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FUKAI, Taiyo
University of Tokyo

ICHIMURA, Hidehiko
University of Arizona / University of Tokyo

KITAO, Sagiri
RIETI

MIKOSHIBA, Minamo
University of Tokyo

Research Institute of Economy, Trade & Industry, IAA

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

Taiyo FUKAI, University of Tokyo†

Hidehiko ICHIMURA, University of Arizona and University of Tokyo‡

Sagiri KITAO, Research Institute of Economy, Trade and Industry§

Minamo MIKOSHIBA, University of Tokyo**

Abstract

This paper analyzes individuals' medical expenditure risks over the life-cycle and roles of the national health insurance system using nationwide administrative data of health insurance claims (NDB) in Japan. Health shocks are highly persistent and estimated distribution of lifetime medical expenditures varies greatly with the assumed order of persistence. We build a structural life-cycle model for males and females, and single and married households with different labor productivity and assets, and quantify economic and welfare effects of medical expenditure risks and the insurance system. The national health insurance characterized by age-dependent copay rates and progressive out-of-pocket ceilings protects households from expenditure risks well, and has significant effects on their life-cycle savings. Responses to health insurance reform are highly heterogeneous. In response to lower benefits, high-income households turn to self-insurance and increase savings, while low-income households reduce savings and consumption and many of them become recipients of welfare transfers. Welfare effects of such a reform also vary across households and low-income and unhealthy households fare worse than the average. We also show that effects of health insurance reform depend on the generosity of other welfare programs and differ across households.

Keywords: Medical expenditures, Health risks, Health insurance, Precautionary saving, Overlapping-generation model.

JEL classification: D15, E21, I10, I13

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† University of Tokyo, Email: taiyo.f1029@gmail.com

‡ University of Arizona and University of Tokyo, Email: h.ichimura@gmail.com

§ Research Institute of Economy, Trade and Industry (RIETI), University of Tokyo, Email: sagiri.kitao@gmail.com

** University of Tokyo, Email: minamo.mikoshiba@gmail.com

1 Introduction

How do medical expenditure risks affect households' life-cycle decisions and welfare? What are the roles of publicly-provided health insurance and how do medical expenditures and insurance interact with other social insurance programs? To answer these questions, we develop a structural model of heterogeneous individuals that differ in age, gender, education, marital status, assets, and health status over multiple periods. First, we carefully examine medical expenditure data to evaluate risks individuals face over their life-cycle and use them as an input for a life-cycle model.

This paper makes contributions in multiple dimensions. We use the medical expenditure panel data that Fukai et al. (2021) constructed from the nationwide health insurance claims database (NDB), an administrative medical expenditure data set which covers essentially all individuals in Japan, and present various analyses of medical expenditure risks. We then use the calibrated medical expenditure process in a life-cycle model of married and single households to evaluate effects of medical expenditure risks on household savings and consumption and quantify roles of publicly-provided national health insurance. We also evaluate how medical expenditure risks and insurance interact with other social insurance systems.

In the first part of the paper, we use the NDB's panel data with a sample of more than 100 million individuals each year, and estimate medical expenditure processes under alternative assumptions about persistence of medical expenditure shocks. The NDB panel contains data on all medical expenditures covered by Japan's national health insurance system and allows us to accurately 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. Males spend more than females on average at each age except for several years around females' child-bearing age, though females' lifetime expenditures are higher on average as they live longer. The average profiles, however, tell us little about medical expenditure risks individuals face, since there is significant heterogeneity within a group of the same gender and age. For example, for males 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. Among females, corresponding averages are 2.3 million yen and 37,000 yen.

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 males aged 50 in bad health (defined as a group in the top 5% of this group in terms of annual medical expenditures), the probability of remaining in bad health over the following year is above 50%. Furthermore, the probability of remaining in bad health for two consecutive years is reflected in an increase in medical expenditures in the previous year. Papers including De Nardi et al. (2018), Fukai et al (2018, 2021) pointed out and emphasized high persistence of health and medical expenditure risks beyond one year and we confirm their findings. According to the NDB panel data, bad health will continue with a probability 74% if the male individual was already in bad health in the previous year, while it falls to 21% if he was in good health, defined as a group in the bottom 50% in medical expenditures.

Simulating lifetime gross medical expenditures of a large number of individuals under different specifications about persistence, we obtain the coefficient 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 males, and similarly for females. The skewness of simulated samples varies from 1.40 to 0.94, 0.22 and -0.48, falling in persistence of medical expenditure 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 in quantifying lifetime medical expenditure risks as well as in evaluating fiscal costs of health insurance.

In the second part, we study effects of medical expenditure risks on heterogeneous individuals' life-cycle savings and evaluate roles of health insurance and social insurance programs. We build a structural model of overlapping generations, who differ in age, gender, education, earnings, marital status, assets, and current and past health status. Each of the dimensions of heterogeneity plays a role in evaluating heterogeneous effects of medical expenditure risks and insurance programs. 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 protected from persistent expenditure risks.

We find that most individuals are well insured against expenditure shocks by comprehensive health insurance coverage. Health insurance copayment rates are independent of economic status of the insured individuals, but the coverage rates increase from 70% at or below age 69, to 80% at age 70–74, and then to 90% at age 75, providing more generous coverage as expenditures rapidly rise at old ages.[1] Moreover, the High-Cost Medical Expense (HCME) benefits provide additional coverage with progressive income-dependent ceilings on out-of-pocket expenditures across all age groups and help individuals reduce the risk of depleting assets when faced with catastrophic expenditure shocks.

We find that without insurance average savings would rise by as much as 40%. Such

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

effects, however, are not uniform across different types of households. In an economy without insurance, married couples and high-skilled singles would start accumulating wealth at an early stage of their life to insure against large expenditures later in their life-cycle. Other low-income groups including low-skilled single females would be severely hit by the lost coverage and many would have no choice but to reduce savings and consumption and be 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 much larger welfare loss in an economy with a less generous welfare program and many individuals would respond by raising private savings more aggressively. Results suggest that an evaluation of health insurance reform needs to take into account how other redistributive policies operate and whether different types of households have alternative ways other than self-insurance to protect themselves against expenditure risks.

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.[2] Capatina (2015) builds a life-cycle model with health shocks and evaluates roles of various channels through which health affects wealth and income inequality. Capatina et al. (2020) study effects of health shocks on earnings inequality with endogenous human capital. De Nardi et al. (2018) 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. (2020) evaluate effects of health on employment and earnings, using a frailty index that represents an individual's health status, developed in Hosseini et al. (2021). De Nardi et al. (2021) estimate a model populated by couples and singles and show that a household structure, medical expenditures, and bequest motives jointly play an important role in accounting for patterns of the elderly's savings. Nakajima and Telyukova (2018) and Kopecky and Koreshkova (2014) also study the interaction of medical expenditure risks and savings of the elderly. French and Jones (2011) use the Health and Retirement Survey (HRS) to estimate effects of medical expenses and health insurance arrangements on retirement decisions.

Many papers focus on the roles of insurance policies in models with health and medical expenditure risks. Conesa et al. (2018) and Attanasio et al. (2011) study roles of Medicare, a public health insurance for the elderly in the U.S., 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). Kitao (2014), Low and Pistaferri (2015) and Michaud and Wiczer (2020) study effects of disability insurance on economic decisions and welfare in a quantitative model with health and

[2]For earlier studies, see, for example, Palumbo (1999), French (2005), and Jeske and Kitao (2009).

disability shocks.[3]

Many papers study roles of means-tested social insurance programs and some papers investigate an interaction with health risks. Hubbard et al. (1995) is an earlier work, which shows that a welfare program discourages savings of the poor and helps explain a lower tail of wealth distribution. Papers including 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 rich model with uninsurable medical expenditure risks and wealth heterogeneity. De Nardi et al. (2010) also demonstrate that social insurance programs affect behavior and welfare of 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. Brown and Finkelstein (2008) also 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.

Studies listed above are mainly focused on the U.S. but obviously medical expenditure risks and roles of a health insurance system are important issues in any economy, especially in countries that face rapid demographic aging and fiscal issues since health-related expenditures quickly rise in age and pose challenges not only at a household level but also at an aggregate level through rising public expenditures.[4]

We consider the case of Japan, an economy with the most rapidly aging demographics and significant macroeconomic and fiscal challenges from rising age-related expenditures. There is no national survey of health and medical expenditures in Japan, with the same degree of comprehensiveness and coverage as the Health and Retirement Survey (HRS) or the Medical Expenditure Panel Survey (MEPS), which would enable us to estimate medical expenditure process over the life-cycle together with the transition of other economic variables such as earnings, wealth, and labor supply.

There are studies that use insurance claim data of selected insurance groups and estimate medical expenditure processes at an individual level, including Fukai et al. (2018) and Kan and Suzuki (2015). Kan and Suzuki (2015) use insurance claim data of 111 corporations and estimate a medical expenditure process of working-age individuals. 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. They demonstrate high persistence of medical expenditure shocks and suggest that accounting for persistence beyond the first order is important in evaluating risks faced by individuals. Given the

[3]See also Fonseca et al. (2021), Cole et al. (2019), Hansen et al. (2014), and Ozkan (2017) for more studies on medical expenditures, policies, and their macroeconomic and distributional effects.

[4]See, for example, Imrohoroglu and Zhao (2018) and Bairoliya et al. (2018), for models with medical expenditures and health insurance in China.

nature of the database, the analysis is mostly focused on working-age male individuals, 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 females and males over 60. In this paper, we use the results and panel data constructed by Fukai et al. (2021).

There are recent papers including Braun and Joines (2015), Kitao (2015) and İmrohoroğlu et al. (2016) that 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. An exception is Hsu and Yamada (2019), which include uncertainty of medical expenditures in the model and calibrate an expenditure process based on the estimates of Kan and Suzuki (2015), which is based on samples of working-age individuals in selected corporations.

In summary, we develop a full life-cycle model of individuals, from their entry to the economy to death, who face medical expenditure shocks that we obtained from panel data constructed with the administrative database of the entire nation. 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. In a model where individuals differ in age, gender, marital status, skills, earnings, assets, and health, we carefully model and evaluate roles of the national health insurance system and study how it protects heterogeneous types of 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 affect individuals' decisions and welfare in a unified framework. Our use of the NDB panel helps evaluate medical expenditure process of the nation accurately and improves analysis of health risks and public insurance policies on heterogeneous households.

