Financing National Health Insurance: Challenge of Fast Population Aging

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Abstract

This paper studies the impacts of rapid population aging on financing a national health insurance program, as anticipated and observed in many newly industrialized countries (NICs). A dynamic stochastic general equilibrium model with endogenous working and saving decisions is employed to quantify the impacts. Taiwan, which has been implementing its National Health Insurance (NHI) since 1995 and whose old population ratio will double within 20 years, is selected as an example for our analysis. Our results suggest that an additional 16 percent labor income tax will be required in 2050 if the current trend of population aging cannot be improved. Moreover, the impact of medical price inflation is also discussed. We find that the NHI would be unsustainable if the annual growth rate of real medical price is higher than 2 percent, on top of productivity growth. Finally, deferring retirement and financing NHI by different methods are discussed for possible alleviation of tax burden and welfare analysis.

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1 Introduction

Many developed countries have reached a high level of the old-age dependency ratio. As shown in Table 1, they became aging societies before the 1950s and aged societies before the 1980s.[1] As Figure 1 shows, the percentages of the old population (aged 65 and above) in the UK and the USA were around 10 percent in 1960. They will stay around 25 percent in 2056. In contrast, the newly industrialized countries (NICs) just started to encounter population aging, but the speed of aging is expected to be much faster than that in developed countries. Figure 1 also suggests that the percentage of the old population in Asia Tigers will rise sharply and double within 20 years, although the ratio was still below 5 percent in 1960. According to Table 1, the NICs are expected to become aged societies within 3 years (Taiwan and Korea) and super-aged societies before 2026.

Fast population aging raises a number of public issues. One important issue is a rapidly growing demand for health care. Universal health insurance (UHI, a public version is also named as national health insurance, NHI) is widely adopted in developed countries and encouraged by the World Health Organization (2008 annual report) because it provides health care equally. Some NICs recently achieved the universal coverage through public provisions (e.g., Korea, Singapore, and Taiwan). Other NICs are currently pursuing NHI, such as China, Mexico, and Turkey. The NICs are at the beginning of population aging, so the costs of health care are relatively low.

However, the NICs are expected to encounter fast population aging. The ability to finance health care will become a challenge in the near future. As a consequence of population aging, the shrinking working-age population has to shoulder the burden of an increasing demand for health care because the elderly require more medical care. This paper seeks to investigate the impacts of fast population aging on financing an NHI program. In particular, using the projected demographic changes, we focus on how large the increase in the tax would have to be to ensure that the NHI will be sustainable in the long run.

To take into account an individual's responses to changes in demographic and in economic factors, we establish a dynamic general equilibrium framework to perform the analysis. The life cycle is modeled as a stochastic transition. In the model, an individual enters the economy as a young agent and faces both idiosyncratic income and medical expenditure shocks. The individual makes decisions on labor supply, consumption, and savings every period. When the young individual is struck by an aging-retirement shock, she/he retires and is out of the labor market. In addition, the retired individual faces a larger medical expenditure shock. An old individual

[1]According to the definition made by the United Nations, an economy with more than 7 percent of its population aged 65 and above becomes an aging society; one with 14 percent is an aged society; and one with 20 percent is called a super-aged society.

makes consumption and saving decisions every period until she/he is struck by a death shock.[2]

Market incompleteness is considered and individuals cannot fully insure themselves against uncertainties. Precautionary assets will be accumulated for the purpose of self-insurance. The existence of a NHI program also provides a partial insurance against the medical expenditure risk.[3]

To provide a quantitative analysis, Taiwan is selected as a target in our calibration for the following reasons. First, Taiwan has implemented its NHI program, which has been sponsored by the government since 1995. Second, Taiwan is expected to face a rapid population aging in the near future because of its low fertility rate and the large increase in life expectancy. Specifically, Taiwan is expected to become a super-aged society in 2025.[4] Other NICs, such as Korea, Hong Kong, and Singapore, have similar patterns. Thus, Taiwan can be a representative sample for the NICs. Third, Taiwan has good-quality household survey data that enable us to estimate income/medical expenditure shocks. The data have been widely used in the empirical literature to study the influence of the NHI.[5] Taiwan also has sufficient aggregate level data that are required for the calibration.

In the numerical analysis, the benchmark model is calibrated to the Taiwanese economy in the 2000s. We compare the stationary equilibrium of the benchmark economy to two aged economies in which the population projection reported by Taiwanese government is employed.

First, we consider an optimistic scenario that the current trend of population aging will continue until 2030, and then the age structure in 2030 will be maintained.[6] Assuming the average age for starting to work (21) and the retirement age (55) remain unchanged, the old/retired (55+) to young/working (21-54) ratio will become 85.2 percent in the aged economy (compared with 38.9 percent in the benchmark). By investigating the economic features in the stationary equilibrium, we find that the NHI cost per capita will increase by 39 percent in the aged economy, compared with the benchmark. If all other government expenditures and the debt to output ratio are fixed at the benchmark level, an additional 7 percentage points of labor income tax will be required to sustain the NHI program. The second aging scenario, which may be more likely to happen, is that the current demographic trend will continue until 2050. In this scenario, the NHI

[2]Similar life-cycle settings can be found in Castaneda et al. (2003), Heathcote (2005), and Jeske and Kitao (2009).

[3]This is the main feature in Aiyagari-Bewley type models.

[4]As reported in Table 1, the expected time for Taiwan to become an aged society from an aging society is 24 years. In contrast, it took 115 years in France, 46 years in the UK, and is expected to take 73 years in the United States to move to an aged society from an aging society. It is further projected that, in a very short period of time, only 8 years, Taiwan will become a super-aged society.

[5]See, for example, Chou et al. (2003) and Chou et al. (2004).

