ . The reason is that the length of the work week (hours per worker)

³⁰The values of maximum adjustment costs relative to illiquid asset holdings are 2.54 percent and 23.92 percent in Table A.2. These values are higher than the targets stated in Section 3.6, which specifies targets of 2 and 20 percent in a steady state with survival probabilities for 2014. The results here are for the steady state that uses survival probabilities for 2060 and the same values of $\gamma_a(0)$ and $\gamma_a(1)$ reported in Table A.1.

is common to all working-age households and is set by a labor union planner who integrates over their preferences. Equation (5) shows that the work week then depends on the weighted average marginal utility of consumption and the weighted average efficiency of labor of working-age households, and these averages move little as the age distribution shifts. Between 2015 and 2040 hours per worker grow at 0.07 percent per year while labor input falls at 0.56 percent per year. Labor input declines because of who is working, not because of how much each worker works, and ν governs the response of the work week.

Our first conclusion, that aging exerts persistent downward pressure on real interest rates, inflation and output per capita, is robust to these alternative preference parameters. When $\sigma = 1.1$ and $\nu = 2$ the real interest rate falls from 2.79 percent in 2015 to 1.99 percent in 2040, the inflation rate is -0.66 percent in 2040, and the government debt–output ratio continues to rise throughout the transition. Output per capita falls faster than in our baseline, at an average rate of 0.39 percent per year between 2015 and 2040 as compared to 0.26 percent per year. A higher elasticity of intertemporal substitution does not insulate the economy from aging. It deepens the decline.

Our second conclusion, that stronger monetary and fiscal reactions have small effects on aggregate demand in the medium term, is also robust, and in fact holds more strongly under these parameters than under our baseline. Figure A.13 reports the same three policy counterfactuals considered in Section 4.2 for the economy with $\sigma = 1.1$ and $\nu = 2$. In the output panel the four paths are indistinguishable. Average annual output growth between 2015 and 2040 ranges from -0.365 percent under interest rate smoothing to -0.395 percent under strict inflation stabilization, a difference of 0.030 percentage points. The corresponding spread in our baseline economy is 0.073 percentage points. Put differently, the most effective of the three policies offsets about 28 percent of the aging-induced decline in output growth in our baseline and about 7 percent when $\sigma = 1.1$. For consumption the comparable figures are 18 percent and 7 percent. The mechanism is straightforward. A higher elasticity of intertemporal substitution does make consumption more responsive to the real interest rate, and the behavioral factor is correspondingly larger. But aging is pushing the real interest rate down, so a more responsive household cuts consumption by more. The behavioral factor grows in magnitude but not in the direction that would allow policy to offset the demographic factor.

Our baseline specification allows the nominal interest rate to go negative and it is negative in 19 of the 21 years between 2020 and 2040. In contrast, when $\sigma = 1.1$ the nominal interest rate remains positive in every one of those years and is 0.27 percent in