The rest of the paper is organized as follows. In section 2, we describe our data source and medical expenditures 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 Medical Expenditure Data (NDB)

2.1 Data Description

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, hereinafter "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, except for recipients of social welfare benefits, whose medical expenditures are covered by the welfare program. 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 2012 and 2014. We also use data of two additional years before and after this time range for the computation of a second-order Markov process. In computing the transition process, we include samples that are identified in the database for three consecutive years. The sample size for each year is 104.4, 110.3, and 113.0 million individuals for 2012, 2013 and 2014, respectively. 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 Life-cycle Profiles of Medical Expenditures

Figure 1 shows average annual medical expenditures over the life-cycle for males and females, separately. Expenditures increase nearly monotonically in age, except for several years of higher spending among females 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. They start to rise sharply from the age of 50 and particularly above the age of 60.

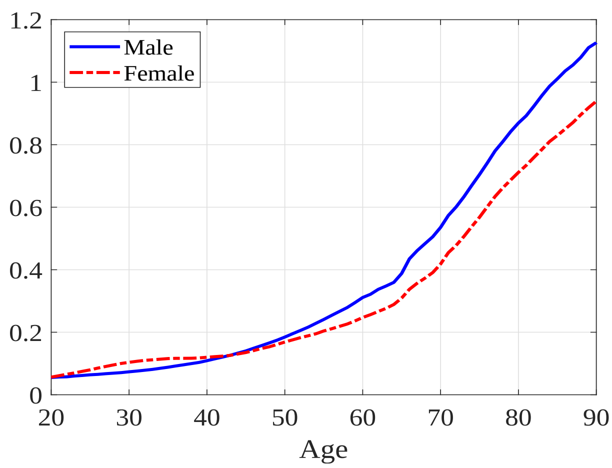
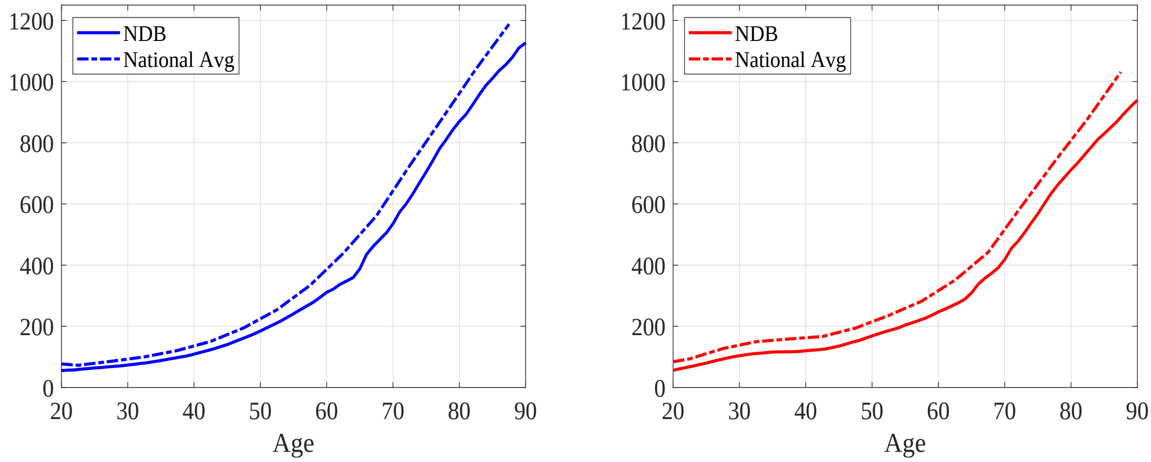


Figure 1: Annual Medical Expenditures by Age and Gender (in 1,000 JPY)

Males spend more on average than females at all ages above 45. As we discuss, however, in the next section, average lifetime expenditures are higher for females because they live longer than males on average. To demonstrate the comprehensiveness of the NDB, Figure 2 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.[5] As discussed

[5]The data is from the Estimates of National Medical Care Expenditure in 2015.

in section 2.1, there are differences in covered items between the NDBs and the national medical expenses, which explains the difference in the two profiles.



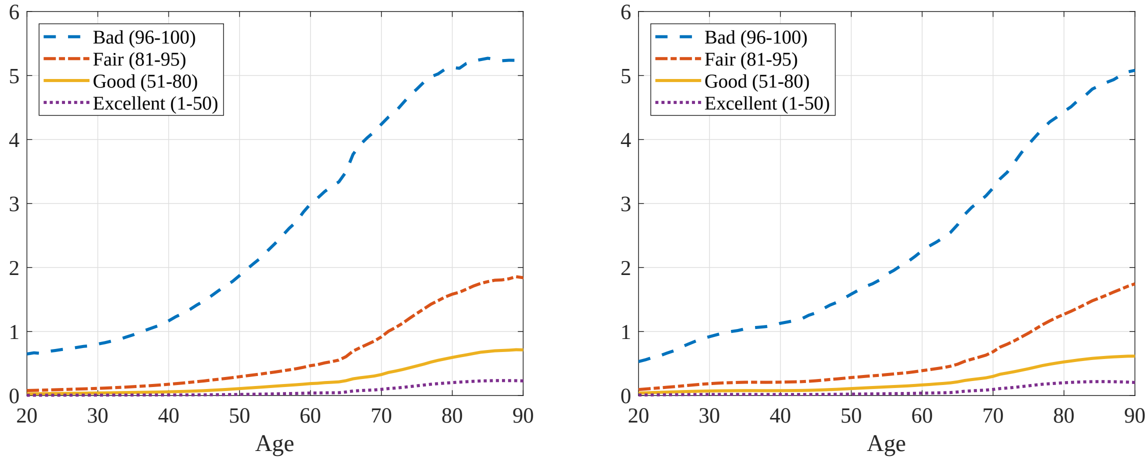
(a) Male (b) Female

Figure 2: Annual Medical Expenditures: NDB and National Data (in 1,000 JPY)

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 percentile 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 annual age 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 3 shows medical expenditures by health status over the life-cycle for males and females. 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 males and females, while the top 5% spend as much as 1 million yen if they are above their mid-30s. Expenditures of the top 5% reach 3.5 million by age 65 for males and exceed 5 million in their late 70s. For females, expenditures of the top 5% are more moderate than males, but they reach 2.7 million by 65 and exceed 5 million in the late 80s. The large heterogeneity suggests that average expenditure profiles shown in Figure 1 do not satisfactorily capture medical expenditure risks faced by individuals and that one needs to take into account heterogeneity in evaluating risks. They are also likely to be important factors in accounting for savings and consumption behavior of individuals over the life-cycle as well as in evaluating the roles of publicly-provided health insurance.

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) Male (b) Female

Figure 3: Annual Medical Expenditures by Health Status (in JPY mm)

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

2.3 Persistence of Medical Expenditures

In the previous section, we confirmed that there is a large difference in medical expenditures across individuals of the same age and gender. We now show that medical expenditures are very 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. Table 1 displays the transition matrices of individuals of age 50 as an example, and shows the distribution of their health status in the next period when they turn 51, conditional on their current health status, ranging from excellent to bad.

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

	Health status in $t+1$					
Male	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 $t+1$					
Female	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

Health status is highly persistent and individuals of any current health status and gender will 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 rises to 2.3% and 6.9% if his current health status deteriorates to good or fair. If the current health status is bad already, the probability that he will remain in bad health is 51.2%.

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}, conditional on bad health status in the current period, h_t. 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 and 0.72 for males and females, respectively, 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).

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

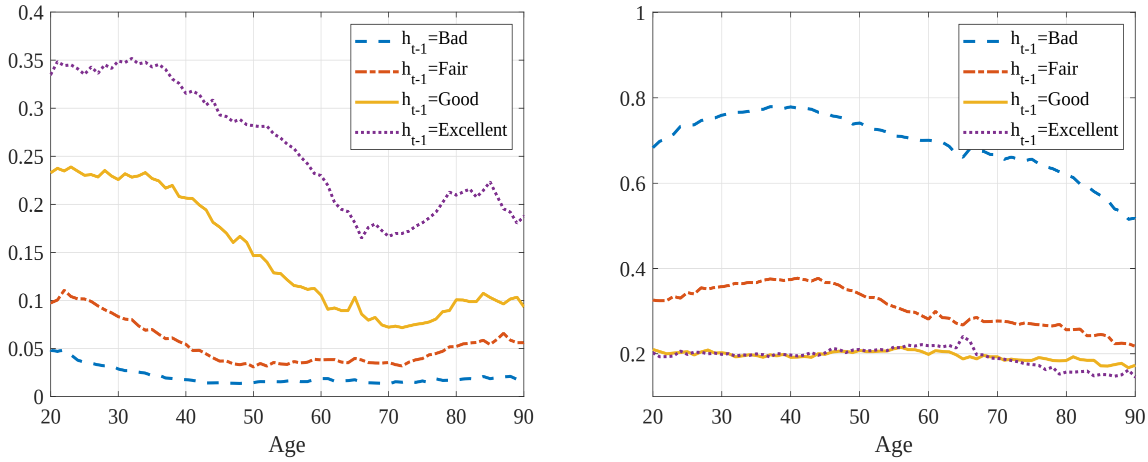
	Health status in $t+1$					
Male	Excellent	Good	Fair	Bad	Death	Total
M(1)	0.073	0.121	0.277	0.512	0.017	1.000
M(2) by h_{t-1}						
Excellent	0.282	0.256	0.234	0.210	0.019	1.000
Good	0.146	0.327	0.306	0.208	0.013	1.000
Fair	0.031	0.124	0.496	0.340	0.009	1.000
Bad	0.015	0.030	0.193	0.741	0.021	1.000

	Health status in $t+1$					
Female	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

Table 2 is for individuals of a particular age, but the same historical dependency of transition probabilities is observed for all age groups. Figure 4 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 shown in Figure 4a, 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 4b 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.[6]