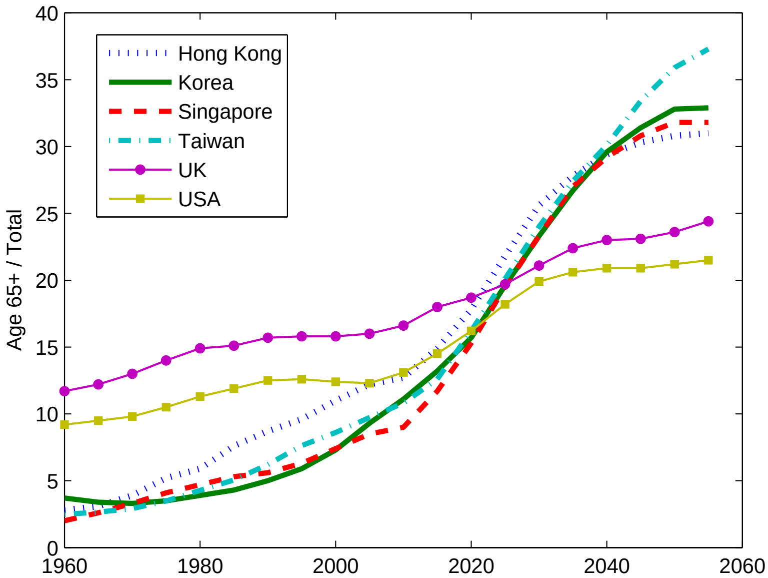
[6]This scenario indicates that the fertility can be significantly improved to stabilize the age structure.

Table 1: Speed of Population Aging

	Starting Year			Years Needed	
	Aging Society (7%)	Aged Society (14%)	Super-aged Society (20%)	Transition of Old-age Population Ratio (65+) 7 → 14%	14 → 20%
Taiwan	1993	2017	2025	24	8
Korea	2000	2017	2026	17	9
Singapore	2000	2016	2023	16	7
Hong Kong	1983	2013	2023	30	10
China	2001	2026	2036	25	10
Japan	1970	1994	2005	24	11
France	1864	1979	2020	115	41
Germany	1932	1972	2009	40	36
Sweden	1887	1972	2015	85	43
United States	1942	2015	2034	73	19
United Kingdom	1929	1975	2026	46	51

Source: Projections of the Population of Taiwan, Republic of China 2008 to 2056, Council for Economic Planning and Development, Executive Yuan, Taiwan.

Figure 1: Ratios of Old Age in Asia Tigers



Source: World Population Prospects: The 2010 Revision, United Nations; Projections of the Population of Taiwan 2008-2056, Council for Economic Planning and Development, Executive Yuan, Taiwan.

cost per capita will be 61 percent higher than that in the benchmark and the government has to tax additional 16 percentage points on labor income to sustain the NHI program.

Then, based on the above two scenarios, productivity growth and the growth of medical price are further considered in our analysis. Because the NICs on average enjoy higher economic growth, we investigate the cases that the productivity grows faster than real medical price. The results suggest that if the growth rate of total factor productivity (TFP) is constantly 1 percent on top of the medical price growth, the labor tax rate can be maintained at the benchmark level, even with a population aging.

However, the fast growth of medical price makes the situation less positive. Attanasio et al. (2011) has reported that the annual medical price growth rate is 0.6 percent on top of productivity growth in the United States. We also observe that real medical costs in Taiwan have grown rapidly in recent years, even faster than the productivity growth. If medical price grows at a rate with an extra 0.5 percent on top of TFP growth in the aged economy with the 2050 age structure, our results indicate that an additional 24 percentage points of labor tax will be required. Moreover, we find that the NHI will be unsustainable if the extra annual growth rate of medical price is more than 2 percent.

Then, we investigate a policy that can potentially reduce the tax burden on the working-age population: encouraging the delay of retirement. Currently, the average retirement age is 55. If it is postponed to 75, the extra labor tax burden can be reduced to 8 percent (compared with 16 percent in the case of retirement age 55). This also improves an individual's welfare.

Finally, financing NHI by different methods are explored. We find that, compared with taxing on labor income, taxing on consumption or capital income both improve welfare. In contrast, adjusting social welfare (the minimum level of consumption) to partially finance the additional cost of NHI makes people worse off.

A study close to this paper is Attanasio et al. (2011), which employed a general equilibrium life cycle model to evaluate alternative financing schemes for the public health insurance program, Medicare, in the United States, given projected demographic and medical expenditure trends for the next 75 years. Because of the immigration, the speed of population aging in the United States is slower than that in other countries, especially in the NICs. A rapid population aging will shorten the time that the government can react to. Therefore, instead of investigating developed countries, this paper focuses on the NICs.

This study contributes to the literature pioneered by Kotlikoff (1989) analyzing the effects of health expenditure shocks on precautionary savings, and to the literature of dynamic equilibrium models with heterogeneous agents in incomplete markets.[7] Recent studies have examined the impacts of health and medical expenditures in Aiyagari-Bewley type models.[8] However, with a few exceptions, health insurance systems are outside the scope of the previous studies. This paper also contributes to the literature on understanding the impacts of population aging on social programs. For example, Attanasio et al. (2007) studied the impacts of demographic changes on the sustainability of the Pay-As-You-Go pension systems. We focus on the NHI program instead.

The rest of this paper is organized as follows. Section 2 describes the model. Data and calibration are summarized in Section 3. Section 4 provides quantitative results and policy experiments. Section 5 concludes this paper.

2 The Model

This paper undertakes a structural approach to analyze the impacts of population aging on financing an NHI program. There is no aggregate uncertainty in the model economy. However,

[7]Bewley (1986), Imrohoroglu (1989), Huggett (1993), and Aiyagari (1994) pioneered the literature.

[8]For example, Livshits et al. (2007) and Chatterjee et al. (2007) suggested that the medical expenditure shock is an important reason for consumer bankruptcy. Palumbo (1999), De Nardi et al. (2010), and Scholz et al. (2006) studied medical expenses for understanding the pattern of retirement savings.

households face an idiosyncratic labor productivity shock and a medical expenditure shock. Although, financial markets are incomplete due to a borrowing constraint, households can, first of all, partially self-insure by accumulating precautionary asset holdings. Second, with the NHI coverage, they can partially insure against medical expenditure shocks.

