Medical Expenditure Risk and Liquidity Premium*

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Abstract

Over the past few decades, the Japanese economy has experienced a widening gap between returns on illiquid capital and liquid bonds (i.e., the liquidity premium). This paper focuses on the role of medical expenditure risk on household asset portfolios and examines the impact of structural changes, including demographics and medical systems, on the trends of the gap. I develop a general equilibrium overlapping generations model with two kinds of assets, liquid and illiquid, in which households face uncertainty in health and medical costs. I find that both structural changes could have resulted in the increasing liquidity premium. The aging of the population has pushed down the bond return much more than the capital return. The rise in out-of-pocket medical costs has led to higher capital return and lower bond return by shifting the asset portfolio of older households from illiquid to liquid. In particular, the decomposition shows that the latter contribution would be significant. The results suggest that future structural changes will lead to a further increase in the premium, even after accounting for the larger supply of government bonds.

Keywords: Medical Expenditure Risk; Demographic Aging; Liquidity Premium; Overlapping Generations

JEL classification: E21, G51, I10, J11

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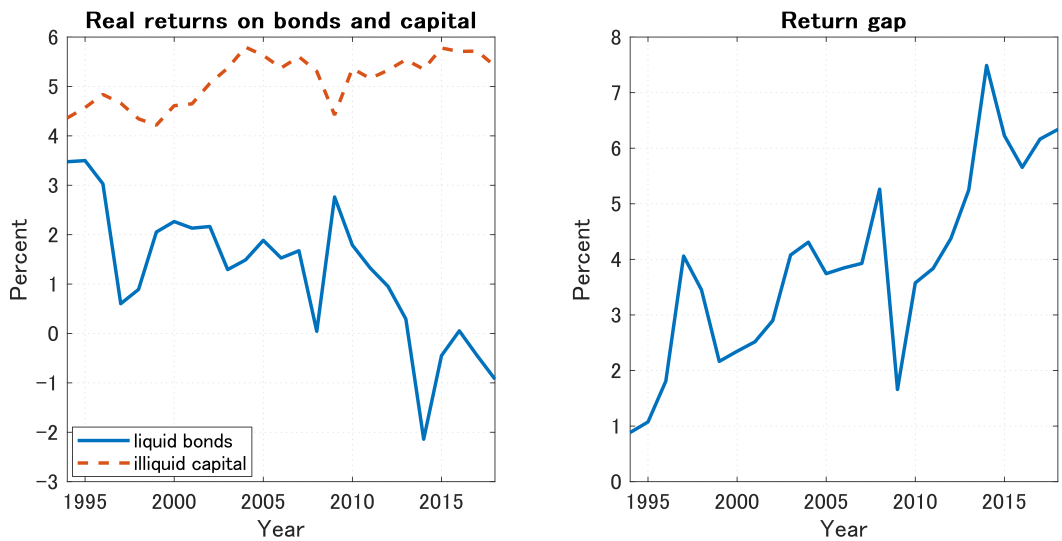
1 Introduction

In many advanced countries, including Japan, the return on liquid assets such as deposits and bonds has declined over the past few decades. This decline in the interest rate, called "secular stagnation" in Rachel and Summers (2019), has been recently refocused attention and concerned, mainly because it could increase the risk of asset bubbles and limit the effectiveness of the monetary policy. On the other hand, the return on illiquid assets such as equities and capital has remained stable or increased slightly.

Figure 1: Returns on Liquid and Illiquid Assets and the Return Gap in Japan



Source: The System of National Accounts (SNA), OECD economic outlook

Figure 1 shows the trends in the real returns on liquid and illiquid assets in Japan. Here, the return on liquid bonds represents the real interest rate on 10-year Japanese government bonds, which is calculated by subtracting the CPI inflation rate from the nominal yield. The return on illiquid capital is calculated by dividing the real operating surplus by total illiquid assets, including financial stocks and non-financial fixed assets. While the bond return has largely dropped from 3.5% in 1994 to -0.9% in 2018, the capital return has slightly increased from 4.4% in 1994 to 5.4% in 2018. These different trends have led to an increase in the gap between the two rates (i.e., the liquidity premium), as shown in the right panel of the figure. The premium has widened significantly by around 5%pt.[1] What is behind the expansion of the liquidity premium? Will

[1]Looking the return on short-term bonds (1-year), we see a similar pattern of declining bond return and increasing return gap.

the trends of the increasing premium continue in the future?

To answer these questions, this paper builds a large-scale general equilibrium overlapping generations model with two main features. First, individuals can invest in two types of assets: liquid bonds and illiquid capital. Second, they face uncertainties regarding their future health status and out-of-pocket medical expenses. As discussed below, the novelty of the paper is to focus on the role of medical expenditure risk on the demand for liquid assets and the liquidity premium. I then quantitatively investigate the impact of changes in economic structures, including demographics and the healthcare system, on two asset returns and the gap.

The potential drivers of the secular decline in the real interest rate have been the subject of a lot of research. Using macroeconomic models, many papers show that most of this decline can be explained by the aging of the population . (Carvalho et al., 2016; Lisack et al., 2017; Cooley and Henriksen, 2018; Eggertson et al., 2019; Gagnon et al., 2021; Papetti, 2021).[2] The mechanism of low interest rates through the demographic channel is that the decline in the marginal productivity of capital is driven by the rise in the capital-labor ratio due to the shrinking young working-age population and the increasing old population with higher savings. However, almost all of these models do not explicitly distinguish between bonds and capital and assume that the two assets have the same rate of return. Such single-asset models cannot explain the findings in Japan in Figure 1, where the real interest rate has significantly dropped but the return on capital has not declined at all.

In recent years, some papers have developed overlapping generations models with two types of assets, liquid bonds and illiquid capital, and addressed the explanation of the return gap between these assets. They try to reproduce the demand for liquid assets by introducing household preferences for bonds (Muto et al., 2016; Sudo and Takizuka, 2020) or various shocks, such as stochastic capital depreciation (Gomes and Michaelides, 2008), idiosyncratic income risk (Aladangady et al., 2021), idiosyncratic risk on capital (Brunnermeier et al., 2022), and aggregate productivity shocks (Kopecky and Taylor, 2022). These ideas are based on the global savings glut and agents' precautionary saving for liquid or safe assets to insure themselves against shocks, discussed in Caballero et al. (2016, 2017) and Caballero and Farhi (2018). For example, Aladangady et al. (2021)

[2]To explore different channels, other papers focus on the rise in income and wealth inequality (Straub, 2019; Auclert and Rognile, 2020; Mian et al., 2021), the decline in the price of the investment goods (Eichengreen, 2015; Sajedi and Thwaites, 2016), and the rising market power and intangibles (Farhi and Gourio, 2019).

find that greater polarization of household labor income has contributed to the widening gap between the risk-free rate and the return on capital in the U.S. Kopecky and Taylor (2022) find that, in an economy with aggregate risk, aging can simultaneously reproduce the falling risk-free rate and the increasing risk premium.

My paper also uses a two-asset macroeconomic model, but I focus specifically on the role of idiosyncratic medical expenditure risk on household saving behavior. In Japanese household level data, households over age 70 continue to hold higher levels of wealth, especially in the form of liquid assets. In addition, the Bank of Japan's survey suggests that many households are concerned about their old lives due to a rise in out-of-pocket costs for medical care and long-term care and have large savings to prepare for health-related events. These facts imply that the uncertainties about health and medical expenses would work as potentially important drivers of high demand for safe or liquid assets. According to this view, past changes in demographics and healthcare systems could have contributed to a larger aggregate demand of liquid bonds, leading to a decline in the bond return and a rise in the liquidity premium. This is because aging leads to an increase in the population of the elderly who have higher liquid asset holdings, and the rise in out-of-pocket medical costs encourages households to hold more liquid assets.

I start with a two-period, partial equilibrium, model and analytically provide the role of medical expenditure risk on the demand and the return of liquid assets. The features of the model are as follows. First, individuals choose their asset portfolio: liquid bonds and illiquid capital. Second, they face a medical expenditure risk, and they incur medical costs when they are old and in poor health. Finally, they need to pay for costs of holding or maintaining illiquid capital. The results show that individuals facing medical uncertainty have more liquid bonds with lower return to avoid the additional costs of holding illiquid capital. If health risk or medical costs increase, the bond demand also increases, leading to a decline in the equilibrium bond return and an expansion of the premium.

The next task is to extend the model to a general equilibrium setting, populated by long-lived individuals who differ in their age, labor productivity, capital depreciation, wealth, and health status. In the model, individuals choose consumption, labor supply, and bond and capital holdings, and need to pay for medical care, using labor income, capital income, bond income, pension benefits, and means-tested transfers. The representative firms produce output by using capital and labor inputs. The government issues new government debt and taxes consumption, labor income, bond income, and capital income to finance government expenditure, interest payments on its debt, pension benefits, medical benefits, and a transfer. I calibrate the model to the Japanese economy in 2014, and quantitatively examine the effects of changes in demographics and healthcare systems on macroeconomic variables.

My main quantitative findings are that both structural changes in demographics and healthcare systems could have brought about the widening of the liquidity premium. Population aging has increased aggregate demand for both liquid bonds and illiquid capital and led to a decline in the returns on these assets. Because the bond return falls much more sharply than the capital return, it has resulted in a small increase in the premium. On the other hand, the rise in per capita medical expenditure and the copayment rate increase have simultaneously led to a lower bond return and a higher capital return, because higher medical expenditure risk has changed household asset portfolio from illiquid to liquid. It has also increased the premium, and the contribution of these medical changes is much larger than that of demographic changes.

The model reproduces a positive change in the liquidity premium from 1990 to 2014, 1.7%pt, which is relatively large but smaller than the actual value of 3.4%pt. While about one-third of the total change (0.4%pt) is explained by demographic factors, two-thirds (1.3%pt) of them is explained by medical factors. Upcoming trends in the liquidity premium depend on future economic conditions, including demographic dynamics, medical systems, and government debt. If population aging and the increase in the individual medical burden continue, a further increase in the premium is expected in the future. Nonetheless, the rise in government debt might put upward pressure on the bond return, resulting in a smaller increase in the premium.

The remainder of the paper is organized as follows. Section 2 provides a motivation for my analysis of the relationship between medical expenditure risk and the liquidity premium in Japan. Section 3 presents its analytical results using a simple two-period model. Section 4 builds a dynamic, stochastic, general equilibrium, overlapping generations model. Section 5 calibrates the model to the Japanese economy. Section 6 reports the numerical results and quantitatively compares aggregate characteristics under different steady states, and concluding remarks are given in Section 7.

2 Motivation

This section motivates my central focus in this paper, which is the impact of demographic and healthcare system changes on the liquidity premium in Japan. First, I review the characteristics of the total wealth and asset portfolios of the Japanese households over the life-cycle, using data from the National Survey of Family Income and Expenditure (NSFIE) and from the Public Opinion Survey on Household Financial Assets and Liabilities (hereafter, I call SHFAL). These data suggest that Japanese elderly people have a high level of wealth, especially in the form of safe and liquid assets, to prepare for the risk of health and medical expenses. Next, I discuss the potential positive impact of past structural changes, including aging and an increase in out-of-pocket medical expenditures, on the liquidity premium. Both of these changes could have contributed to large aggregate demand for liquid assets by households facing medical expenditure risk, resulting in lower bond return.

2.1 Household Net Worth and Holdings of Liquid and Illiquid Assets by Age

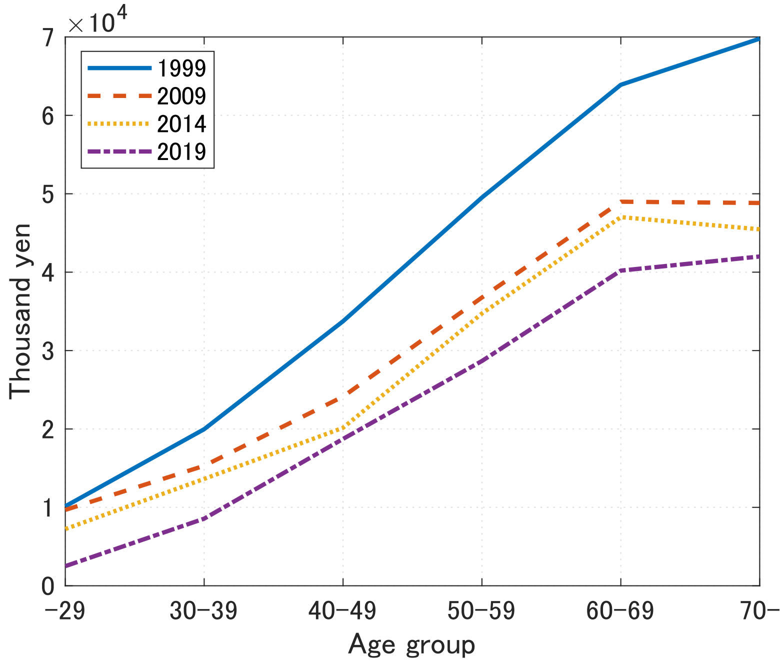
The NSFIE has been conducted every five years since 1959 and provides detailed information on household consumption, income, and wealth by age group or region. Figure 2 shows the average net wealth of households by age group using data from the 1999, 2009, 2014, and 2019 NSFIE. Here, total net worth is the sum of net liquid assets and gross illiquid assets. Net liquid assets are gross liquid assets, including cash, deposits, bonds, and money trusts, minus all liabilities such as housing loans and installment.[3] Gross illiquid assets consist of both risky financial assets, including stocks and life insurances, and physical assets, including real estate such as land, housing, and durable consumption.[4]

As can be seen from the figure, total wealth increases monotonically with age in all years. In particular, households continue to hold larger assets after the age of 70. These properties are distinct in Japan and are not observed in the other advanced countries, including the U.S. and UK. Figure 3 shows average household net wealth by age in the U.S. and UK. In both countries, households increase their wealth as they age, but begin to withdraw it after age 60 or 65.