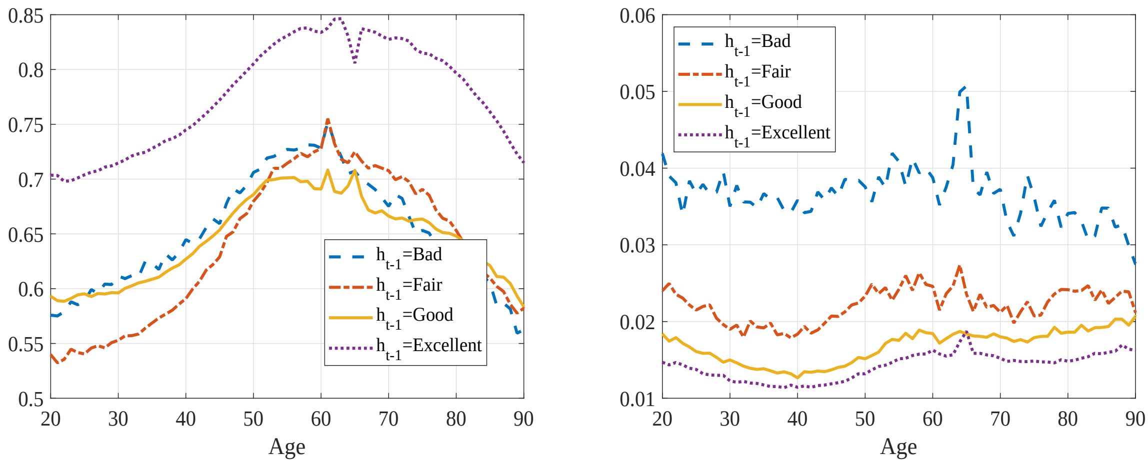
[6]Note that probabilities of the four health status do not sum to 1 since there are individuals who die at $t+1$.



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

Figure 4: 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 5 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 5: Transition Probabilities of Health Status *from Excellent Health* at t

Many studies that incorporate medical expenditure risks calibrate the process based on the medical 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 and verify the importance of taking into account health dependence of mortality risks.

Figure 6 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 section 2.1, 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.

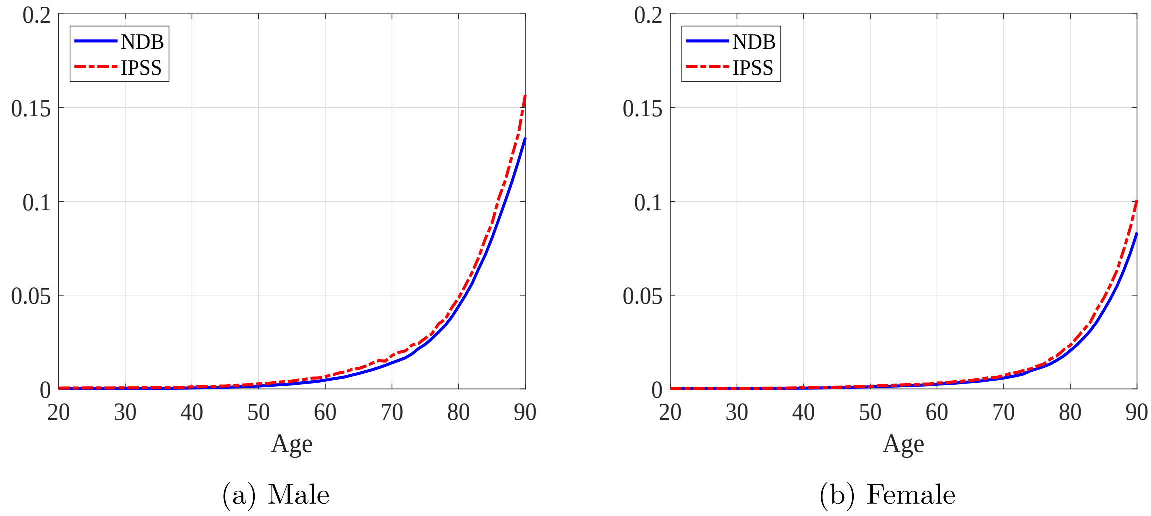
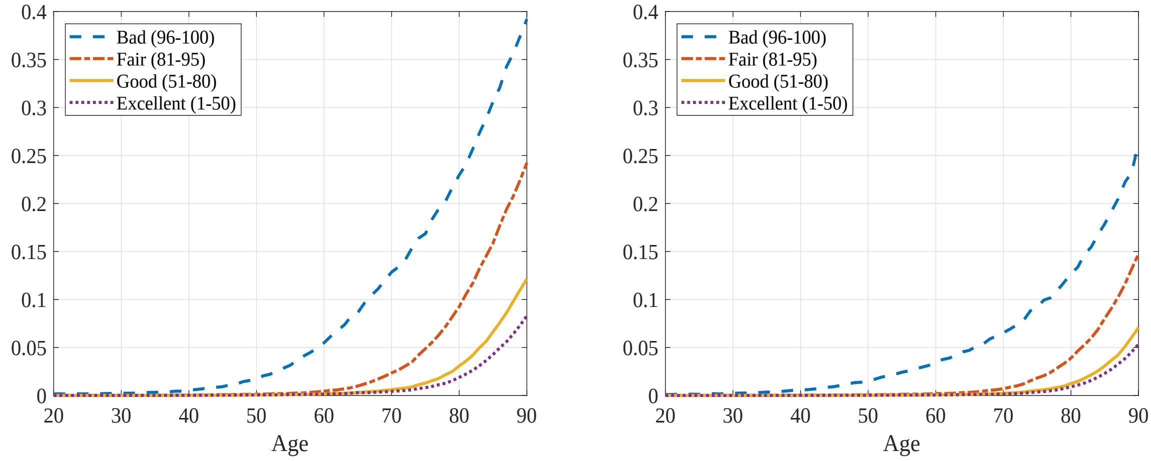


Figure 6: Death Probabilities of the NDB and the IPSS

Survival probabilities differ not only by age but also by health status as shown in Figure 7, which shows death probabilities by individuals' current health status. Those in bad health face a much higher probability of death across age groups and genders. As we discuss in section 2.4, health dependence of mortality risks is an important factor in quantifying distribution of lifetime medical expenditures.



(a) Male

(b) Female

Figure 7: Death Probabilities by Health Status

2.4 Lifetime Medical Expenditures

In sections 2.2 and 2.3, 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 of health status and expenditures that we computed for each gender, age, and health status, we simulate life-cycle 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 in computing one's own lifetime expenditures, the age range that we use in the model analysis in section 3.

Expenditures incurred during the final year of life, which tend to be very high with intensive medical treatments are not included in the survivors' expenditure levels reported in the previous sections, for example, in Figure 1. Figure 8 shows average expenditures during the year of death by age and these are taken into account when computing lifetime medical expenditures in this section.

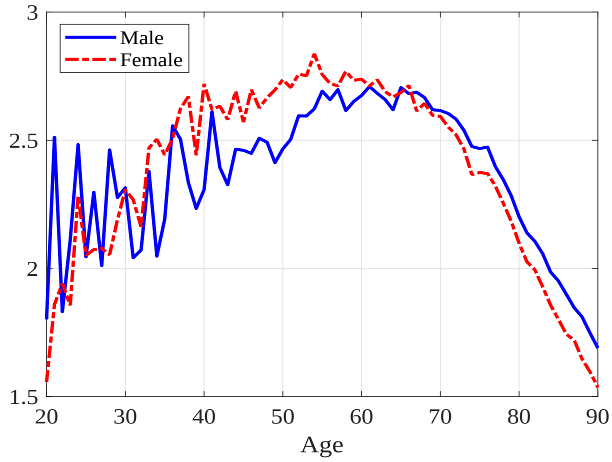


Figure 8: Medical Expenditures in the Year of Death (in million JPY)

As reported in Table 3 total expenditures stand at 20.5 and 21.4 million yen for males and females, respectively. As shown in Figure 1, average expenditures are higher for males than females, except for several years in the late 20s and early 30s, but the average lifetime expenditures are higher for females than males because of a longer life expectancy.

Higher moments are also reported in Table 3 and there is a significant heterogeneity in the total medical expenditures one would face over the life-cycle, which is not surprising given persistent and large expenditure shocks that we studied in section 2.3. The distribution has positive skewness given the large right tail. As we saw in sections 2.2 and 2.3, 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.

Table 3: Lifetime Medical Expenditures and Moments: Baseline M(2)

	Male	Female
Mean	20.5	21.4
Std. dev.	10.9	10.2
Coeff. of var.	0.53	0.48
Skewness	1.49	1.43

Note: Mean and standard deviation are in million JPY.

As mentioned above, in many applications and economic models with medical expenditures, authors use a simple deterministic path of age-dependent expenditures, or use panel data such as the Medical Expenditure Panel Survey (MEPS) to calibrate a first-order Markov process of medical expenditures. In Table 4, we compare the moments across alternative specifications of medical expenditures based on the NDB. For the M(1) process, for example, we ignore information about health status in the previous period and use the transition matrices that are also reported above in Table 1 and expenditures in each health grid.

Standard deviations of lifetime expenditures of males, as shown in the second row of the table, decline from 10.9 million yen when we assume an M(2) process 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 negative in a deterministic case.

Table 4: Moments under Alternative Expenditure Processes

	Male				Female			
	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 million JPY.

To quantify and visualize the tails of the distribution, Table 5 reports distribution over a fixed range of lifetime medical expenditures under the four specifications and Figure 9 shows probability distribution.[7]

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.

[7] 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.

Table 5: Distribution of Lifetime Medical Expenditures (%)

	Male				Female			
	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

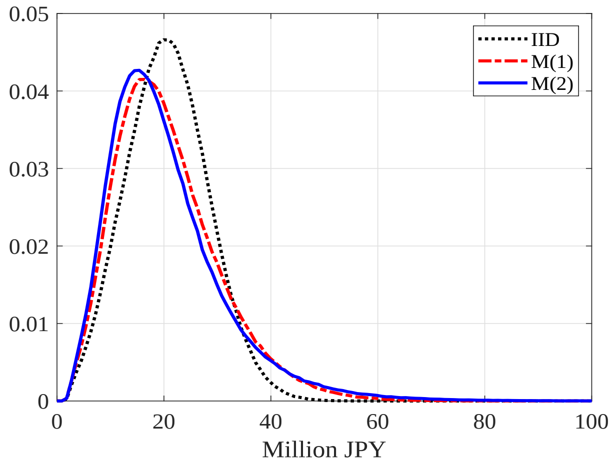


Figure 9: Probability distribution of Lifetime Medical Expenditures under Alternative Processes (Males)

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

Finally, we examine roles of health dependence of mortality risks. As shown in Figure 7, death probabilities vary 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 6 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 males and females, respectively.