2.1 Demographics

The economy is populated by a continuum of finitely-lived individuals, and the measure of total population is normalized to one. These individuals maximize expected discounted lifetime utility derived from consumption and leisure. The population consists of two generations: the young and the old. The young supply labor and earn wage income in every period. In contrast, the old retire from market work and consume the previous savings. The young become aged/retired with a probability ρ_o. The old pass away with a probability ρ_d. On average, the young work for $\frac{1}{\rho_o}$ years, and the old live for $\frac{1}{\rho_d}$ years before death. This setting implies that every period the proportion of the old is $\frac{\rho_o}{\rho_o+\rho_d}$ and the proportion of the young is $\frac{\rho_d}{\rho_o+\rho_d}$. Population aging results in a higher proportion of old people and a smaller working/tax-paying population.

In each period, the economy has new-born young agents who replace the deceased. This assumption implies that the measure of total population stays constant (because it is a relative measure). However, the age structure varies, which reflects different degrees of population aging.

2.2 Income Uncertainty

A young individual's effective labor supply depends on the hours worked and on the idiosyncratic labor productivity shock z, which is stochastic. In each period t, an idiosyncratic labor productivity shock takes one of $l < \infty$ values in a finite set $Z = \{z_1, z_2, ..., z_l\}$. Each household's productivity shock independently evolves according to a first-order Markov process with the transition probability matrix π_z, which is $l \times l$, and the corresponding invariant distribution $\bar{\pi}_z$.

2.3 Medical Expenditure and Health Insurance

Medical Expenditure

Both the young and the old face medical expenditure shocks x, which are also stochastic. In each period t, a medical expenditure shock takes one of $m < \infty$ values in a finite set $X_i = \{x_{1,i}, x_{2,i}, ..., x_{m,i}\}$ for $i \in \{o, y\}$, representing the old and the young, respectively. Each agent's medical expenditure shock independently evolves according to a first-order Markov process with the transition probability matrix $\pi_{x,i}$, which is $m_i \times m_i$ for $i \in \{o, y\}$. The corresponding invariant distribution is $\bar{\pi}_{x,i}$ for $i \in \{o, y\}$. The price of medical expenditure is denoted by P_x.[9]

National Health Insurance

We consider a NHI program, which provides universal coverage to all agents. The NHI is obligatory. It covers a constant fraction ω of an individual's medical expenditure x. Under the NHI coverage, the out-of-pocket medical payment is $(1-\omega)\, P_x x$. The NHI program is financed by an income-contingent premium (P_{NHI}, equivalently, a labor income tax) and the government's general revenues.

2.4 Government

The government's revenues consist of labor income tax (with a rate τ_n), capital income tax (with a rate τ_k), consumption tax (with a rate τ_c), the income-contingent premium for national health insurance, and the newly issued government debt D'.

The government runs two social programs. One is the NHI program, as described above. The other is a social insurance program (safety net) that guarantees a minimum level of consumption $\underline{c}$ for every agent. Here we consider a simple rule of the social insurance as in Hubbard et al. (1995). A transfer T that supplements an individual's income will be made if the individual's disposable income plus assets (net after the medical expenditure) fall below the minimum level of consumption $\underline{c}$.[10]

The government budget constraint is given by:

$$G + \int [T + \omega P_x x] d\Phi + (1+r)D = \int [\tau_n (wzn) + \tau_k r(a+b) + \tau_c c + P_{NHI}] d\Phi + D', \tag{1}$$

where G is government consumption, which is a residual that balances the budget constraint in the benchmark economy given the tax rates and the debt level. Φ is the distribution of the whole population over state variables, a is individual asset holdings, and b is accidental bequests, which are equally distributed to all survivors. The definition of b is given by:

$$b = \frac{\rho_d \rho_o}{\rho_o + \rho_d} \int a d\Phi_o, \tag{2}$$

[9] The price of medical expenditure is normalized to be one in this paper, except in the discussion of medical price inflation (Section 4.3).

[10] In a model with expenditure shocks, it is possible that an unlucky individual encounters an expenditure shock which is larger than his/her income and assets, so that the individual cannot sustain a positive consumption. To prevent this problem, a mechanism providing minimum consumption support is necessary. See the similar settings, for example, in Jeske and Kitao (2009) and Attanasio et al. (2011).

where Φ_o is the distribution of the old population over state variables. In the experiments with an aged economy or with a policy reform, we assume that G is fixed at the benchmark level and the government adjusts the tax rates to balance its budget.

2.5 Production

There is a representative firm operating a technology with constant returns to scale. Aggregate output Y is given by:

$$Y = F(K, L) = AK^{\theta}L^{1-\theta},$$

where K and L are aggregate capital and effective labor employed by the firm. A is total factor productivity which is constant. θ denotes the capital income share. Capital depreciates at the rate of δ every period.

2.6 Individuals

Preference

This paper adopts the standard constant relative risk aversion (CRRA) utility function:

$$u(c, n) = \frac{\left[c^{\phi}(1-n)^{1-\phi}\right]^{1-\mu}}{1-\mu}, \tag{3}$$

where c denotes consumption, n is labor supply, ϕ is the labor/leisure parameter, and μ governs both the intertemporal elasticity of substitution for consumption and the labor supply elasticity. The coefficient of relative risk aversion is given by $\gamma = 1 - \phi + \phi\mu$.[11] The utility function is consistent with a balanced growth path and widely used in the growth literature.

Young Agent

The state of an agent is summarized by a vector $s = (a, z, x)$, where a denotes asset holdings, z is the idiosyncratic shock to labor productivity, and x represents the idiosyncratic medical expenditure shock.

A young agent faces the probability ρ_o of being retired and aged. Thus, a young agent solves the following maximization problem:

$$V_y(s) = \max_{c,n,a'} \left\{ u(c, n) + \beta(1-\rho_o) E\left[V_y(s')\right] + \beta\rho_o E\left[V_o(s'_o)\right] \right\}$$

[11]See Heathcote et al. (2008) for the details.

subject to

$$(1+\tau_c)c + a' = Wel_y + T; \tag{4}$$

$$Wel_y \equiv (1-\tau_n)\, wzn + [1+(1-\tau_k)\, r]\,(a+b) - [1-\omega]\, P_x x - P_{NHI}; \tag{5}$$

$$P_{NHI} = \tau_{NHI}(wzn); \tag{6}$$

$$T = \max\{0,\ (1+\tau_c)\underline{c} - Wel_y\}; \tag{7}$$

$$a' \geq 0;\ \ 1 > n \geq 0, \tag{8}$$

where V_o is the value when the agent becomes old and retired, β is the subjective discount factor, w is the effective wage rate, and τ_{NHI} is the tax rate (premium) for the national health insurance. Accidental bequests b left by old agents are equally distributed to all surviving agents.

