Medical Expenditures over the Life-Cycle: Persistent Risks and Insurance*

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Abstract

This paper builds a life-cycle model of single and married households and evaluates the roles of the national health insurance system. We use the administrative data on nationwide health insurance claims in Japan to analyze medical expenditure risks and calibrate the model with the stochastic process that varies by age and gender. Economic and welfare effects of health insurance reform depend on household income levels and generosity of the welfare program. Without health insurance, high-income households turn to self-insurance, significantly increasing aggregate savings. Low-income households, especially low-skilled single men and women, reduce savings and many of them become welfare recipients. Raising copayment rates for the elderly increases household savings, but depletes wealth of low-income households and leads to a rise in the number of welfare recipients.

Keywords: Medical expenditures, Health risks, Health insurance, Life-cycle model, Fiscal Sustainability, Japan.
JEL Classification: D15, E21, I10, I13

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1 Introduction

How do medical expenditure risks affect households' consumption and saving decisions over the life-cycle? What are the roles of publicly-provided health insurance? Do the effects of health insurance reform differ across heterogeneous households and how do they depend on households' ability to self-insure or on the existence of other welfare programs? We develop a structural model populated by heterogeneous individuals to answer these questions.

This paper builds a full life-cycle model of individuals, from their entry to the economy to death, and households differ in age, gender, education, marital status, asses and health status. Individuals face medical expenditure shock processes based on panel data constructed with the health insurance claims database (NDB) in Japan. Our model incorporates dynamics of a household structure, in which individuals of different skills are randomly matched and married, and become widowed as their spouse dies. We use the model to evaluate roles of the national health insurance system and study how it protects heterogeneous households from expenditure risks. We also model a means-tested transfer program and evaluate how medical expenditure risks, health insurance and social insurance programs interact and jointly affect individuals' decisions and welfare in a unified framework. Our use of the NDB panel helps evaluate medical expenditure processes across all ages accurately and enables us to analyze insurance policies whose benefits and contributions are age-dependent.

This paper makes contributions in multiple dimensions. We use the medical expenditure panel data that Fukai et al. (2021) constructed from the health insurance claims database (NDB) in Japan. This is the first paper that uses the nationwide administrative data of health expenditures in a rich structural life-cycle model. To the best of our knowledge, this is also the first paper modeling single and married households and medical expenditure risks over all of the life-cycle. Both the dynamics of the family structure and an accurate assessment of medical expenditure risks are critical elements in evaluating the roles of the insurance system.

In the first part of the paper, we use the NDB's panel data and estimate gross medical expenditure processes. The NDB panel contains a sample of more than 100 million individuals each year and information about all of their medical expenditures covered by Japan's national health insurance system. It allows us to quantify expenditure risks that individuals of different gender and ages face over the life-cycle. It has a significant advantage over studies based on survey data, such as the Medical Expenditure Panel Survey (MEPS) or the Health and Retirement Survey (HRS) in the U.S., or health insurance claim data of selected insurers in Japan, in its comprehensiveness and thorough coverage.

Medical expenditures rise quickly in age, especially after their 60s. Men spend more than women on average at each age except for several years around child-bearing ages, though women's lifetime expenditures are higher on average since they live longer. The average profiles, however, tell us little about medical expenditure risks individuals face. There is significant heterogeneity within a group of the same gender and age. For example, for men of age 60, medical expenditures in the highest 5 percentiles are 3.0 million yen on average while the average in the bottom 50% is 39,000 yen.[1]

Moreover, it is not enough to consider cross-sectional heterogeneity in quantifying lifetime expenditure risks. Panel analysis reveals that both good and bad health status are highly persistent over time and shocks persist for more than a year. For example, for 50-year old men in bad health (defined as those in the top 5% in terms of annual medical expenditures), the probability of remaining in bad health over the following year is above 50%. Furthermore, that probability is higher if an individual was in bad health in the year before, than if an individual was in good health. Papers including De Nardi et al. (2024) and Fukai et al. (2018) pointed out high persistence of health risks beyond one year and we confirm their findings.

Simulating lifetime gross medical expenditures under different specifications about persistence, we obtain the coefficients of variations that range from 0.53 (second-order Markov) to 0.47 (first-order Markov), 0.37 (i.i.d.) and 0.33 (deterministic) for men, and similarly for women. The skewness of simulated samples varies from 1.40 to 0.94, 0.22 and -0.48, from second-order Markov to deterministic processes. The thin and long tail of the distribution associated with the occurrence of persistently high expenditures is not captured well with truncated persistence. We also show that mortality risks are highly correlated with medical expenditures, an important factor to consider in quantifying lifetime medical expenditure risks in a structural model.

In the second part, we build a model to study the effects of medical expenditure risks and the roles of the national health insurance system. Our model is populated by overlapping generations of households, who differ in various dimensions including age, gender, education, marital status, assets, and current and past health status. We let them face medical expenditure and mortality risks estimated with the NDB data and include details of health insurance policy as well as the social insurance program to assess how individuals are exposed to and protected from persistent expenditure risks.

We find that the comprehensive health insurance protects individuals well from expenditure risks. Insurance copayment rates are independent of economic or health status of individuals, but the coverage rates increase from 70% at age below 70, to 80% at age 70–74, and then to 90% at age 75, providing more generous coverage when expenditures rise on average.[2] Moreover, the High-Cost Medical Expense (HCME) benefits provide ad-

[1] Among women, corresponding averages are 2.3 million yen and 37,000 yen, respectively. The nominal amount is in 2015 Japanese yen (JPY).

[2] The coverage rate for children age 6 or below is 80%, and some municipalities offer an additional coverage.

ditional coverage when individuals are faced with catastrophic expenditure shocks, with progressive income-dependent ceilings on out-of-pocket expenditures.

Without health insurance, national savings would rise by as much as 40%. Such effects, however, are not uniform across different types of households. In an economy with no insurance, married couples and high-skilled singles would start accumulating wealth at an early stage of their life to prepare for large expenditures later in their life-cycle. Low-income individuals, however, are unable to increase savings by much. Once they are hit by large expenditure shocks, they deplete savings and more households are covered by the welfare program.

We also show that a means-tested welfare program plays a key role in accounting for the pattern of life-cycle savings and that it provides an important bottom-line insurance against medical expenditure shocks. Removing health insurance would bring a greater welfare loss in an economy with a less generous welfare program. Many households would respond by raising private savings more aggressively, while low-income households reduce savings even further. Results suggest that an evaluation of health insurance reform needs to consider how other redistributive policies operate and whether different types of households have alternative ways other than self-insurance to protect themselves against expenditure risks.

We also show that raising copayment rates for the elderly and imposing a common copayment of 30% for all age groups would raise the aggregate savings by 5.5%. Older households, however, are more exposed to expenditure risks and the number of welfare recipients increases by about 10%.

The paper builds on multiple lines of literature. We contribute to a large and growing literature that investigates economic effects of health and medical expenditure risks in a quantitative model of heterogeneous households.[3] Capatina (2015) builds a life-cycle model with health shocks and evaluates roles of various channels through which health affects wealth and income inequality. De Nardi et al. (2024) focus on persistence of bad health for many periods over the life-cycle and evaluate implications on lifetime economic inequality and welfare. Hosseini et al. (2024) evaluate effects of health on employment and earnings, using a frailty index that represents an individual's health status, developed in Hosseini et al. (2022). De Nardi et al. (2023) estimate a model populated by single and married retirees and show to study factors that account for patterns of the elderly's savings. French and Jones (2011) use the Health and Retirement Survey to estimate effects of medical expenses and insurance on retirement decisions.

Many papers focus on the roles of insurance policies in structural models with health

[3]For earlier studies, see, for example, Palumbo (1999), French (2005), and Jeske and Kitao (2009). See also Capatina et al. (2020), who study effects of health shocks on earnings inequality with endogenous human capital, and Nakajima and Telyukova (2023) and Kopecky and Koreshkova (2014), who analyze the interaction of medical expenditure risks and savings of the elderly.

and medical expenditure risks. Conesa et al. (2018) and Attanasio et al. (2011) study roles of Medicare in a general equilibrium life-cycle model. Pashchenko and Porapakkarm (2013) and Jung and Tran (2016) build a structural model to evaluate implications of the Affordable Care Act (ACA).[4]

Our paper is also related to the research on the roles of means-tested social insurance programs. Hubbard et al. (1995) is an earlier work, which shows that a welfare program discourages savings of low-income households. Scholz et al. (2006) and De Nardi et al. (2010) show that social insurance programs such as Medicaid help explain low assets of the poorest households in a model with uninsurable medical expenditure risks. De Nardi et al. (2010) also demonstrate that social insurance programs affect not only the poor but also high-income households since large medical expenditures at old ages can bring their assets down and make them live at the subsistence level guaranteed by a consumption floor.[5]

Studies listed above are mainly focused on the U.S. economy and this paper considers the case of Japan, an economy with rapidly aging demographics and significant macroeconomic and fiscal challenges from rising age-related expenditures. Recent papers such as İmrohoroğlu et al. (2016), Braun and Joines (2015) and Kitao (2015) build a life-cycle model calibrated to the Japanese economy and include medical expenditures, but they assume a deterministic process based on the publicly available data. Exceptions are Hsu and Yamada (2019) and Hagiwara (2022), which include uncertainty of medical expenditures and calibrate an expenditure process using the estimates of Kan and Suzuki (2015) and Fukai et al. (2018), respectively. Kan and Suzuki (2015) is based on samples of working-age individuals in selected corporations.[6] Fukai et al. (2018) use insurance claim data of the Japan Medical Data Center (JMDC), which covers a large number of employment-based health insurance schemes, and analyze medical expenditure processes faced by individuals. Given the nature of the database, the analysis is mostly focused on working-age men, and we revisit their findings with the national data that covers individuals of all ages and gender. Fukai et al. (2021) use the NDB and the same methodology as Fukai et al. (2018) to extend the results to women and men over 60. In this paper, we use the panel data constructed by Fukai et al. (2021).

The rest of the paper is organized as follows. In section 2, we describe our data

[4] See also Fonseca et al. (2021), Cole et al. (2019), Hansen et al. (2014), and Ozkan (2023) for more studies on medical expenditures, policies, and their macroeconomic and distributional effects. Kitao (2014), Low and Pistaferri (2015) and Michaud and Wiczer (2021) study effects of disability insurance in a quantitative model with health and disability shocks.

[5] See also Brown and Finkelstein (2008), who find that an incomplete coverage of Medicaid causes a welfare loss for most of the wealth distribution. Braun et al. (2017) study the optimal size of means-tested social insurance programs in a model with idiosyncratic labor productivity and medical expenditures.

[6] Kan and Suzuki (2015) use insurance claim data of 111 corporations and estimate a medical expenditure process of working-age individuals.

source and medical expenditure processes over the life-cycle. In section 3, we present our quantitative life-cycle model and section 4 describes parametrization of the model. Section 5 presents numerical results and section 6 concludes.

2 Institutional Settings and the NDB Data

2.1 National Health Insurance System in Japan

Japan has a universal health insurance system, which covers all citizens and provides them with a common set of benefits. The insurance covers essentially all health care expenses including inpatient and outpatient services, prescription drugs and dental care. The insurance system has two tiers of coverage, age-dependent copayment rates and High-Cost Medical Expense (HCME) benefits. Copayment rates are 30% for those aged below 70, 20% for those aged 70-74 and 10% for those aged 75 and above. The HCME sets a cap on individuals' out-of-pocket expenditures, protecting individuals from a large amount of expenditures, and the maximum payment varies by age and progressively by earnings. For example, individuals whose annual earnings are less than 1 million yen face a maximum monthly payment of 35,400 yen if aged below 70 and 15,000 yen if aged 70 or above.

In 2015, total national health expenditures were 42.3 trillion yen, or 7.8% of the GDP. Out of the total national health expenditures, 79.9% were covered by the national health insurance, 11.1% by patients' out-of-pocket copayments for the insured amount, and 7.3% by other public insurance programs including the means-tested welfare program.[7] With the comprehensive coverage of the national insurance system, a private insurance market for the out-of-pocket expenditures or for items not covered by the public insurance is extremely thin.

Individuals with low income and wealth can be eligible for benefits from the means-tested welfare program, through which health care services are covered as part of benefits. The main welfare program (*seikatsu-hogo*) is administered by a local government and provides an eligible individual with cash payment that is enough to cover minimum living expenses.

In the next section, we describe our data source, the NDB, the administrative health insurance database that essentially covers entire payments made through the national health insurance and analyze gross medical expenditure processes of individuals over the

[7] The remaining small part, 1.3% of the national health expenditures, is not eligible for the coverage by either the health insurance or other public programs and is fully paid by individuals. These figures are taken from the report of the Ministry of Health, Labour and Welfare, "Overview of the National Medical Expenditures in 2015 (*kokumin iryohi no gaikyo*)." For more details including the history of the national health insurance system in Japan and a comprehensive analysis, see papers included in the special issue of the Lancet, "Japan: Universal Health Care at 50 Years" (2011), available at https://www.thelancet.com/series/japan.

life-cycle. We focus on *gross* expenditures, which include both parts paid by individuals and by the public insurance. In appendix A, we take into account details of Japan's health insurance system and repeat the analysis for life-time *out-of-pocket* medical expenditures. In the quantitative model that we present in section 3, we incorporate gross expenditure process estimated from the NDB database, as well as details of the national health insurance system and main features of means-tested programs and quantify roles of public insurance.

2.2 The NDB Data

The data source of our analysis is the nationwide health insurance claims database (National Database of Health Insurance Claims and Specific Health Checkups of Japan: "NDB") provided by the Ministry of Health, Labour and Welfare. The NDB is administrative data comprising health insurance claims and covers every Japanese citizen as long as he or she incurs medical expenditures covered by the national health insurance system.[8] We use the NDB panel data constructed by Fukai et al. (2021), who use the health insurance identification number of each individual to build a panel of gross medical expenditures and employ their data between 2011 and 2015.[9] The sample size is over 100 million individuals for each year. The rich database enables us to construct a large-scale panel data and estimate rich medical expenditure processes with persistence beyond one year, which vary by gender and age.

2.2.1 Life-cycle Profiles of Medical Expenditures

Figure 1 shows average annual medical expenditures over the life-cycle for men and women. They are gross medical expenditures, which include both out-of-pocket expenditures paid by individuals and part covered by the national health insurance. Expenditures increase monotonically in age, except for several years of higher spending among women in their late 20s and early 30s associated with child birth and hospitalization. Expenditures remain relatively low and stay below 200,000 yen until age 50, but they start to rise sharply from the age of 50 and particularly above the age of 60.

[8] The dataset does not include part of social welfare recipients, whose medical expenditures are entirely covered by the welfare program.

[9] Fukai et al. (2021) constructed a panel dataset from the NDB for the years 2009-2018. In doing so, they identify the individuals' deaths by using the discharge status flag assigned to the samples. They excluded individuals who used medical services only once during the entire sample period, as it is not possible to rule out the possibility that death may have occurred for reasons not captured by the discharge flag, such as death at home, suicide, or an accident. Additionally, the sample does not include individuals who incurred no medical expenditures throughout the entire sample period.

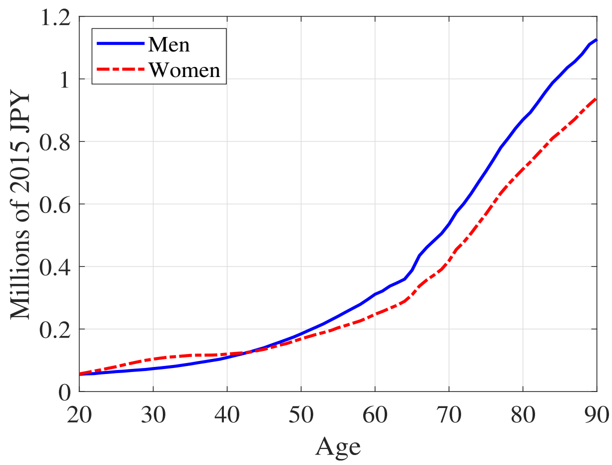


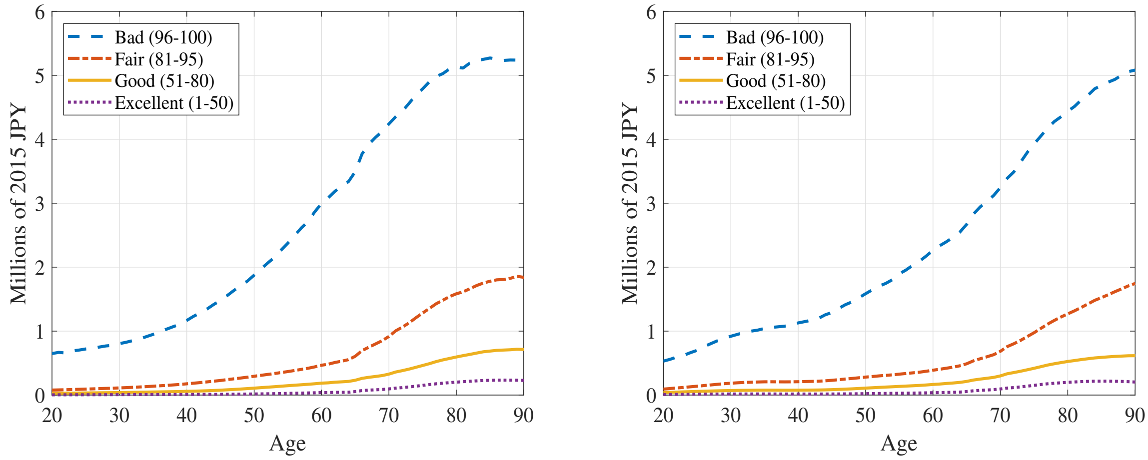
Figure 1: Individuals' Annual Medical Expenditures by Age and Gender

Men spend more on average than women at all ages above 45. As we discuss, however, in the next section, average lifetime expenditures are higher for women because they live longer than men on average.[10]

Although average profiles provide good information on expected expenditures over the life-cycle, they do not tell much about risks individuals face. In order to visualize dispersion of medical expenditures over the life-cycle, we group individuals at each age into four health status, based on the percentiles of annual medical expenditures. We make four groups of unequal sizes, and call the health status *excellent* if expenditures are between 1 and 50 percentiles from the bottom within each age and gender group, *good* if between 51 and 80 percentiles, *fair* if between 81 and 95, and *bad* if they are in the top five percentiles, between 96 and 100.