[3] I assume that all loans are assigned to liquid assets.

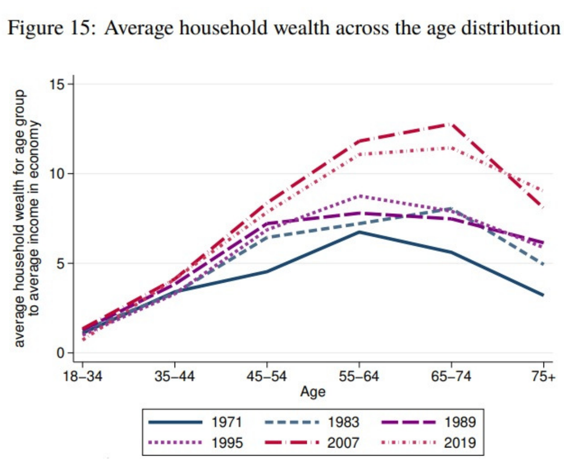
[4] This classification into liquid and illiquid assets follows Kaplan et al. (2018) and Braun and Ikeda (2021).

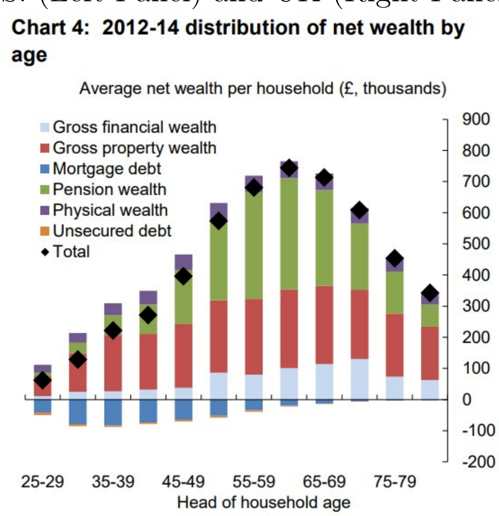
Figure 2: Net Wealth by Age Group in Japan



Source: The National Survey of Family Income and Expenditure (NSFIE)

Figure 3: Net Wealth by Age Group in the U.S. (Left Panel) and UK (Right Panel)

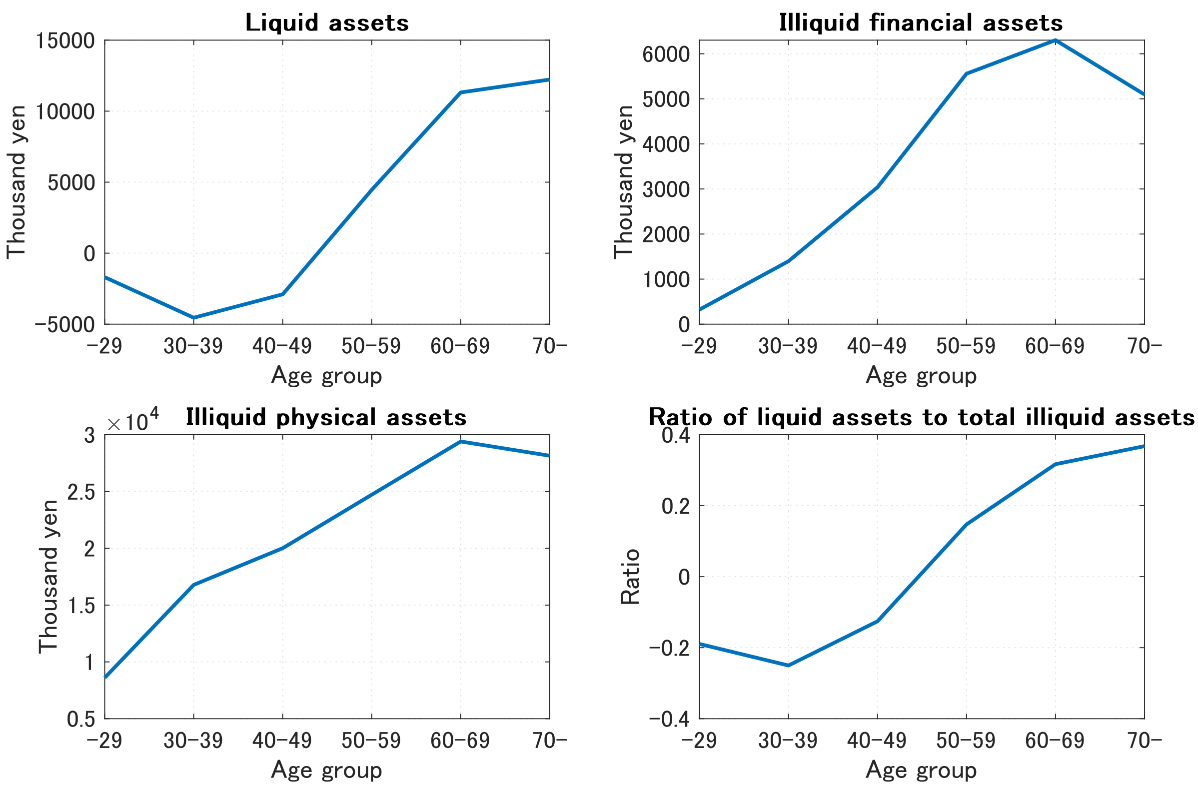




Note: The left panel shows the average wealth over the life-cycle of U.S. households and the right panel shows the distribution of net wealth by age for UK households.
Source: Left panel, based on data from the Survey of Consumer Finances Plus (SCF+), is taken from Mian et al. (2021), and right panel, based on data from the Wealth and Asset Survey (WAS), is taken from Haldane (2018).

Next, I look at each type of asset, liquid and illiquid, held by households by age. Figure 4 shows the liquid, illiquid financial, and illiquid physical wealth of households and the ratio of households' holding of liquid to illiquid assets by age group from the 2014 NSFIE. First, we can see that all types of assets show an upward trend with age. Second, the ratio of liquid to illiquid assets increases with age. It increases from -0.25 in the 30-39 age group to 0.15 and 0.37 in the 50-59 and 70- age groups, respectively.

Figure 4: Liquid and Illiquid Wealth by Age Group in Japan



Source: NSFIE
Note: The left top panel shows the net liquid wealth, which is calculated by gross liquid assets minus liabilities. The right top panel shows the illiquid financial wealth, and the left bottom panel shows illiquid real assets. The right bottom panel shows the ratio of liquid assets to the sum of illiquid financial and illiquid physical assets.

To further consider why Japanese old households have higher wealth levels and prefer for liquid assets to illiquid assets, I summarize the results of the SHFAL questionnaire. The SHFAL is the survey conducted annually since 1963 by the Central Council for Financial Services Information of the Bank of Japan. This survey provides the information on households' current status and plans regarding financial savings and liabilities.

From the 2014 SHFAL, there are four key facts. First, the two common reasons for older households' savings are "for old lives" and "for risks of unanticipated disaster and illness".[5] The former reason is supported by 84.0% (79.8%) of households of age 60s (or over 70), compared to 51.0% of households of age 40s. Moreover, the latter reason is supported by 69.1% (74.6%) of households of age 60s (or over 70). Second, 82.7% of households have concerns about their lives after the retirement. In addition, half of them say that they are "very" worried about their old lives. Third, almost all households (94.5%) say that they feel that pension income is not enough for their lives. Their most common reason, supported by 63.4% of households, is "because they believe that pension benefits will be cut". Furthermore, 48.4% of them support the reason, "because individual burden for medical and long-term care will increase". Fourth, young and old people have different criteria for determining their asset portfolios. Older households value the safety and liquidity rather than profitability when choosing investments. For households of age 60s (30s), the profitability, safety, and liquidity of assets are preferred by 15.8% (18.7%), 41.9% (44.5%), and 30.6% (21.0%) of them.

These facts imply that Japanese elderly people have higher levels of savings, especially in the form of safe and liquid assets, to prepare for uncertainties regarding health and medical expenses. This is consistent with the findings of several empirical papers that health condition and medical expenditure risk induce households to rebalance their portfolios from risky assets towards safer assets (Rosen and Wu, 2004; Christelis et al., 2005; Goldman and Maestas, 2013).[6]

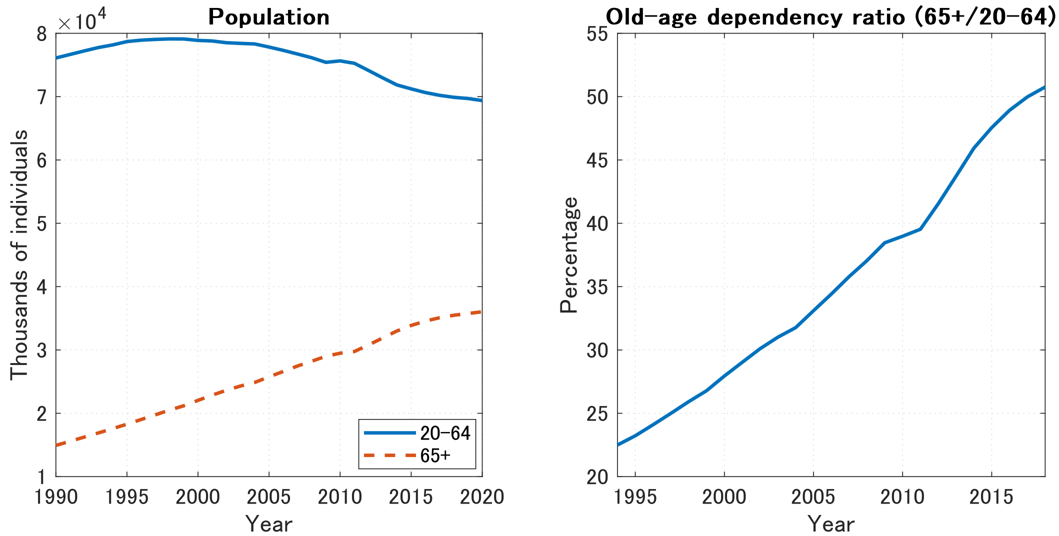
2.2 Demographics and Healthcare Systems

In Japan, demographic aging has progressed significantly due to increased longevity and the lower fertility since the 1990s. Figure 5 shows the demographic change in Japan over the past three decades. While the population of younger generations has been slowly declining since the 2000s, that of older generations has been increasing at rapid

[5] In the survey, households can answer at most three reasons for their savings. For younger people under 40s, the most common reason is "for children's education" and the second common reason is "for risks of unanticipated disaster and illness". For example, while the first reason is supported by 67.6% of households of age 40s, the second reason is supported by 52.3% of them.

[6] Atella et al. (2012) and Goldman and Maestas (2013) find that individuals' health insurance status also affects their holdings of risky assets. In contrast, Love and Smith (2010) find that there is no longer a statistically significant relationship between health measures and household portfolio decisions, if unobserved household heterogeneity is adequately taken into account.

Figure 5: Demographic Change

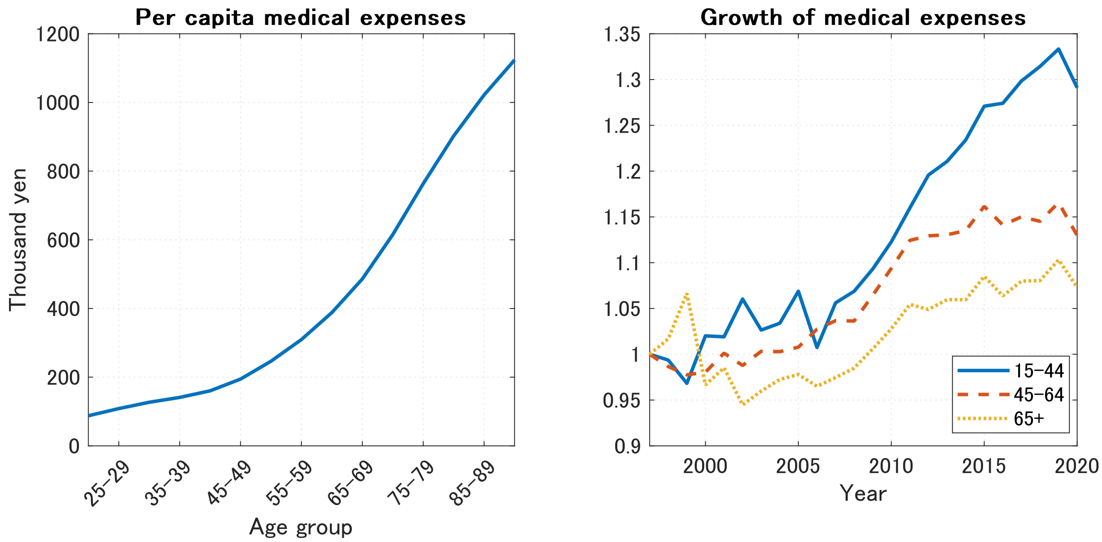


Source: The National Institute of Population and Social Security Research (IPSS)
Note: The left panel shows the number of individuals ate 20-64 and 65 and over and the right panel shows the ratio of population aged 65 and over to age 20-64.

pace since the 1990s. These trends have dramatically changed the composition of the population, as shown in Figure 6. The dependency ratio, defined as the ratio of the population aged 65 and over to age 20-64, has risen from 19.6% in 1990 to 27.9% in 2000 and 51.9% in 2020. Such an increasing relative size of the old population could have led to larger aggregate liquid asset demand, as older households have more liquid assets as seen in the previous section.