Equation (3) and the above maximization problem imply that labor supply can be expressed as a function of consumption and effective wage rate:

$$n = 1 - \frac{(1-\phi)(1+\tau_c)c}{\phi(1-\tau_n)wz}. \tag{9}$$

Others being equal, equation (9) shows that labor supply declines as the labor income tax or the consumption tax increases.

Old Agent

Retired agents do not supply labor and have no labor income. The labor productivity z is fixed at zero. Therefore, old agents only face medical expenditure shocks. The state of an old agent is summarized by a vector $s_o = (a, z = 0, x_o)$ An old agent chooses consumption and asset holdings to solve the following maximization problem:

$$V_o\left(s_o\right) = \max_{c,a'} \left\{ u\left(c, 0\right) + \beta\left(1-\rho_d\right) E\left[V_o\left(s_o'\right)\right]\right\}$$

subject to

$$(1+\tau_c)c + a' = Wel_o + T; \tag{10}$$

$$Wel_o \equiv [1+(1-\tau_k)\, r]\,(a+b) - [1-\omega]\, P_x x - P_{NHI}; \tag{11}$$

$$P_{NHI} = 0.6 \int \tau_{NHI}(wzn) d\Phi; \tag{12}$$

$$T = \max\{0,\ (1+\tau_c)\underline{c} - Wel_o\}; \tag{13}$$

$$a' \geq 0, \tag{14}$$

where ρ_d is the death probability. Retired agents do not have labor income, so they pay a fixed NHI premium (60 percent of the average NHI premium paid by workers), according to the current rule in Taiwan.

2.7 Recursive Competitive Equilibrium

A stationary recursive competitive equilibrium for the benchmark economy consists of individual decision rules for asset holdings a', labor supply n, and consumption c, a set of firm decision rules with regard to capital rented K and effective labor employed L, a price system of w and r, and a stationary distribution of individuals over the state variables Φ, under a set of government policies of tax rates τ_n, τ_k, τ_c, and τ_{NHI}, a government debt D, a policy of NHI coverage ω, a minimum consumption floor $\underline{c}$, and an exogenous medical price P_x, such that:

a) Given the price system, the decision rules regarding K and L maximize the firm's profit;

b) Given the price system, the insurance premium, and the policy of tax rates, the decision rules regarding (a', n, c) solve young and old individuals' problems;

c) The government budget constraint is satisfied;

d) All markets are cleared: $L = \int (zn) d\Phi$ and $K + D = \int (a + b) d\Phi$;[12]

e) The resource feasibility condition is satisfied:

$$Y = C + G + K' - (1 - \delta)K + P_x X;$$

where $C = \int c d\Phi$ is the aggregate consumption, and X is the aggregate medical expenditure. X is defined as

$$X = \frac{\rho_d}{\rho_o + \rho_d} \sum_{j=1}^{m} \left[x_{j,y} \bar{\pi}_{x,y}(x_{j,y}) \right] + \frac{\rho_o}{\rho_o + \rho_d} \sum_{j=1}^{m} \left[x_{j,o} \bar{\pi}_{x,o}(x_{j,o}) \right].$$

3 Data and Calibration

The benchmark model is calibrated to the Taiwanese economy in the 2000s. The NHI system and demographics in Taiwan are briefly described in Appendix A. We ensure that the medical cost, the NHI cost and the tax burden in the benchmark model match the data in the 2000s. The capital-output ratio and average labor supply in the model are also matched, so that the saving and working decisions in the model are consistent with household behaviors in the real economy.

[12] The aggregate labor market clearing condition can be expressed as

$$L = \int (zn) d\Phi = \frac{\rho_d}{\rho_o + \rho_d} \int (zn) d\Phi_y(a, z, x),$$

where Φ_y is the stationary distribution of young individuals over state variables a, z, and x.

Moreover, the income and medical expenditure shocks are calibrated according to the micro survey data to capture the main uncertainties that individuals face. Then, we compare the stationary equilibrium of this benchmark economy to two aged economies with the same set of parameter values but different demographic structures (i.e., projected demographics in 2030 and in 2050).

Demographics

According to Taiwanese labor statistics, the average age of entering the labor market is 21, and the average age for retirement is 55.[13] Therefore, on average, an agent works for 34 years, which implies $\rho_o = \frac{1}{34}$. The fraction of the working-age population (age 21-54) as a percentage of total population ($\frac{\rho_d}{\rho_o+\rho_d}$) is 72 percent in the 2009 data.[14] Thus, ρ_d is equal to 0.076.

Based on the current trend of life expectancy and fertility rate, Taiwanese government reports the population projection every two years. According to the projection, if the fertility rate is not significantly improved, the old-age dependency ratio (65+/15-64) will increase to 37.6 percent in 2030 and to 68.6 percent in 2050. If the age of starting to work and the retirement age remain unchanged, the ratio of old (55+) to young (21-54) will be 85 percent in 2030 and 133 percent in 2050. More details of the demographic changes and the projection are provided in Appendix A2.

Preferences

The model period is set to be one year. The discount factor β is chosen to be 0.803 so that the capital-output ratio is equal to 2, which is reported in the empirical study by Chow and Lin (2002) for the Taiwanese economy. The utility parameter μ is chosen to be 2. The leisure utility parameter ϕ is chosen to be 0.487 in order to match aggregate labor hours 0.3, which is consistent with the labor hours per capita.[15] The setting of μ and ϕ implies that the relative risk aversion is roughly equal to 1.5, which is within the range of micro estimates in the literature (see Attanasio, 1999, for a survey). In Section 4.5, sensitivity tests for μ is summarized.

Production

In the production function, the capital income share θ is 0.544.[16] Following Chow and Lin (2002), the annual depreciation rate of capital δ is 0.04. The scaling production parameter A is equal to 1 to normalize the average wage income into unity.

[13]Source: Council of Labor Affairs, Executive Yuan, Taiwan.