Figure 2 shows medical expenditures by health status over the life-cycle for men and women. The profiles exhibit significant heterogeneity within age groups. Average annual expenditures of the healthiest 50% do not exceed 100,000 yen until age 70 for both men and women, while the top 5% spend as much as 1 million yen above the mid-30s. Expenditures of the top 5% reach 3.5 million yen by age 65 for men and exceed 5 million in their late 70s. For women, expenditures of the top 5% are more moderate than men, but they reach 2.7 million by 65 and exceed 5 million in their late 80s.

[10]To assure the comprehensiveness of the NDB, we confirm that the life-cycle profiles of medical expenditures are in line with the national data reported by the Ministry of Health, Labour and Welfare. See appendix A for more details.



(a) Men

(b) Women

Figure 2: Individuals' Annual Medical Expenditures by Health Status

In the next section, we exploit panel properties of the NDB data and examine persistence of individuals' medical expenditures over multiple periods.

2.2.2 Persistence of Medical Expenditures

In the previous section, we showed that there is a large cross-sectional difference in medical expenditures across individuals of the same age and gender. We now demonstrate that medical expenditures are far from deterministic and that expenditure shocks are highly persistent.

Using the same health status defined above by the percentiles of medical expenditures, we compute a first-order Markov process, denoted as M(1), and a transition matrix of health status for each gender and age. Given the current health status, we compute the distribution of health status in the next period, which also include an incidence of death. As an example, Table 1 displays the transition matrix for men aged 50, and shows the distribution of their health status in the next period when they turn 51, conditional on their current health status.

Table 1: Health Status Transition $h_t \to h_{t+1}$: M(1), Samples of Age 50, Men

	Health status in $t+1$					
Men	Excellent	Good	Fair	Bad	Death	Total
Excellent	0.778	0.178	0.029	0.014	0.001	1.000
Good	0.317	0.544	0.115	0.023	0.001	1.000
Fair	0.076	0.275	0.579	0.069	0.001	1.000
Bad	0.073	0.121	0.277	0.512	0.017	1.000

Health status is highly persistent and individuals of any current health status and gender most likely remain in the same health status in the next period. The probability, however, of staying in the same health status is much less than unity, ranging between 0.78 to 0.50, and there are high probabilities of transiting to a different health status, sometimes traveling by more than two ranges, from excellent to bad or bad to excellent, though such probabilities are small. Likelihood of a 50-year-old man falling in bad health in the next period is very low at 1.4% if he is in excellent health today, but it increases to 2.3%, 6.9% and 51.2%, if his current health status deteriorates to good, fair and bad, respectively.

Fukai et al. (2018) use the data of the Japan Medical Data Center (JMDC) and analyze persistence of individuals' medical expenditures. The JMDC covers claims data of individuals enrolled in employer-based health insurance systems. As such, the database covers a limited fraction of the population, unlike the NDB used in the current paper. Despite the difference, they also find that medical expenditure processes are highly persistent. Using the JMDC data, they also demonstrate and argue that one needs to know how an individual has transited to the current health status dating back to his health status in the past in order to make more accurate predictions of health status in the next period. In particular, they point out that a very bad shock to health status is highly persistent and a first-order Markov process fails to capture the magnitude of risks over a long horizon.

To verify this with the NDB, we computed transition matrices assuming a model of the second-order Markov process and obtained transition matrices. As an example, Table 2 shows distribution of the health status in the next period, h_{t+1}, for 50-year old men who are now in bad health status. Also reported in the table are the transition probabilities conditionally on the health status of previous period, h_{t-1}. Probability of staying in bad health at $t+1$ is 0.74, if an individual has been in bad health for two consecutive periods and it is much higher than the probability of remaining in bad health for individuals whose health status was better at $t-1$, confirming the finding of Fukai et al. (2018).[11]

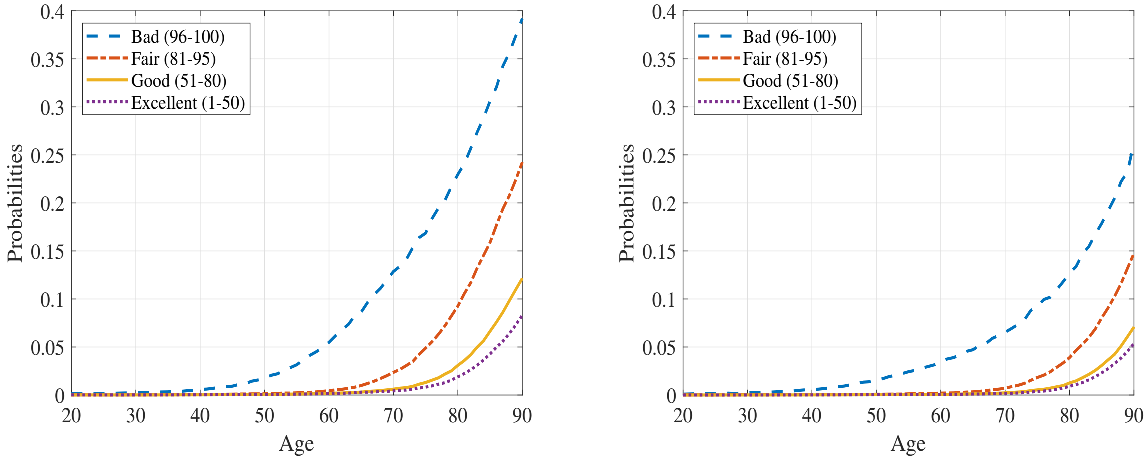
[11] Table 2 is for men of a particular age, but the same historical dependency of transition probabilities is observed for both men and women of all age groups.

Table 2: Transition from Bad Health: M(1) and M(2), Samples of Age 50

	Health status in $t+1$					
Men	Excellent	Good	Fair	Bad	Death	Total
M(1)	0.073	0.121	0.277	0.512	0.017	1.000
M(2) by h_{t-1}						
Excellent	0.282	0.256	0.234	0.210	0.019	1.000
Good	0.146	0.327	0.306	0.208	0.013	1.000
Fair	0.031	0.124	0.496	0.340	0.009	1.000
Bad	0.015	0.030	0.193	0.741	0.021	1.000

Many studies that incorporate medical expenditure risks calibrate the process based on the expenditures of survivors, for whom expenditure data is available over multiple periods of interest. We exploit the strength of the NDB data in that we can identify individuals who pass away in a given period.

Survival probabilities differ not only by age but also by health status as shown in Figure 3. Those in bad health face a much higher probability of death across age groups and genders. We incorporate these heterogeneity and health dependent mortality risks in our structural model.[12]



(a) Men (b) Women

Figure 3: Death Probabilities by Health Status

[12]In appendix A, we also confirm that the survival probabilities that we compute from the NDB are inline with the estimates of the estimates of the National Institute of Population and Social Security Research (IPSS). The appendix also presents the distribution of lifetime medical expenditures when we abstract from health dependence of mortality risks.

2.2.3 Lifetime Medical Expenditures

In previous sections, we studied levels and risks of medical expenditures individuals face in each year over the life-cycle. Individuals are engaged in savings for various reasons over the life-cycle. Precautionary savings motive is an important factor for a risk-averse individual who benefits from smoother consumption profile. One would need to consider not only the level but also risks of expenditures including persistence and variance of shocks and evaluate how much savings would be appropriate to cover expenditures at different stages of the life-cycle. Even young individuals whose immediate medical expenditures are low need to consider expected expenditures in the future and make consumption-saving decisions to remain appropriately insured against such risks. In this section, we study lifetime expenditure risks, based on the shock processes that we estimated from the NDB as presented in previous sections.

Using the transition matrix that we computed for each gender, age, and health status, we simulate lifetime medical expenditures of a large number, one million, of individuals. We then compute moments of the distribution of lifetime medical expenditures of these individuals. We focus on expenditures of adults aged between 25 and 96, the age range that we use in the model analysis in section 3. Note that medical expenditures incurred during the final year of life tend to be very high and they are taken into account when computing lifetime medical expenditures in this section.[13]

Based on our baseline M(2) specification, the average lifetime medical expenditures stand at 20.5 and 21.4 million yen for men and women, respectively. As shown in Figure 1, average expenditures are higher for men than women, except for several years in the late 20s and early 30s, but the average lifetime expenditures are higher for women than men because of their longer life expectancy. Higher moments are also reported in the first and fifth column of Table 3 and there is a significant heterogeneity in the total medical expenditures individuals face over the life-cycle. The distribution has positive skewness given the large right tail. As we saw above, bad health status involves large annual expenditures as well as high persistence, which together contribute to a certain number of individuals who incur extremely large lifetime expenditures.

In Table 3, we also compare the moments across alternative specifications of medical expenditures based on the NDB. The standard deviation of lifetime expenditures of men, as shown in the second row of the table, is 10.9 million yen when we assume an M(2) process, but it falls to 9.8 million yen with M(1), 7.6 million with i.i.d. and 6.8 million under a deterministic process. In the deterministic case, expenditures at each age are the same for everyone and distribution is associated with mortality risks only. Coefficients of variations also move in the same direction as means are essentially the same across specifications. Skewness falls under expenditure processes with low persistence and turns

[13] See appendix A for data of medical expenditures in the year of death.

negative in a deterministic case.

Table 3: Moments under Alternative Expenditure Processes

	Men				Women			
	M(2)	M(1)	iid	det.	M(2)	M(1)	iid	det.
Mean	20.5	20.7	20.7	20.7	21.4	21.6	21.6	21.6
Std. dev.	10.9	9.8	7.6	6.8	10.2	9.1	6.8	5.6
Coeff. of var.	0.53	0.47	0.37	0.33	0.48	0.42	0.32	0.26
Skewness	1.49	0.94	0.22	-0.48	1.43	0.89	0.06	-1.11

Note: Mean and standard deviation are in millions of 2015 JPY.

Analysis in this section confirms that if one wants to analyze expenditure risks over the life-cycle, it is important to take into account high persistence and dependence of mortality risks on health status, as well as heterogeneity of risks by gender and age. Accurate evaluation of risks is also important in accounting for the roles of publicly-provided health insurance and other redistributive programs.

In the next section, we build a life-cycle model of heterogeneous individuals who face medical expenditure risks and calibrate it to the Japanese data including not only medical expenditure processes based on the NDB but also income heterogeneity across age, gender, education, and marital status. We study roles of public health insurance and other redistributive policies which together provide a mix of insurance and redistribution opportunities across heterogeneous households.

3 The Model

In this section we build a life-cycle model of heterogeneous households, which is simulated in section 5 with the medical expenditure processes described in section 2. The sources of uncertainty in the model are health status which determine medical expenditures, longevity, and marital status. Individuals' heterogeneity is in the dimensions of age, gender, skills, health status, marital status, and assets. The government operates social insurance programs including health insurance, long-term care insurance, means-tested welfare transfer program, and social security program, and collects taxes to finance expenditures.

3.1 Demographics

The economy is populated by overlapping generations of individuals aged $j = \{1, \cdots, J\}$ and gender $g = \{m, f\}$.[14] Individuals of age j, gender g, and health status $\mathbf{h}$, face conditional probability $\pi_{j,g,\mathbf{h}}$ of surviving from age $j-1$ to age j. $\pi_{1,g,\mathbf{h}} = 1$ and $\pi_{J+1,g,\mathbf{h}} = 0$ for all g and $\mathbf{h}$ by assumption. Individuals also differ by skill types, denoted by $s = \{l, h\}$, representing the state of low- and high-skilled individuals. We define individuals as high-skilled if they have a college or higher degree, and low skilled otherwise.

3.2 Marital Status

Individual's marital status is denoted as $\zeta \in \{S, M, W\}$, representing single, married, or widowed. Marital status is stochastic and changes over the life-cycle. A single individual of gender g and age j are randomly matched and married with probability $\xi_{j,g}$. An individual of skill s is matched with a spouse of skill s' with probability $\nu_{s,s'}$, which takes into account educational assortative mating. We assume that an individual is married to a spouse of the same age. A married individual whose spouse dies becomes widowed, and we assume a widow or a widower is an absorbing state and abstract from divorce and remarriage.

3.3 Health Status and Medical Expenditures

In each period, individuals face uncertainty in medical expenditures. We denote by $\mathbf{h}$ the health status of an individual, which represents categories of medical expenditures as we discussed in section 2. In our baseline model, $\mathbf{h}$ is a vector that contains information on an individual's health status in the current and previous periods, $\mathbf{h} = \{h, h_{-1}\}$. The law of motion of health status is denoted as $\mathbf{h}' \sim f^h(j, g, \mathbf{h})$, and depends on an individual's age and gender.

$m = m^h(j, g, h)$ represents gross medical expenditures, which depend on age j, gender g and current health status h. Individuals' out-of-pocket expenditures are determined by gross expenditures and insurance copayment rates as explained below. In our model, health status affects medical expenditures and individuals' mortality risks.[15]

[14] Gender affects survival rates, medical expenditures, earnings, and transition of marital status in the model.

[15] In section 5, we consider a scenario where health status and earnings are correlated. See, for example, Capatina (2015), Capatina et al. (2020), and De Nardi et al. (2024), for other possible channels through which health might affect individuals, which we abstract from in our model.

3.4 Preferences and Endowment

Individuals value consumption over the life-cycle, $\{c_j\}_{j=1}^J$, according to time separable preferences. We denote by $u(c/\eta_\zeta)$ a period utility function, where η_ζ is an equivalence scale in consumption, which varies by the marital status of individuals ζ. β represents a subjective discount factor.

We assume that individuals possess warm-glow bequest motives and that they derive utility from leaving bequest, denoted as $\chi(a')$, where a' denotes the assets that an individual leaves when he dies.

Labor supply is exogenous and earnings of an individual, denoted as y, depends on age j, gender g, skill s, and marital status ζ. Earnings are subject to labor income tax at rate τ^l. We assume that individuals enter the economy with zero initial asset, i.e. $a_1 = 0$. They can purchase a non-negative amount of one-period riskless assets, a_{j+1}, which pays a constant interest rate r, when they turn age $j+1$ in the next period. We let R denote gross after-tax return on savings, $R = 1 + r(1-\tau^a)$, where τ^a represents the tax rate on capital income.

3.5 Government

The government operates four social insurance programs: health insurance, long-term care insurance, public pension, and means-tested welfare transfer program.

Health Insurance: The universal health insurance program covers a fraction $(1-\lambda_j)$ of gross medical expenditures m, based on copayment rates, λ_j, which depend on age.

Out-of-pocket medical expenditures paid by an individual are capped by a ceiling, denoted as $\overline{m}$, which depends on an individual's age and earnings. The adjustment is based on the high-cost medical expense (HCME) benefit formula embedded in the national health insurance system of Japan and more details are provided in section 4. The difference between the HCME ceiling and payment based on age-dependent copayment rates, if positive, is paid back to individuals. Out-of-pocket expenditures paid by each individual are denoted as m^{op} and given as:

$$m^{op} = \lambda_j m - \max\{0, \lambda_j m - \overline{m}\}.$$

Long-term Care Insurance: All individuals aged 40 and over are enrolled in the long-term care insurance program. Denote by e gross long-term care expenditures of an individual. We assume that long-term care expenditures are exogenously given and depend on age and gender. Age-dependent copayment rates of long-term care insurance are denoted as θ_j and out-of-pocket expenditures are given as $e^{op} = \theta_j e$.