Table 6: Health-dependence of Mortality Risks

	Male		Female	
	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 million 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 males and females, 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 6, there would be many more individuals in the lower and upper tails of the distribution under the experiment, as also visualized in Figure 10.

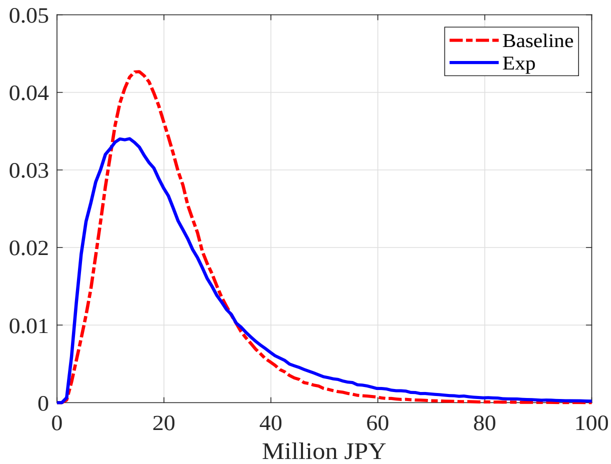


Figure 10: Probability Distribution of Lifetime Medical Expenditures (Males): Health-dependence of Mortality Risks

Note: Exp. is a counterfactual experiment in which death probabilities are independent of health status. The horizontal axis indicates simulated lifetime medical expenditures in million 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 persistence beyond a simple Markov process and dependence of mortality risks on health status. Accurate evaluation of risks is also important in accounting for roles of publicly-provided health insurance and other redistributive programs, as well as private insurance through precautionary savings and other possible market arrangements.[8]

In the next section, we build an overlapping generations 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 evaluate effects of medical expenditures on households' consumption and savings. We also 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 and calibrate a simple partial equilibrium life-cycle model, which is simulated with the medical expenditure processes described in section 2. We quantify effects of medical expenditure risks on individuals' life-cycle consumption and savings, and evaluate roles of health insurance as they interact with households' consumption-saving decisions and other fiscal parameters.

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 $g = \{m, f\}$.[9] 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.

[8] Online appendix (Fukai et al. 2021) includes the analysis of lifetime out-of-pocket expenditures, taking into account details of health insurance coverage.

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

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. 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 and assume that medical expenditures and survival probabilities depend on health status.

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.[10]

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 $u(c/\eta)$ a period utility function, where η is an equivalence scale in consumption, which varies by the marital status of individuals. 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 depends on age j, gender g, skill s, and marital status ζ. Earnings are denoted simply as y, rather than $y_{j,g,s,\zeta}$, to simplify the notation. 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,

[10]There can be other possible channels through which health affects individuals. See, for example, Capatina (2015), Capatina et al. (2020), and De Nardi et al. (2018). In section 5, we also consider scenarios where health status and earnings are correlated.

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. 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. They pay the remainder. Out-of-pocket expenditures paid by an 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 denoted 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.[11]

[11]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

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.[12] Disposable assets $\underline{a}$ of singles are denoted as:

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

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

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 S: 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.

---

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.

[12] We follow the strategy of existing papers such as Hubbard et al. (1995), French and Jones (2011), Kitao (2014) and Fan et al. (2018), to model a means-tested transfer program in a parsimonious way.

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

subject to

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

An individual of age j and gender g survives until the next period with probability $\pi_{j,g,\mathbf{h}}$. Conditional on surviving, the 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.[13]

Value Function of Married Couples M: The state vector of a married couple consists of five 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.

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

subject to

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

[13]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.

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

Two individuals in a married couple jointly make savings and consumption decisions to maximize 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 W: The state vector of a widow or a widower is the same as that of a single individual.

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

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 7 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.[14] 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, $\nu_{s,s'=s} = 0.7$ and the probability that the spouse is of a different education level is 0.3, $\nu_{s,s'\neq s} = 0.3$.[15]

[14]The rate of first marriage is very low among those aged 65 and above, standing at 0.017% and 0.013% for males and females 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)

[15]The probability is based on the average of male's and female's probabilities of marrying a spouse of the same education type.

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; (1) good, (2) fair, (3) bad, and (4) 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. In section 5, we also simulate the same model assuming alternative processes including M(1) and deterministic processes.

Preferences: The equivalence scale of consumption η is set at 1.7 for married couples and 1.0 for single and widowed individuals, based on the OECD equivalence scale.[16] 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 given as

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

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 asset level corresponding to that estimated in De Nardi et al. (2010), which is 1.4 times median earnings. The parameter ϕ is set so the marginal propensity to bequeath is at 0.8, in the range of values used in the literature, as surveyed in Pashchenko (2013). Parameter values are reported in Table 7.

Endowment: Earnings of an individual, $y = y_{j,g,s,\zeta}$, differ by age, gender, skill, and marital status, and they are computed using the Employment Status Survey (ESS).[17]

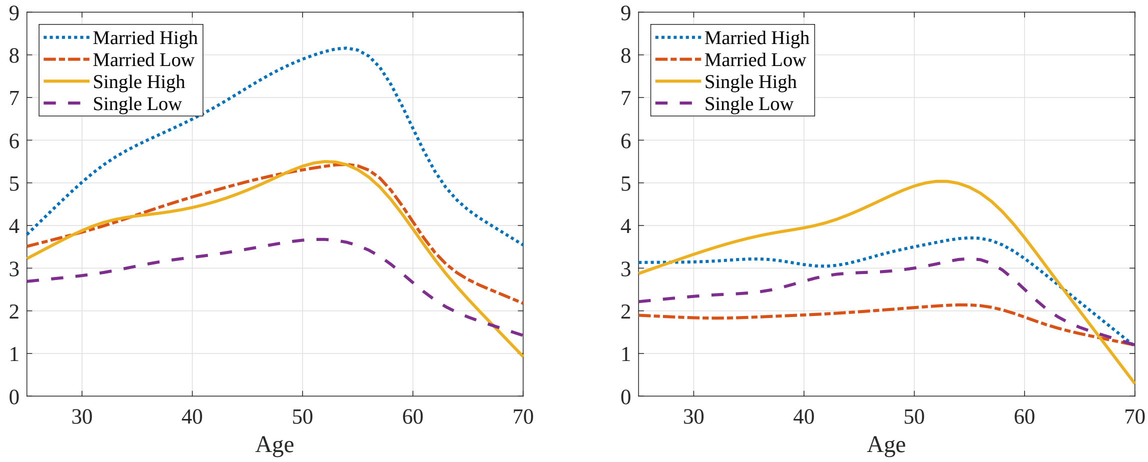
Figure 11 shows life-cycle profiles of earnings by gender, age, marital status, and skill. Earnings $y_{j,g,s,\zeta}$ represent the average earnings of all individuals of a particular group, and therefore they are obtained by multiplying earnings by participation rates, which are shown in Figure 12.

The figures reveal that there is a large difference in both earnings and participation rates across genders, marital status, and skill levels. Gender difference in earnings is well

[16] There is a range of equivalence scales used in the literature. See Atkinson et al. (1995) for a review.

[17] 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).

documented in papers including Kitao and Mikoshiba (2020), and it can be confirmed by comparing Figures 11a and 11b. What is notable is that the ordering of the four profiles is very different between males and females. High-skilled married males 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, married workers earn more among males, but it is single workers who earn more among females.



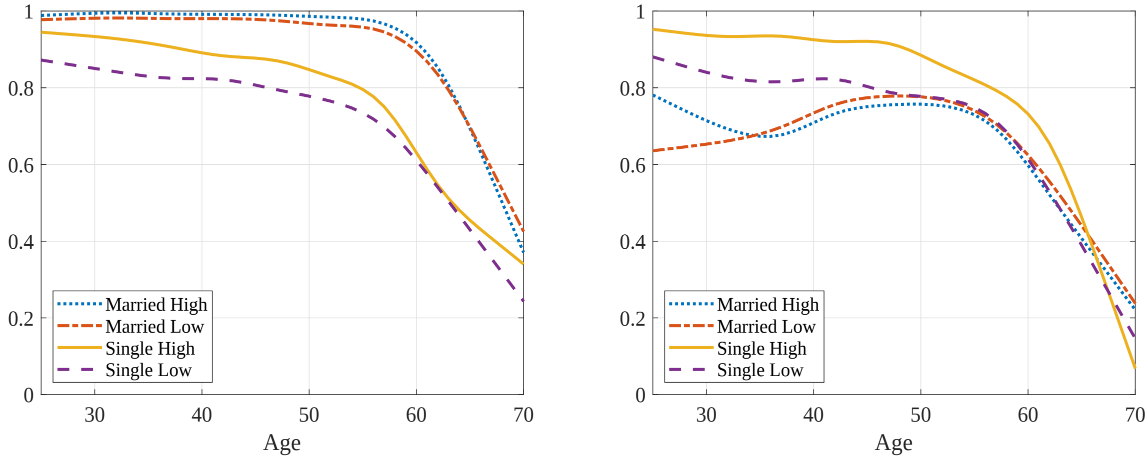
(a) Male (b) Female

Figure 11: Earnings of Workers by Age, Marital Status, and Skill (in million JPY)

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 12, patterns of participation rates are also very different between males and females. Nearly all married males work at least until they reach their mid-50s and participation rates of singles are much lower. It is the opposite among females, and married females participate less often than single females. 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 females.

Although our model does not 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.



(a) Male

(b) Female

Figure 12: 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.

Out-of-pocket medical expenditures are capped above 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.[18] 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 and plays an important role as we study in section 5.

[18]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 (in Japanese)

Long-term care expenditures cover expenditures for individuals aged 40 and above. Expenditure data are obtained from the Statistics of Long-term Care Benefit Expenditures of the Ministry of Health, Labour and Welfare (MHLW).[19] 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 13 shows the life-cycle profile of gross long-term care expenditures. Publicly-provided long-term care insurance covers 90% of expenditures and copayment rates θ_j are set to 10% for all ages.