[14]Source: Directorate-General of Budget, Accounting and Statistics (DGBAS), Executive Yuan, Taiwan.

[15]Source: DGBAS, Executive Yuan, Taiwan.

[16]Source: DGBAS, Executive Yuan, Taiwan.

Labor Productivity Shocks

The Panel Study of Family Dynamics (PSFD) provides abundant panel survey data for Taiwanese households. We use household income data from 2004 and 2005 to calculate the states of labor productivity shocks and the corresponding transition probabilities. Only those samples in which the respondents are household head, or the household head's spouse are included. We exclude samples of single households who are retired and married households that both spouses are retired. Household income is divided by the number of household members to compute per capita household income.

The samples are divided into four groups according to per capita household income: the bottom 25 percent, the 25-50 percent, the 50-75 percent, and the top 25 percent. The proportional deviations from the sample mean are defined as the four states of labor productivity shocks. The states are reported in Table 2. Given the initial states in 2004, we further compute the transition probabilities of labor income shocks from 2004 to 2005. The transition probabilities are presented in Table 3.

Table 2: States of Labor Productivity Shocks

State	Income Range	Average (NT$ in 2004)	As of Sample Mean (2004)
State 1	0 – 25 %	12,399	30.1%
State 2	25 – 50 %	26,772	64.9%
State 3	50 – 75 %	40,300	97.8%
State 4	75 – 100 %	91,427	221.8%

Note: Household income in the table is monthly household income per capita. Source: PSFD and author's calculation.

Medical Expenditure Shocks

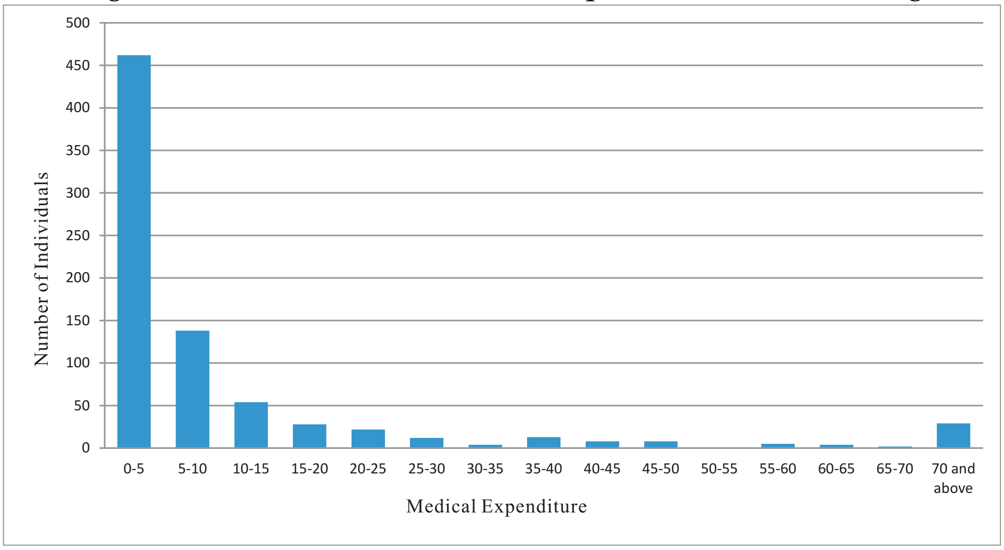
To compute medical expenditure shocks, we use the panel data from PSFD. However, the following samples are excluded: (1) the respondent is neither household head nor his or her spouse; (2) the respondent is living with his/her parents, grandparents, the spouse's parents, or the spouse's grandparents. Because we use the household head's age to represent the age of the household, living with the elderly may increase the medical expenditures for that age group. Thus, these samples are excluded to avoid possible biases.

Table 3: Transition Probabilities of Labor Shocks

	State 1	State 2	State 3	State 4
State 1	0.7108	0.2304	0.0392	0.0196
State 2	0.1345	0.5965	0.2515	0.0175
State 3	0.0455	0.1717	0.6161	0.1667
State 4	0.0118	0.0588	0.1588	0.7706

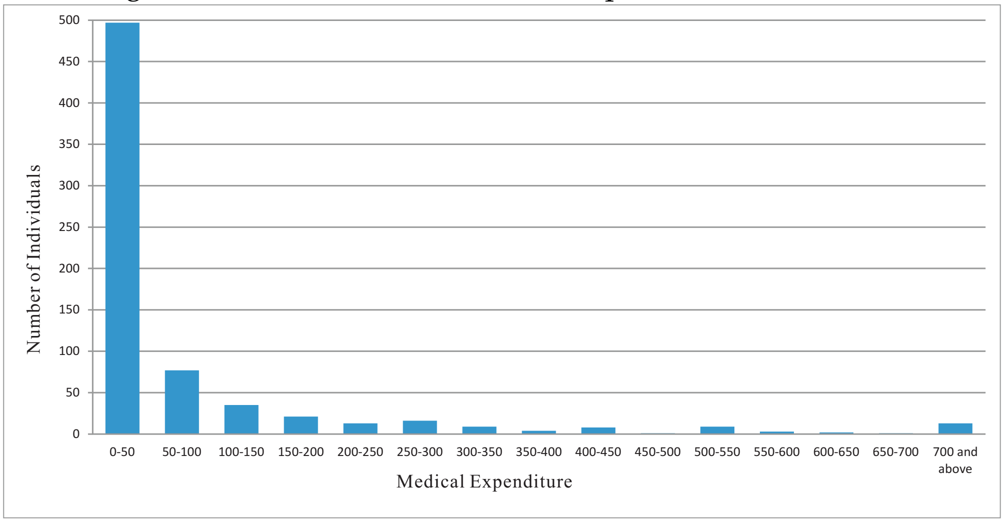
Source: PSFD and author's calculation.

Figure 2: Distribution of Medical Expenditure for the Young



Note: The unit of medical expenditure is 1000 NT dollars. Source: PSFD and author's calculation.

Figure 3: Distribution of Medical Expenditure for the Old



Note: The unit of medical expenditure is 1000 NT dollars. Source: PSFD and author's calculation.