Public Pension: Individuals receive public pension benefits p_j once they reach the full retirement age j_R. We assume that benefits are determined by the formula

$$p_j = \kappa \frac{\overline{y}_j}{j^R - 1}$$

where κ is the replacement rate of pension benefits relative to each individual's average past earnings. $\overline{y}_j$ denotes cumulated past earnings and is computed recursively as:

$$\overline{y}_j = \begin{cases} y_j & \text{if } j = 1 \\ y_j + \overline{y}_{j-1} & \text{if } 1 < j < j^R \\ \overline{y}_{j-1} & \text{if } j \geq j^R. \end{cases}$$

$p_j = 0$ for those aged below j_R.[16]

Means-tested Welfare Transfer Program: A means-tested transfer, tr, is provided to guarantee a minimum consumption level, denoted as $\underline{c}$, which may differ by marital status.[17] Disposable assets $\underline{a}$ of singles are denoted as:

$$\underline{a} = Ra + (1 - \tau^l)y + p_j - m^{op} - e^{op} - \tau^{ls} \tag{1}$$

Disposable assets of couples are defined similarly, adding spouses' earnings and pensions and subtracting their out-of-pocket medical and long-term care expenditures. The transfer amount for an individual is given as

$$tr = \max\{0, (1 + \tau^c)\underline{c} - \underline{a}\} \tag{2}$$

Taxes: The government imposes proportional taxes on consumption at rate τ^c, labor income at τ^l, capital income at τ^a, and lump-sum tax τ^{ls} on each individual. The government budget constraint is given as (3).

$$\tau^l Y^l + \tau^a Y^a + \tau^c C + \tau^{ls} N = SS + HI + LTC + TR + G \tag{3}$$

where Y^l, Y^a and C denote aggregate labor income, capital income, and consumption, respectively, and N denotes the total number of individuals. SS, HI, LTC, and TR each denote total expenditures for public pension, health insurance, long-term care insurance, and means-tested welfare transfer programs, respectively. G denotes government consumption expenditures.

[16]Payment depends on earnings history of each individual and therefore on the transition of marital status, which would affect earnings in our model. Since it is not feasible computationally to allow for the dependence of benefits on the entire earnings history, we compute pension benefits of married and widowed individuals based on the average earnings for each gender and skill type. For singles, we use the earnings history of single individuals of each gender and skill group.

[17]We follow the strategy of existing papers such as Hubbard et al. (1995), French and Jones (2011), Kitao (2014) and Fan et al. (2024), to model a means-tested transfer program in a parsimonious way.

In the baseline model, we assume τ^{ls} is zero and let G absorb the imbalance and satisfy the equation (3). In numerical experiments presented in section 5, we consider various policy scenarios and adjust τ^{ls} to satisfy the government budget.

3.6 Households' Problem

We define the problem of individuals with three value functions for singles, married couples, and widows and widowers, which are denoted as S, M and W, respectively.

Value Function of Singles: The state vector of a single individual is given as $(j, g, s, a, \mathbf{h})$, where j denotes age, g gender, s skill, a asset, and $\mathbf{h}$ health status. As explained above, $\mathbf{h}$ consists of current health status h and that of previous period h_{-1}. Given the states, an individual optimally chooses consumption c and savings a' to maximize utility over the life-cycle. The value function is given as follows.

$$
\begin{aligned}
S(j, g, s, a, \mathbf{h}) \quad = \quad & \max_{c,a'} \{u(c/\eta_S) + \beta\,[\pi_{j,g,\mathbf{h}}(1-\xi_{j,g})ES(j+1, g, s, a', \mathbf{h}') \\
& +\pi_{j,g,\mathbf{h}}\xi_{j,g}EM(j+1, s_m, s_f, a' + \overline{a}, \mathbf{h}'_m, \mathbf{h}'_f)] \\
& +(1-\pi_{j,g,\mathbf{h}})\chi(\widetilde{a}')\}
\end{aligned}
$$

subject to

$$
\begin{aligned}
& (1+\tau^c)c + a' + m^{op} + e^{op} = Ra + (1-\tau^l)y + p + tr - \tau^{ls} \\
& a' \geq 0
\end{aligned}
$$

Conditional on surviving with probability $\pi_{j,g,\mathbf{h}}$, an individual is matched with a spouse and marries with probability $\xi_{j,g}$. The new value function M has a state vector that includes health status and skill of the spouse and the assets of the married couple will be $a' + \overline{a}$, where the second term $\overline{a}$ denotes the assets of the spouse that the individual is matched with. With probability $(1-\xi_{j,g})$, he will remain single.

With probability $(1-\pi_{j,g,\mathbf{h}})$, he will not survive and derive utility from leaving assets as a bequest, denoted as $\chi(\widetilde{a}')$. $\widetilde{a}'$ represents assets that remain after paying out-of-pocket medical expenditures before an individual dies in the next period and is given as $\widetilde{a}' = a' - m^{d,op}$, where $m^{d,op}$ denotes out-of-pocket expenditures incurred in the next period before death.[18]

Value Function of Married Couples: The state vector of a married couple consists of six elements, $(j, s_m, s_f, a, \mathbf{h}_m, \mathbf{h}_f)$, where s_m and s_f denote skill of the husband and the wife, respectively, and $\mathbf{h}_m$ and $\mathbf{h}_f$ are the health status of each member.

[18]We assume that $m^{d,op}$ is capped above by the bequest a' and an amount that remains unpaid, if any, is added to government expenditures.

$$
\begin{aligned}
M(j, s_m, s_f, a, \mathbf{h}_m, \mathbf{h}_f) &= \max_{c,a'} \{u(c/\eta_M) + \beta\left[\pi_{j,m,\mathbf{h}}\pi_{j,f,\mathbf{h}} EM(j+1, s_m, s_f, a', \mathbf{h}'_m, \mathbf{h}'_f)\right. \\
&+ (1-\pi_{j,m,\mathbf{h}})\pi_{j,f,\mathbf{h}} EW(j+1, f, s_f, \widetilde{a}', \mathbf{h}'_f) \\
&+ \left.(1-\pi_{j,f,\mathbf{h}})\pi_{j,m,\mathbf{h}} EW(j+1, m, s_m, \widetilde{a}', \mathbf{h}'_m)\right] \\
&+ (1-\pi_{j,m,\mathbf{h}})(1-\pi_{j,f,\mathbf{h}})\chi(\widetilde{a}')\}
\end{aligned}
$$

subject to

$$
\begin{aligned}
&(1+\tau^c)c + a' + m_m^{op} + m_f^{op} + e_m^{op} + e_f^{op} \\
&= Ra + (1-\tau^l)(y_m + y_f) + p_m + p_f + tr - 2\tau^{ls} \\
&a' \geq 0
\end{aligned}
$$

Note that out-of-pocket medical and long-term care expenditures, earnings and pensions carry a subscript of m or f, representing male and female individuals in a household.

Two individuals in a married couple jointly make savings and consumption decisions to maximize the sum of utility from consumption in the current period and the discounted value. With probability $\pi_{j,m,\mathbf{h}_m}\pi_{j,f,\mathbf{h}_f}$, both individuals survive and remain married. If one of the two does not survive, the remaining spouse will be widowed and carry the value function W.

Value Function of Widows and Widowers: The state vector of a widow or a widower is the same as that of a single individual. Their problem is given as follows.

$$
W(j, g, s, a, \mathbf{h}) = \max_{c,a'} \{u(c/\eta_W) + \beta\pi_{j,g,\mathbf{h}} EW(j+1, g, s, a', \mathbf{h}') + (1-\pi_{j,g,\mathbf{h}})\chi(\widetilde{a}')\}
$$

subject to

$$
\begin{aligned}
&(1+\tau^c)c + a' + m^{op} + e^{op} = Ra + (1-\tau^l)y + p + tr - \tau^{ls} \\
&a' \geq 0
\end{aligned}
$$

4 Calibration

This section describes how parameters of the model are calibrated. Table 4 summarizes the description and values of the parameters. The model's frequency is annual.

Demographics: Survival probabilities $\pi_{j,g,\mathbf{h}}$ are computed based on the NDB data that we described in section 2. In the baseline model, we assume that survival probability depends on both current and previous health status $\mathbf{h} = \{h, h_{-1}\}$. In section 5, we consider alternative assumptions of medical expenditure process as well as mortality risks.

Marital Status: Probabilities of getting married $\xi_{j,g}$ are based on the distribution of never-married and ever-married individuals by age obtained from the Census data of 2015. We assume that $\xi_{j,g} = 0$ for those aged 65 and above.[19] The degree of assortative mating by education levels of spouses, $\nu_{s,s'}$, is calibrated based on Fukuda et al. (2019), who use the Census data between 1980 and 2010. Married couples exhibit a high degree of sorting and we assume that the probability that the matched spouse is of the same education level is 0.7, $\nu_{s,s'=s} = 0.7$.[20]

Health Status and Medical Expenditures: We use the NDB data for calibration of health status and medical expenditures. Following the method described in section 2, we group individuals of each age and gender into four health status; good, fair, bad, and very bad. They correspond to the bottom 50% of the distribution of medical expenditures within each group, the next 30% (from 51 to 80 percentiles), 15% (from 81 to 95 percentiles), and the top 5% (from 96 to 100 percentiles), respectively. In the baseline simulations, we assume an M(2) process for the transition of health status.[21]

Preferences: The equivalence scale of consumption η is set at 1.7 for married couples ($\eta_M = 1.7$) and 1.0 for single and widowed individuals ($\eta_S = \eta_W = 1.0$), based on the OECD equivalence scale. Coefficient of relative risk aversion σ is set at 3.0. Subjective discount factor β is related to a consumption profile and associated life-cycle savings of individuals. Kitao and Yamada (2019) show that the peak of household assets is at around age 60, in the amount of 20 million yen, based on the National Survey of Family Income and Expenditure (NSFIE). We calibrate β to match this data.

The utility from leaving a bequest $\widetilde{a}$ is assumed to take the form

$$\chi(\widetilde{a}) = \phi \frac{(\widetilde{a} + k)^{1-\sigma}}{1-\sigma}.$$

ϕ represents utility weight on bequest motives relative to the utility from consumption and k represents the curvature of the function and a positive value of k represents the degree that bequests are luxury goods. We set the parameter k so that the bequest is operative at the relative asset level corresponding to that estimated in De Nardi et al. (2010). The parameter ϕ is set so the marginal propensity to bequeath is at 0.8, in the

[19]The rate of first marriage is very low among those aged 65 and above, standing at 0.017% and 0.013% for men and women and at age 65, for example, and the rates decline further in age, according to the Census data. `https://www.mhlw.go.jp/toukei/saikin/hw/jinkou/tokusyu/konin16/dl/02.pdf` (in Japanese, Table 2)

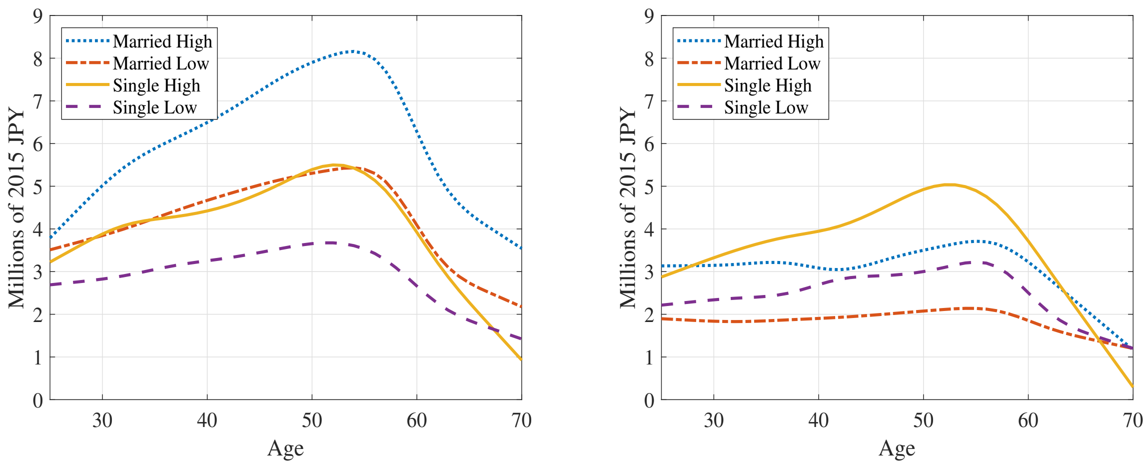
[20]The probability is based on the average of men's and women's probabilities of marrying a spouse of the same education type.

[21]In appendix B, we also simulate the same model assuming alternative processes including M(1), i.i.d. and deterministic processes.

range of values used in the literature, as surveyed in Pashchenko (2013).[22] Parameter values are reported in Table 4.

Endowment: Earnings of an individual differ by age, gender, skill, and marital status, and they are computed using the Employment Status Survey (ESS).[23] Figure 4 shows life-cycle profiles of earnings by gender, age, marital status, and skill. Earnings y of our model represent the average earnings of all individuals of a particular group, and therefore they are obtained by multiplying earnings by participation rates, which are shown in Figure 5.

Figures 4a and 4b reveal that earnings profiles are very different between men and women. High-skilled married men earn the most among male workers, but among female workers, high-skilled singles earn the most, at least until their late 60s. Conditional on skill level and across marital status, married men earn more than single men, but it is single women who earn more than married women.



(a) Men (b) Women

Figure 4: Earnings of Workers by Age, Marital Status, and Skill

Note: Figures show the life-cycle profile of average annual earnings of workers by gender, age, marital status, and skill. The married includes widowed and divorced. We use the data of 2017 and adjust to the 2015 level using the CPI. The data is from the Employment Status Survey (ESS) by the Ministry of Internal Affairs and Communications (MIC)

Moreover, as shown in Figure 5, patterns of participation rates are also very different between men and women. Nearly all married men work at least until they reach their mid-50s and participation rates of singles are much lower. It is the opposite among women,

[22]In the baseline model, the average assets at the time of death would be 2.49 million yen, which is similar to and slightly smaller than, the data average of 3.43 million yen (Horioka 2008).

[23]We used the ESS data of 2017, provided as order-made data from the Statistics Bureau of the Ministry of Internal Affairs and Communications (MIC).

and married women participate less often than single women. The so-called M-shaped pattern, in which female workers exit from the labor force at child-bearing ages and come back later, is observed among the married and high-skilled, but such a temporary decline or a rise in participation is not observed among single women.

Although our model does not endogenously explain the pattern of labor supply over the life-cycle or these heterogeneous patterns by marital status and education level, we take into account earnings differences since they are important factors in analyzing effects of medical expenditure risks and roles of publicly-provided insurance and private households savings.[24]

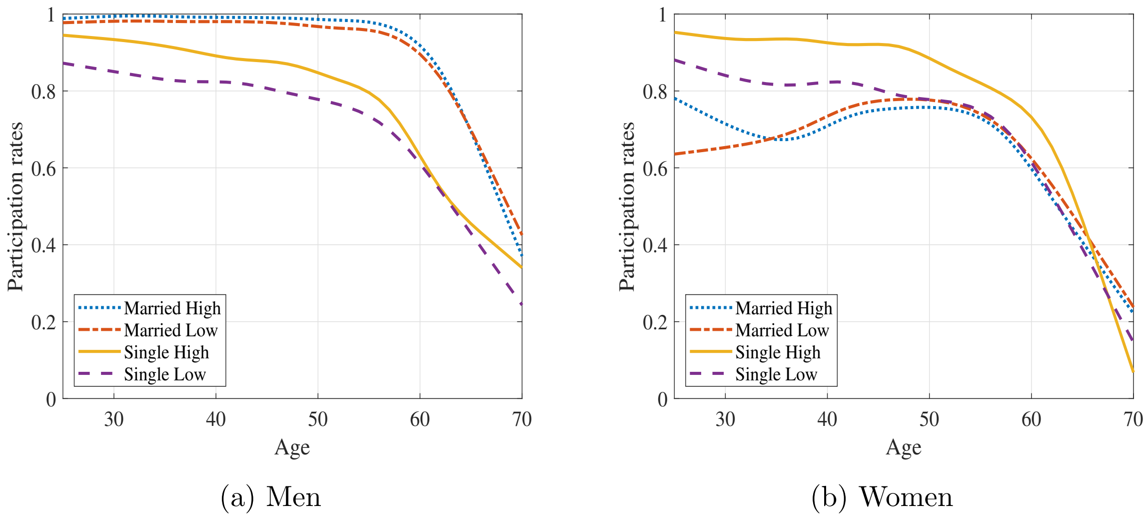


Figure 5: Participation Rates by Age, Marital Status, and Skill

Note: Figures show the labor force participation over the life-cycle by gender, age, marital status, and skill. The married includes widowed and divorced. The data is from the Employment Status Survey (ESS) conducted in 2017 by the Ministry of Internal Affairs and Communications (MIC).

Factor prices are exogenous in the model and the interest rate r set to 2%.

Government: The government operates health insurance, long-term care insurance, public pension, and means-tested welfare transfer programs.

Health insurance covers part of medical expenditures according to the age-dependent coverage schedule. The copayment rate λ_j varies by age and it is 30% for those aged 69 and below, 20% for those aged between 70 and 74 and 10% for those above 75.