Japanese healthcare systems have also undergone major changes over the past few decades. In Japan, public universal healthcare is provided to all residents. Since almost all medical costs (approximately 88% in 2020) are covered by taxes and premium revenues, individuals can purchase medical services by paying a small copayment. However, the individual out-of-pocket medical costs have risen for two reasons. First, per capita medical expenditures have increased for all age gropus. Figure 6 represents the average healthcare expenditures by age and the changes in the amount of spending. Healthcare expenditures increase with age and rise sharply after ages 55-59. Importantly, the amount of medical expenditures has increased due to various factors, including technological progress in medical care, the revision of medical fees (*shinryo-hoshu*), and the rise in household income levels. Second, the government has raised the copayment

Figure 6: Medical expenditures by age



Source: The Ministry of Health, Labour and Welfare (MHLW)
Note: The left panel shows the average healthcare expenditures by age and the right panel shows the growth of expenditures for three age groups, 15-44, 45-64, and 65+. In the right panel, values in each age group are represented by normalizing the value for that group in 1997 as one.

rates several times since the establishment of public health insurance in 1961.[7] For young people, the copayment rate for employee himself/herself was raised from a small fixed amount to 10% in 1984, to 20% in 1997, and to 30% in 2003. For the elderly, their copayment rates were zero until 1983, but have thereafter been raised to 10-20%. The higher medical burden of individuals could have brought about larger aggregate demand for liquid assets, as households are likely to have more safe or liquid assets to prepare for the uncertainties about their future health and medical payments.

If these views are correct, both structural changes put downward pressure on the return on liquid assets and contributed to the expansion of the liquidity premium. Below, I begin with a simplified theoretical model framework that I can use to explore analytically the relationship between medical expenditure risk and the demand and return of liquid assets and discuss again the implications of changes in demographics and medical systems.

[7]In the current system, copayment rates depend on age and are 30% for those under age 70, 20% for those aged 70-74, and 10% for those aged 75 and over.

3 Two-Period Model

This section presents a simple two-period model and provides the economic intuition behind the role of medical expenditure risk on the demand for liquid assets and the gap between the returns of liquid and illiquid assets. In particular, the model shows that, when individuals face costs of holding illiquid capital, the increase in health risk or medical expenses can encourage them to hold more liquid bonds, leading to a decline in the bond return and an increase in the return gap (i.e., the liquidity premium).

3.1 Environment

In the model, households live for two periods. They are young in the first period and become old in the second period. In the first period, individuals are endowed with income y and save in two forms of assets, liquid and illiquid. While liquid assets, denoted by b, include money and bonds, illiquid assets, denoted by k, include stocks and capital. Both asset holdings yield positive returns, but the return on illiquid capital S is assumed to be equal to or greater than the return on liquid bonds R $(S \geq R)$. Thus, illiquid capital has an advantage over liquid bonds, in terms of its higher return. In the second period, individuals have no income endowment and receive interest income from their asset holdings. Households face a health risk and they can get one of two health states, good g or bad b, when they enter the second old period. The probability of getting bad health is $\phi \in (0, 1)$ and individuals know the probability in their first young period. If individuals have good health, they choose consumption c^g. On the other hand, those with bad health choose consumption c^b and have to pay for medical care $m\,(> 0)$. In the model, medical expenditure risk can be thought of as a composite of health risk ϕ and medical costs m.

3.2 Costs of Holding Illiquid Capital

As in Kaplan and Violante (2014), individuals face costs on holding illiquid assets. These costs include all potential costs associated with holding and maintaining illiquid and risky capital, which are both pecuniary and non-pecuniary (e.g., opportunity time costs of gathering the information about assets or psychological costs). I define these costs as

$$\chi = \chi\,(k, m) = \varepsilon k^2 m, \tag{1}$$

where $\varepsilon\,(\geq 0)$ is the parameter that governs the severity of the costs.

These costs have three main features. First, the costs depend on current holdings of illiquid assets, following Kim (2022). Second, the costs increase with capital holdings (i.e., $\partial\chi/\partial k > 0$). When individuals have higher illiquid assets, they incur more physical or psychological costs to maintain the assets. Finally, the costs depend positively on the amount of medical spending. It implies that only unhealthy individuals incur positive costs, because healthy individuals have zero medical spending. Moreover, if unhealthy people need more medical care, they incur higher costs of holding illiquid capital (i.e., $\partial\chi/\partial m > 0$). This assumption is based on the economic theory proposed by Pratt and Zeckhauser (1987), Kimball (1993), Gollier and Pratt (1996). Their papers argue that, when individuals face a background risk, they are discouraged to bear other risks. In my model, medical expenditure risk and costs of holding illiquid or risky capital can be regarded as background risk and other risks, respectively. In the real economy, when individuals suffer from serious illness, they may feel worse and find it harder to take enough time or take action to preserve their illiquid assets. In addition, hospitalization would require them to immediately pay large amounts of medical costs in cash. Thus, holding illiquid capital can pose additional risks for individuals facing medical uncertainty, while providing a higher return. It helps to create a wedge between the returns on bonds and capital.

3.3 Utility Maximization Problem

The household's utility maximization problem is defined as follows.

$$\max_{c^g, c^b, b, k} u = (1-\phi)\log\left(c^g\right) + \phi\log\left(c^b\right), \tag{2}$$

subject to

$$b + k = y, \tag{3}$$

$$c^g = Rb + Sk \quad (\text{w.p. } 1-\phi), \tag{4}$$

$$c^b + m + \chi\left(k, m\right) = Rb + Sk \quad (\text{w.p. } \phi), \tag{5}$$

where $\chi\left(\cdot\right)$ is a cost of holding capital. Solving the above problem and using the first-order conditions, we obtain

$$S - R = \frac{2\varepsilon k m \phi c^g}{\phi c^g + (1-\phi)\, c^b} \geq 0. \tag{6}$$

The above equation (6) represents the return gap between liquid and illiquid assets, which is the liquidity premium. If the severity of capital holding costs ε is zero, the model produces a zero premium (i.e., $S = R$). In this case, the choice of holding either bonds or capital is indifferent to individuals, and medical expenditure risk does not affect their asset portfolio. However, when there are positive capital holding costs (i.e., $\varepsilon > 0$), the positive premium can be generated and is affected by both medical costs m and health uncertainty ϕ. Below, I assume the positive capital holding costs.

3.4 Role of Medical Expenditure Risk on Household Asset Portfolio

Using equations (4), (5), and (6), I analyze the impact of medical expenditure risk on household saving decisions. I take the derivatives of the demand for liquid bonds b with respect to medical spending m and health risk ϕ as follows:[8]

$$\left(\frac{\partial b}{\partial m}\right) > 0 \quad \text{and} \quad \left(\frac{\partial k}{\partial m}\right) < 0, \tag{7}$$

$$\left(\frac{\partial b}{\partial \phi}\right) > 0 \quad \text{and} \quad \left(\frac{\partial k}{\partial \phi}\right) < 0. \tag{8}$$

Equations (7) and (8) show that larger medical costs or a higher probability of bad health lead to more liquid bond holdings and less illiquid holdings. These results imply that a higher expected medical burden in old age, represented as ϕm, encourages individuals to hold more bonds, because holding capital is more costly due to costs χ in case of poor health. Thus, individuals shift their asset portfolio from illiquid capital to liquid bonds. Some empirical papers find the negative relationship between medical expenditure or health risk and the share of risky capital (Edwards, 2002; Rosen and Wu, 2004; Goldman and Maestas, 2013).

3.5 Return on Bonds and Liquidity Premium

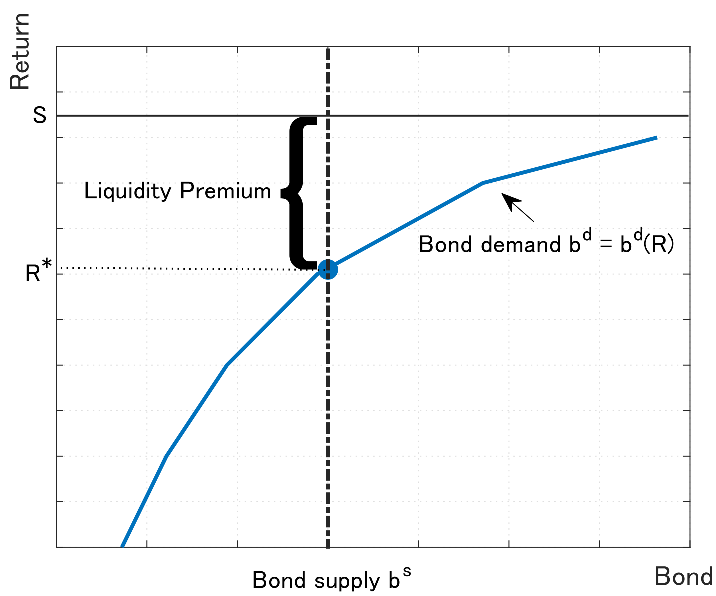
Using equations (4), (5), and (6), we also find that the demand for liquid bonds is an increasing function of the return on bonds (i.e., $\left(\frac{\partial b}{\partial R}\right) > 0$).[9] If the bond return becomes higher, individuals have more bond holdings to earn more interest income. I

[8]For details of the derivation of equations (7) and (8), see Appendix C.
[9]For details of the derivation of the relationship, see Appendix C.

here assume that the supply of bonds b^s is fixed by the governments. In the equilibrium, the return on bonds R^* is determined so that the household's demand for bonds, denoted by b^d, matches the supply of bonds. Given a constant return on capital S, the liquidity premium is expressed as $S - R^*$. Figure 7 displays the determination of the equilibrium interest rate in the model.

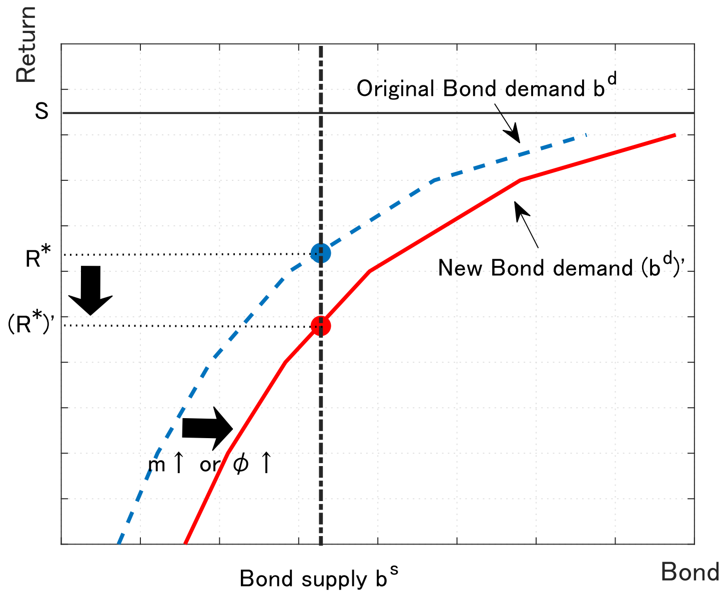
Now, consider the situation where medical costs m or the probability of getting poor health ϕ increase. As equations (7) and (8) show, the bond demand curve shifts to the right, given the value of the return on bonds. If the amount of bond supply is exogenous and unchanged, the equilibrium bond return falls, leading to an expansion of the liquidity premium. Figure 8 illustrates this mechanism. Thus, the existence of capital holding costs (1) can generate the positive relationship between medical expenditure risk and the gap between two asset returns.

Figure 7: Bond Return and Liquidity Premium



Note: This figure depicts the determination of bond return in the equilibrium. The solid blue line corresponds to the bond demand curve.

Figure 8: Relationship between Medical Expenditure Risk and Bond Return



Note: The dashed blue line corresponds to the baseline bond demand curve, and the solid red line to the bond demand curve after the rise in medical costs. The variables with a prime notation, $(b^d)'$ and R', represent the bond demand and equilibrium bond rate in the economy with higher medical costs or health risk, respectively.

3.6 Discussion

Finally, based on the results of the two-period analysis, I discuss the implications of two main structural changes that I will focus on in this paper: the changes in healthcare systems and demographics.