The selected sample is divided into two groups, below age 55 and equal/above age 55 (according to the household head's age), to represent the young generation and the retired generation, respectively. The medical expenditures in PSFD are expenditures for all household members. They are divided by the number of household members to calculate per capita medical expenditure. Besides, the medical expenditure in PSFD is the out-of-pocket payment of households. The proportion paid by the NHI is not included. Therefore, the average medical expenditure from PSFD is lower than the national average medical cost (see 2008 National Health Expenditures, Department of Health, Taiwan). To solve this problem, the per capita medical expenditure from PSFD is adjusted proportionally to match (1) per capita "total medical cost" (including out-of-pocket payment and the part paid by the NHI) of the young and the old separately; and (2) the ratio of national medical cost to GDP to be 6 percent as in 2004.[17] Figure 2 and 3 provide the distribution of medical expenditure for the young and the old, respectively.

To characterize medical expenditure shocks, four medical expenditure states are defined: "low", "fair", "high", and "very high". As shown in Figure 2 and 3, the distributions of per capita medical expenditure for the young and the old are similarly skewed to the right, i.e., bunched up toward the left and with a "tail" stretching toward the right. Thus, we choose the bottom 61 percent, 61-85 percent, 85-95 percent, and the top 5 percent to represent the state for "low", "fair",

[17]The data of "total medical cost" is obtained from National Health Expenditure 2005, Department of Health, Executive Yuan, Taiwan.

"high", and "very high", respectively.[18] Table 4 summarizes the states of medical expenditure shocks for the young and the old. The medical expenditures, from "low" to "very high", were 0.4 percent, 1.8 percent, 5.9 percent, and 26.2 percent of per capita income in 2004 for the working-age population. For the retired population, they were 1.8 percent, 11.6 percent, 41.2 percent, and 135.7 percent of per capita income in 2004.

Given the initial states in 2004, we use the data from PSFD in 2005 to determine the corresponding states in 2005 and calculate the transition probabilities of medical expenditure. The results are summarized in Table 5. In the period that a young agent becomes retired, we assume that he still faces the transition probabilities of medical expenditure for the young. After that period, the transition probabilities of the old are applied. When implementing the medical expenditure shocks into the model, we further assume that they are completely independent of labor income.

Table 4: States of Medical Expenditure Shocks

State	Expenditure Range	Average (NT$ in 2004)	As of Average Income (2004)
Young Agent			
Low	bottom 61%	1,857	0.4%
Fair	61 – 85%	9,234	1.8%
High	85 – 95%	29,509	5.9%
Very High	95 – 100%	131,434	26.2%
Old Agent			
Low	bottom 61%	8,883	1.8%
Fair	61 – 85%	58,365	11.6%
High	85 – 95%	206,561	41.2%
Very High	95 – 100%	681,059	135.7%

Source: PSFD, DGBAS, and author's calculation.

[18] 61% is chosen because the values of per capita medical expenditure around the 60th percentile are the same.

Table 5: Transition Probabilities of Medical Shocks

	Low	Fair	High	Very High
Young Agent				
Low	0.7140	0.1983	0.0647	0.0230
Fair	0.4059	0.4307	0.1238	0.0396
High	0.3698	0.3151	0.2466	0.0685
Very High	0.2857	0.3714	0.1429	0.2000
Old Agent				
Low	0.7140	0.2092	0.0698	0.0070
Fair	0.4393	0.3873	0.1156	0.0578
High	0.2714	0.2714	0.3572	0.1000
Very High	0.3055	0.1667	0.2222	0.3056

Source: PSFD and author's calculation.

National Health Insurance

The data show that the proportion of medical expenditures paid by households on average was 35 percent during 2000-2008.[19] Therefore, the expenditure coverage rate of the NHI, ω, is set at 65 percent. According to the current rules of the NHI premium in Taiwan, the premium tax rate of the NHI is 5.17 percent of an employee's registered labor income. 90 percent of the premium tax rate is paid by employers and employee. The remaining 10 percent is subsidized by the government. Those without labor income pay 60 percent of the average NHI premium.

Safety Net and Government Taxes

The average social subsidy, with income and asset tests made by the government, was 21,155 New Taiwan dollars in 2008.[20] It was roughly equal to 5 percent of average labor income in 2008. Therefore, the minimum consumption floor provided by the safety net is set to be 5 percent of the average labor income in the calibration.

The consumption tax rate was 5 percent in the 2000s. There is no capital income tax in Taiwan,

[19]Source: *2008 National Health Expenditures*, Department of Health, Executive Yuan, Taiwan.

[20]Source: DGBAS, Taiwan.

so τ_k is equal to zero. The average labor income tax was 14.3 percent in 2007.[21] The government debt to GDP ratio was 32.5 percent in 2009.[22] In the calibration (the benchmark economy), the debt to GDP ratio is matched and government consumption G is a residual that balances the government budget constraint. The price of medical expenditure is set to be 1. Parameter values are summarized in Table 6.

4 Quantitative Analysis

The benchmark economy is calibrated to match the Taiwanese economy in the 2000s. Specifically, the population age structure is set to match the data of 2009. Therefore, in the benchmark model the ratio of the old (retired, 55+) to the young (working, 21-54) is 38.9 percent. Properties of the stationary equilibrium in the benchmark economy are presented in the first row of Table 7. The total labor tax burden is labor income tax ($\tau_n = 14.3$ percent) plus NHI premium tax ($\tau_{NHI} = 4.65$ percent).

To study the impacts of population aging on financing the NHI program, the benchmark economy is compared with an alternative economy with the projected age structure in Taiwan. Two scenarios are explored: the population projection in 2030 and in 2050. Both are compared in the stationary equilibrium. In addition, based on the two scenarios of population projection, we further consider the productivity growth and the growth of real medical cost. Finally, the policy of deferring retirement is discussed.

4.1 Impacts of Population Aging

To study the impacts of population aging using the dynamic stochastic general equilibrium framework, we compare the stationary equilibrium in the benchmark economy (initial steady state) with an alternative economy with the same set of parameters but different demographics.[23]

First, a more aged economy with the population projection of Taiwan in 2030 is considered.[24] We assume that the age of starting to work and the retirement age remain unchanged. Based on the population projection, the ratio of old (55+) to young (21-54) in the aged economy will

[21]Source: Ministry of Finance, Taiwan.