[24]We also note that the model abstracts from idiosyncratic income shocks, which would account for additional degrees of heterogeneity within each socioeconomic group of households, as well as more dispersion in wealth and consumption. We chose to abstract from them mainly because the model is already rich with heterogeneity in various dimensions. Considering idiosyncratic income shocks and other dimensions of heterogeneity for the model to improve the alignment of variables with the data is left for future research.

Out-of-pocket medical expenditures are capped by a ceiling, denoted as $\overline{m}$, based on the rules of the High-Cost Medical Expense (HCME) benefit program. The ceiling level varies by age and earnings of an individual.[25] The HCME benefit program is complicated as the ceiling depends on multiple individual characteristics, but it provides a generous insurance coverage for those who incur very high medical expenditures.

Long-term care insurance covers expenditures for individuals aged 40 and above. Expenditure data by gender and age are obtained from the Statistics of Long-term Care Benefit Expenditures of the Ministry of Health, Labour and Welfare (MHLW). The public long-term care insurance covers 90% of expenditures and copayment rates θ_j are set to 10% for all ages.

The welfare program in our model provides a means-tested transfer to eligible households. The consumption floor $\underline{c}$ in equation (2) is set at 870,000 yen for single and widowed individuals and 1,320,000 yen for married couples.[26]

Pension replacement rate κ is set to one-third, based on an estimate of the average gross replacement rate of public pensions from OECD (2019).

The government taxes consumption, labor income and capital income at proportional rates. We set τ^c at 8%, based on the tax rate in 2015, and τ^l and τ^a at 30% and 35%, respectively, in line with estimates of effective income tax rates in the literature.[27] [28]

[25]For individuals aged below 70 with annual earnings of less than 3.7 million yen, the maximum monthly payment is 57,600 yen. The maximum payment is adjusted upwards for individuals with higher earnings. For those aged 70 and above, the maximum monthly payment is 24,600 yen, if the beneficiary has no earnings. The ceiling is adjusted upwards as earnings rise. If an individual's monthly payment hits the maximum more than three months during a year, the payment for the fourth month and thereafter is adjusted downward further.

For details of the program, see the description on the website of the Ministry of Health, Labour and Welfare. https://www.mhlw.go.jp/content/000333279.pdf(inJapanese).

[26]The amount is set to lie in the range of average payments of the Public Assistance (*seikatsu hogo*) program by the family size. For details of the program, see for example, https://www.mhlw.go.jp/content/12002000/000488808.pdf (in Japanese).

[27]See, for example, Gunji and Miyazaki (2011).

[28]In the baseline model, there would be government consumption expenditures G, which accounts for 11.4% of aggregate tax revenue. According to the government's report, a similar amount, 10.9% of tax revenue, consisting of income tax and consumption tax revenue, was spent on non-social security programs.

Table 4: Parameters of the Model

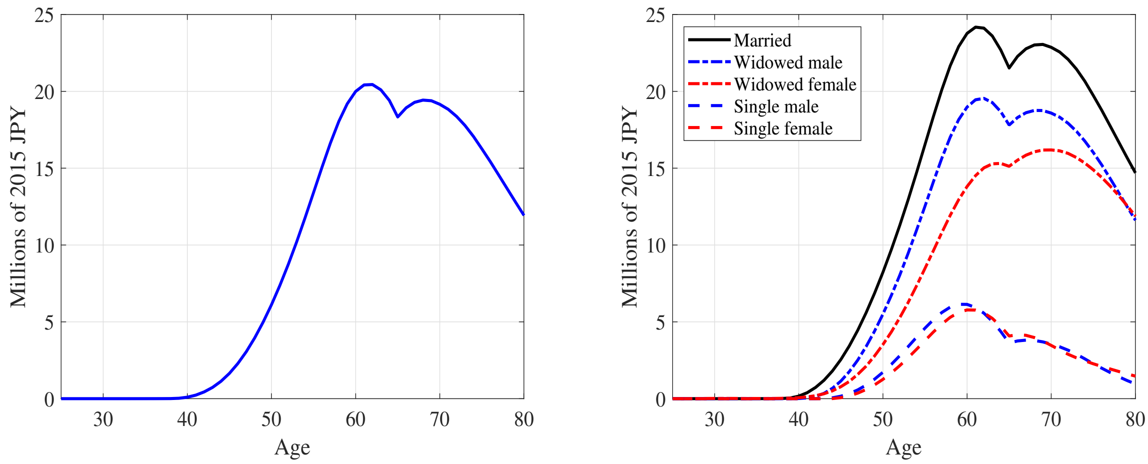
Parameter	Description	Value/Source
Demographics		
J^R	Retirement age	65 years
J	Maximum age	97 years
$\pi_{j,g,\mathbf{h}}$	Survival probability	NDB data
Marital Status		
$\xi_{j,g}$	Prob. of marriage	Census data
$\nu_{s,s'}$	Degree of assortative mating	Fukuda et al. (2019)
Preference		
β	Subjective discount factor	0.9586
σ	Risk aversion parameter	3.0
ϕ	Bequest parameter	64.0
k	Bequest parameter	6.35
η_ζ	Equivalence scale	1.0 (single and widowed)
		1.7 (married)
Endowment		
$y_{j,g,s,\zeta}$	Earnings	ESS (2017)
Health and Medical & Long-term Care Expenditures		
m	Gross medical expenditures	NDB data
$f^h(j,g,\mathbf{h})$	Health transition dynamics	NDB data
e	Gross long-term care expenditures	MHLW data
Government		
λ_j	Health insurance copay. rates	30,20,10% (varies by age)
$\overline{m}$	High-cost medical expense benefit	see text
θ_j	Long-term care insurance copay. rates	10%
κ	Public pension replacement rate	1/3
$\underline{c}$	Consumption floor for the welfare program	see text
τ_c	Consumption tax rate	8%
τ_l	Labor income tax rate	30%
τ_a	Capital income tax rate	35%
Other Parameters		
r	Interest rate	2%

5 Numerical Analysis

This section presents numerical results of our quantitative model. We will first review outcomes of the baseline model. We then analyze roles of the health insurance program in accounting for individuals' life-cycle consumption and saving decisions and in mitigating expenditure risks. We then consider some alternative specifications of the model.

5.1 Baseline Model

Households of different types choose the path of consumption and saving taking into account expected household income and medical expenditures over the life-cycle. Figure 6 shows profiles of assets by age and by marital status and gender. Household savings peak at around age 60 and slowly decline thereafter.[29] There is a large difference in the level of assets not only across different ages, but also across different types of households. Married households own more than singles on average, perhaps not surprisingly. Among singles and widows/widowers, women own fewer assets than men though the difference shrinks as they age.



(a) By Age (b) By Age, Marital Status and Gender

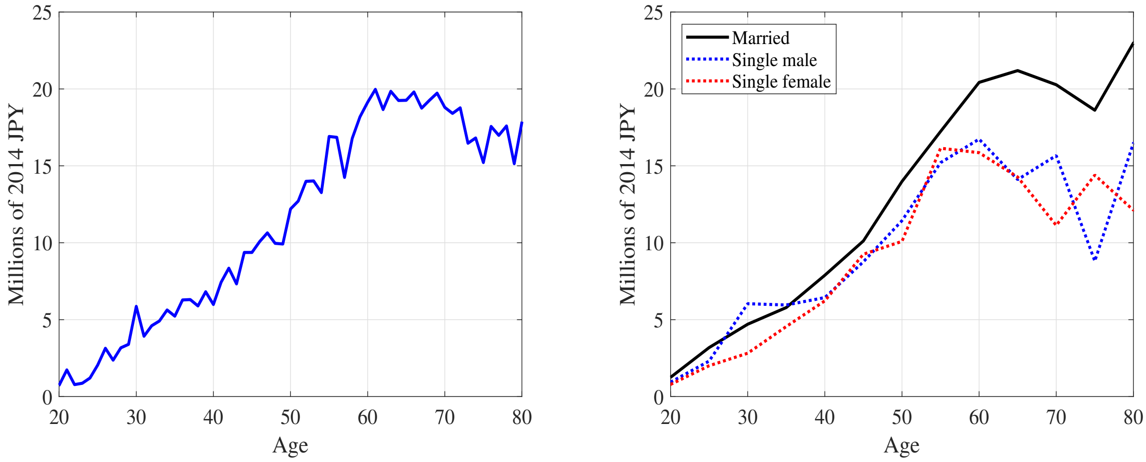
Figure 6: Average Assets of Households by Age and Marital Status

For comparison, Figure 7 plots average asset profiles of households from the National Survey of Family Income and Expenditure (NSFIE) data in 2014.[30] Note that "single" households in the data include both never-married singles and widowed individuals, which

[29]Note that a discrete change in assets at age 65 is due to our assumption that individuals start to receive public pension benefits at that age. There is a discrete increase in income at age 65 and some households deccumulate assets faster right before 65 and dissaving slows down after age 65. The discrete change in assets would disappear if there was no public pension or if the initial age of pension receipt was spread out over some age groups.

[30]The NSFIE is cross-sectional national survey data on household asset and income, conducted by the Statistics Bureau of the Ministry of Internal Affairs and Communications. Assets are computed as the sum of financial assets held by households and indexed by the age of the household head. The profiles do not include real assets such as housing and durable assets or debt associated with real assets such as mortgages.

cannot be distinguished in the survey. The model generates an overall asset pattern over the life-cycle and differences across households' marital status, which in our model is driven by the retirement saving motives and precautionary saving motives for mortality and medical expenditure risks.[31]



(a) By Age

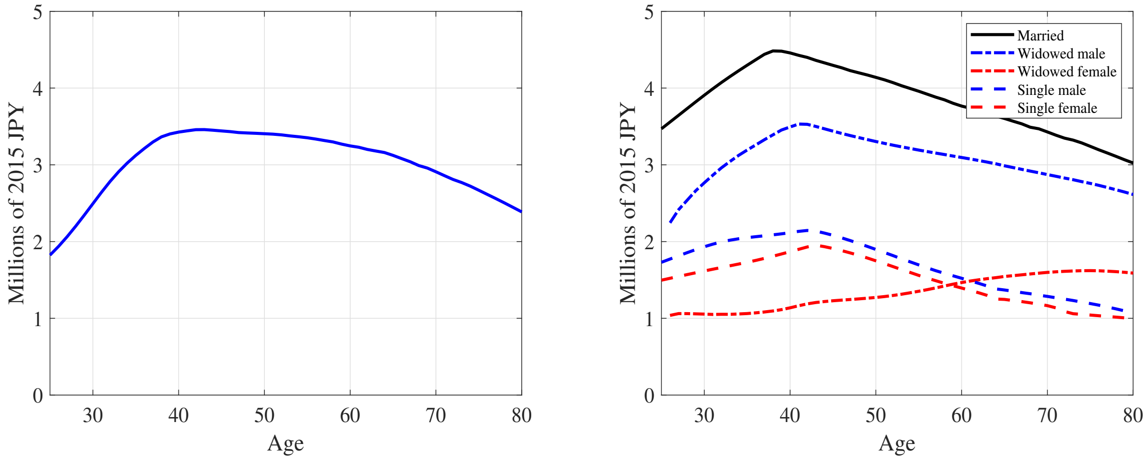
(b) By Age, Marital Status and Gender

Figure 7: Average Assets of Households (in millions of 2014 JPY): NSFIE Data (2014)

In our model, assets also differ by skills and health status within a group of the same gender and marital status. High-skilled individuals own more than the low-skilled for each gender. Among single households, high-skilled women save the most, even more than high-skilled men, since women live longer and have stronger life-cycle saving motives. Low-skilled women, however, save the least and less than low-skilled men because their earnings are too low for stronger saving motives to dominate.

Figure 8 shows consumption profiles of all households and by marital status and gender. They exhibit a mildly hump-shaped pattern as reported in studies such as İmrohoroğlu et al. (2016). Note that average consumption of widowed women increases in age and shows no decline, since those who become widowed later in their lives succeed accumulated wealth of married couples.

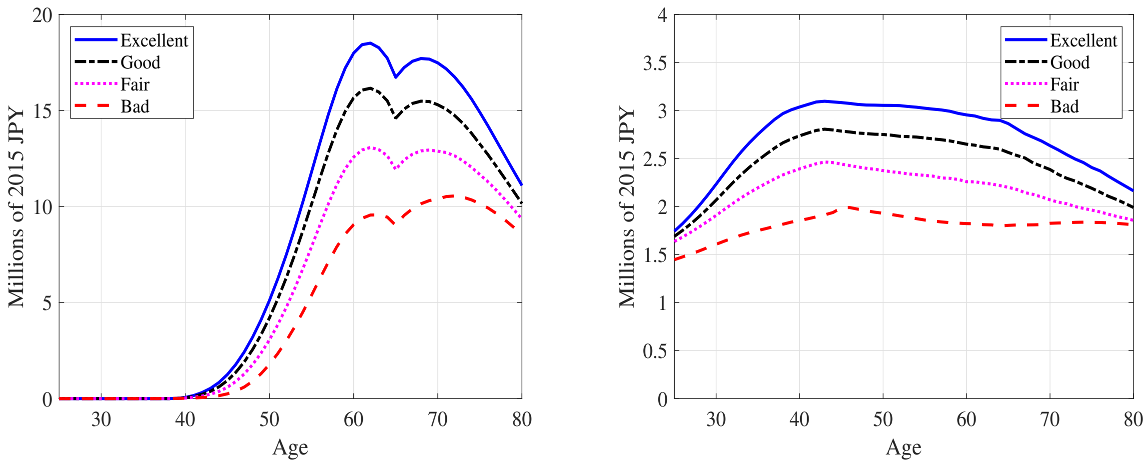
[31]The paper focuses on effects of medical expenditure risks and life-cycle saving motives and abstracts from other risks such as, for example, labor productivity and unemployment risks, which likely would contribute to more savings at younger ages.



(a) By Age (b) By Age and Marital Status

Figure 8: Average Consumption of Households by Age and Marital Status

Consumption and asset levels also differ by health status in our model. Figure 9 plots average asset and consumption by health status of members of households. For married couples, we include households with both members in a given health status. In the baseline model, bad health reduces savings through two channels. First, large expenditures reduce disposable income that can be allocated to savings, or force households to dissave if net income is not enough to cover out-of-pocket expenditures. Second, bad health implies high mortality risks and reduces preference weight on future utility from consumption and discourages savings.



(a) Asset (b) Consumption

Figure 9: Average Assets and Consumption of Households by Age and Health Status

5.2 Roles of Health Insurance

Japan's national health insurance system is universal and provides a common set of coverage for every Japanese citizen. The system has age-dependent copayment rates; 30% for adults up to 69 years old, 20% for those aged between 70 and 74 and 10% for those aged 75 and above. Moreover, as explained in section 4, it provides additional coverage for large expenditures with an out-of-pocket ceiling that decreases in earnings and varies by age.

To understand the roles of the health insurance program and its structure, we simulate the model under counterfactual insurance arrangements and evaluate how they affect individuals of different characteristics. We also evaluate roles of the means-tested welfare program and how it interacts with medical expenditure risk and the health insurance system. Lastly, we consider alternative scenarios, in which, first, earnings depend on health status, and second, medical expenditures follow a process with lower persistence.

An Extreme Scenario - An Economy without Health Insurance: To highlight roles of health insurance, we first consider an extreme scenario in which no health insurance is provided and individuals are responsible for all medical expenditures. In the first simulation, we make no adjustment in taxes so that we can isolate the effects of medical expenditure risks and focus on changes in household behavior over the life-cycle. In the second, we adjust a lump-sum tax rate τ^{ls} to account for a change in net government revenues to balance the budget in equation (3).

Table 5 shows changes in some aggregate variables and welfare. Without health insurance, households would save significantly more and average savings are almost 40% higher. Consumption falls by 10% on average to accumulate more wealth. The rise in savings, however, is not common across households as we will see below. The number of welfare transfer recipients would also rise dramatically, more than tripling from 1.7% of the population in the baseline to 5.8%. Not surprisingly, welfare effects of removing health insurance are very negative, standing at a loss of 10%, evaluated in terms of consumption equivalence. The welfare measure is computed as a percentage change in consumption required in all possible states so that individuals are indifferent between the baseline and the simulated scenario. Men and women would experience a welfare loss of a similar magnitude but within each gender group, low-skilled individuals face a slightly larger welfare loss.[32]

[32] In evaluating the welfare effects of a reform relative to the baseline economy, it is important to consider changes to the government budget constraint. This includes explicitly accounting for how additional expenditures are financed, or how additional revenues are transferred back to households. Nonetheless, we present welfare outcomes both with and without tax adjustment here. The former isolates welfare effects driven solely by changes in insurance and allows for comparisons of these effects across different household groups.