The changes in Japanese healthcare systems over the several decades includes the increase in out-of-pocket medical costs. As mentioned earlier, this is due to two factors. First, per capita medical expenditures have increased due to the development of medical technology. Second, the government has raised copayment rates for all ages. Such an increase in individual medical burden m could have contributed to the larger liquid asset demand b^d and the decline in the interest rate R.

Demographic aging could also have caused the bond return to fall. It increases the population share of the elderly who have large bond holdings b^d due to the higher probability of poor health ϕ and greater medical costs m. Thus, aggregate bond demand increases and the bond return R decreases, leading to an expansion of the liquidity premium $S - R$. It is important to note that, even if the amount of medical costs does not increase, changes in the composition of the population would bring about higher aggregate bond demand because the average medical costs and health risks of people in the economy will increase.

4 A Quantitative General Equilibrium Model

In this section, I extend the two-period model to general equilibrium settings of overlapping generations with intra-generational heterogeneity in income, wealth, capital returns, and health status. The model features two types of assets, liquid and illiquid, and focuses on individuals' decisions to hold these assets over the life-cycle. While liquid assets b includes cash and bonds, illiquid assets k includes stocks and capital. Importantly, I also incorporate the costs of holding illiquid capital χ to create the relationship between medical expenditure risk and savings portfolios. These settings allow us to quantify the impact of demographic and medical changes on the return of liquid bonds and the liquidity premium. I abstract the notation of the time period in the model because the paper focuses mainly on the steady states of the economy.

4.1 Demographics and Medical Expenditure Risk

Time is discrete and one period corresponds to a year. The economy is populated by overlapping generations of individuals of model age $j = 1, 2, \cdots, 80$. Individuals enter the economy with no initial assets at actual age 21 ($j = 1$) and work and retire at age 65 ($j_r + 1 = 45$). There is no aggregate risk in the economy, but individuals face idiosyncratic uncertainty about their health status. At age j, an individual's health status h_j can be either "good" ($h_j = g$) or "bad" ($h_j = b$), and the health status evolves via a Markov chain $\Pi(h_j, h_{j+1})$. Individuals have to pay medical expenses $m_{j,h}$, depending on their age and health status. The amount of medical expenditure is completely exogenous, and individuals in poor health incur more medical expenditure than healthy individuals. However, a fraction, $1 - \lambda_j$, of the medical expenditure is covered by the government. The actual medical costs faced by individuals are only $\lambda_j m_{j,h}$ and λ_j represents the copayment rate at age j.[10] In the model, medical expenditure risk can be thought of as a composite of health uncertainty h, copayment rates λ, and medical

[10]The model does not reproduce the refund systems, including high-cost medical expense benefit system (*kogaku ryoyohi seido*) and medical deductions (*iryohi kojo*), for simplicity. Since they could make medical costs or tax burden faced by patients relatively light, it would be interesting to incorporate these medical systems into the model and investigate the effects of them.

spending m. Individuals also face mortality risk and the maximum age is 100 ($j_f = 80$). Let ψ_j denote the probability that an individual of age j survives to the next age $j+1$. The survival probability of age j_f is zero, that is, $\psi_{j_f} = 0$.

4.2 Uncertainties Regarding Labor Income and Capital Return

There is an idiosyncratic uncertainty about individual labor productivity. The labor productivity η_j of age j evolves stochastically according to a Markov chain $\Pi\left(\eta_j, \eta_{j+1}\right)$. Individuals are endowed with one unit of time that can be allocated to work and leisure. During the working period, earnings are given by $w\eta_j e_j l_j$, where w is the wage rate, e_j is a labor efficiency profile of age j, and l_j is hours worked at age j. In addition, following Aladangady et al. (2021), I assume that the return on capital has an idiosyncratic risk as follows.

$$r_j^k = MPK - \bar{\delta} - \delta_j, \tag{9}$$

where r_j^k is the return on illiquid capital k and MPK is the marginal productivity of capital. The depreciation rate of capital is denoted by δ. In particular, $\bar{\delta}$ is the average depreciation which is the same for all individuals, and δ_j is the stochastic depreciation of age j, which evolves via a Markov chain $\Pi\left(\delta_j, \delta_{j+1}\right)$. Individuals can partially insure themselves against idiosyncratic risks to health, labor productivity, and capital returns by accumulating precautionary savings.

4.3 Preferences

Individuals choose consumption c_j and leisure $1 - l_j$ in each period, which bring utility:

$$u\left(c_j, l_j\right) = \frac{\left[c_j^{\sigma}\left(1 - l_j\right)^{1-\sigma}\right]^{1-\gamma}}{1-\gamma}, \tag{10}$$

where σ is a consumption share in utility and γ is the relative risk aversion.

To summarize, the individual's expected lifetime utility is given by

$$U = \mathbb{E}\left[\sum_{j=1}^{j_f} \beta^{j-1}\psi_j u\left(c_j, l_j\right)\right], \tag{11}$$

where $\mathbb{E}$ is the expectation operator and β denotes a subjective discount factor.

4.4 Costs on Holding Illiquid Assets

As in the two-period analysis in Section 3, I assume that individuals incur costs by holding their illiquid capital. It is worth emphasizing that these costs include not only monetary costs of holding or maintaining capital but also non-monetary costs, such as the time costs of gathering the information about the assets or psychological costs. The costs are formulated as

$$\chi_j = \varepsilon k_j^2 \left(\lambda_j m_{j,h}\right), \tag{12}$$

where ε governs the size of the costs. The term $\lambda_j m_{j,h}$ represents the out-of-pocket medical expenditures and is affected by individual's age and health status, copayment rate , and medical spending. These capital holding costs create a stronger motive for older individuals to hold more liquid bonds relative to illiquid capital, because they are likely to face higher medical expenditure risk. It therefore generates a large aggregate demand for liquid assets, despite its lower return.

4.5 Production Technology

Firms are competitive and produce a homogenous good using capital stock and labor according to a constant returns to scale technology:

$$Y = K^{\alpha} \left(ZN\right)^{1-\alpha}, \tag{13}$$

where Y is aggregate output, K is aggregate capital, Z is labor-augmented TFP, N is aggregate effective labor, and α is capital's share of output. A homogenous good can be used as either consumption, medical consumption, or investment.

Firms maximize profits by setting the marginal productivity of labor equal to the wage rate:

$$w = MPL = \left(1-\alpha\right) Z^{1-\alpha} \left(K/N\right)^{\alpha}, \tag{14}$$

where MPL is the marginal productivity of capital, and the marginal productivity of capital is given by

$$MPK = \alpha Z^{1-\alpha} \left(K/N\right)^{\alpha-1}. \tag{15}$$

4.6 Government

The general budget of the government is balanced in every period. Revenues consist of newly issued bonds $D^{'}$ and taxes on consumption, labor income, capital income, and bond income with the corresponding tax rates given by τ^c, τ^l, τ^k, and τ^b, respectively. Expenditures consist of an exogenous government expenditure G, an interest payment on bonds $\left(1+r^b\right)D$, pension benefits PB, medical benefits MB, and a government transfer TR, where r^b is the return on liquid bonds b. Following Conesa et al. (2018) and Hsu and Yamada (2019), the government operates a pay-as-you-go public pension system, given by

$$PB = \sum_{s|j \geq j_r+1} p_j \mu_j \Phi\left(s\right), \tag{16}$$

where

$$p_j = \begin{cases} 0 & \text{if } j < j_r + 1 \\ \theta w N & \text{if } j \geq j_r + 1 \end{cases}, \tag{17}$$

where p_j is pension benefits, μ_j denotes the population of age j, $\Phi\left(s\right)$ is a distribution function over individual state variables $s = \{j, x, \eta, \delta, h\}$, where j is age, x is cash on hand, η is an individual labor productivity, δ is an individual capital depreciation, and h is health status. The social security replacement rate is denoted by θ. Next, MB is the medical benefits that are covered by the government sector, given by

$$MB = \sum_s \left\{\left(1-\lambda_j\right) m_j\right\} \mu_j \Phi\left(s\right), \tag{18}$$

where $1-\lambda_j$ denotes the coverage rate. Finally, the government also provides a transfer benefit TR, given by

$$TR = \sum_s tr\left(s\right) \mu_j \Phi\left(s\right), \tag{19}$$

where tr is a means-tested transfer. I consider a simple transfer rule that guarantees each individual a minimum subsistence level of consumption $\underline{c}$, proposed by Hubbard et al. (1995). This safety-net program serves to prevent individuals from suffering from small or possible negative consumption when confronting with out-of-pocket medical costs.

Put together, the government's budget constraint is given by

$$G + \left(1+r^b\right)D + PB + MB + TR = D^{'} + \sum_s \left(\tau^c c\left(s\right)\right)\mu_j \Phi\left(s\right) +$$

$$\sum_{s|j<j_r+1} \left(\tau^l w\eta_j e_j l\left(s\right)\right) \mu_j \Phi\left(s\right) + \sum_s \left(\tau^k r_j^k \left(k\left(s\right) + beq\right)\right) \mu_j \Phi\left(s\right) + \sum_s \left(\tau^b r^b b\left(s\right)\right) \mu_j \Phi\left(s\right), \tag{20}$$

where beq is a transfer of accidental bequests. I assume that all bequests by the deceased are left in the form of illiquid capital, including housing or lands, and that these bequests are distributed to all survivors in a lump-sum fashion:[11]

$$beq = \frac{\sum_s \left(1-\psi_{j-1}\right) k\left(s\right) \mu_{j-1} \Phi\left(s\right)}{\sum_{j=1}^{j_f} \mu_j}. \tag{21}$$

4.7 Individuals Problem

Individuals choose consumption, capital holdings, and bond holdings, and pay for medical care and capital holding costs, using capital and bond interest income, labor income, pension benefits, and transfer benefits. Their budget constraint is defined as

$$\left(1+\tau^c\right) c + k^{'} + b^{'} = x + tr, \tag{22}$$

where

$$x = \left[1 + \left(1-\tau^k\right) r_j^k\right] \left(k + beq\right) + \left[1 + \left(1-\tau^b\right) r^b\right] b + \left(1-\tau^l\right) w\eta_j e_j l + p - \lambda_j m - \chi, \tag{23}$$

$$\chi = \varepsilon k^2 \left(\lambda_j m\right), \tag{24}$$

$$tr = \max\left\{0, \left(1+\tau^c\right) \underline{c} - x\right\}, \tag{25}$$

$$k^{'} \geq 0 \quad \text{and} \quad b^{'} \geq 0, \tag{26}$$

where x is cash on hand, which represents the individual's disposable income, excluding medical-related costs. Equation (24) shows the cost friction of holding capital. As equation (25) documents, a transfer tr can be positive, if cash on hand is below the consumption floor $\underline{c}$. Because of the borrowing constraint (26), individuals are not allowed to borrow both capital and bonds against future income.

For tractability, I here transform the budget constraint (22) in several aspects. First, I define total assets a as the sum of liquid bonds b and illiquid capital k: that

[11] There are no bequest motives in the model. Horioka (2021) suggests that, in Japan, the selfish life-cycle model with unintended or accidental bequests is more applicable rather than the dynasty or altruism model.

is, $a = k + b$. In addition, I introduce a new variable κ, which represents the share of illiquid capital in total assets: that is, $k = \kappa a$. Individuals choose total asset holdings and the investment ratio of capital, instead of choosing capital and bond holdings. Second, after-taxed gross return is defined as R: that is, $R_j^k = 1 + \left(1 - \tau^k\right) r_j^k$ and $R^b = 1 + \left(1 - \tau^b\right) r^b$. Third, total labor income, including pension benefits, is defined as y: that is, $y = \left(1 - \tau^l\right) w \eta_j e_j l + p$. Thus, individuals' budget constraints (22)-(26) can be rewritten as follows:

$$x^{'} = \left[R^b + \kappa^{'} \left(R_{j+1}^k - R^b\right)\right] a^{'} + y^{'} + R_{j+1}^k beq - \lambda_{j+1} m^{'} - \chi^{'}, \tag{27}$$

where

$$\chi^{'} = \varepsilon \left(\kappa^{'} a^{'}\right)^2 \left(\lambda_{j+1} m^{'}\right), \tag{28}$$

$$a^{'} = x - (1 + \tau^c) c + tr, \tag{29}$$

$$a^{'} \geq 0 \quad \text{and} \quad 0 \leq \kappa^{'} \leq 1. \tag{30}$$

The individual's problem can be formulated recursively. An individual chooses consumption c, labor supply l, savings $a^{'}$, and capital investment ratio $\kappa^{'}$ in order to maximize the expected discounted sum of utility in the rest of the life. The value function $V(s)$ of an individual in state $s = \{j, x, \eta, \delta, h\}$ is given as follows:

$$V(s) = \max_{c, l, a^{'}, \kappa^{'}} \left[u(c, l) + \beta \psi_j \mathbb{E}\{V(s')\}\right], \tag{31}$$

subject to equations (27)-(30), where $s^{'} = \left\{j + 1, x^{'}, \eta^{'} = \eta_{j+1}, \delta^{'} = \delta_{j+1}, h^{'} = h_{j+1}\right\}$ is the state in the next period.