[22]Source: The World Factbook.

[23]We assume that the Taiwanese economy in 2009 is an initial steady state (i.e., on a balanced growth path) for the calibration purpose. In addition, the population growth rate is relatively stable in the 2000s. Specifically, the annual population growth rates between 2004 and 2009 stay around 0.4 percent.

[24]This setting implies that the fertility can be improved to maintain the 2030 age structure such that the economy can converge to a new steady state.

Table 6: Summary of Parameter Values

Parameter	Notations	Values
Utility		
Discount Factor	β	0.803
Utility Parameter	μ	2.00
Labor Parameter	ϕ	0.487
Production		
Depreciation Rate	δ	4%
Capital Income Share	θ	0.544
Total Factor Productivity	A	1.00
Population		
Probability of Being Retired	ρ_o	1/34
Fraction of the Young	$\frac{\rho_d}{\rho_o+\rho_d}$	72%
National Health Insurance		
NHI Coverage Rate	ω	65%
NHI Premium Tax Rate	τ_{NHI}	$0.9 \times 5.17\%$
Others		
Min. Consumption Floor	$\underline{c}$	5% $\bar{y}$
Consumption Tax Rate	τ_c	5%
Capital Tax Rate	τ_k	0%
Labor Tax Rate	τ_n	14.3%
Debt/GDP Ratio		32.5%
Price of Medical Expenditure	P_x	1

Note: $\bar{y}$ denotes the average earnings.

become 85.2 percent (compared with 38.9 percent in the benchmark). We also assume that other parameters are the same as those in the benchmark and the government's consumption G and the debt to output ratio are fixed at the benchmark level. The government changes the labor income tax rate so that the government budget constraint, equation (1), is satisfied. The results of the stationary equilibrium for this aged economy are reported in the row labeled "Aging 2030" in Table 7.

Table 7 shows that, in this aged economy, labor supply (aggregate labor hours) decreases to 0.24, which is 20 percent lower than the benchmark level. The decrease in labor supply results from population aging. The additional tax burden further discourages labor supply. We also find that population aging induces more savings (a higher capital-output ratio). Besides, the ratio of medical expenditure to output increases from 6 percent in the benchmark to 10 percent in the aged economy. The average NHI cost (NHI cost per capita) is also higher. Compared with the benchmark, the NHI cost is 39 percent higher in the aged economy with the 2030 age structure. Therefore, the labor income tax rate has to increase to 21.4 percent in response to the population aging (additional 7 percentage points labor income tax).

However, this scenario, which implies that the fertility will be significantly improved and the aging will be maintained in the 2030 level, is an optimistic case. We further investigate an alternative aged economy with the age structure in 2050: the ratio of the old (55+) to the young (21-54) is 132.5 percent. Similar to the previous scenario, we assume that the government changes labor income tax in response to the population aging, while all other parameters are the same as those in the benchmark. In Table 7, the last row, labeled "Aging 2050", represents the simulated results. In this aged economy, the aggregate labor declines by 37 percent and the per capita NHI cost is 61 percent higher than that in the benchmark. Therefore, the government has to collect additional 16 percent labor income tax to finance its expenditures.

4.2 Productivity Growth

The NICs on average experience higher productivity growth than developed countries. For example, the literature suggests that the annual growth rate of TFP in Taiwan ranged from 1.2 to 2.9 percent, based on its history of development: the TFP growth rate in 1973-1984 was 1.2 percent estimated by Maddison (1989); 2.9 percent in 1978-1992, reported by Fare et al. (2001); 2.5 percent in 1960-1993, estimated by Liang (2002); and 2.7 percent during 1951-1999, according to Chow and Lin (2002). If the productivity grows faster than the price of medical care, it will help to release the tax burden, even if population aging occurs.

To discover the scenarios in which TFP grows faster than the price of medical care, our experiments here build on the two aged economies in Section 4.1. We further assume that the annual

Table 7: Impacts of Population Aging

Economy	Old/ Young	τ_n	Total labor tax burden	$\Delta\tau_n$	Labor	$\frac{X}{Y}$	$\frac{K}{Y}$	Δ NHI Cost (% change)
				Initial steady sate				
Benchmark	38.9%	14.3%	18.95%	0.00%	0.30	0.06	2.00	0.00
				Final steady sate				
Aging 2030	85.2%	21.41%	26.06%	7.11%	0.24	0.10	2.10	38.89
Aging 2050	132.5%	29.93%	34.58%	15.63%	0.19	0.14	2.13	61.40

Note: τ_n refers to labor income tax rate excluding NHI tax; Total labor tax burden is $\tau_n + \tau_{NHI}$; $\Delta\tau_n$ is the extra labor tax needed compared with the benchmark; X/Y denotes the ratio of medical cost to output; K/Y is capital-output ratio; Δ NHI cost represents percentage changes in per capita NHI cost compared with the benchmark.

TFP growth rate is 0.5 percent, 1 percent, 1.5 percent, and 2 percent higher than the growth rate of the medical price until 2030 or 2050 in the aged economy. Then the economy converges to a steady state (a balanced growth path).

The results are summarized in Table 8. The first panel is the results by assuming that the TFP and the medical price grow at the same rate. The second panel presents the scenarios in which the TFP grows 0.5 percent faster than the medical price annually until 2030 or 2050. We find that the additional tax burden can be reduced to 2.4 percent in the aged economy with the 2030 age structure, compared with the 7.1 percent in the case without faster TFP growth. If Taiwan keeps the faster TFP growth until 2050, the additional tax burden in the aged economy with the 2050 age structure would be reduced to 3 percent compared with the 16 percent in the case without faster TFP growth. The results also suggest that if the annual TFP growth rate is constantly 1 percent on top of the medical price growth, no additional tax burden are required even if the population is aging.[25]

4.3 Growth of Medical Price

The last sub-section shows that the tax burden could be released if the economy continuously has a high TFP growth. However, the phenomenon of the continuous growth of medical costs has been discussed in the literature. Various factors drive this growth, such as medical price inflation, demographic changes, and the availability of new technology. See the discussion in

[25]With TFP growth, labor supply also slightly increases. However, the magnitude is small and negligible. Therefore, in Table 8, the values of labor supply are rounded to the second digit.