When lump-sum taxes are adjusted to balance the government budget, there would be an annual lump-sum subsidy of 290,000 yen to each individual. Tax compensation raises disposable income of households and aggregate savings will rise by more than 50%, as shown in the second column of Table 5. As a result of much higher savings and a large lump-sum transfers that benefits low-income households more than high-income households, households are able to smooth consumption at a higher level for all ages, as shown in Figure 10. Then, welfare effects are positive and higher for low-skilled individuals than high-skilled, and for women than men.

Table 5: Extreme Scenario: No Health Insurance (Changes from the Baseline Model)

	No tax change	Tax adjusted
Change in avg. savings	+38.3%	+51.8%
Change in avg. consumption	-10.0%	+3.4%
Transfer recipients	5.78%	2.79%
	(+239.7%)	(+64.1%)
Lump-sum tax (JPY)	–	-290,000
Welfare effects		
- All	-10.1%	+4.8%
- Men: low/high	-11.1%/-9.1%	+4.8%/+3.1%
- Women: low/high	-9.9%/-9.5%	+6.1%/+3.5%

Note: The row "Transfer Recipients" indicates the fraction of the population receiving welfare transfers in each experiment. A percentage change in the number of recipients from the baseline model is indicated in parentheses. Lump-sum tax is expressed as an annual tax collected in Japanese yen. A negative number indicates a positive transfer from the government to each individual.

Figure 10 shows changes in life-cycle profiles of savings and consumption averaged across all households. Without health insurance, savings are higher across age groups and consumption is lower. When taxes are adjusted, there will be a large lump-sum transfer to all households, which enables households to smooth consumption over the life-cycle, consuming slightly more when households are in their 20s to 30s, as well as when they are old and aged above 70, as shown in Figure 10b. The average consumption is also higher with the lump-sum tax and the welfare effects turn positive as shown in Table 5.

The changes, however, in average profiles mask large heterogeneity in life-cycle savings and consumption across different types of households.

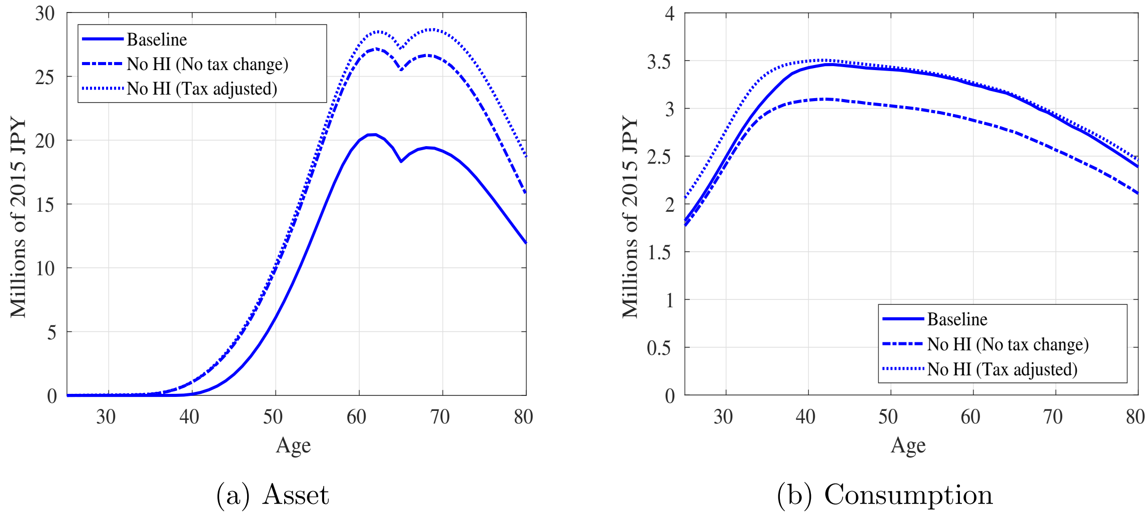


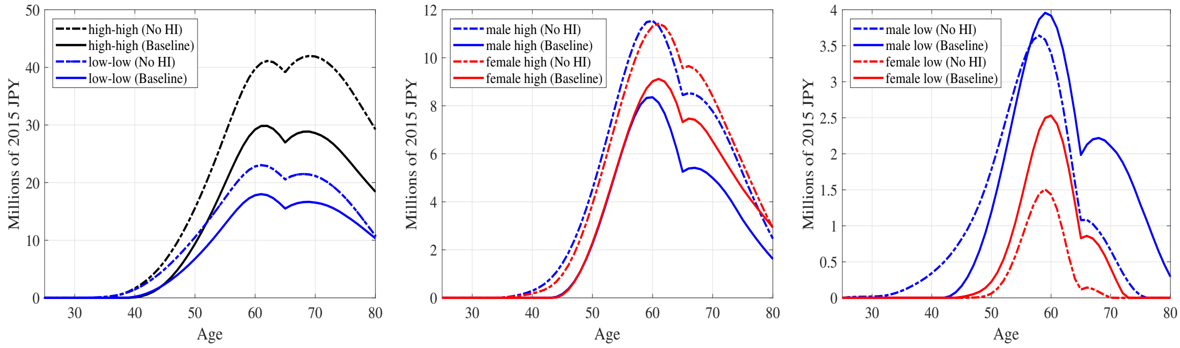
Figure 10: Average Assets and Consumption by Age with and without Health Insurance

Figure 11 shows asset profiles for married and single households and also by skill levels of household members.[33] Married households save more without health insurance and high-skilled couples increase savings by more than low-skilled couples. Among singles, high-skilled men and women save more, but low skilled women save much less without health insurance and so do low-skilled men after their mid-50s.

While most households accumulate more precautionary wealth in preparation for large health expenditure shocks, some households, in particular low-skilled and single women, save less. Their earnings are so low that they do not have enough to save, especially after facing large expenditure shocks. A large number of single households exhaust their savings earlier than in the baseline and start to receive welfare transfers at an earlier age. The rise in the aggregate saving is driven by a large increase in saving of married households.[34]

[33] For married couples, there are four different combination of skill levels: high-high, high-low, low-high and low-low. The figure shows profiles of high-high and low-low couples as there would be too many lines to show all.

[34] Aggregate savings increase by 38.3% as shown in Table 5 and changes in savings of married households account for 91.7% of the rise.

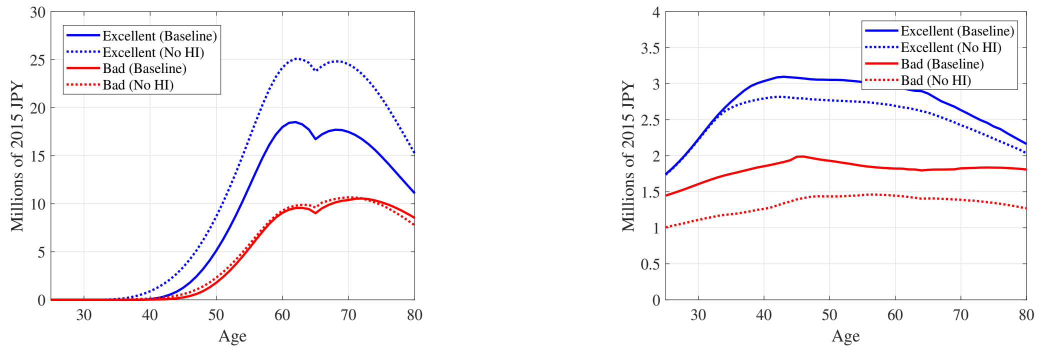


(a) Married (b) Single (High-skilled) (c) Single (Low-skilled)

Figure 11: Average Assets by Marital Status and Skills with and without Health Insurance (With No Tax Change)

Next, we examine how consumption and saving profiles differ across health status in order to quantify the change in households' exposure to health shocks. Figure 12 shows life-cycle profiles of assets and consumption averaged for households in excellent and bad health status, in the baseline and no-insurance economy.

The rise in the aggregate savings reported in an economy without health insurance is largely driven by those with higher earnings as we saw above, and also by those in better health, as shown in Figure 12a. Figure 12b shows that a bad health shock not only prevents individuals from accumulating enough savings but also has them decrease consumption by more than healthier individuals.



(a) Assets (b) Consumption

Figure 12: Average Assets and Consumption by Health Status with and without Health Insurance: Levels and Differences (With No Tax Change)

Table 6 goes one step further into household heterogeneity by comparing effects of bad health on savings by marital status and skill levels of individuals. To simplify comparison, average asset levels for each type of households are displayed in the table. The level of assets owned by those in bad health in the baseline is about 50% of that of the healthiest individuals on average, but the difference is smaller among married couples than singles and among high-skilled than low-skilled households. The same pattern is observed for consumption (not displayed), implying that those who earn more are better insured against expenditure shocks.

Table 6: Average Assets by Health Status with and without Health Insurance (in 1,000 JPY)(With No Tax Change)

		Married		Single Men		Single Women	
	All	Low	High	Low	High	Low	High
Baseline							
Excellent	6,581	9,254	15,163	644	1,371	258	1,632
Bad	3,265	8,052	14,132	414	1,082	138	1,340
Bad/Exc. Ratio	49.6%	87.0%	93.2%	64.3%	79.0%	53.6%	82.1%
No Health Insurance							
Excellent	9,325	12,855	23,502	709	2,368	141	2,302
Bad	3,172	7,111	17,200	296	1,354	42	1,376
Bad/Exc. Ratio	34.0%	55.3%	73.2%	41.8%	57.2%	29.9%	59.8%

Roles of Welfare Transfers and Health Insurance: Experiments presented above show that health insurance policy interacts with a welfare transfer program and changes the number of welfare recipients and fiscal costs associated with it. While a reform to reduce insurance benefits, for example, may induce more precautionary and life-cycle savings on average, it may make more individuals deplete assets and be eligible to receive welfare transfers. A reform may discourage savings of some individuals with low assets and in bad health if they anticipate being on the welfare program soon, though such incentives would depend on the generosity of transfers.

To understand the roles of welfare transfers first, Table 7 shows the simulation results when we assume different degrees of generosity of the welfare program. In the two experiments, we adjust the consumption floor $\underline{c}$, the minimum consumption level guaranteed by the program, by 50% upwards and downwards from the baseline level.

As shown in the first row, generosity of a welfare program has a large influence on household savings. Irrespective of the tax adjustment, average savings would rise by about 8% when the consumption floor is reduced by 50% and it would fall by about 20% when it rises by 50%. Many more individuals will receive transfers in the latter, not only directly from the expansion of eligibility, but also because the policy discourages savings and makes more people run down their assets and stay close to the threshold.

Table 7: Alternative Generosity of Welfare Programs

Cons. Floor $\underline{c}$	50% down	50% up
Avg. savings	+8.1%	-19.2%
Avg. consumption	-0.3%	+1.2%
Transfer Recipients	0.02%	6.22%
	(-98.6%)	(+265.8%)
Welfare effects		
- All	-0.66%	+1.65%
- Men: low/high	-0.52%/-0.18%	+1.89%/+0.59%
- Women: low/high	-1.22%/-0.12%	+2.44%/+0.57%

Note: The table shows changes in variables relative to those in a baseline model. The row "Transfer Recipients" indicates a fraction of the population receiving welfare transfers in each experiment. Taxes are not adjusted in each experiment.

Next we remove health insurance in economies with these two different welfare programs. Results are summarized in Table 8, where comparison is relative to a baseline model with a different vale of a consumption floor $\underline{c}$ and changes represent effects of removing health insurance under each regime.

In the baseline, as also reproduced in the first column of Table 8, households increase savings by 38% on average. If the welfare program is less generous, saving incentives are much stronger and average savings would rise by more than 80%. Welfare loss from losing health insurance is much larger in such an economy as shown in the bottom section of the table. If the economy has a more generous welfare program, the removal of health insurance is not as damaging, but the number of welfare recipients increases to reach 15% of the population.

Table 8: No Health Insurance under Alternative Welfare Programs

	Baseline	$\underline{c}$ 50% down	$\underline{c}$ 50% up
Avg. savings	+38.3%	+82.2%	+6.4%
Avg. consumption	-10.0%	-11.5%	-7.6%
Transfer recipients	1.70% → 5.78%	0.02% → 1.17%	6.22% → 14.52%
Welfare effects			
- All	-10.1%	-14.6%	-6.7%
- Men: low/high	-11.1%/-9.1%	-15.5%/-11.2%	-6.6%/-7.4%
- Women: low/high	-9.9%/-9.5%	-16.4%/-11.6%	-5.8%/-7.6%

Note: The table shows changes in variables relative to those in a baseline model with a different value of $\underline{c}$. The row "Transfer Recipients" indicates a fraction of the population receiving welfare transfers in each experiment. Taxes are not adjusted in each experiment.

Age-dependence of Copayment Rates: Given rapid demographic aging and rising fiscal pressures to finance age-related social security and insurance expenditures, various policy options to mitigate fiscal tension are being debated. In this section, we simulate a reform to raise copayment rates of health insurance for the elderly from 10% and 20%, depending on their age, to the common copayment rate of 30%.

Table 9 summarizes results in cases with and without tax adjustment. Higher copayments increase savings by more than 5%, since individuals expect to spend more during the retirement years. Although individuals save more on average, large expenditures after retirement deplete wealth of low-income households and the number of welfare recipients increase by about 10%, or 4% with the tax adjustment.

Welfare effects are negative without tax changes. The severity of welfare loss from higher copayment rates also depends on the likelihood of qualifying for welfare benefits. Welfare recipients, whose out-of-pocket expenditures are covered by the welfare program, are less negatively impacted by the increase in the copayment rates. Low-skilled women have a significantly higher proportion of welfare recipients compared to other groups, which explains their smaller welfare loss.[35]

When a surplus from higher copayments is paid back as a lump-sum transfer, individuals will receive a subsidy of 21,000 yen annually and welfare effects become positive. More savings and additional lump-sum transfers increase consumption and offset the welfare loss from additional expenditure risks that individuals are exposed to.

Table 9: Raising Copayment Rates of the elderly to 30% (Changes from the Baseline Model)

	No tax change	Tax adjusted
Avg. savings	+5.5%	+5.4%
Avg. consumption	-0.7%	+0.3%
Transfer recipients	1.88%	1.77%
	(+10.3%)	(+3.8%)
Lump-sum tax (JPY)	–	-21,000
Welfare effects		
- All	-0.45%	+0.70%
- Men: low/high	-0.53%/-0.45%	+0.67%/+0.45%
- Women: low/high	-0.39%/-0.47%	+0.93%/+0.49%

[35] In the baseline model, the proportion of welfare recipients is 5.7% for low-skilled women, 0.4% for high-skilled women, 1.3% for low-skilled men and 0.0% for high-skilled men. While the proportions increase in the experiment, the relative differences remain the same.

5.3 Alternative Model Specifications

Correlation between Health Status and Labor Productivity: In the baseline model, we assumed that earnings depend on age, gender, skill, and marital status, but they are not correlated with health status. One reason for the assumption is lack of a reliable data source to connect medical expenditures from the NDB to labor market data, such as earnings and participation rates.

We attempted to estimate the linkage between health status and earnings by studying the correlation between health and labor force participation rates from the Japanese Study of Aging and Retirement (JSTAR), a survey of middle and old-age individuals at and above 50 years old.[36] Although the survey includes some questions about medical expenditures, they are not entirely comparable to those of the NDB. Therefore, we instead computed a "frailty index" from JSTAR, following the method of Hosseini et al. (2022). Hosseini et al. (2024) use the PSID data to derive a linkage among health status, medical expenditures, and labor force participation rates of working-age individuals. Since the JSTAR does not cover individuals below age 50, we extrapolate our estimates towards younger ages, assuming that non-participation rates by health status will decline at the same speed as Hosseini et al. (2024) estimated.[37]

Table 10 shows changes in savings and other variables when earnings are correlated with health status. Since earnings are lower when individuals are in bad health, effects of medical expenditure shocks are exacerbated. As shown in the first column, individual like to accumulate more precautionary savings against shocks that are now more severe, and average savings will rise by 2.6%. At the same time, the number of welfare recipients will increase by about 3%. A rise in copayment rates to 30% in this economy will raise savings and lower welfare, and the effects are similar to those in the baseline model.

[36]The survey has been conducted by the Research Institute of Economy, Trade and Industry (RIETI), Hitotsubashi University and The University of Tokyo since 2007. Website: `https://www.rieti.go.jp/en/projects/jstar/index.html`

[37]For adjustments below age 50, we use the age-profiles of participation rates according to the frailty index shown in Figure 4 of Hosseini et al. (2024). We thank Kai (Jackie) Zhao for kindly sharing data of their estimates. More details of the computation are given in appendix C.

Table 10: Health-Dependent Earnings Scenario

	vs Baseline	Copayment 30%
Avg. savings	+2.6%	+5.3%
Avg. consumption	+0.12%	-0.72%
Transfer recipients	1.75 (+2.8%)	1.93% (+10.2%)
Welfare effects		
- All	-0.38%	-0.45%
- Men: low/high	-0.28%/-0.25%	-0.52%/-0.44%
- Women: low/high	-0.51%/-0.41%	-0.38%/-0.46%

Note: The first column shows changes relative to the baseline model with health-independent earnings and the second column shows effects of raising copayment rates to 30% in an economy with health-dependent earnings. The row "Transfer Recipients" indicates the fraction of the population receiving welfare transfers in each experiment. A percentage change in the number of recipients from the baseline model is indicated in parentheses.