4.8 Competitive Stationary Equilibrium

A competitive stationary equilibrium for this economy consists of a sequence of individuals' decision rules $\{c(s), l(s), x(s)\}$, firms' decision rules $\{K, N\}$, factor prices $\left\{r_j^k, w\right\}$, bond return r^b, government tax systems $\left\{\tau^c, \tau^l, \tau^k, \tau^b\right\}$, government expenditure G, government bonds D, pension systems θ, medical systems λ_j, means-tested transfers $tr(s)$, accidental bequests beq, and a stationary population distribution $\Phi(s)$ such that:

1. Individuals solve the optimization problems described in Section 4.7.

2. Firms maximize their profits and factor prices are determined competitively.

3. The budget constraint for the government sector is satisfied.

4. The labor, capital, and bond markets are cleared:

$$N = \sum_{s|j<j_r+1} \left(\eta_j e_j l\left(s\right)\right) \mu_j \Phi\left(s\right), \tag{32}$$

$$K = \sum_{s} \left(k\left(s\right) + beq\right) \mu_j \Phi\left(s\right), \tag{33}$$

$$D = \sum_{s} b\left(s\right) \mu_j \Phi\left(s\right). \tag{34}$$

5. The goods market clears:

$$Y - X = C + \delta K + G + M, \tag{35}$$

where X is aggregate capital holding costs and C is aggregate consumption, given by

$$X = \sum_{s} \chi\left(s\right) \mu_j \Phi\left(s\right), \tag{36}$$

$$C = \sum_{s} c\left(s\right) \mu_j \Phi\left(s\right). \tag{37}$$

Table 1: Parameters Set Outside the Model

Parameter	Description	Source	Value
Preference			
γ	risk aversion	Hsu and Yamada (2019)	3.0
Labor productivity process			
ρ_η	persistence parameter	Hsu and Yamada (2019)	0.98
σ_η	standard deviation	Hsu and Yamada (2019)	0.09
Production technology			
Z	TFP parameter	normalized	1.0
α	capital share	Imrohoroglu and Sudo (2011)	0.377
$\overline{\delta}$	average capital depreciation	Sudo and Takizuka (2020)	0.06
Capital depreciation process			
ρ_δ	persistence parameter	Aladangady et al. (2021)	0.90
σ_δ	standard deviation	Unconditional Std. dev. = 3.58%	0.0156
Government			
D	government bond supply	Net liquid assets	119.4% of GDP
r^b	return on liquid bonds	Real return on liquid assets	0.05%
τ^c	consumption tax	in 2014	8.0%
τ^k	tax on illiquid capital	Imrohoroglu and Sudo (2011)	39.8%
τ^b	tax on liquid bonds	Kitao (2015)	20.0%
τ^l	labor income tax	Kitao (2015)	35.0%
λ_j	copayment rate	MHLW (2010)	{30.0%, 20.0%, 10.0%}
$\underline{c}/\overline{C}$	fraction of consumption floor	Hsu and Yamada (2019)	10.0%

Table 2: Parameters Calibrated Specific to the Model

Parameter	Description	Target	Value
Preference			
β	subjective discount factor	$K/Y = 3.52$ (Gross illiquid assets)	1.0321
σ	weight on consumption	Average work time = 40%	0.427
ε	severity of capital holding costs	Bond market is cleared.	0.625
Government			
G/Y	government spending of GDP	Government budget is satisfied.	17.9%
θ	replacement ratio	$PB/Y = 10.0\%$	50%

5 Calibration

This section describes the calibration of parameters. The model parameters consist of two groups. Parameters in the first group are standard in the literature, and their values are summarized in Table 1. Parameters in the second group are specific to my model. Specifically, I calibrate the model to the Japanese economy of 2014 by assuming that the economy is in a steady state. Table 2 lists the calibrated parameters.

5.1 Demographics

The population distribution is set to the actual data in 2014, where the data are taken from the National Institute of Population and Social Security Research (IPSS).[12] The survival rates ψ_j are also set using the IPSS data.

5.2 Health Shock and Medical Expenditure

As mentioned by Hsu and Yamada (2019), micro-level panel data on health and medical expenditure are not publicly accessible in Japan. To obtain the medical expenditure profiles, this paper uses Fukai et al. (2018), who estimate the health expenditure level by age using data from the Claims Database of Japan Medical Data Center (JMDC). They provide the rich micro-based results regarding health distribution and age- and health-dependent medical expenditure. In my model, an individual health status is binary, "good" ($h = g$) or "bad" ($h = b$). The classification of health group is based on the amount of medical expenditure, according to Fukai et al. (2018).[13] The health transition probabilities in my model are set by using the population distribution of health conditions by age group reported by their paper. The calibrated health transition probabilities and health distribution are shown in Figure 9. The probability of transitioning from "good" to "bad" is monotonically increasing with age, whereas that from "bad" to "good" declines with age.

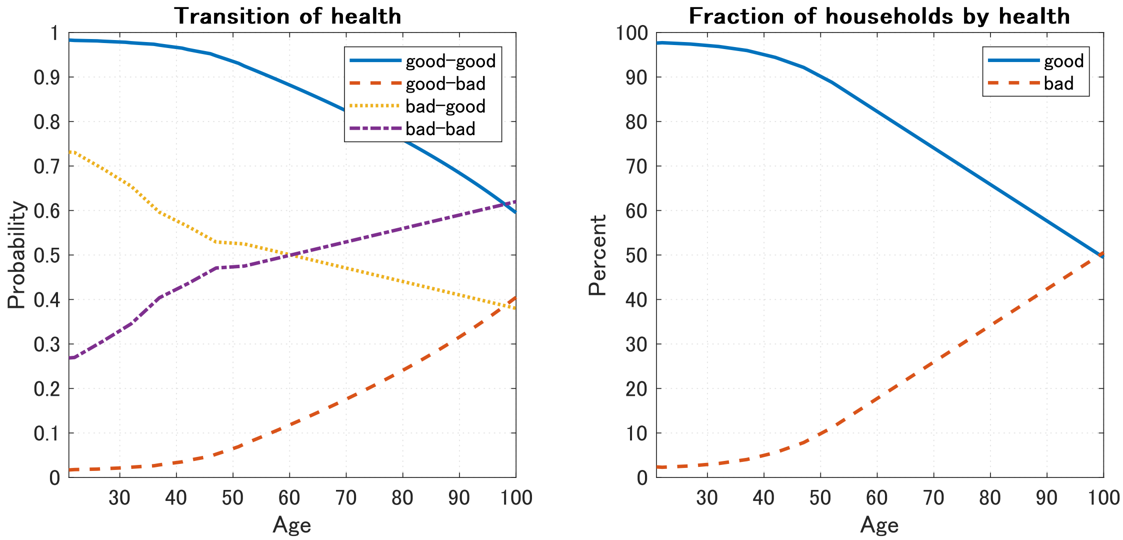
Fukai et al. (2018) also report the distribution of annual medical expenditure by age group. Using these data, the life-cycle profiles of medical expenditure for "good" and "bad" health conditions are calibrated, as shown in Figure 10.[14]

[12] I simulate the steady-state economy using the actual population in 2014, which is not stationary. I assume that individuals solve the optimization problem given the survival probabilities of 2014, and aggregate variables are calculated using the actual age-distribution of 2014.

[13] According to this classification, the healthy group would include low-income individuals who, despite their poor health, have few medical expenses. More precisely, health shocks should be considered as medical expenditure shocks in the model.

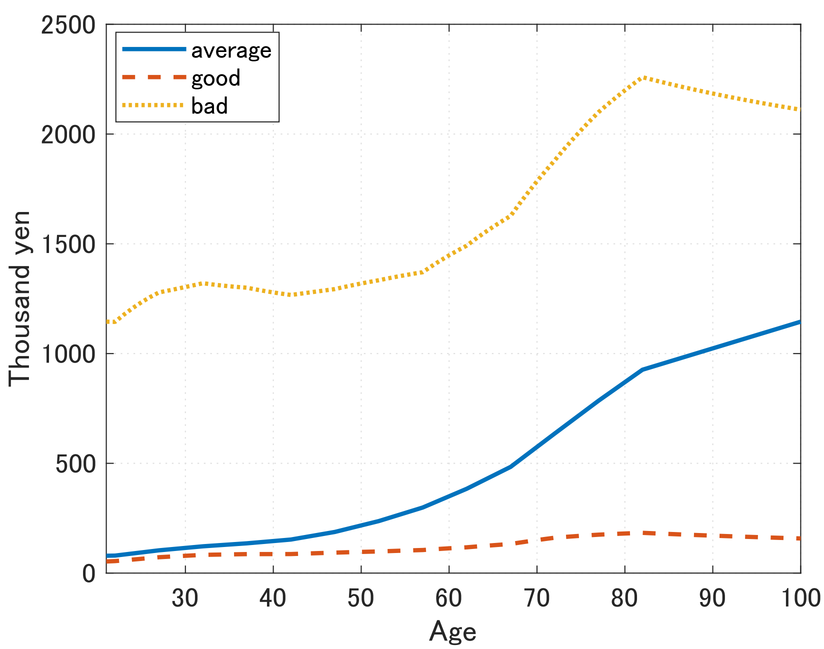
[14] For more details about the computation of age- and health-dependent medical expenditure, see Appendix A.

Figure 9: Health Transition (Left Panel) and Health Distribution (Right Panel)



Source: The author's calculations from Fukai et al. (2018).

Figure 10: Medical Expenditure by Age and Health



Source: The author's calculations from Fukai et al. (2018) and the Ministry of Health, Labour and Welfare (MHLW).

5.3 Preference

I classify household assets into two groups: liquid and illiquid. I define liquid assets as the sum of cash, deposits, and bonds, and illiquid assets as the sum of stocks, private life insurance and pensions, and capital (including housing and other real estate). The subjective discount factor β is chosen so that $K/Y = 3.52$, which is the (gross) illiquid assets of GDP in 2014. The weight on consumption σ is set so that individuals spend approximately 40% of their disposable time on work. The risk aversion parameter γ is set to 3 as in Hsu and Yamada (2019). In my baseline model, based on the consumption weight σ of 0.427, we obtain the risk aversion over consumption $(\gamma - 1)\,\sigma + 1$ of 1.854. This value is consistent with many macroeconomic literatures.

In the model, the capital holding cost parameter ε is the key parameter for generating the demand for liquid bonds with lower return. I calibrate this value so that the aggregate bond market is cleared (i.e., $\sum_s b\,(s)\,\mu_j \Phi\,(s) = D$), given the 2014 values of bond return r^b and the supply of government bonds D as mentioned later in Section 5.6.

5.4 Endowments and Labor Productivity Shock

The individual labor efficiency e_j is set using data from the Basic Survey on Wage Structure (BSWS) by the Ministry of Health, Labour and Welfare (MHLW). The estimated wage profile is shown in Figure 11. The individual labor productivity shock η is approximated by an AR (1) process with a three-state Markov chain using the method of Tauchen (1986):

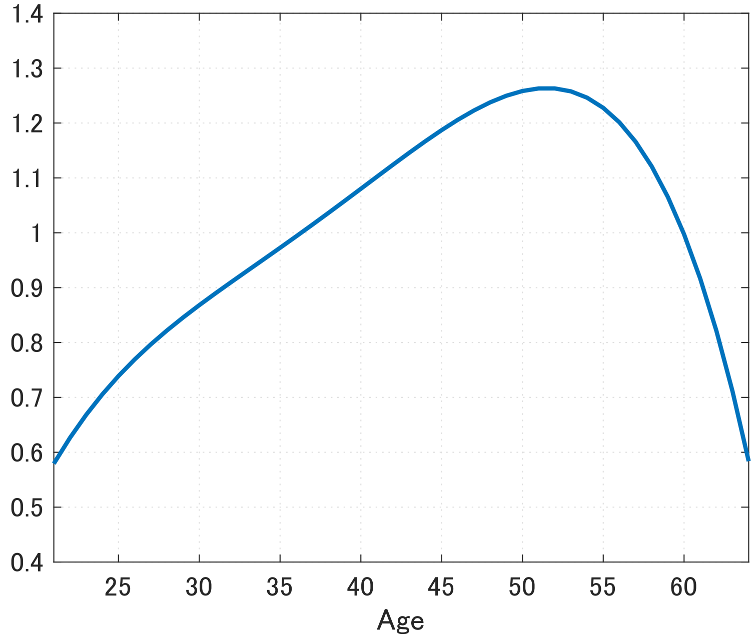
$$\log(\eta_{j+1}) = \rho_\eta \log(\eta_j) + \pi_{\eta,j}, \tag{38}$$

where $\pi_{\eta,j} \sim N\left(0, \sigma_\eta^2\right)$. Following Hsu and Yamada (2019), the persistence parameter ρ_η is set at 0.98, and the standard deviation of the shock σ_η is set at 0.09.