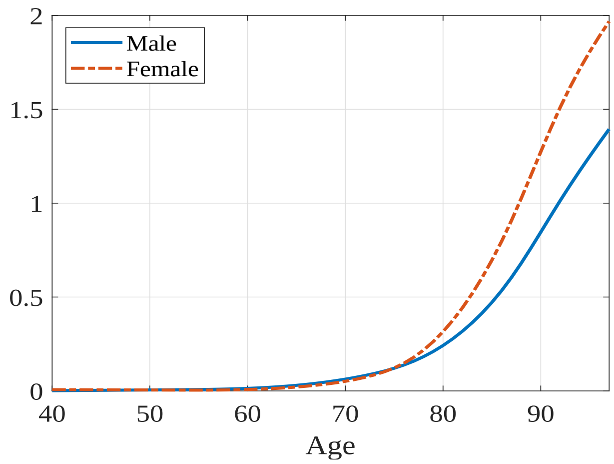


Figure 13: Annual Long-term Care Expenditures by Age and Gender (in million JPY)

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).

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.[20]

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, τ^c, τ^l, and τ^a, respectively. We set the consumption tax rate at 8%, based on

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

[20]The amount is set to lie in the range of average payments of the Public Assistance (*seikatsu hogo*) program by the family size. The monthly payment is multiplied by 12. For details of the program, see for example
https://www.mhlw.go.jp/content/12002000/000488808.pdf (in Japanese).

the tax rate in 2015. The labor and capital income tax rates are set at 30% and 35%, respectively, in line with estimates of effective income tax rates in the literature.[21]

Table 7: Parameters of the Model: A Simple Partial Eq.

Parameter	Description	Value/Source
Demographics		
J^R	Retirement age	65 years
J	Maximum age	97 years
$s_{j,g,h}$	Survival probability	NDB and IPSS 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	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	MLHW 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%

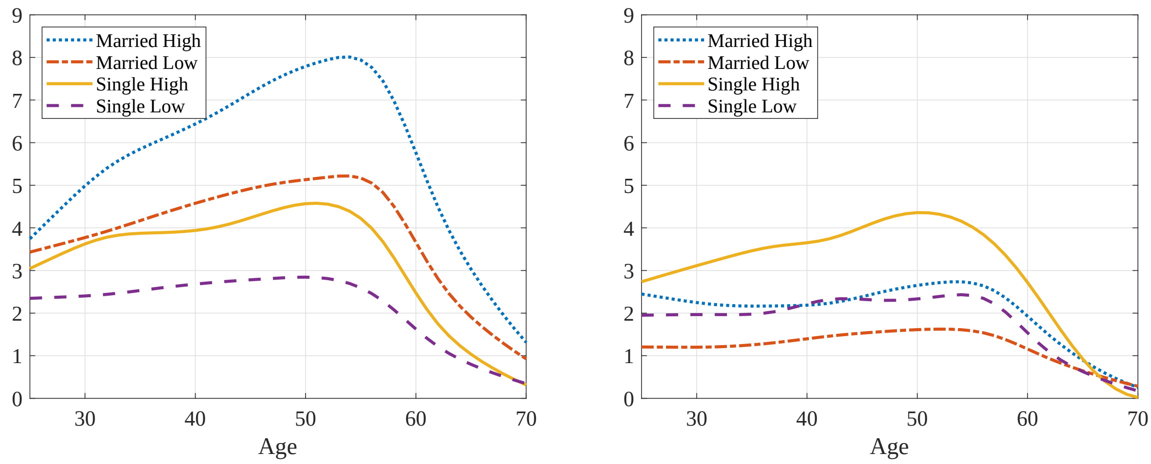
[21]See, for example, Gunji and Miyazaki (2011).

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 individuals would face without insurance. We then consider alternative specifications of medical expenditure risks.

5.1 Baseline Model

As explained in section 4, we assume that average earnings of an individual depend on his or her age, skill (education), and marital status. Based on participation rates and working individuals' earnings data from the ESS, we compute $y_{j,g,s,\zeta}$, age-earnings profiles of individuals by gender, skill and marital status, as shown in Figure 14.



(a) Male (b) Female

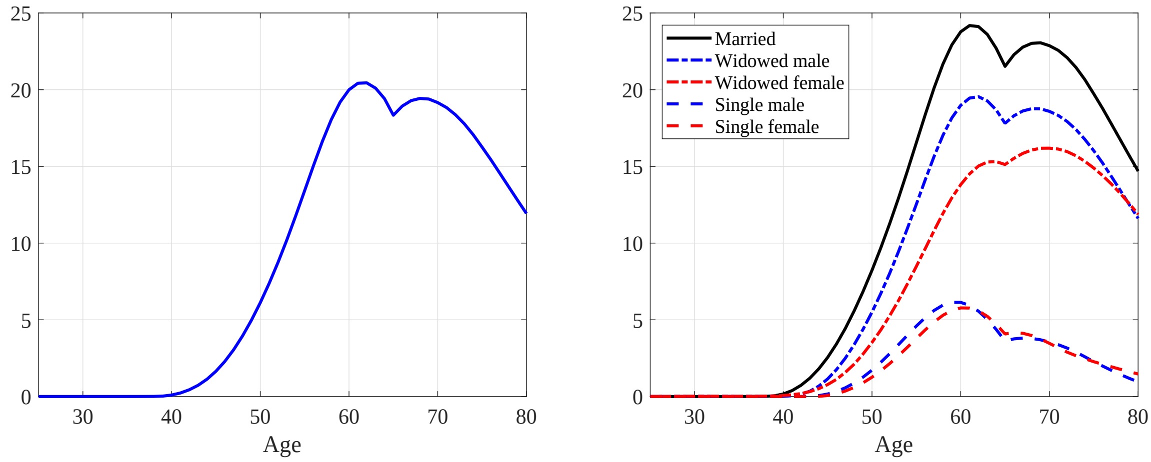
Figure 14: Average Earnings of All Individuals by Age, Gender, Marital Status, and Skill (in million JPY) (ESS Data Used in the Model)

Note: Figures show the life-cycle profile of average annual earnings of all individuals by gender, age, marital status, and skill. The married include 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).

Assets are owned by households in the model, that consist of either one or two individuals. Figure 15 shows life-cycle profiles of assets for all households and for each marital status and gender. Household assets peak at around age 60 and slowly decline thereafter.[22] There is a large difference in the level of assets not only across different ages,

[22]Note that a discrete change in assets at age 65 is due to our assumption that individuals start to

but also across different types of households. Married households own more than singles on average, perhaps not surprisingly. Among singles and widows/widowers, females own fewer assets than males though the difference shrinks as they age.



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

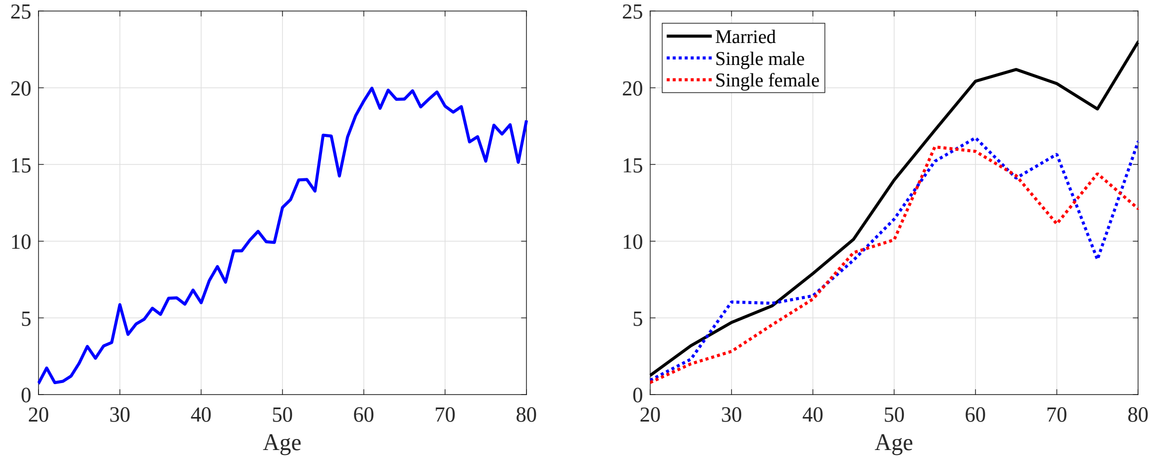
Figure 15: Average Assets of Households by Age and Marital Status (in million JPY)

For comparison, Figure 16 plots average asset profiles of households from the National Survey of Family Income and Expenditure (NSFIE) data in 2014.[23] Note that "single" households in the data include both never-married singles and widowed individuals, which 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.[24]

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.

[23]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.

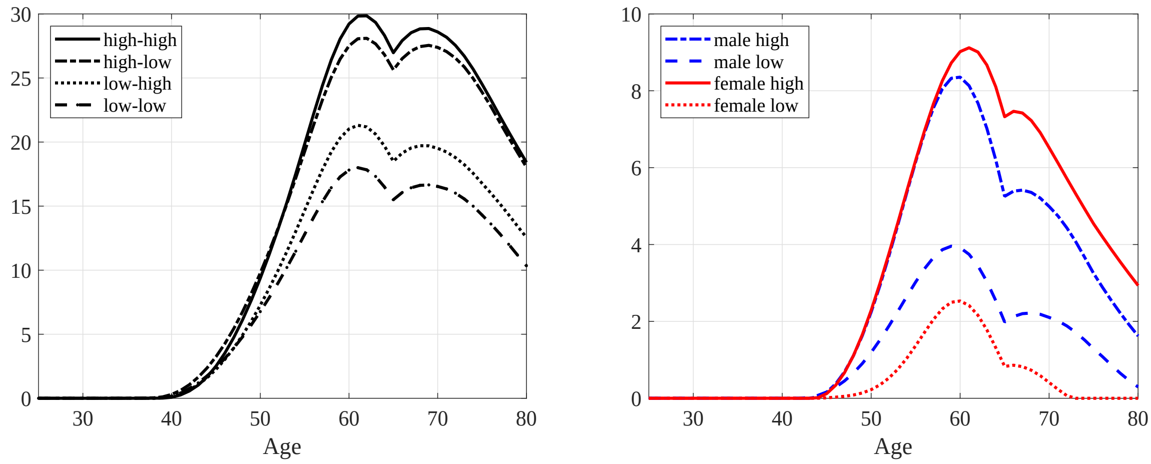
[24]The paper focuses on effects of medical expenditure risks and life-cycle saving motives and abstracts from other risks such as, for example, labor productivity and unemployment risks, which likely would contribute to more savings at younger ages.