Alternative Specification of Medical Expenditure Risks: We use the second-order Markov process of medical expenditures in the baseline model. When we instead assume the first-order Markov, i.i.d., and a deterministic process, and simulate the model, average savings are higher than in the baseline model, although the difference is very small. Under the M(2) process, bad health status is more persistent, and the shocks are more likely to reduce asses and consumption. At the same time, however, death probability is higher for individuals who suffer from persistent negative health shocks, which offsets the effect on precautionary savings and the number of welfare recipients.

Another reason why medical expenditure risks do not increase savings much is the combination of the means-tested welfare program and the HCME. While some households increase savings, others who expect to run down assets and be eligible for the means-tested transfers would have weak incentives to save. The cap on out-of-pocket expenditures through the HCME has similar effects. Therefore, the sign of the net effect under an alternative specification would be ambiguous. Our results that medical expenditure risks do not have significantly large effects on average savings, while higher levels of expenditures at old ages matter is consistent with findings of De Nardi et al. (2010) and Hubbard et al. (1995).[38]

[38] See the appendix B for more details of the experiments of alternative specifications of medical expenditure risks.

6 Conclusion

This paper develops a life-cycle model of heterogeneous individuals to study effects of medical expenditures on life-cycle savings and welfare as well as the roles of health insurance and means-tested transfer programs. Individuals in our model differ in age, gender, marital status, skills, earnings, and assets, as well as current and past health status. Each dimension of heterogeneity affects responses to medical expenditure risks and impacts of insurance and redistributive policies in different ways.

The medical expenditure risks, which we feed into the dynamic model, are computed based on the NDB data, the nationwide health insurance claims database, which covers all medical expenditures incurred by every Japanese citizen enrolled in the national health insurance system. Fukai et al. (2021) constructed panel data of individuals' medical expenditures from the NDB, and we use their data in our analysis. To the best of our knowledge, this is the first paper that uses the nation-wide administrative data of medical expenditures in a structural life-cycle model of heterogeneous agents to study roles of medical expenditures and insurance programs. In terms of the quantitative model, this is also the first paper that models single and married households and individuals' medical expenditures over all of the life-cycle.

Lifetime medical expenditures significantly differ across individuals and we show the importance of including not only cross-sectional differences, but also higher orders of persistence of expenditure shocks, if one aims to account for the distribution of lifetime medical expenditures more accurately. We also show that mortality risks are positively correlated with medical expenditures especially at old ages and constitute an important element in accounting for lifetime expenditure risks.

Our model incorporates details of the national health insurance system in Japan, including age-dependent copay rates and progressive ceilings on out-of-pocket expenditures through high-cost medical expense benefits. We show that the health insurance system protects Japanese individuals well from expenditure risks and affects saving behavior substantially. Without health insurance, individuals would save by as much as 40% more on average. The effects, however, are not uniform across individuals. Households with higher lifetime income, including high-skilled singles and married couples, would increase savings by significantly more but low-income individuals such as low-skilled single women would reduce savings and be more likely to become recipients of means-tested transfers. Low-income households face more fluctuations of assets and consumption in response to medical expenditure shocks and welfare effects of losing insurance are more negative than those of high-income households. We also show that economic and welfare effects of health insurance reform depend on the generosity of welfare transfer programs.

In this paper we focus on effects of medical expenditures and insurance programs in a demographically stationary economy and abstract from impacts of demographic changes.

Demographic trends that Japan and countries across the world face, including rising longevity, declining fertility rates, and changing family structures, may well interact with economic and welfare evaluations of alternative policy reforms related to medical expenditures, which we leave for future research. Moreover, this paper focuses on the effects of medical expenditure risks on heterogeneous individuals over the life cycle, but does not consider alternative specifications of medical expenditure risks, such as the stochastic process with a higher order and some permanent hidden type, and abstracts additional heterogeneity of income and wealth within cohorts, driven, for example, by idiosyncratic shocks and preference heterogeneity. We would like to explore further in future research.

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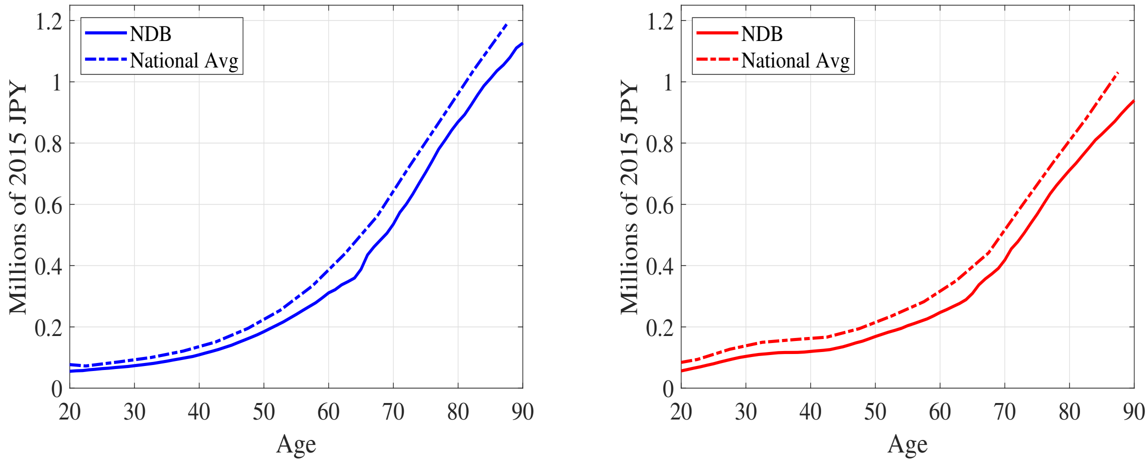
A More Details of the NDB Data

This section provides more detailed analysis of the NDB data, which is not covered in section 2.

A.1 Life-cycle Profiles: NDB and National Data

To demonstrate the comprehensiveness of the NDB, Figure 13 shows that the life-cycle profiles of medical expenditures are in line with the national data reported by the Ministry of Health, Labour and Welfare.[39] As discussed in section 2, there are differences in covered items between the NDBs and the national medical expenses, which explains the difference in the two profiles.

[39]The data is from the Estimates of National Medical Care Expenditure in 2015.
https://www.mhlw.go.jp/toukei/list/37-21.html (in Japanese)
https://www.mhlw.go.jp/english/database/db-hss/enmce.html (in English)



(a) Men (b) Women

Figure 13: Annual Medical Expenditures: NDB and National Data

A.2 Persistence of Medical Expenditures

Tables 11 and 12 reproduce Tables 1 and 2 but includes data for women as well. Figure 14 shows probabilities of transiting from bad current health status h_t at time t to either excellent or bad health status in the next period, h_{t+1}, conditional on the health status of the previous period, h_{t-1}. As discussed in the paper, medical expenditure processes are highly persistent and the persistence goes beyond the first order, for both men and women and across all age groups.

Table 11: Health Status Transition $h_t \to h_{t+1}$: M(1), Samples of Age 50, Men and Women

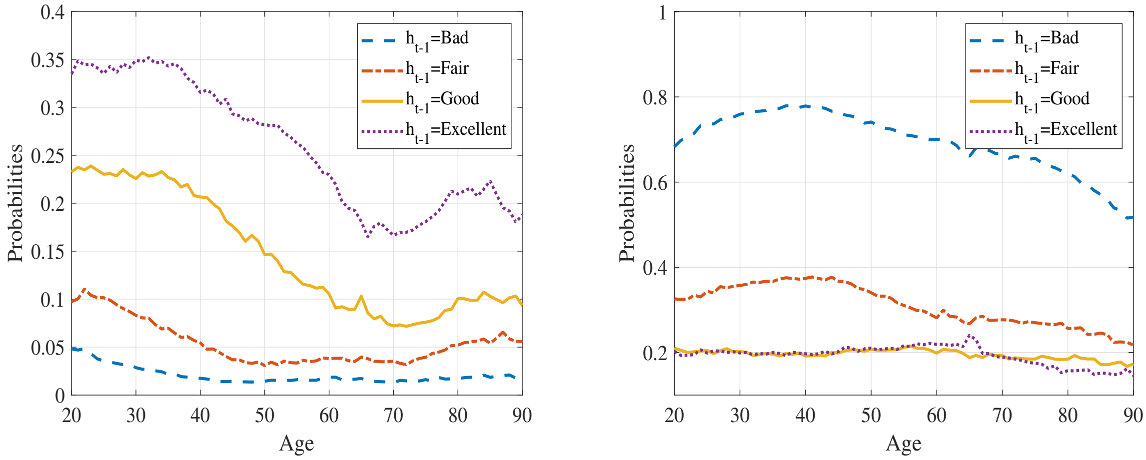
	Health status in $t+1$					
Men	Excellent	Good	Fair	Bad	Death	Total
Excellent	0.778	0.178	0.029	0.014	0.001	1.000
Good	0.317	0.544	0.115	0.023	0.001	1.000
Fair	0.076	0.275	0.579	0.069	0.001	1.000
Bad	0.073	0.121	0.277	0.512	0.017	1.000
	Health status in $t+1$					
Women	Excellent	Good	Fair	Bad	Death	Total
Excellent	0.765	0.192	0.029	0.014	0.000	1.000
Good	0.336	0.513	0.126	0.024	0.000	1.000
Fair	0.079	0.291	0.557	0.073	0.001	1.000
Bad	0.084	0.127	0.276	0.497	0.016	1.000

Table 12: Transition from Bad Health: M(1) and M(2), Samples of Age 50, Men and Women

	Health status in $t+1$					
Men	Excellent	Good	Fair	Bad	Death	Total
M(1)	0.073	0.121	0.277	0.512	0.017	1.000
M(2) by h_{t-1}						
Excellent	0.282	0.256	0.234	0.210	0.019	1.000
Good	0.146	0.327	0.306	0.208	0.013	1.000
Fair	0.031	0.124	0.496	0.340	0.009	1.000
Bad	0.015	0.030	0.193	0.741	0.021	1.000
	Health status in $t+1$					
Women	Excellent	Good	Fair	Bad	Death	Total
M(1)	0.084	0.127	0.276	0.497	0.016	1.000
M(2) by h_{t-1}						
Excellent	0.281	0.248	0.220	0.237	0.014	1.000
Good	0.189	0.322	0.277	0.203	0.010	1.000
Fair	0.055	0.136	0.463	0.339	0.007	1.000
Bad	0.014	0.034	0.210	0.721	0.021	1.000

As shown in Figure 14a, if an individual was in excellent health at time $t-1$, even though he is in bad health at t, he is much more likely to be in excellent health at $t+1$, than those who have been in bad health for more than one period. Figure 14b shows that the probability of staying in bad health in the next period at $t+1$ is significantly higher for those who were in bad health at $t-1$ across all age groups.[40]

[40] Note that probabilities of the four health status do not sum to 1 since there are individuals who die at $t+1$.

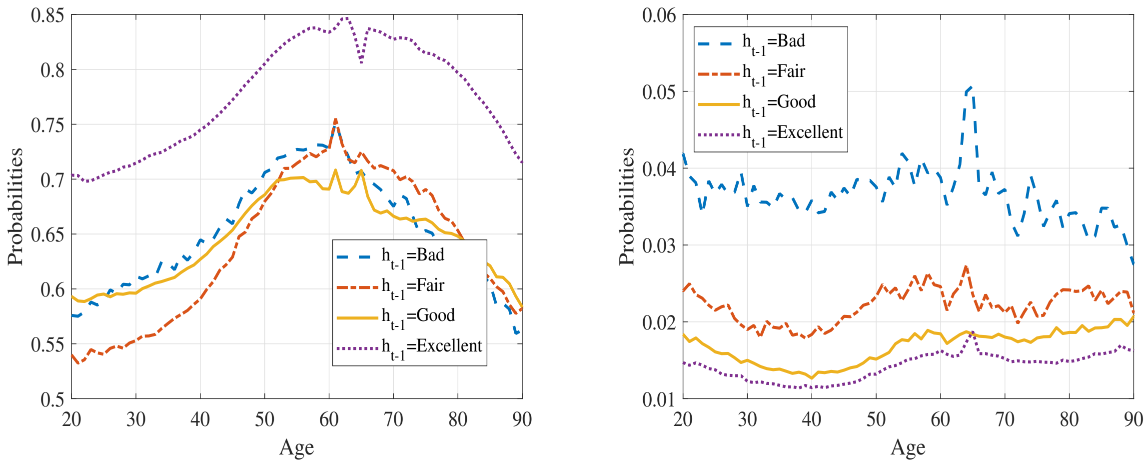


(a) Bad (h_t) to Excellent (h_{t+1})

(b) Bad (h_t) to Bad (h_{t+1})

Figure 14: Transition Probabilities of Health Status *from Bad Health* at t

It is not only bad health but also good health that is persistent beyond the first order. Figure 15 shows probabilities of transiting from excellent health status at time t to either excellent or bad health status in the next period at $t+1$, by health status of the previous period, at time $t-1$. The figures indicate that it is important to consider a higher-order persistence of medical expenditure shocks over the life-cycle among both very healthy and unhealthy individuals.



(a) Excellent (h_t) to Excellent (h_{t+1})

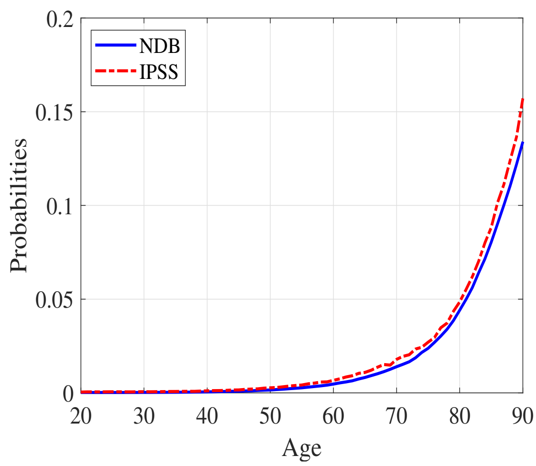
(b) Excellent (h_t) to Bad (h_{t+1})

Figure 15: Transition Probabilities of Health Status *from Excellent Health* at t

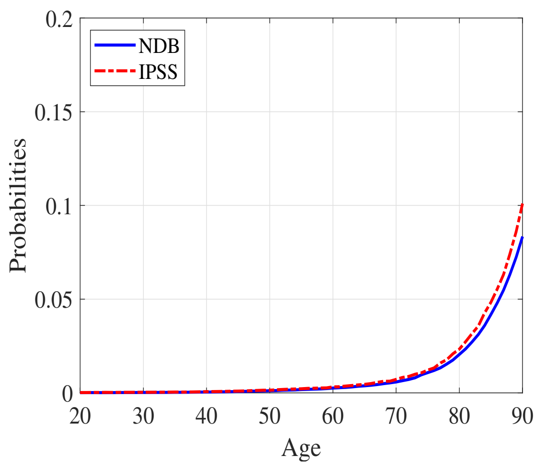
A.3 Mortality Risks and Health Expenditures

As discussed in the paper, we use the NDB data to identify individuals who pass away in a given period and compute mortality risks by age and gender, and incorporate them in the structural model. In this section, we first show that our estimated mortality risks are in line with those of the National Institute of Population and Social Security Research (IPSS). We then compare the distributions of lifetime medical expenditures when mortality risks are assumed to be independent of health status.

Mortality Risks of the NDB and the IPSS: Figure 16 shows the probability that individuals do not survive until the next year by age and compares the outcome of the NDB with that reported in the national data of the IPSS. The profiles are in line with each other, but note that the death probabilities of the NDB are slightly lower since, as discussed in the paper, the NDB includes only samples of individuals who use medical services and file claims and does not include individuals who never use services covered by national health insurance. For example, it does not include those who remain and pass away at home or in other facilities whose service fees are not covered by the national insurance.



(a) Men



(b) Women

Figure 16: Death Probabilities of the NDB and the IPSS

Health-Dependence of Mortality Risks and Lifetime Medical Expenditures: In this section, we study how health-dependence of mortality risks affect the distribution of lifetime medical expenditures. As discussed in the paper, death probabilities vary not only by age, but also by health status. Although bad health is highly persistent and expenditures accumulate to a large amount, it also comes with high mortality risks, which lowers the effects of bad health on total lifetime expenditures, since expenditures are zero after death.

To isolate effects of health dependence, we simulate lifetime expenditures of many individuals, assuming that mortality risks are independent of health status and depend only on age and gender, based on the unconditional mortality risks of the NDB. Table 13 summarizes moments under the baseline M(2) process and the alternative M(2) with health-independent mortality risks, indicated as Exp. in the second and fourth columns for men and women, respectively.