5.5 Technology and Capital Depreciation Shock

The labor-augmented TFP Z is normalized to 1. The capital share α is set to 0.377, based on Imrohoroglu and Sudo (2011). The depreciation of capital has two parts: deterministic and stochastic. First, the deterministic part, denoted by $\overline{\delta}$, represents the average depreciation and I set the value at 0.06, following Sudo and Takizuka (2020). Second, the stochastic part partially contributes to the demand for liquid bonds due

Figure 11: Labor Efficiency Profile



Source: The author's calculations from the MHLW.

to the riskiness of illiquid capital. The depreciation shock δ is approximated by an AR (1) process with a two-state Markov chain:

$$\log(\delta_{j+1}) = \rho_\delta \log(\delta_j) + \pi_{\delta,j}, \tag{39}$$

where $\pi_{\delta,j} \sim N(0, \sigma_\delta^2)$. Following Aladangady et al. (2021), the persistence parameter ρ_δ is set at 0.90. Regarding the standard deviation of the shock σ_δ, I set the value of 0.0156, such that the unconditional standard deviation of the autoregressive process is 3.58%.

5.6 Government

I set the supply of government bonds $D/Y = 1.194$, which is the net liquid assets of GDP in 2014. I assume that the ratio is constant over time.[15] The return on bonds is

[15]The assumption of a fixed bond supply would be a strong and unrealistic, since the public debt has increased significantly over these several decades. However, it allows for us to clearly understand the impact of demographic aging and changes in healthcare systems, as noted in Kopecky and Taylor (2022). In Section 6.3, I relax the assumption and analyze the impact of changes in the supply of government bonds.

Table 3: Aggregate Moments: Model vs Data

Parameter	Description	Steady-state value	Data
r^k	Average return on capital	4.71%	5.48%
r^b	Return on bonds	0.05%	0.05%
$r^k - r^b$	Average liquidity premium	4.66%	5.43%
$R^k - 1$	Post-tax return on capital	2.83%	3.31%
$R^b - 1$	Post-tax return on bonds	0.04%	0.04%
$R^k - R^b$	Post-tax premium	2.79%	3.27%
D/Y	Debt-output ratio	1.19	1.19
K/Y	Capital-output ratio	3.52	3.52
G/Y	Government expenditures of output	0.18	0.13
PB/Y	Pension benefits of output	0.10	0.10
M/Y	Medical expenditures of output	0.07	0.08
MB/Y	Medical benefits of output	0.06	0.07
$(M - MB)/Y$	Out-of-pocket medical costs of output	0.01	0.01
X/Y	Transaction costs of output	0.03	–

set at 0.05%. This is the average value of the real interest rate on 10-year bonds during 2010-2018, which is calculated by the long-term nominal interest rate minus the CPI inflation rate. The consumption tax rate τ^c is set at 8% in 2014. The capital income tax rate τ^k is set at 39.8% following Imrohoroglu and Sudo (2011), and the bond income tax rate τ^b is set at 20.0% according to Kitao (2015). The labor income tax rate τ^l is set at 35.0% according to Kitao (2015), which includes insurance premiums for public pensions and public health care in the real economy. These tax rates are assumed to be constant. The government spending of GDP G/Y is set so that the government budget (20) holds. The replacement rate θ is set to 50.0% and the implied total pension benefits are 10.0% of GDP, close to the real value in 2014. All residents benefit from universal health care provided by the government. The copayment rate λ_j currently depends on age: 30% under age 70, 20% between age 70 and 74, and 10% at age 75 and over.[16] I set the consumption floor $\underline{c}$ at 10% of average consumption $\overline{C}$, following Hsu and Yamada (2019).

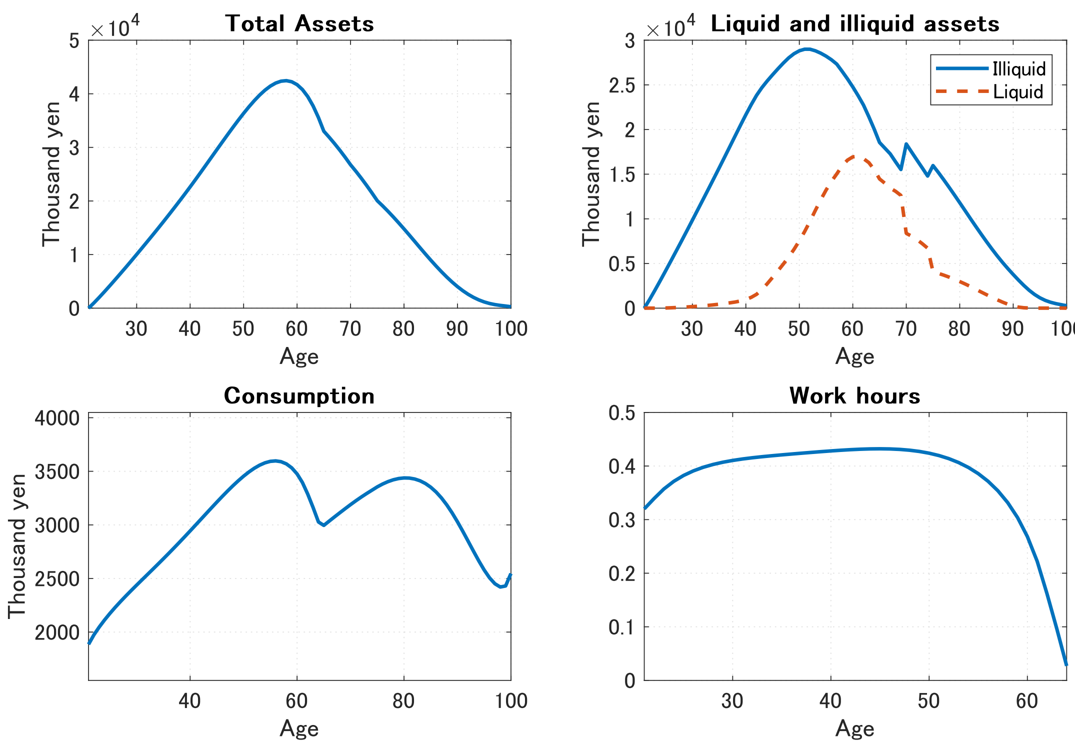
[16] In the actual economy, the copayment rate is still 30% for those who are over age 70 but have as much income as active workers. However, they represent only 7% of the population, and I therefore omit them.

5.7 Model Fit

Table 3 shows the aggregate moments in the steady state of my model and the data. The model reproduces some of key features of the Japanese economy, including returns on bonds and capital, aggregate liquid bonds, aggregate illiquid capital, and the composition of aggregate output.

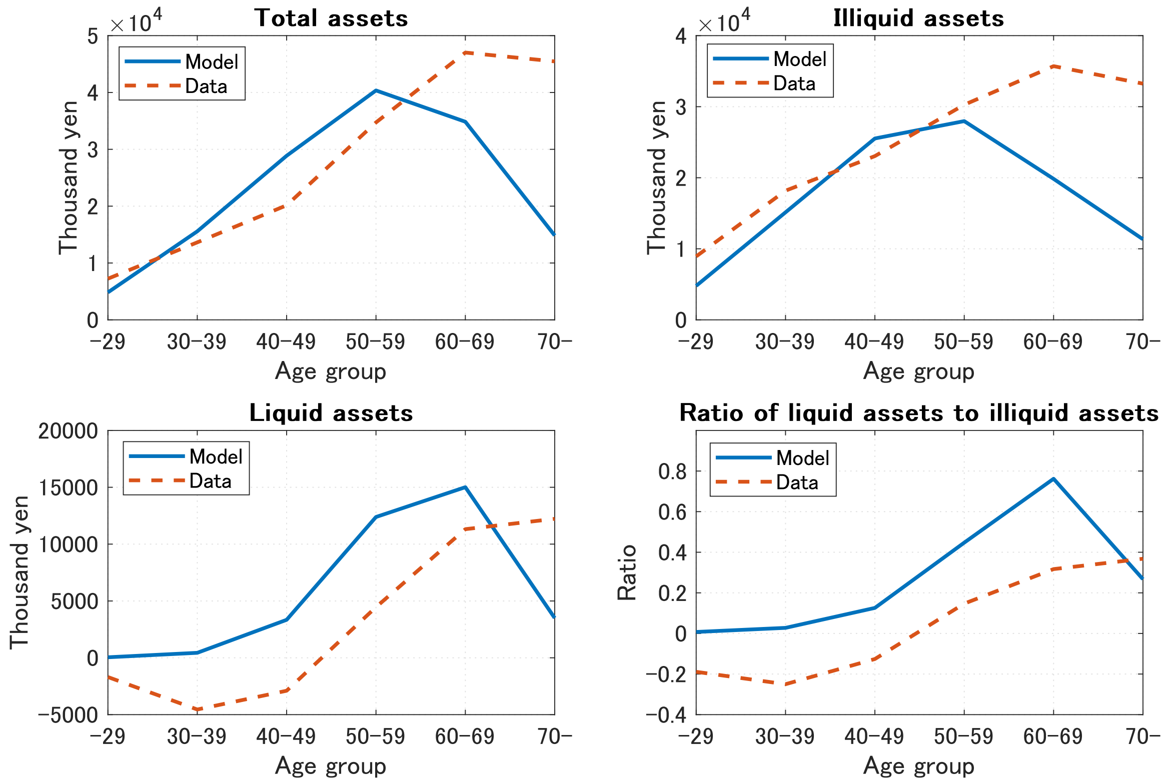
Figure 12 shows life-cycle profiles of assets, consumption, and work hours in the model. First, individuals accumulate wealth after entering the economy and start to dissave as they approach retirement age. Next, consumption rises sharply during the working period and declines thereafter, exhibiting a mild hump-shaped profile. Finally, hours worked are relatively flat until around age 50, but then decline sharply in the 50s and 60s. These life-cycle patterns are consistent with data from Kitao (2015) and Imrohoroglu et al. (2016).

Figure 12: Assets, Consumption, and Work Hours over the Life-Cycle



Next, Figure 13 represents total, liquid, and illiquid assets over the life-cycle in the model and the data. To compare the levels and proportions of different types of assets in the model with those in the data, I compute the average values within six age groups

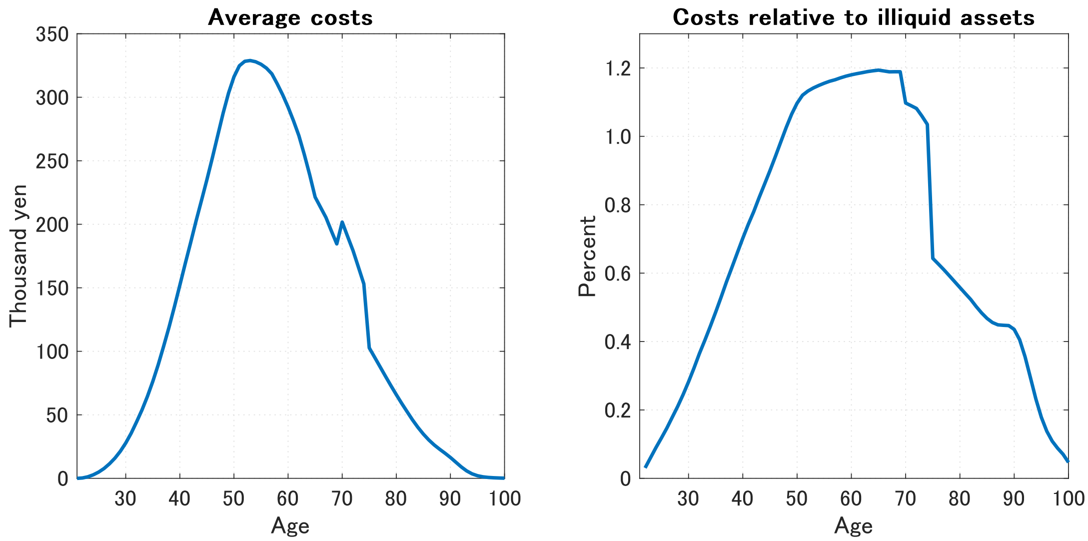
Figure 13: Liquid and Illiquid Asset Holdings by Age Group: Model vs Data



(under 29, 30-39, 40-49, 50-59, 60-69, and over 70). First, the model captures well the level and the shape of all asset holdings over the life-cycle relatively. Individuals tend to increase their wealth as they age. Second, those aged over 70 in the model have a much lower assets than households in the real economy. This is mainly because of the assumption that the level of wealth becomes finally zero at age 100 and the absence of the bequest motive in the model. Third, however, the model successfully generates the household asset portfolio by age in the real economy. The share of liquid assets to illiquid assets increases with age because older individuals with higher medical expenditure risk prefer to hold more liquid assets due to the existence of capital holding costs.

Finally, Figure 14 documents the average capital holding costs over the life-cycle. The costs have hump-shaped profile because they positively depend on the size of capital holdings and medical expenses. From the left panel of the figure, we see that the average of the amount of costs can be 132 thousand yen. In addition, the right panel shows that these costs are 0.69% of illiquid asset holdings in average. This value is consistent

Figure 14: Costs on Holding Illiquid Assets over the Life-Cycle



with many literatures, including Kaplan and Violante (2014), Campanale et al. (2015), Kaplan et al. (2018), and Braun and Ikeda (2021).