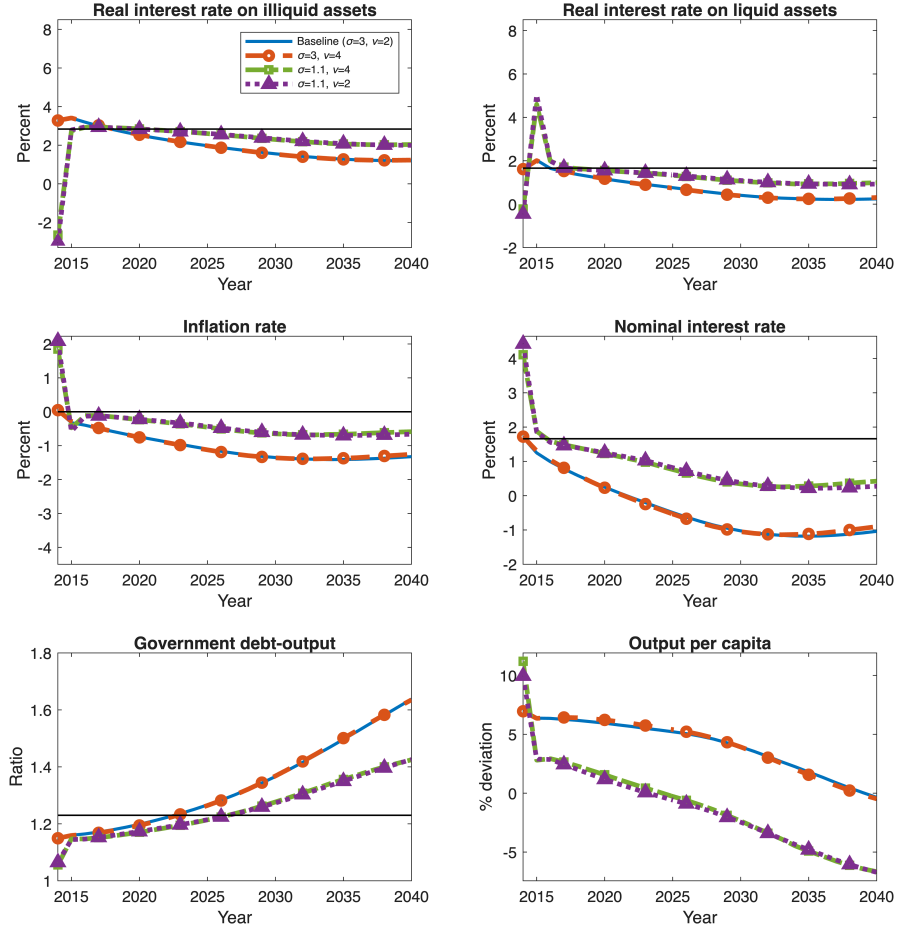


Figure A.12: Responses to aging under alternative preference parameters

Notes: Responses to the demographic transition for the four parameterizations reported in Table A.2. The solid black line in each panel is the terminal steady state value. The two $\sigma = 1.1$ scenarios are nearly indistinguishable from each other, as are the two $\sigma = 3$ scenarios.

2040, as compared to -1.04 percent in our baseline. Thus, the conclusions in this robustness analysis do not depend on whether or not a floor is imposed on the nominal interest rate.

Finally, we are not proposing these alternative calibrations of the model as better representations of the Japanese economy. Our purpose here is to establish that our conclusions about the relative size of the demographic and behavioral factors, and about the limited scope for demand-side policy to offset aging, survive when preference parameters are chosen to favor the opposite conclusion.

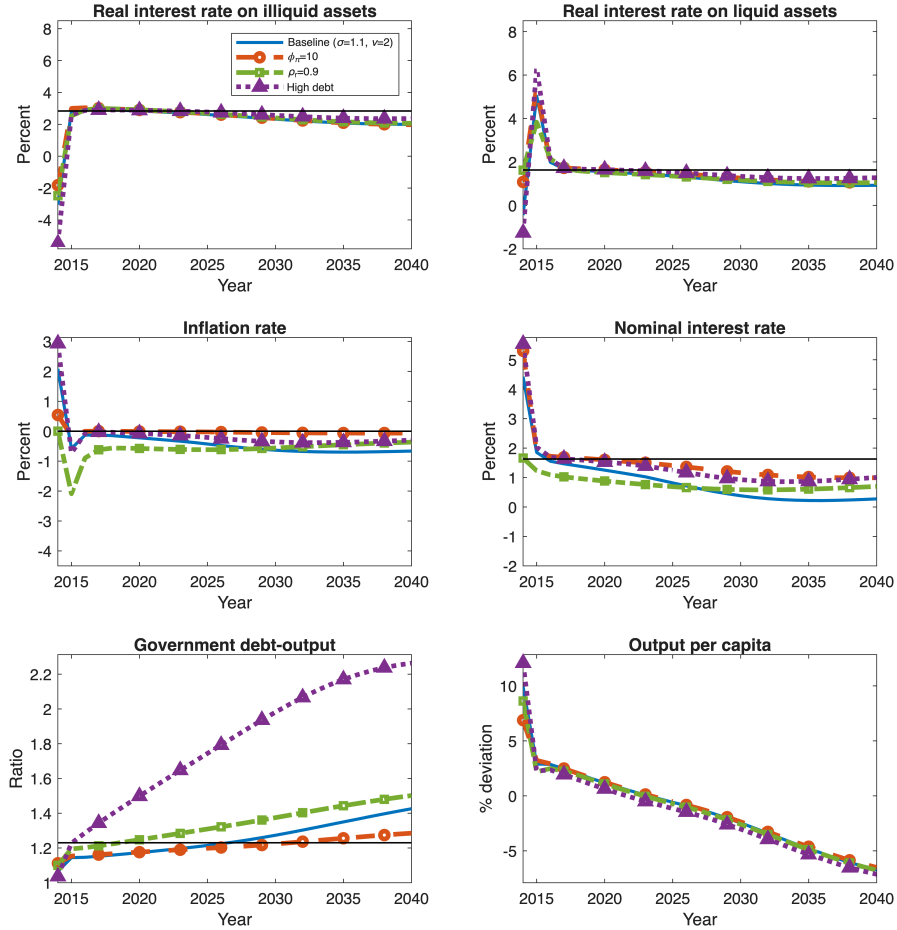


Figure A.13: Responses to aging under alternative policies when $\sigma = 1.1$

Notes: The baseline here sets $\sigma = 1.1$ and $\nu = 2$ and is otherwise the specification of Section 4.2. The three alternatives are the interest rate smoothing, strict inflation stabilization and higher government debt scenarios considered in Sections 4.2.2 and 4.2.3. The solid black line in each panel is the terminal steady state value.