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

Figure 16: Average Assets of Households (in million JPY): NSFIE Data (2014)

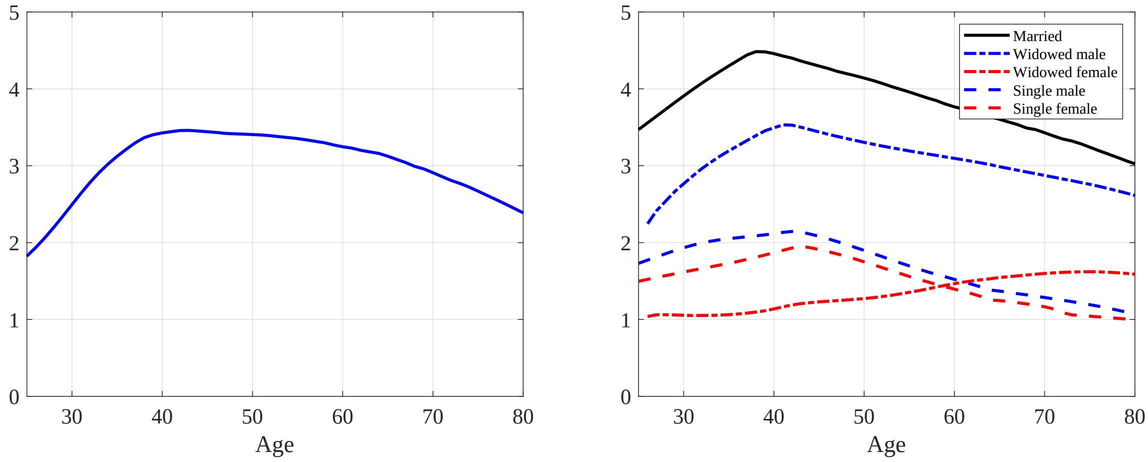
In our model, assets also differ by skills and health status within a group of the same gender and marital status, as shown in Figure 17. Figure 17a shows asset profiles of married couples by combination of male and female skill levels, where high-low, for example, indicates a couple comprising a high-skilled male and a low-skilled female. Among singles, high-skilled individuals own more than the low-skilled for each gender, as shown in Figure 17b. High-skilled females save more than high-skilled males although their earnings are not very different from their male counterparts on average as shown in Figure 14, since females live longer than males and have stronger life-cycle saving motives. Low-skilled females, however, save much less than low-skilled males as the difference in earnings dominates the difference in longevity.



(a) Married (b) Singles

Figure 17: Average Assets of Households by Age, Marital Status and Skills (in million JPY)

Figure 18 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 females increases in age and shows no decline, since those who become widowed later in their lives succeed accumulated wealth of married couples.



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

Figure 18: Average Consumption of Households by Age and Marital Status (in million JPY)

Consumption and asset levels also differ by health status. Figure 19 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. For example, a profile for a married couple of bad health shows a profile of consumption by a husband and a wife who are both in bad health. In the baseline model, bad health reduces savings through two channels. First, large expenditures reduce disposable income that can be allocated to savings, or lower savings directly if earnings are not even 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. In section 5.2 where we compare the baseline with a scenario of full insurance, we show that both channels are operative in the baseline model.

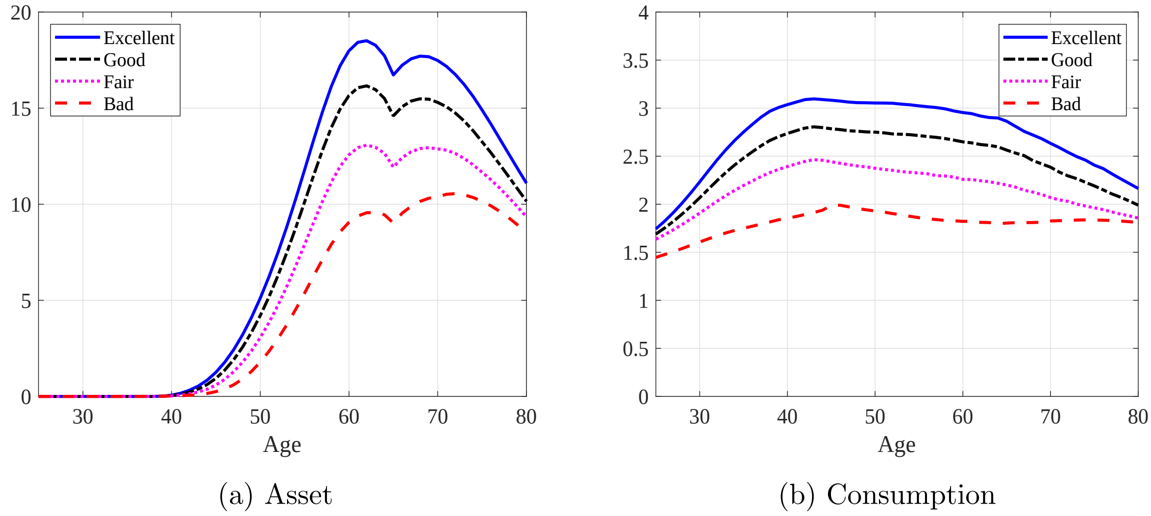


Figure 19: Average Assets and Consumption of Households by Age and Health Status (in million JPY)

5.2 Roles of Health Insurance

Japan's national health insurance system is universal and provides a comprehensive coverage of medical expenditures for every Japanese citizen and resident. 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 roles provided by health insurance and its detailed 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. We then simulate some reforms that are being debated in Japan. Lastly, we consider an alternative scenario, in which earnings depend on health status and evaluate roles of health insurance in such an environment.

Some Extreme Scenarios - No Insurance and Full Insurance: We first simulate two extreme scenarios to highlight roles of health insurance. In the first, we assume that no health insurance is provided and that individuals are responsible for all medical expenditures. In the second, we let individuals be fully insured against any medical expenses and pay none out of pocket. In both scenarios, we first make no adjustment in taxes to isolate effects of medical expenditures and focus on changes caused by different expenditure risks faced by households over the life-cycle. Then, we simulate an economy where 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 8 shows changes in some aggregate variables and welfare. Without health insurance, households would save significantly more. Average savings, or aggregate savings since the population is unchanged, would be almost 40% higher and additional savings are financed by lower consumption, which falls by 10% on average. The rise, however, in savings 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 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. Males and females would experience a welfare loss of a similar magnitude but within each gender group, low-skilled individuals face a slightly larger welfare loss. Full insurance, as shown in the second column of Table 8 would reduce aggregate savings by 3% and lower the number of welfare recipients by 21%.

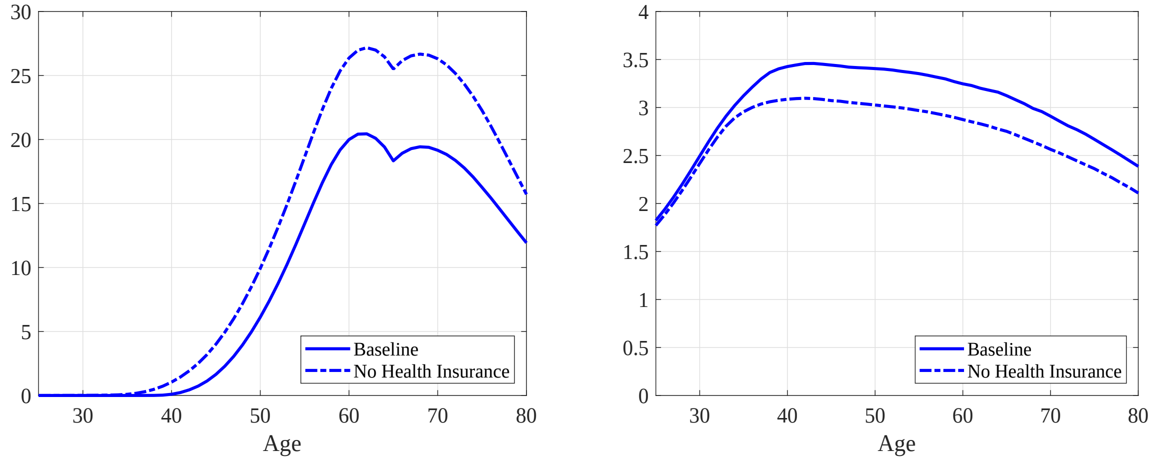
When lump-sum taxes are adjusted to balance the government budget, there would be an annual lump-sum subsidy of 290,000 yen to each individual when health insurance is removed. Tax compensation would further raise saving capacity of households and aggregate savings will rise by more than 50%, as shown in the third column of Table 8. Full insurance would require a lump-sum tax of 58,000 yen collected from each individual and reduce aggregate savings by approximately 3%.

Table 8: Extreme Scenarios: No Health Insurance and Full Insurance (Changes from the Baseline Model)

	No tax change		Tax adjusted	
	No ins.	Full ins.	No ins.	Full ins.
Change in avg. savings	+38.3%	-3.3%	+51.8%	-2.9%
Change in avg. consumption	-10.0%	+2.6%	+3.4%	-0.2%
Transfer recipients	5.78%	1.34%	2.79%	1.64%
	(+239.7%)	(-21.0%)	(+64.1%)	(-3.7%)
Lump-sum tax (JPY)	–	–	-290,000	58,000
Welfare effects				
- All	-10.1%	+2.6%	+4.8%	-0.7%
- Male: low/high	-11.1%/-9.1%	+2.7%/+2.0%	+4.8%/+3.1%	-0.7%/-0.6%
- Female: low/high	-9.9%/-9.5%	+2.9%/+2.1%	+6.1%/+3.5%	-0.9%/-0.6%

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.