6 Steady State Results

The focus of this section is to analyze the role of population aging and medical expenditure risk on macroeconomic variables, including aggregate output, demand for liquid bonds and illiquid capital, and returns on these assets and the liquidity premium. Specifically, I first compute the steady-state equilibrium in the benchmark year 2014. Then, I simulate the model under real structures in terms of demographics and healthcare systems in the years 1990 and 2000. Here I assume that these also represent a steady state where all the above structures are stable.[17]

6.1 Changes in Demographics and Medical Systems

In Japan, demographic structure has significantly changed in recent decades. Due to the lower fertility and longer life expectancy, Japanese economy has experienced a sharp rise in the ratio of the old, retired population to the young working-age population. Table 4 shows the aging rate and the old-age dependency ratio in the three years: 1990, 2000, and 2014. According to the IPSS, the aging rate was only 16.8% in 1990. However, it

[17]For details of the numerical procedures, see Appendix B.

Table 4: Demographic Change

	1990	2000	Bench (2014)
Aging rate	16.8%	22.1%	31.9%
Dependency ratio	20.2%	28.3%	46.7%

Notes: Aging rate is the ratio of the population of aged 65 and over to the population aged 21-100, and the dependency ratio is the ratio of the population aged 65 and over to the population aged 21-64.

has increased to 22.1% in 2010 and 31.9% in 2014. In addition, the dependency ratio more than doubled from 20.2% in 1990 to 46.7% in 2014.

In addition, medical structures have changed considerably over the past thirty years. Table 5 shows healthcare systems in the three specific years. Per capita medical expenditure has increased due to the advanced medical technology and an increase in household income. According to the MHLW, in 1990, the average per capita expenditure was 70,000 yen for those of aged 21 to 44, while it was 594,000 yen for those of over age 65. However, over the twenty years, the former expenditure has increased to 121,000 yen and the latter expenditure has increased to 861,000 yen.

Apart from the amount of medical costs, the government has increased the copayment rates for public health insurance. In 2014 and now, the copayment rates are 30.0% for those aged 21-69, 20.0% for those aged 70-74, and 10.0% for those aged 75 and above. These rates in 1990 and 2000 were trivial compared to those in 2014, not only for the elderly but also for the younger. In 1990, the individual burden of the elderly for outpatient medical care was only 400 yen per day.[18] In the model, I assume that people in good health ($h = g$) should visit medical institutions once a month and those in poor health ($h = b$) four times a month. Accordingly, their average annual payment for medical care is 4,800 yen (=400 yen$*$1 time$*$12 months) and 19,200 yen (=400 yen$*$4 times$*$12 months), respectively. On the other hand, the copayment rate for younger people was 10.0% for the employee's health insurance. In 2000, these copayment rates were higher than those in 1990, but the rates were 10.0% for the elderly over 70 and 20.0% for those under 69 with the employee's health insurance.

As I discussed in Section 3.6, changes in both demographics and medical systems could increase the demand for liquid assets and reduce the return on bonds. When individuals face medical expenditure risk, they value liquid bond holdings that do not carry the additional cost or risk. While population aging leads to an increasing number

[18] For impatient medical care, including hospitalization, out-of-pocket medical expenditure was only 300 yen per day.

Table 5: Changes in the Healthcare Systems

	1990	2000	Bench (2014)
Per capita medical expenditure (thousand yen)			
21-44	70	105	121
45-64	180	248	279
65+ (75+)	594 (673)	772 (860)	861 (976)
Copayment rates			
21-69	10.0%	20.0%	30.0%
70-74	400 yen per day	10.0%	20.0%
75+	400 yen per day	10.0%	10.0%

Table 6: Model Equilibrium Macroeconomic Variables

	1990	2000	Bench (2014)
Capital K	2.82	2.50	2.20
Labor supply N	0.34	0.33	0.29
Average work hours l	0.36	0.38	0.37
Output Y	0.75	0.71	0.62
Consumption C	0.41	0.38	0.37
Bond $D (= 1.19 * Y)$	0.90	0.84	0.74
Medical spending of output M/Y	2.8%	4.6%	7.0%
Wage w	1.38	1.34	1.34
Average return on capital r^k	4.08%	4.68%	4.71%
Return on bonds r^b	1.72%	1.12%	0.05%
Return gap $r^k - r^b$	2.36%	3.56%	4.66%

of elderly people with higher health risk and larger medical expenditures, the increase in individual medical burden leads to a rise in medical expenditure risk. These changes would increase the aggregate demand for liquid assets and lower the equilibrium interest rate to clear the bond market. It puts upward pressure on the return gap between liquid and illiquid assets.

6.2 Model Aggregate Outcomes

In Table 6, I show the aggregate values in the three steady states: 1990, 2000, and 2014 (benchmark year). I focus on the benchmark year 2014 and discuss the changes from the years 1990 and 2000.

First, the aggregate capital stock has decreased. This is mainly because the effect of capital declines due to the portfolio rebalancing through the cost of holding capital would dominate the effect of capital increases due to demographic aging and the growth of medical expenditures. In general, the decline in mortality rates and the increase in out-of-pocket medical expenditures encourage individuals to save more for longer their lives in old age. It increases the aggregate capital stock. However, at the same time, the rise in medical expenditure risk causes individuals to change their asset portfolios from illiquid to liquid, and aging increases the population ratio of the old with higher risk to the young with lower risk. It leads to a decline in the aggregate capital. In the simulation, the former effect is overwhelmed by the latter effect.

Second, hours worked have increased, but the aggregate labor supply has declined. Longer longevity also promotes individuals to work more. However, the overall impact on aggregate labor is negative because of the large decline in the size of the younger population.

Third, output has declined because of the decrease in both capital and labor. It leads to a decline in the aggregate bond demand, assuming that the debt-to-output ratio remains constant. In addition, the ratio of medical expenditures to output has risen sharply in line with changes in healthcare systems.

Finally, while the return on capital has slightly increased, the return on bonds has largely dropped. The main factor behind this result is the costs of holding illiquid capital and medical expenditure risk. Individuals can accept lower bond return because holding liquid bonds have larger advantage in terms of no additional other risks for them with higher medical expenditure risk. From 1990 to 2014, the increase in the capital return is 0.63%pt (=4.71%−4.08%) and the decline in the bond return is 1.67%pt (=1.72%−0.05%). Thus, the return gap, that is liquidity premium, has increased by 2.30%pt. Table 7 compares the changes in the two asset returns and the gap in the model and data. Here I compute the post-tax returns $R^k - 1$ and $R^b - 1$, and the post-tax premium $R^k - R^b$. As can be seen in the table, the model can reproduce well the changes in both returns and the widening gap observed in the data. The model generates the positive and relatively large premium changes of 1.71%pt from 1990 to 2014, which is the half of the data value of 3.42%pt.

6.3 Decomposition of Changes in Two Asset Returns and Liquidity Premium

Next, to further investigate the increase in the capital return and the decline in the bond return, I decompose these changes in the model into three components. The first effect

Table 7: Two Asset Returns and the Gap

	1990	2000	Bench (2014)	Change direction
Model				
Post-tax return on capital $R^k - 1$	2.45%	2.82%	2.83%	$\Uparrow$
Post-tax return on bonds $R^b - 1$	1.38%	0.90%	0.04%	$\Downarrow$
Post-tax liquidity premium $R^k - R^b$	1.08%	1.92%	2.79%	$\Uparrow\Uparrow$
Data				
Post-tax return on capital $R^k - 1$	2.63%	2.95%	3.31%	$\Uparrow$
Post-tax return on bonds $R^b - 1$	2.78%	1.62%	0.04%	$\Downarrow$
Post-tax liquidity premium $R^k - R^b$	−0.15%	1.33%	3.27%	$\Uparrow\Uparrow$

Table 8: Decomposition of Changes in Returns and Premium

	Liquidity premium $R^k - R^b$	Capital return $R^k - 1$	Bond return $R^b - 1$
Total changes (from 2000 to 2014)	+0.87%	+0.02%	−0.86%
(i) Demographics	+0.20%	−0.51%	−0.71%
(ii) Medical expenditures	+0.16%	+0.12%	−0.04%
(iii) Copayment rates	+0.51%	+0.41%	−0.10%
Total changes (from 1990 to 2014)	+1.72%	+0.38%	−1.34%
(i) Demographics	+0.43%	−0.86%	−1.28%
(ii) Medical expenditures	+0.55%	+0.48%	−0.06%
(iii) Copayment rates	+0.74%	+0.75%	+0.01%

is related to the changes in the demographic structure, such as the rise in the ratio of the old, retired population to the young working-age population. The second effect is due to the increase in per capita medical expenditure. The third effect is due to the rise in copayment rates. The second and third effects are related to the changes in the medical system. The decomposition allows us to identify the major contributors to premium changes over several decades in Japan. I calculate the demographic contribution by simulating again the model in 1990 and 2000, changing the demographics but keeping the medical structures in 2014. The medical contributions are calculated under the opposite assumption.

Table 8 shows the results of the decomposition. The second and sixth rows show the total changes in the two asset returns and the gap from 2000 to 2014 and from 1990 to 2014, respectively. From the third to the fifth row and from the seventh to the ninth row, the contributions of each structural change are shown.

First, the demographic aging (i) has depressed both returns on capital and bonds. Changes in the composition of the population could increase both aggregate demand for capital and bonds, because older people are likely to have more liquid and illiquid assets. The increase in the capital reduces the marginal productivity of capital and the return on illiquid capital. On the other hand, given a constant aggregate supply of bonds, the increase in bond demand allows the equilibrium return on liquid bonds to fall. Since demographic change has the larger negative impact on the bond return, it has increased the liquidity premium. However, the contribution is only 0.20% from 2000 to 2014 (0.43% from 1990 to 2014), which is very small compared to the total change of 0.87% from 2000 to 2014 (1.72% from 1990 to 2014).

Second, the increase in out-of-pocket medical expenditure, (ii) and (iii), has pushed down the return on bonds, while increasing the return on capital. These changes are simultaneously explained as follows. Higher medical expenditure risk induces individuals to shift their asset portfolio from illiquid assets to liquid assets in order to reduce the additional cost of holding capital. As a result, aggregate demand for bonds has increased significantly, leading to a further decline in the equilibrium interest rate on bonds. On the other hand, aggregate capital demand has decreased and the capital return has increased, which is greater than its decline due to aging. The results show that the contribution of the reform of the copayment increase is larger than that of the increase in per capita medical costs.

Overall, the increasing premium over the several decades can be generated from the upward pressure on the capital return and downward pressure on the bond return, caused by the mixture of two changes in demographics and healthcare systems.

6.4 Future Projections

Finally, this section discusses the future projections for two asset returns and the liquidity premium. Specifically, I simulate the model in 2030 and 2060 under the projected situations of (i) further aging, (ii) further increase in per capita medical expenditures, (iii) reform of raising copayments. In addition, I relax the assumption of a constant debt-to-GDP ratio and allow for increasing government bonds, which I refer to as (iv). Table 9 summarizes the model's assumptions about these future economic situations in the three years: 2014 (benchmark year), 2030, and 2060.

First, population aging is expected to worsen in the future. According to the IPSS population projection data, the aging rate will increase from 31.9% in 2014 to 37.2% in 2030 and 44.6% in 2060. Second, I assume that per capita medical expenditure will increase in the future at the same rate of change from 2000 to 2014. The growth rates

Table 9: Assumptions about the Future Economy

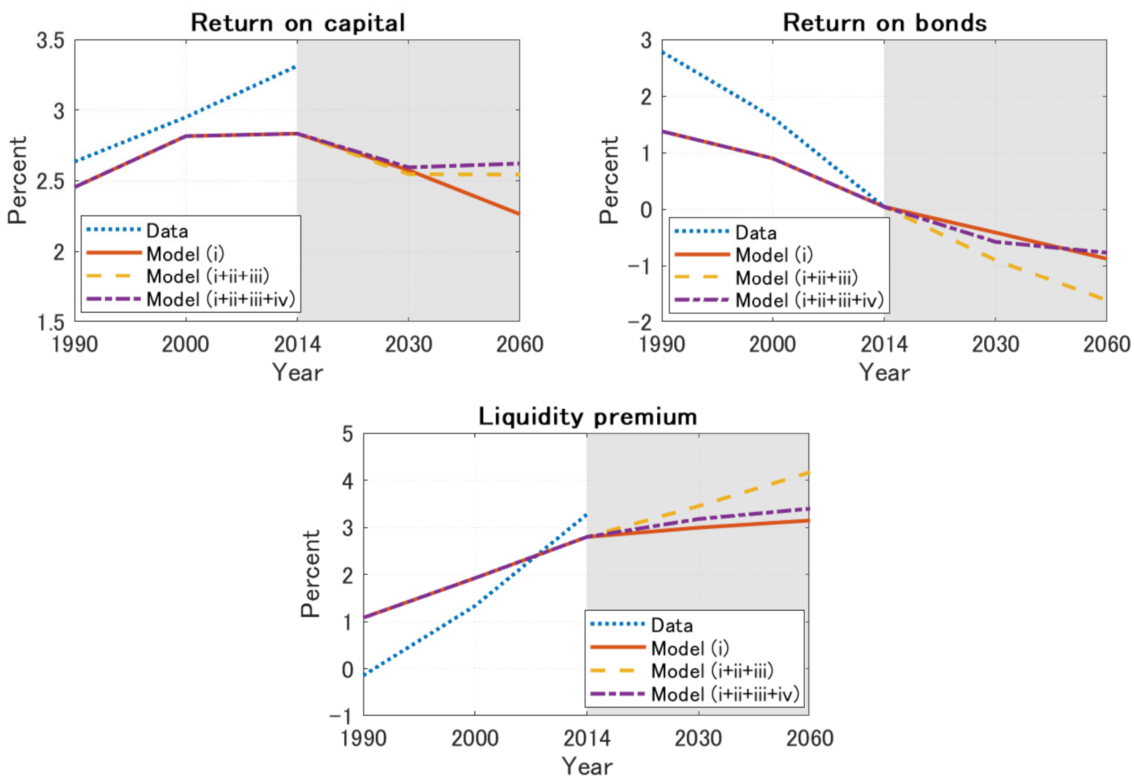
	Bench (2014)	2030	2060
(i) Population aging			
Aging rate	31.9%	37.2%	44.6%
Dependency ratio	46.7%	59.1%	80.5%
(ii) Per capita medical expenditure (thousand yen)			
21-44	121	139	185
45-64	279	314	397
65+	861	960	1194
(iii) Copayment rates			
75+	10.0%	20.0%	20.0%
(iv) Government bond supply			
Debt-to-GDP ratio	119.4%	144.3%	194.0%