Table 13: Lifetime Medical Expenditures: Health-dependence of Mortality Risks

	Men		Women	
	Base	Exp.	Base	Exp.
Mean	20.5	22.5	21.4	22.6
Std. dev.	10.9	16.3	10.2	13.5
Coeff. of var.	0.53	0.72	0.48	0.60
Skewness	1.49	1.98	1.43	1.74
% below JPY 10 mm	12.9	19.6	7.9	12.4
% above JPY 40 mm	5.6	11.8	5.4	9.7

Note: Mean and standard deviation are in millions of 2015 JPY.

Total expenditures would be estimated to be higher if mortality risks are assumed to be independent of health status. More individuals with high-risk and expenditures survive longer. Moreover, healthier individuals who survive long in the baseline M(2) are assumed to die sooner in the counterfactual experiment. Risks are much larger as well, and the coefficients of variation would be 0.72 and 0.60 for men and women, respectively, under the experiment and they are much higher than 0.53 and 0.48 in the baseline model. As shown in the last two rows of Table 13, there would be many more individuals in the lower and upper tails of the distribution under the experiment.

A.4 Medical Expenditures in the Year of Death

Expenditures incurred during the final year of life tend to be very high with intensive medical treatments. Figure 17 shows average expenditures during the year of death by age. These are taken into account when computing lifetime medical expenditures in this section.

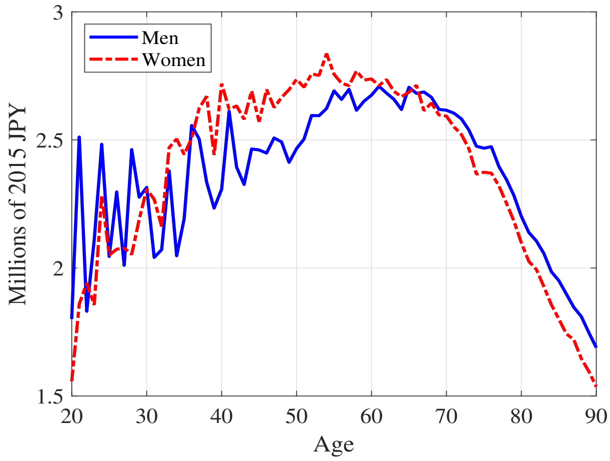


Figure 17: Medical Expenditures in the Year of Death

A.5 More on Lifetime Medical Expenditures

To quantify and visualize the tails of the distribution of lifetime medical expenditures, Table 14 reports distribution over a fixed range of expenditures under the four specifications and Figure 18 shows probability distribution.[41]

The second-order Markov process would imply the largest fraction of population in the group with the lowest lifetime expenditures of less than 10 million yen, as well a group with the largest expenditures of above 40 million yen. Using a first-order Markov process, for example, the probabilities of being in these extreme groups decline, and one would underestimate the variation of lifetime expenditures at both low and high ends of the distribution.

Table 14: Distribution of Lifetime Medical Expenditures (%)

	Men				Women			
	M(2)	M(1)	iid	det.	M(2)	M(1)	iid	det.
$\leq$ 10m JPY	12.9	11.2	8.0	8.4	7.9	6.7	4.9	5.3
$\leq$ 20m JPY	44.0	42.2	30.3	32.1	44.8	42.2	35.6	28.0
$\leq$ 30m JPY	27.4	30.6	41.3	57.3	30.9	34.8	49.0	66.7
$\leq$ 40m JPY	10.1	11.7	10.6	2.2	10.9	12.4	10.0	0.0
$>$ 40m JPY	5.6	4.4	0.8	0.0	5.4	3.9	0.5	0.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[41] A deterministic case is not included in the figure since the distribution depends only on the timing of death and is very non-smooth with high peaks.

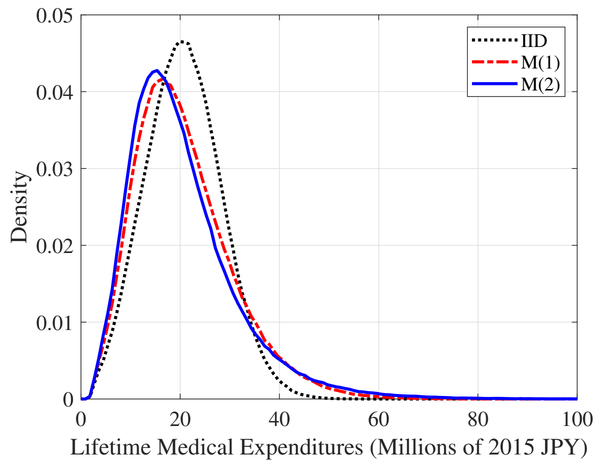


Figure 18: Probability distribution of Lifetime Medical Expenditures under Alternative Processes (Men)

Note: The horizontal axis indicates simulated lifetime medical expenditures in millions of 2015 JPY.

A.6 Lifetime "Out-of-pocket" Medical Expenditures

In this section, we take into account the details of Japan's health insurance program and simulate lifetime out-of-pocket (OOP) medical expenditure process across individuals. Lifetime OOP expenditures are not a simple linear transformation of gross expenditures since copay rates depends on age as well as income and expenditure levels of each individual.

Age-dependent Copay Rates and High-Cost Medical Expense (HCME) Benefits: Based on gross expenditures computed from the NDB, we compute OOP expenditures based on age-dependent copay rates, 30% for adults aged 69 and below, 20% for 70-74 and 10% for 75 and above. OOP expenditures are further adjusted according to High-Cost Medical Expense (HCME) benefits. The maximum copay set by HCME depends on age and annual earnings of each individual. We compute earnings of individuals for each age and gender using the Employment Status Survey (ESS). Using the second order Markov transition matrices of expenditures we computed, we simulate lifetime OOP expenditures of many individuals and compute various moments.

Figure 19 compares probability distribution of lifetime gross and OOP medical expenditures. OOP expenditures are significantly lower than gross expenditures and almost no one pays above 15 million yen, with a peak at around 2.5 million.

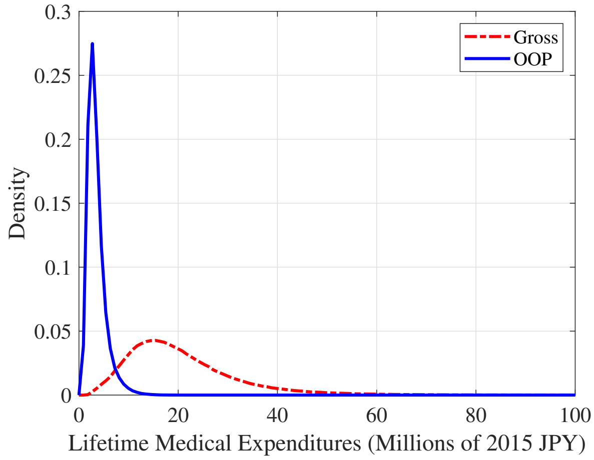


Figure 19: Probability Distribution of Lifetime Medical Expenditures (Men): Gross and Out-of-pocket

Note: The horizontal axis indicates simulated lifetime medical expenditures (gross or out-of-pocket) in million JPY.

Age-dependent copay rates provide significant insurance since coverage rates are high when individuals are old and are more likely to face not only high average expenditures but a large risk of incurring extremely high expenditures. On top of the age-dependent copay rates, HCME benefits provide additional insurance by imposing a ceiling on OOP and providing individuals with a shield against shocks that involve catastrophic expenses. Figure 20 plots probability distribution of OOP expenditures with and without HCME benefits and shows that the right tail of the distribution is thinner with HCME.

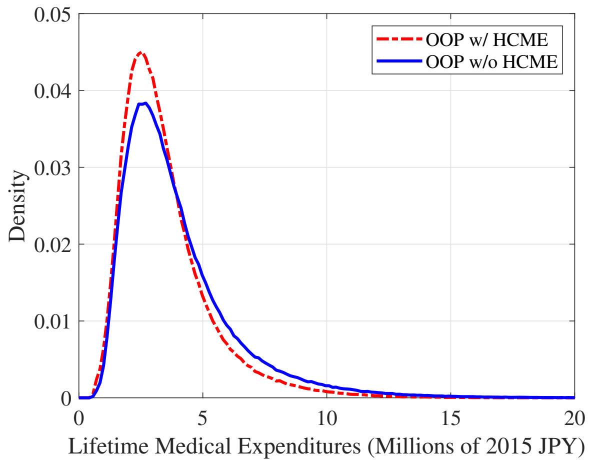


Figure 20: Probability Distribution of Lifetime Medical Expenditures (Men): Out-of-pocket with and without HCME

Note: The horizontal axis indicates simulated lifetime medical expenditures (out-of-pocket with and without HCME) in million JPY.

Table 15 shows moments of the lifetime OOP expenditures for men and women, with moments for gross expenditures for comparison. Distribution of the OOP without HCME has a higher skewness, consistent with the thick right tail in Figure 20.

Table 15: Moments of Lifetime Medical Expenditures: Gross, OOP with HCME (1) and OOP without HCME (2)

	Men			Women		
	Gross	OOP(1)	OOP(2)	Gross	OOP(1)	OOP(2)
Mean	20.5	3.5	4.0	21.4	3.6	3.9
Std. dev.	10.9	1.8	2.3	10.2	1.6	1.9
Coeff. of var.	0.53	0.52	0.58	0.48	0.46	0.50
Skewness	1.49	1.81	1.92	1.43	1.63	1.73

Note: Mean and standard deviation are in million JPY.

Alternative Medical Expenditure Process: Table 16 shows moments of lifetime OOP medical expenditures for men and women under alternative assumptions about persistence of expenditure shocks. Probability distributions are displayed in Figure 21. Qualitatively, the differences across specifications are similar to those for gross medical expenditures examined in Table 3.

Table 16: Moments of Lifetime Out-of-pocket Medical Expenditures Under Alternative Processes

	Men				Women			
	M(2)	M(1)	iid	det.	M(2)	M(1)	iid	det.
Mean	3.49	3.54	3.54	3.99	3.57	3.61	3.61	3.93
Std. dev.	1.83	1.50	0.96	0.83	1.63	1.34	0.85	0.65
Coeff. of var.	0.52	0.42	0.27	0.21	0.46	0.37	0.23	0.17
Skewness	1.81	1.04	0.15	-1.22	1.63	0.96	0.07	-1.81

Note: Mean and standard deviation are in million JPY.

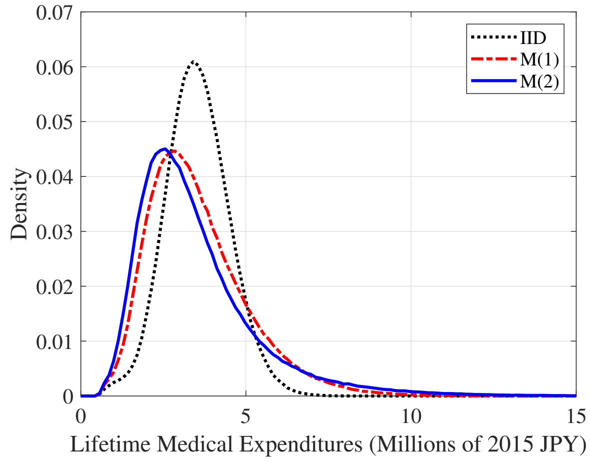


Figure 21: Probability distribution of Lifetime Out-of-pocket Medical Expenditures under Alternative Processes (Men)

Note: The horizontal axis indicates simulated lifetime medical expenditures in million JPY.

High persistence of bad health shocks in the M(2) specification relative to others is reflected in the higher standard deviation and skewness of lifetime OOP expenditures than those under different specifications. There is not much difference in average expenditures across specifications between M(2) and M(1) processes. The small difference, however, at the macro level conceals different experiences across individuals who face persistent bad health shocks.

To demonstrate such differences, we computed lifetime gross and OOP expenditures for individuals who face a bad health shock for the first time in their lives at different ages, followed by another bad health shock in the next period. Average lifetime gross and OOP expenditures are summarized in Table 17.

Table 17: Lifetime Gross and OOP Expenditures and Persistent Bad Health Shocks

Bad at age	30	40	50	60	70	All
Gross M(2)	24.4	25.5	25.7	26.0	26.3	20.5
Gross M(1)	23.0	23.6	25.3	26.0	26.7	20.7
OOP M(2)	4.67	5.04	5.28	4.88	3.32	3.49
OOP M(2)	4.17	4.47	4.74	4.76	3.48	3.53

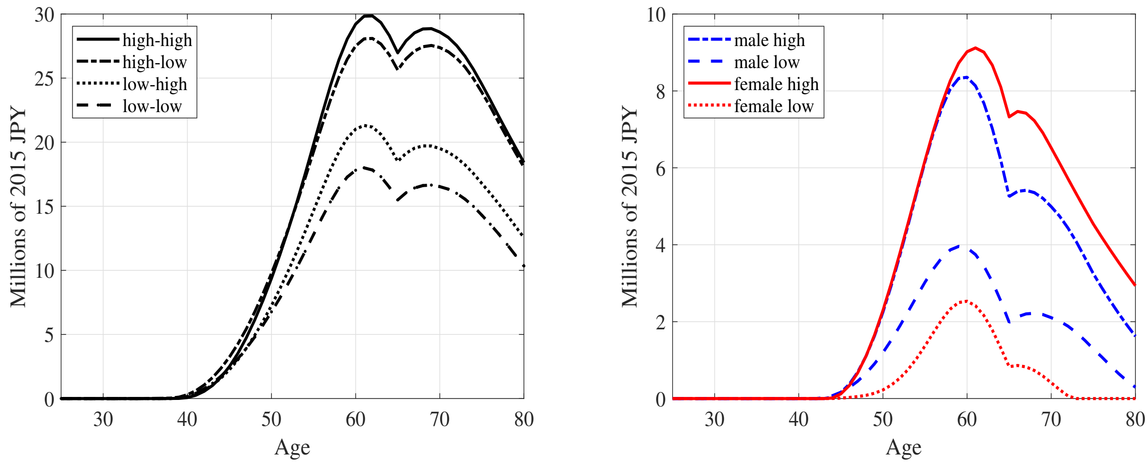
Note: Age denotes the age at which individuals received a bad health shock for the first time, followed by another bad shock in the next period. Expenditures are in million JPY.

As demonstrated in section 2, for an individual in bad health in the current period at time t, the probability of staying in bad health in the following period at $t+1$ is higher if the individual was already in bad health in the previous period at time $t-1$. This long persistence of health shocks beyond one period is captured in the M(2) process, but not in the M(1). As shown in Table 17, those who receive bad shocks for two periods have higher lifetime expenditures under the M(2) process, at least for those who experienced such shocks for the first time before age 60. Recall also that death probability is positively correlated with expenditures especially at older ages and this is reflected in the reversal of lifetime expenditures between M(1) and M(2) at older ages. Those who receive bad shocks in their 60s or 70s, for example, are more likely to die sooner, which offsets the positive effects of more persistent bad health shocks on lifetime expenditures.

B More Details on the Structural Model and Quantitative Results

B.1 Savings by Skill Levels in the Baseline Model

In our baseline model, assets differ by skills and health status within a group of the same gender and marital status, as shown in Figure 22. Figure 22a shows asset profiles of married couples by combination of skill levels of men and women, where high-low, for example, indicates a couple comprising a high-skilled husband and a low-skilled wife. Among singles, high-skilled individuals own more than the low-skilled for each gender, as shown in Figure 22b. High-skilled women save more than high-skilled men although their earnings are not very different from their male counterparts on average, since women live longer than men and have stronger life-cycle saving motives. Low-skilled women, however, save much less than low-skilled men as the difference in earnings dominates the difference in longevity.



(a) Married (b) Singles

Figure 22: Average Assets of Households by Age, Marital Status and Skills

B.2 Roles of the High-cost Medical Expense (HCME) Benefits

High-cost medical expense (HCME) benefits protect individuals from very high medical expenses, with progressive generosity for low income households. Table 18 shows changes in some variables when we assume that the HCME benefits do not exist. Given higher expenditure risks, households increase savings. Although the aggregate savings are higher, large medical expenditure shocks will make more individuals be eligible to receive welfare transfers. Loss of the HCME benefits will lower welfare of both high and low-skilled men and women.

Table 18: No High-Cost Medical Expense (HCME) Benefits (Changes from the Baseline Model)

	No tax change	Tax adjusted
Avg. savings	+1.8%	+1.8%
Avg. consumption	-0.3%	+0.2%
Transfer recipients	1.78%	1.73%
	(+5.2%)	(+1.9%)
Lump-sum tax	–	-9,000
Welfare effects		
- All	-0.24%	+0.26%
- Men: low/high	-0.30%/-0.23%	+0.22%/+0.15%
- Women: low/high	-0.20%/-0.20%	+0.36%/+0.21%

B.3 Alternative Specification of Medical Expenditure Risks

This section presents numerical results of the simulations under alternative specifications of medical expenditure processes. Table 19 shows changes in average savings, consumption and transfer recipients when we assume the first-order Markov process of medical expenditures, M(1), i.i.d., and deterministic processes. In the deterministic process, we assume that all households face the same age and gender specific expenditures, computed as an average across all individuals of the same age and gender group.