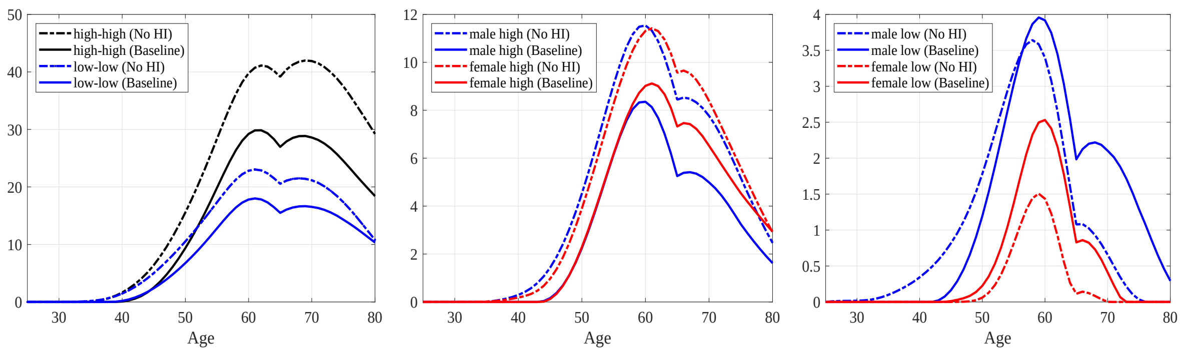
Figure 20 shows changes in life-cycle profiles of savings and consumption averaged across all households. Without health insurance, savings are higher across age groups and consumption is lower. The changes, however, in average profiles mask large heterogeneity in life-cycle savings and consumption across different types of households.



(a) Asset (b) Consumption

Figure 20: Average Assets and Consumption by Age with and without Health Insurance (With No Tax Change) (in million JPY)

Figure 21 shows asset profiles for married and single households and also by skill levels of household members.[25] Married households save more without health insurance and high-skilled couples increase savings by more than low-skilled couples. For singles, high-skilled males and females save more, but low skilled females save much less without health insurance and so do low-skilled males after their mid-50s.

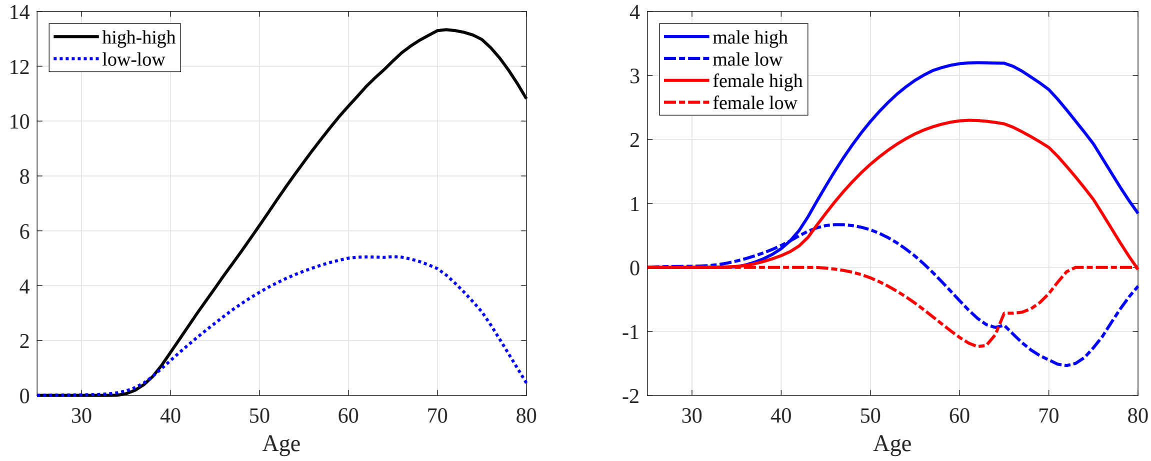


(a) Married (b) Single (High-skilled) (c) Single (Low-skilled)

Figure 21: Average Assets by Marital Status and Skills with and without Health Insurance (With No Tax Change) (in million JPY)

[25] 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.

To highlight the change in savings for different groups of households, Figure 22 shows the difference in savings between the baseline and the no-insurance economy, by subtracting savings under the baseline from that of the no-insurance economy. While most households accumulate more precautionary wealth in preparation for large health expenditure shocks, some households, in particular low-skilled and single females, save less. Their earnings are so low that they do not have enough to save, especially after facing large expenditure shocks. A larger number of male and female single households exhaust their savings earlier than in the baseline and start to receive welfare transfers at an earlier age.



(a) Married

(b) Single (High and Low-skilled)

Figure 22: Difference in Average Assets by Marital Status and Skills between those with and without Health Insurance (With No Tax Change) (in million JPY)

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 23 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 top panels show the levels and the bottom panels show the difference in assets and consumption between the two health status.

A large rise in the aggregate savings reported in Table 8 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 23a. Figure 23b shows that a bad health shock will not only prevent individuals from accumulating enough savings but also have them decrease consumption by more than healthier individuals.

The bottom panels of Figure 23 highlight the difference in the effects of bad health in the two economies with and without health insurance. They also include the difference in an economy with full insurance. As discussed in section 5.1, bad health induces low savings not only through the direct effect of large expenditures but also through lower life-cycle saving motives because of higher mortality risks. Lines for full insurance cases displayed in Figures 23c show the magnitude of the latter when effects of the former are eliminated by insuring away medical expenditure shocks. 23d shows that consumption is also lower for those in bad health. Although life-expectancy of those in bad health is short, mortality risks remain and lower savings enables them to consume less than healthier individuals even without expenditure risks.[26]

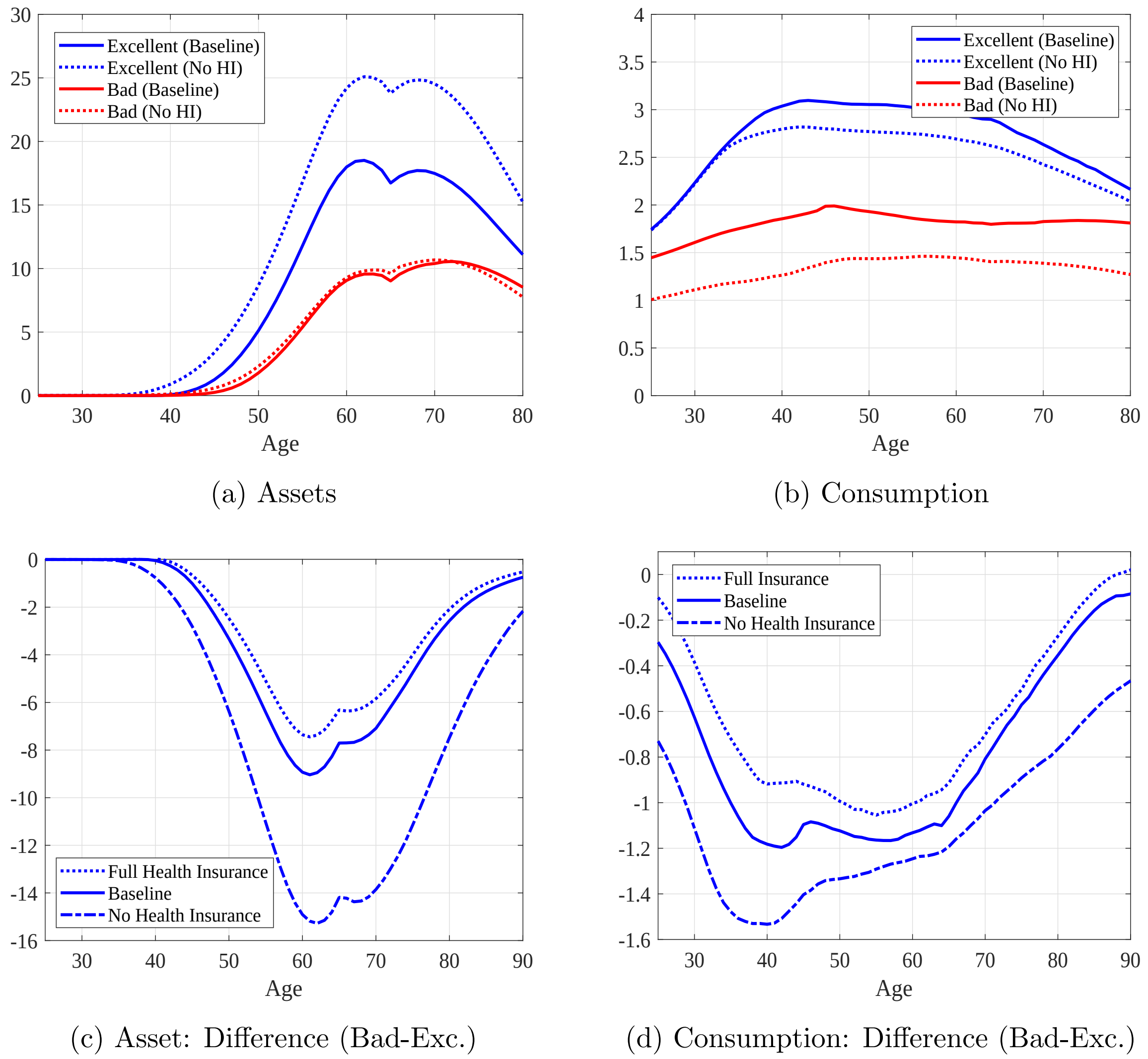


Figure 23: Average Assets and Consumption by Health Status with and without Health Insurance: Levels and Differences (in million JPY)

Note: The top panels show average levels of assets and consumption by health status. The bottom panels show the difference in the top panel after subtracting assets and consumption of households in excellent health from those of households in bad health.

[26]Figures when lump-sum taxes are adjusted are not displayed to save space, but they show the same pattern.

Table 9 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. Assets of those in bad health in the baseline are about 50% of assets of the healthiest 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 with a smaller difference, who earn more, are better insured against expenditure shocks.