Notes: Aging rate is the ratio of the population of aged 65 and over to the population aged 21-100, and the dependency ratio is the ratio of the population aged 65 and over to the population aged 21-64.

are 15.2% for those aged 21-44, 12.5% for those aged 45-64, and 11.5% for those aged over 65. Third, I assume that the government will increase the copayment rates for those over 75 from the current 10.0% to 20.0%. Finally, I consider changes in the debt-to-output ratio and assume that the Japanese economy will experience a significant increase in government debt. As mentioned in Section 5.6, I set the debt-to-output ratio, D/Y, constant at 1.19 in the benchmark simulation. However, the ratio was relatively low in 1990s: 0.82 in 1994 and 0.95 in 2000. I assume that the net liquid assets of GDP will increase in the future at the same rate of change from 2000 to 2014. Since the increase in the supply of government bonds would put upward pressure on the bond rate, the magnitude of the positive premium changes could be mitigated.

In Figure 15, I show the past and future projected changes in the return on bonds, the return on bonds, and the liquidity premium in the model and the data. In the model with only demographic change (i), both capital and bond returns will decline after 2014. Although the premium will increase due to a larger decline in the bond rate, the increase is trivial; the premiums are 2.99% in 2030 and 3.14% in 2060, compared to 2.79% in 2014. On the other hand, in the model that also includes changes in medical costs (ii) and the copayment rates (iii), bond return will decline significantly and the premium will become larger: 3.45% in 2030 and 4.17% in 2060. Finally, the model (i+ii+iii+iv) shows the results of all changes including the increase in the supply of bonds (iv). Taking into account the future increase in the bond supply, the increase in the premium will be moderate: 3.18% in 2030 and 3.39% in 2060. This is because, as shown in the upper right panel of Figure 15, the rise in the bond return would be mitigated by the upward pressure on the return from a larger bond supply. Thus, the premium is expected to rise further in the future. However, it is important to note that it depends heavily on the magnitude of the effects of (i)-(iv) and other economic factors not included for in the model, such as tax reform and changes in the TFP level.

Figure 15: Future Projections of Two Asset Returns and Liquidity Premium



Note: Model (x) (x=i, i+ii+iii, and i+ii+iii+iv) shows the model simulation results with future assumption x. Here, (i), (ii), (iii), and (iv), respectively, represent the changes in demographics, per capita medical expenses, copayment rates, and the government debt. Shade areas show the future projection of two asset returns and the gap.

7 Conclusion

Over several decades in Japan, while the return on liquid assets, including cash, deposits, and bonds, has significantly declined, the return on illiquid assets, including equity and capital, has slightly increased. Thus, the gap between them (i.e., the liquidity premium) has widened. This paper focuses on medical expenditure risk as a potentially important factor in household saving behavior and quantifies the impact of changes in demographics and healthcare systems on two asset returns and the liquidity premium.

I start with a simple two-period, partial equilibrium, model. My analytical results show that, when individuals face uncertainties about health and medical expenses, they could have incentives to shift their asset portfolio from illiquid capital to liquid bonds in order to avoid the additional cost of holding illiquid capital. The rise in medical expenditure risk leads to an increase in the demand for liquid bonds, which reduces the return on bonds and increases the liquidity premium in equilibrium.

Then, I extend the model to a dynamic stochastic general equilibrium setting with overlapping generations, and quantitatively study the role of medical expenditure risk on household saving behavior and the impact of demographic aging and the increase in individual medical burdens over the past two decades on the liquidity premium. I have three main findings. First, the widening of the liquidity premium has been driven by structural changes in both demographics and healthcare systems. Second, the contribution of the latter changes is more significant. Aging has lowered both capital and bond returns due to higher aggregate asset demand, and the larger decline in the bond return has led to a small increase in the premium. On the other hand, the increase in out-of-pocket medical expenditure has simultaneously caused the decline in bond return and the increase in capital return, contributing to a large expansion in the premium. This is because higher medical expenditure risk encourages individuals to hold more liquid bonds without additional holding costs. As a result, it has led to higher aggregate bond demand and put significant downward pressure on the bond return. Finally, if further demographic aging of the population and rising medical expenditure are expected in the future, the liquidity premium will widen more. Nonetheless, it might be mitigated by the continued substantial rise in government debt.

I also note that the healthcare system and medical services in the actual economy are more complex than assumed in this paper: high-cost medical expense benefits (*kogaku ryoyohi seido*), medical deductions (*iryohi kojo*), private health insurance. In addition, in this paper, I abstract from the long-term care insurance system. In general, the average expenditure for long-term care is much higher than that for medical care. It would be important to include these systems in the model and to precisely capture the medical burden of households, in order to assess the impact of the economic structural changes on the liquidity premium. These extensions are left for future research.

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Appendix

A Calculation of Medical Expenditure Profiles

In this paper, I compute age- and health-dependent medical expenditure as follows. First, using the population distribution by age and health group reported by Fukai et al. (2018), I calculate the population share of those with “good” health and “bad” health. Their paper classified people into five health groups according to annual medical expenditure: 0-7,800 yen for Q1 (best health condition), 7,801-24,000 yen for Q2, 24,001-54,000 yen for Q3, 54,001-266,999 yen for Q4, and 267,000 yen and over for Q5 (worst health condition). I assume that “good” and “bad” health groups in my model correspond to Q1-Q4 and Q5 groups in their paper.

Next, by combining the population share with the distribution of medical expenditure by age group, I calculate medical expenditure by age and health group. Fukai et al. (2018) also present the average medical expenditure in the percentiles of each age group: 1%, 5%, 10%, 25%, 50%, 75%, 90%, 95% (top 5%), and 99% (top 1%). First, in all age groups, I linearly interpolate these medical expenditures and obtain the medical expenditure by health group. Second, I linearly interpolate the medical expenditure of each age group over age and then obtain the age- and health-dependent medical expenditure.

However, there was a gap between these calculated medical expenditures and average health care expenditure in 2014 reported by the MHLW. For this reason, finally, given the health distribution, I recalibrate the medical expenditures in the model so that they match the actual medical costs.

B Computational Algorithm

In this section, I describe detailed algorithms to compute the steady state. The numerical method of the stationary equilibriums is basically the same as Huggett (1996). For example, consider the steady state under the benchmark economy. We find a set of capital-labor ratio K/N that leads to the equilibrium prices $\left\{r_j^k, w\right\}$, government expenditure G/Y that balances the government budget, and return on bonds r^b such that bond market is cleared. Computational steps are described below.

1. Guess aggregate capital K^{ini}, aggregate labor supply N^{ini}, bequests beq^{ini}, and

consumption floor $\underline{c}^{ini}$, and calculate factor prices $\left\{r^k, w\right\}$. Set initial value of government expenditures of output $(G/Y)^{ini}$ and initial value for return on bonds r^b.

2. Given $\left\{r_j^k, w\right\}$ and government policies $\left\{D^s/Y, \tau^c, \tau^l, \tau^k, \tau^b, \theta, \lambda_j\right\}$, compute policy functions using the Endogenous Grid Method (EGM) backwardly.

3. Compute the population distribution function Φ from policy functions.

4. Using the distribution function, calculate aggregate variables such as capital K^{new}, labor supply N^{new}, bequests beq^{new}, consumption C, and consumption floor $\underline{c}^{new}$ and bond demand D^d.

5. Find the government spending output ratio $(G/Y)^{new}$ so that the budget constraint of the government sector holds.

6. First, check if K^{ini}, N^{ini}, beq^{ini}, $\underline{c}^{ini}$, and $(G/Y)^{ini}$ are close to K^{new}, N^{new}, beq^{new}, $\underline{c}^{new}$, and $(G/Y)^{new}$, respectively.

7. Second, check if the bond demand D^d is equal to the bond supply D^s.

8. If both above checks pass, stop the computation. Otherwise, update the initial values, and restart from Step 2.

C The Properties of Bond Demand

In this section, I describe the derivation of equations (7) and (8) and the positive relationship between bond demand and its return, $\left(\frac{\partial b}{\partial R}\right) > 0$, in the two-period analysis in Section 3.

C.1 Impact of Medical Costs on Household Asset Portfolio

First, equation (6) can be transformed as follows:

$$(1-\phi)(S-R)\,c^b = \phi c^g \left\{2\varepsilon km - (S-R)\right\}. \tag{C.1}$$

If $S > R$, the left-hand side of the above equation is positive. Thus, $2\varepsilon km > (S-R)$ holds, so that the right-hand side becomes positive as well. Using equations (3)-(5), consumption of healthy and unhealthy old individuals is given as

$$c^g = (R - S)\, b + Sy, \tag{C.2}$$

$$c^b = (R - S)\, b + Sy - m \left\{1 + \varepsilon\, (y - b)^2\right\}. \tag{C.3}$$

Taking the derivatives of these consumption $\left\{c^g, c^b\right\}$ with respect to bond demand b yields the following relations.

$$\left(\frac{\partial c^g}{\partial b}\right) = R - S < 0, \tag{C.4}$$

$$\left(\frac{\partial c^b}{\partial b}\right) = (R - S) + 2\varepsilon km > 0. \tag{C.5}$$

Here, differentiating both sides of equation (C.1) by medical costs m, we obtain

$$\left(\frac{\partial b}{\partial m}\right) \left[\underbrace{(1-\phi)\,(S-R)\left(\frac{\partial c^b}{\partial b}\right)}_{>0} + \underbrace{\{(S-R) - 2\varepsilon km\}\,\phi \left(\frac{\partial c^g}{\partial b}\right)}_{>0} + \underbrace{2\phi c^g \varepsilon m}_{>0}\right] = \underbrace{2\phi c^g \varepsilon k}_{>0}. \tag{C.6}$$

From equation (C.6), $\left(\frac{\partial b}{\partial m}\right) > 0$ holds. Also, since $k = y - b$ from equation (3), $\left(\frac{\partial k}{\partial m}\right) = \left(\frac{\partial k}{\partial b}\right)\left(\frac{\partial b}{\partial m}\right) = -\left(\frac{\partial b}{\partial m}\right) < 0$.

C.2 Impact of Health Risk on Household Asset Portfolio

Differentiating both sides of equation (C.1) by health risk ϕ, we obtain

$$\left(\frac{\partial b}{\partial \phi}\right) \left[\underbrace{(1-\phi)\,(S-R)\left(\frac{\partial c^b}{\partial b}\right)}_{>0} + \underbrace{\{(S-R) - 2\varepsilon km\}\,\phi \left(\frac{\partial c^g}{\partial b}\right)}_{>0} + \underbrace{2\phi c^g \varepsilon m}_{>0}\right]$$
$$= \underbrace{(S-R)\, c^b}_{>0} + \underbrace{c^g \left\{2\varepsilon km - (S-R)\right\}}_{>0}. \tag{C.7}$$

From equation (C.7), $\left(\frac{\partial b}{\partial \phi}\right) > 0$ holds. Also, $\left(\frac{\partial k}{\partial \phi}\right) = \left(\frac{\partial k}{\partial b}\right)\left(\frac{\partial b}{\partial \phi}\right) = -\left(\frac{\partial b}{\partial \phi}\right) < 0$.

C.3 Relationship between Bond return and Bond Demand

Differentiating both sides of equation (C.1) by bond return R, we obtain

$$\left(\frac{\partial b}{\partial R}\right)\left[\underbrace{(1-\phi)(S-R)\left(\frac{\partial c^b}{\partial b}\right)}_{>0}+\underbrace{\{(S-R)-2\varepsilon km\}\,\phi\left(\frac{\partial c^g}{\partial b}\right)}_{>0}+\underbrace{2\phi c^g\varepsilon m}_{>0}\right]$$
$$=\underbrace{\phi c^g+(1-\phi)\,c^b}_{>0}. \tag{C.8}$$

From equation (C.8), $\left(\frac{\partial b}{\partial R}\right)>0$ holds.