Table 19: Alternative Medical Expenditure Processes

	M(1)	iid	Deterministic
Avg. Savings	+0.15%	+0.09%	+0.98%
Avg. Consumption	-0.02%	-0.05%	-0.33%
Transfer Recipients	1.72%	1.71%	1.76%
	(+0.9%)	(+0.2%)	(+3.4%)

Note: The row "Transfer Recipients" indicates the fraction of the population receiving welfare transfers in each experiment. A percentage change in the number of recipients from the baseline model is indicated in parentheses.

We next compare effects of removing health insurance under the four specifications, including the baseline M(2) process, and the results are summarized in Table 20. Comparison is relative to a benchmark model with a different medical expenditure process and changes represent the effects of removing health insurance in each economy. Changes in average savings and consumption are similar across the four specifications. Savings increase by 37 to 39% and consumption falls by 10 to 11%. Welfare effects are of a similar magnitude, though the welfare loss is larger when the shocks are more persistent. The results suggest that what drives average life-cycle savings and consumption is the average life-cycle profile and expected magnitude of medical expenditures, but that risks do matter at an individual level.

Table 20: No Insurance under Alternative Medical Expenditure Processes

	Baseline M(2)	M(1)	iid	Deterministic
Avg. Savings	+38.3%	+37.9%	+36.9%	+38.5%
Avg. Consumption	-10.0%	-10.2%	-10.5%	-10.8%
Transfer Recipients	1.70%→5.78%	1.72% → 5.78%	1.71% → 5.58%	1.76% → 5.29%
Welfare Effects				
- All	-10.1%	-10.0%	-9.8%	-9.2%
- Men: low/high	-11.1%/-9.1%	-11.1%/-9.0%	-10.7%/-8.7%	-10.1%/-8.3%
- Women: low/high	-9.9%/-9.5%	-9.9%/-9.4%	-9.6%/-9.1%	-9.3%/-8.4%

Note: The row "Transfer Recipients" indicates a fraction of the population receiving welfare transfers in each experiment. Taxes are not adjusted in each experiment.

B.4 Alternative Specification of Pension Benefits

In this section, we present numerical results of the simulation under an alternative specification of pension benefits by considering survivors' benefits. There are some papers that explicitly include survivors' pension benefits in a structural life-cycle model and we follow their modeling strategy.[42] We introduce survivors' benefits for widowed women and assume that they are eligible to receive survivors' benefits that are the higher of the 75% of the benefits for the deceased spouse, or the average of their own benefits and the deceased spouse's benefits.

Table 21 shows the changes in average saving and transfer recipients relative to the baseline model without survivors' benefits. In the economy with survivors' benefits, pension benefits for widowed women increase relative to the baseline, their average savings decrease, and consumption increases on average. The number of welfare recipients decreases because there are fewer widowed women whose assets are low enough to be eligible for welfare benefits.

Table 21: Survivors' Benefits Scenario

	vs Baseline
Avg. Savings	-12.73%
Avg. Consumption	+1.13%
Transfer Recipients	
- All	1.70% → 0.99%
	(-41.7%)
- Widowed Women	13.09% → 0.99%
	(-89.2%)

Note: The row "Transfer Recipients" indicates the fraction of the population receiving welfare transfers in the experiment. A percentage change in the number of recipients from the baseline model is indicated in parentheses.

To confirm the robustness of the results from our main experiment, we compare the effects of removing health insurance under this scenario with survivors' benefits. The results are summarized in Table 22. Savings and consumption move in the same direction, though the saving response is somewhat larger as widowed women are less likely to be welfare recipients and live on their own saving. Welfare effects are similar to the baseline model both qualitatively and quantitatively.

[42] See, for example, Borella et al. (2023), Kotera (2023), and Kitao and Mikoshiba (2024).

Table 22: No Health Insurance under Survivors' Benefits Scenario

	Baseline	Survivor Benefits
Avg. Savings	+38.3%	+53.5%
Avg. Consumption	-10.0%	-10.2%
Transfer Recipients	1.70% → 5.78%	0.99% → 5.05%
Welfare Effects		
- All	-10.1%	-10.3%
- Men: low/high	-11.1%/-9.1%	-11.4%/-9.3%
- Women: low/high	-9.9%/-9.5%	-10.2%/-9.6%

Note: The row "Transfer Recipients" indicates a fraction of the population receiving welfare transfers in the experiment. Taxes are not adjusted in each experiment.

B.5 Alternative Specification of Marital Status

We present numerical results of the simulation under an alternative specification of marital status. We assume that all individuals are born single or married, and that there is no marriage shock for single households, that is, we assume that $\xi_{j,g} = 0$ except for the initial age 25.

Table 23 shows changes in average savings and transfer recipients relative to those in the baseline model. The average savings level of households born as single increases significantly, regardless of gender or skill. Being single for life, individuals cannot share medical expenditure risks with a spouse. Moreover, earnings of single individuals are lower than those of married couples and each individual saves more to insure against expenditure risks. In the aggregate, since the share of singles who have lower savings increases in a model without marriage probability, the average amount of savings decreases, and the average number of welfare recipients increases.

Next we remove health insurance in the economy with no marriage shock. Results are summarized in Table 24. If individuals remain single for life, there will be many more old single individuals in the population. Low-skilled singles are more likely to exhaust their savings when medical expenditure shocks early in life, and their increase in average savings is slower than in the baseline. The number of welfare recipients becomes larger than that of the baseline.

Table 23: No Marriage Shock Scenario

	vs Baseline
Avg. Savings	
- All	-48.33%
- Single Men: low/high	294.44%/217.86%
- Single Women: low/high	415.17%/204.07%
- Married	-2.18%
Transfer Recipients	
- All	1.70% → 6.52% (-282.6%)
- Single Men	2.21% → 3.79% (+71.6%)
- Single Women	6.29% → 12.02% (+91.2%)
- Married	0.002% → 0.004% (+100.0%)

Note: The row "Transfer Recipients" indicates the fraction of the population receiving welfare transfers in the experiment. A percentage change in the number of recipients from the baseline model is indicated in parentheses.

Table 24: No Health Insurance under No Marriage Shock Scenario

	Baseline	No Marriage Shock
Avg. Savings		
- All	+38.3%	+27.1%
- Single Men: low/high	+3.4%/+64.9%	-19.5%/+52.7%
- Single Women: low/high	-53.5%/+34.1%	-43.0%/+29.4%
- Married	+42.8%	+43.8%
Transfer Recipients		
- All	1.70% → 5.78%	6.52% → 14.38%
- Single Men	2.21% → 6.50%	3.79% → 13.29%
- Single Women	6.29% → 11.41%	12.02% → 20.56%
- Married	0.002% → 1.83%	0.004% → 1.45%

Note: The row "Transfer Recipients" indicates a fraction of the population receiving welfare transfers in the experiment. Taxes are not adjusted in each experiment.

B.6 Alternative Parameter Values

In this section we simulate the model under alternative values of preference parameters and quantify their effects on some of our quantitative results.

Discount Factor: In the baseline, we set the value of discount factor β at 0.9586, or approximately 0.96, to match the level of assets at the peak over the life-cycle. We simulate the baseline model where we set the discount factor at 0.95 and 0.97, and compare the effects of extreme scenarios of no insurance with and without taxes. Results are summarized in Table 25. A higher discount factor leads individuals to save more since they place more weight on future consumption. The effects of an extreme scenario of removing health insurance studied in section 5, with and without tax adjustment, do not differ much under alternative values of β.

Table 25: Extreme Scenarios: No Health Insurance and Full Insurance under Alternative Discount Factors β

	No tax change		
Discount factor β	0.95	0.96	0.97
Change in avg. savings	+39.2%	+38.3%	+38.3%
Change in avg. consumption	-9.7%	-10.0%	-10.2%
Transfer recipients	6.9%	5.8%	4.4%
	(+222.4%)	(+239.7%)	(+256.5%)
Lump-sum tax (JPY)	–	–	–
Welfare effects			
- All	-9.2%	-10.1%	-11.2%
- Men: low/high	-10.1%/-8.2%	-11.1%/-9.1%	-12.3%/-10.2%
- Women: low/high	-9.2%/-8.6%	-9.9%/-9.5%	-11.0%/-10.5%
	Tax adjusted		
Discount factor β	0.95	0.96	0.97
Change in avg. savings	+53.7%	+51.8%	+50.7%
Change in avg. consumption	+2.8%	+3.4%	+4.2%
Transfer recipients	3.6%	2.8%	1.9%
	(+68.9%)	(+64.1%)	(+54.4%)
Lump-sum tax (JPY)	-227,000	-290,000	-309,000
Welfare effects			
- All	+5.0%	+4.8%	+4.7%
- Men: low/high	+5.0%/+3.4%	+4.8%/+3.1%	+4.7%/+2.8%
- Women: low/high	+6.2%/+3.8%	+6.1%/+3.5%	+6.1%/+3.3%

Note: The middle column is for the baseline, where β is approximately 0.96 (0.9586). The row "Transfer Recipients" indicates the fraction of the population receiving welfare transfers in each experiment. The percentage change in the number of recipients from the baseline model is indicated in parentheses. Lump-sum tax is expressed as an annual tax collected in Japanese yen. A negative number indicates a positive transfer from the government to each individual.

Risk Aversion: Table 26 shows effects of no insurance under different values of risk aversion parameter σ. As shown in the top panel of the table for the case of no tax change, loss of insurance induces more savings in a model with a higher σ and welfare effects are more negative. Since individuals save more to insure themselves against expenditure risks, fewer individuals would be eligible for means-tested transfers. Government expenditures for welfare transfers would be lower with higher risk aversion, and when taxes are adjusted, a larger lump-sum transfer is given to individuals.

Table 26: Extreme Scenarios: No Health Insurance and Full Insurance under Alternative Risk Aversion Parameter σ

	No tax change		
Risk Aversion Parameter σ	2	3	4
Change in avg. savings	+16.0%	+38.3%	+48.4%
Change in avg. consumption	-9.1%	-10.0%	-10.5%
Transfer recipients	9.4%	5.8%	3.7%
	(+251.0%)	(+239.7%)	(+255.2%)
Lump-sum tax (JPY)	–	–	–
Welfare effects			
- All	-4.4%	-10.1%	-16.5%
- Men: low/high	-4.7%/-4.0%	-11.1%/-9.1%	-18.4%/-15.1%
- Women: low/high	-4.5%/-4.2%	-9.9%/-9.5%	-15.7%/-15.7%
	Tax adjusted		
Risk Aversion Parameter σ	2	3	4
Change in avg. savings	+33.6%	+51.8%	+60.9%
Change in avg. consumption	+1.7%	+3.4%	+4.6%
Transfer recipients	5.7%	2.8%	1.5%
	(+111.3%)	(+64.1%)	(+44.2%)
Lump-sum tax (JPY)	-244,000	-290,000	-321,000
Welfare effects			
- All	+1.6%	+4.8%	+8.5%
- Men: low/high	+1.8%/+1.0%	+4.8%/+3.1%	+7.9%/+5.0%
- Women: low/high	+2.2%/+1.1%	+6.1%/+3.5%	+10.7%/+6.0%

Note: The row "Transfer Recipients" indicates the fraction of the population receiving welfare transfers in each experiment. The percentage change in the number of recipients from the baseline model is indicated in parentheses. Lump-sum tax is expressed as an annual tax collected in Japanese yen. A negative number indicates a positive transfer from the government to each individual.

C More Details of Calibration

C.1 Frailty Index

In this section we explain how we calibrated the frailty index used to introduce correlation between health status and earnings in section 5.

Data Description: We use the Japanese Study of Aging and Retirement (JSTAR) to study the correlation between health and labor force participation. JSTAR is a panel survey of elderly people aged 50 and over, conducted by the Research Institute of Economy, Trade and Industry (RIETI), Hitotsubashi University and The University of Tokyo. The survey has been conducted every two years since 2007. The survey is designed to ensure maximum comparability with preceding surveys such as the Health and Retirement Study (HRS). Although the survey includes some questions about medical expenditures, we found that they are not comparable to those of the NDB. Therefore, we instead computed an objective measure of health status: "the frailty index" from JSTAR, following the method of Hosseini et al. (2024). Hosseini et al. (2022) obtained the frailty index using not only PSID but also HRS, and we can calculate a frailty index using a similar construction method. We use the data between 2007 and 2013.[43]

Construction of Frailty Index: Following the strategy taken in Hosseini et al. (2022), we use 37 variables that take a value between 0 and 1 and calculate the frailty index by summing up all variables with equal weight and then normalizing them to a value between 0 and 1. These variables mainly consist of activities of daily living (ADL)/Instrumental ADL (IADL) variables, past and present disease-related variables, cognitive variables, and health care utilization (outpatient visits, etc.).

- ADL/IADL variables (Difficulties in following activities): Eating using tableware by yourself; putting on and taking off stockings, socks and shoes; getting into and out of bed; using the toilet; bathing by yourself; walking around the room; walking 100 meters; making a phone call without help; managing money;[44] shopping for daily necessities; boiling water in a kettle; getting up from a chair after sitting continuously for a long time; squatting or kneeling; lifting or carrying an object weighing 5kg or more; taking medicine without help; taking one step up the stairs without using the handrail; picking up a small object such as a one-yen coin from a desktop with your fingers; raising your arms above your shoulder; pushing or pulling a large object such as a chair or sofa; going out using public transformation.

- Past and present disease variables (ever had any of the following conditions): High blood pressure; diabetes; cancer or other malignant tumor (including leukemia, lymphoma; excluding benign skin cancer); chronic lung disease (chronic bronchitis, emphysema, etc.; excluding lung cancer); heart disease (angina, heart failure, cardiac

[43] For our research purpose, we don't use the data of seven cities from the 2011 survey because there are not enough variables to calculate the frailty index. The seven cities are: Adachi, Kanazawa, Shirakawa, Sendai, Takikawa, Tosu and Naha.

[44] This variable is calculated using the following three questions: paying bills, making deposits in and withdrawals from your bank or postal account, and filling out documentation such as pension forms. We sum these three variables and normalize them to a value between 0 and 1, with 1 meaning that individuals can't do these activities.

infarction, heart valve disease, etc); stroke; joint disorder; asthma; other serious, chronic conditions (liver disease, parkinson's, etc.); BMI ≥ 30; has ever smoked.

- Cognitive variables (ever had any of the following conditions): Dementia; depression or emotional disorder.

- Health care utilization: Outpatient visit; inpatient visit; formal home care utilization; institutional long-term care utilization.

Using the frailty index, we define health status by dividing it into four categories using ten-year age groups. Then, we compute the correlation between health status and labor force participation by gender and age, and estimate the health-dependent labor force participation by gender, age, skill, and marital status. Since the JSTAR does not cover individuals below age 50, we extrapolate our estimates for younger age groups by using Hosseini et al. (2024)'s estimation results from the PSID and assuming that non-participation rates by health status will decline at the same speed as Hosseini et al. (2024).

C.2 Long-Term Care Expenditures

As discussed in section 4, long-term care expenditures cover expenditures for individuals aged 40 and above. We report below expenditure data obtained from the Statistics of Long-term Care Benefit Expenditures of the Ministry of Health, Labour and Welfare (MHLW).[45] They report total expenditures for different types of long-term care services by gender and age groups. We combine these and demographic data, and compute average long-term care expenditures by age and gender. Figure 23 shows the life-cycle profile of gross long-term care expenditures.

[45] https://www.mhlw.go.jp/toukei/list/45-1.html (Japanese)
https://www.mhlw.go.jp/english/database/db-hss/soltcbe.html (English)

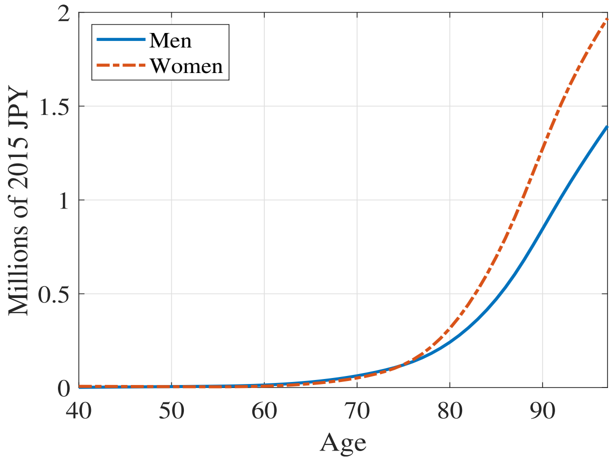


Figure 23: Annual Long-term Care Expenditures by Age and Gender

Note: Figure shows the average gross long-term care expenditures of all individuals by age and gender in 2015. Expenditure data is constructed from monthly data from January 2015 to December 2015, converted to annual data. The expenditure data is from the Statistics of Long-term Care Benefit Expenditures of the Ministry of Health, Labor and Welfare (MHLW). The population data is from the Population Statistics of the National Institute of Population and Social Security Research (IPSS).