Table 9: Average Assets by Health Status with and without Health Insurance (in 1,000 JPY)

		Married		Single Male		Single Female	
	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%

High-cost medical expense (HCME) benefits protect individuals from very high medical expenses, with progressive generosity for low income households. Table 10 shows changes in some variables when we assume that the HCME benefits do not exist. Given higher expenditure risks, households increase savings, whether reduced insurance expenditures are paid back as a lump-sum transfer or not. 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 males and females. With a budget balancing tax transfer of 9,000 yen, although in a relatively small amount, average consumption slightly increases and welfare effects are slightly positive. This is mainly driven by additional consumption of young households with low assets.

Table 10: 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%
- Male: low/high	-0.30%/-0.23%	+0.22%/+0.15%
- Female: low/high	-0.20%/-0.20%	+0.36%/+0.21%

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 copayment rates of health insurance, for example, may induce more precautionary and life-cycle savings, it may make more individuals deplete assets and be eligible to receive welfare transfers, thus offsetting lower expenditures from higher insurance copayments with higher expenditures for another program. 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.

Table 11 shows the simulation results when we assume different degrees of generosity of the welfare program. More precisely, we assume that the consumption floor $\underline{c}$, the minimum consumption level guaranteed by the program, is either reduced or raised by 50% from the baseline level. We assume the same medical expenditure process and health insurance as in the baseline model first, but will consider different scenarios later.

As the first row of Table 11 shows, 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 11: Alternative Generosity of Welfare Programs

	No tax change		Tax adjusted	
Cons. Floor $\underline{c}$	50% down	50% up	50% down	50% up
Avg. savings	+8.1%	-19.2%	+7.7%	-20.7%
Avg. consumption	-0.3%	+1.2%	+0.2%	-0.8%
Transfer Recipients	0.02%	6.22%	0.02%	7.07%
	(-98.6%)	(+265.8%)	(-98.8%)	(+315.8%)
Lump-sum tax (JPY)	–	–	-10,000	44,000
Welfare effects				
- All	-0.66%	+1.65%	-0.05%	-0.66%
- Male: low/high	-0.52%/-0.18%	+1.89%/+0.59%	+0.11%/+0.27%	-0.52%/-1.25%
- Female: low/high	-1.22%/-0.12%	+2.44%/+0.57%	-0.51%/+0.36%	-0.18%/-1.38%

We now consider the same extreme scenario of removing health insurance in economies with these two different welfare programs. Results are summarized in Table 12, 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 a regime.

In the baseline, as also reproduced in the first column of Table 12, households increase savings by 38%. 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 higher in such an economy as shown in the bottom section of the table.

Table 12: 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% $\rightarrow$ 5.78%	0.02% $\rightarrow$ 1.17%	6.22% $\rightarrow$ 14.52%
Welfare effects			
- All	-10.1%	-14.6%	-6.7%
- Male: low/high	-11.1%/-9.1%	-15.5%/-11.2%	-6.6%/-7.4%
- Female: 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.

Reform to Raise 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 30% and another reform to raise copayment rates of all ages to 40%.

Table 13 summarizes results in cases with and without tax adjustment. Qualitative results are as expected and consistent with the extreme scenarios that we investigated above. Higher copayments increase precautionary savings against higher expenditure risks as well as more retirement savings because individuals expect to spend more as they age and in retirement, when copayment rates rise from 10 or 20% in the baseline.

Welfare effects are negative for all categories without tax changes. When a surplus from higher copayments is paid back, individuals will receive 21,000 or 39,000 yen annually in each scenario and welfare effects change the sign and 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.

The bottom rows of the table show how medical expenditures are paid in each scenario. In the baseline model, 16.2% of total expenditures are paid by households as out-of-pocket expenses and the rest, 83.8%, are paid by health insurance and the government. The households' share will rise to 21% and 26% under the two experiments.

Table 13: Raising Copayment Rates to 30% and 40%

	No tax change		Tax adjusted	
Copay. rates	30%	40%	30%	40%
Avg. savings	+5.5%	+6.9%	+5.4%	+6.8%
Avg. consumption	-0.7%	-1.5%	+0.3%	+0.4%
Transfer recipients	1.88%	2.00%	1.77%	1.78%
	(+10.3%)	(+17.4%)	(+3.8%)	(+4.7%)
Lump-sum tax (JPY)	–	–	-21,000	-39,000
Welfare effects				
- All	-0.45%	-1.30%	+0.70%	+0.86%
- Male: low/high	-0.53%/-0.45%	-1.38%/-1.10%	+0.67%/+0.45%	+0.88%/+0.59%
- Female: low/high	-0.39%/-0.47%	-1.39%/-1.18%	+0.93%/+0.49%	+1.08%/+0.61%
Med. paid by				
- Households	21.4%	26.3%	21.4%	26.3%
- Government	78.6%	73.7%	78.6%	73.7%
(HCME)	(8.3%)	(13.3%)	(8.3%)	(13.3%)

5.3 Alternative Specification of Medical Expenditure Risks

In this section, we simulate the model under alternative specification of medical expenditure processes and study how a choice of a different model specification will affect households life-cycle behavior and the evaluation of health insurance.

Table 14 shows changes in average savings, consumption and transfer recipients when we assume the first-order Markov process of medical expenditures, M(1), or a deterministic process. In the latter, 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.

When persistence of medical expenditures is lower under M(1) and deterministic processes, average savings are higher than in the baseline model, although the difference is very small. Transfer recipients are slightly higher under the two scenarios. Under the M(2) process, bad health status is more persistent, and the shocks are likely to reduce assets 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 means-tested welfare program and HCME. While some households increase savings, others who expect to run down assets and be eligible for the mean-tested transfers would have weak incentives save. Therefore, a sign of the net effect under an alternative specification would be ambiguous. Our results that medical expenditure risks do not have large effects on average savings while the expected levels of high expenditures at old ages matter is consistent with findings of De Nardi et al. (2010) and Hubbard et al. (1995).

Table 14: Alternative Medical Expenditure Processes

	M(1)	Deterministic
Avg. Savings	+0.18%	+0.87%
Avg. Consumption	-0.02%	-0.33%
Transfer Recipients	1.71%	1.76%
	(+0.8%)	(+3.7%)

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 three specifications and the results are summarized in Table 15. Comparison is relative to a baseline 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 three specifications. Savings increase by 38 to 39% and consumption falls by 10 to 11%. Welfare effects are of a similar magnitude, though the welfare loss is smaller under a deterministic case.

Results suggest that what drives average life-cycle savings and consumption is the average life-cycle profile and expected level of medical expenditures. This does not, however, imply that the risks do not matter much at an individual level.

Table 15: No Insurance under Alternative Medical Expenditure Processes

	Baseline M(2)	M(1)	Deterministic
Avg. Savings	+38.3%	+37.9%	+39.0%
Avg. Consumption	-10.0%	-10.2%	-10.8%
Transfer Recipients	1.70%→5.78%	1.71%→5.78%	1.76%→5.28%
Welfare Effects			
- all	-10.1%	-10.0%	-9.2%
- Male: low/high	-11.1%/-9.1%	-11.1%/-9.0%	-10.1%/-8.3%
- Female: low/high	-9.9%/-9.5%	-9.9%/-9.4%	-9.3%/-8.4%

Note: The row "Transfer Recipients" indicates a fraction of the population receiving welfare transfers in each experiment.

In the above experiment with a deterministic process, we assumed everyone faces the same expenditures and there is no heterogeneity in life-cycle expenditures. In Table 16, we compare effects of removing health insurance where people face deterministic but heterogeneous life-cycle medical expenditures. More precisely, we consider four types of health status which will remain unchanged throughout their life-cycle. This is a hypothetical experiment but provides some indication on how an individual faced with an extremely persistent health shocks, from good ones to the worst ones, will fare under alternative health insurance policies.

Those in excellent health will have the least lifetime medical expenditures while those in bad health will face the largest expenditures. In response to a removal of health insurance, savings will rise by more among those with worse health since they need to accumulate more wealth to cover larger expenditures later in their life-cycle. The change, however, is not monotonic and average savings fall by 78% among those in bad health. Many of them lose incentives to save since their expenditures are so large that they are unable to pay them on their own and expect to be on the welfare program. About 50% of them will receive welfare transfers.

Welfare loss of removing health insurance increases as the health status deteriorates. This experiment suggests that although there is not a large difference in savings and consumption on average or at the aggregate level when there is a change in health insurance policy, economic and welfare effects are very heterogeneous across individuals of different health status. Individuals who face persistent bad health shocks suffer from large medical expenditures and they are likely to be on the welfare program without health insurance.

Table 16: No Insurance under Deterministic and Heterogeneous Health Status

	Excellent	Good	Fair	Bad
Avg. Savings	+13.2%	+33.6%	+35.6%	-77.5%
Avg. Consumption	-2.4%	-7.6%	-16.2%	-43.2%
Transfer Recipients	1.46%→1.89%	1.64%→3.81%	2.19%→11.1%	4.6%→50.6%
Welfare effects				
- all	-1.7%	-6.4%	-14.7%	-41.4%
- Male: low/high	-1.9%/-1.5%	-6.9%/-5.5%	-15.0%/-14.5%	-42.4%/-44.0%
- Female: low/high	-1.7%/-1.7%	-6.5%/-5.8%	-14.6%/-14.6%	-38.5%/-43.4%

5.4 Alternative Model Specifications

In the baseline model, we assumed that earnings depend on age, gender, skill, and marital status, but not on 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.[27] 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. (2021). Hosseini et al. (2020) 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. (2020) estimated.[28]

Table 17 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 amplified. As shown in the first column, average savings will rise by 2.6% and the number of welfare recipients will increase by about 3%. A rise

[27]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

[28]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. (2020). We thank Kai (Jackie) Zhao for kindly sharing data of their estimates. More details of the computation are given in an online appendix (Fukai et al. 2021).

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.

Table 17: 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%
- Male: low/high	-0.28%/-0.25%	-0.52%/-0.44%
- Female: 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.

6 Conclusion

This paper develops an overlapping generations 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. Lifetime medical expenditures significantly differ across individuals and we show the importance of including not only cross-sectional differences, but also high 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 faced by individuals.

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 females 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. Welfare effects, when redistributing proceeds as a lump-sum transfer and balancing the government budget, are positive on average, but effects are lower or more negative for households with lower income and bad health shocks. We also show that economic and welfare effects of health insurance reform depend on the generosity of welfare transfer programs and do so differently across different households.

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.

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