Table 8: Aging with Faster TFP Growth

Economy	τ_n	Total labor tax Burden	$\Delta\tau_n$	Labor	$\frac{X}{Y}$	$\frac{K}{Y}$
0% annual TFP growth rate (on top of medical price growth)						
Aging 2030	21.41%	26.06%	7.11%	0.24	0.10	2.10
Aging 2050	29.93%	34.58%	15.63%	0.19	0.14	2.13
0.5% annual TFP growth rate						
Aging 2030	16.68%	21.33%	2.38%	0.24	0.08	2.10
Aging 2050	17.29%	21.94%	2.99%	0.20	0.08	2.16
1% annual TFP growth rate						
Aging 2030	13.26%	17.91%	-1.04%	0.24	0.06	2.10
Aging 2050	10.79%	15.44%	-3.51%	0.21	0.05	2.16
1.5% annual TFP growth rate						
Aging 2030	10.64%	15.29%	-3.66%	0.24	0.05	2.10
Aging 2050	7.00%	11.65%	-7.30%	0.21	0.03	2.16
2% annual TFP growth rate						
Aging 2030	8.67%	13.32%	-5.63%	0.24	0.04	2.09
Aging 2050	4.68%	9.33%	-9.62%	0.21	0.02	2.15

Table 9: Aging with Medical Price Inflation

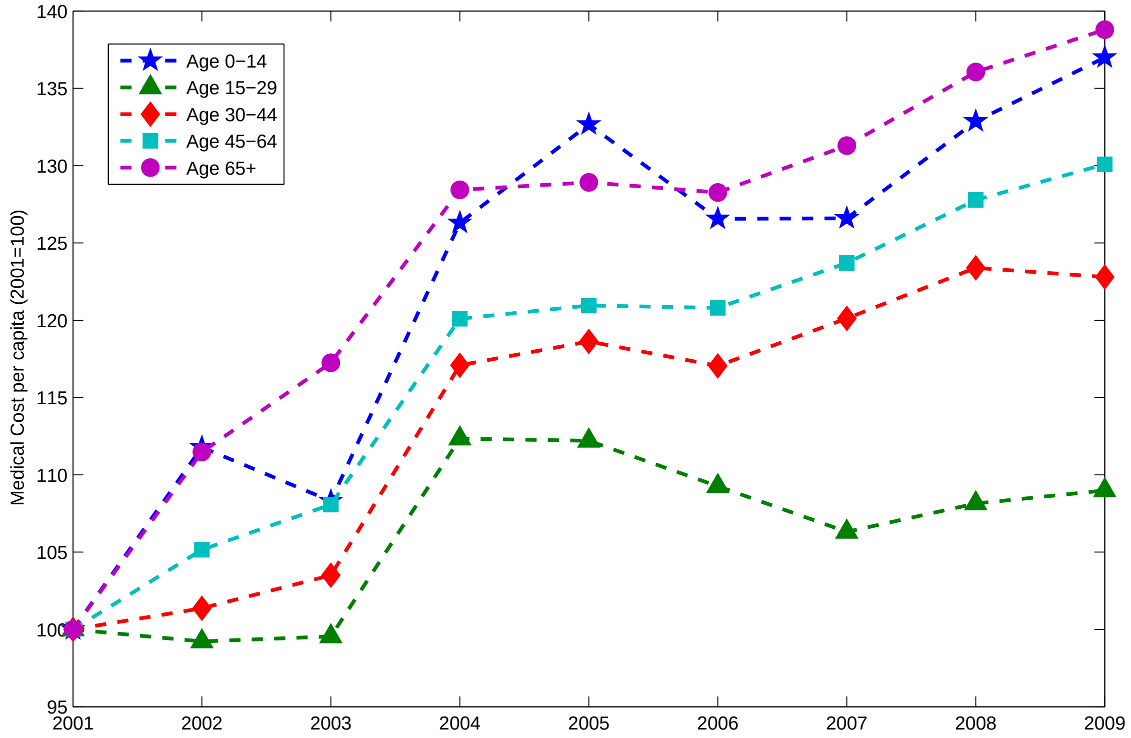
	τ_n	Total labor tax Burden	$\Delta\tau_n$	Labor	$\frac{X}{Y}$	$\frac{K}{Y}$	Δ NHI Cost (% change)
Real medical price grows at 0.5% annually (on top of TFP growth)							
Aging 2030	23.65%	28.30 %	9.35%	0.23	0.11	2.09	54.09
Aging 2050	38.71%	43.36%	24.41%	0.19	0.18	2.09	98.25
Real medical price grows at 1% annually							
Aging 2030	26.25%	30.90%	11.95%	0.23	0.13	2.09	71.05
Aging 2050	57.69%	62.34%	43.39%	0.17	0.27	1.87	142.98
Real medical price grows at 2% annually							
Aging 2030	32.56%	37.21%	18.26%	0.23	0.16	2.08	110.53
Aging 2050	–	–	–	–	–	–	–

Uwe (2003), Dormont et al. (2006), and Werblow et al. (2007). Attanasio et al. (2011) suggest that the real medical price growth rate is 0.6 percent annually on top of the productivity growth in the United States. The growing trend of medical costs is also observed in Taiwan. As Figure 4 shows, per capita medical costs of all age groups continuously increased during 2001-2009. The annual growth rates were in the range of 1 to 4 percent. In particular, population aged 65 and above had the highest growth rate.

When factors other than aging that increase medical costs are considered, the extra tax burden for financing the NHI will be even higher. To investigate the quantitative effects, experiments with annual growth rates of real medical price (the growth of P_x) at 0.5 percent, 1 percent, and 2 percent on top of the TFP growth are performed. We assume that the medical price grows at a higher rate than the TFP until 2030 for the aged economy with the 2030 age structure and until 2050 for the economy with the 2050 age structure. Other assumptions for the government and the parameters are the same as those in Section 4.1. The results are summarized in Table 9.

In the economy with the 2030 age structure, our results suggest that the government has to collect an additional 9 percent labor income tax, with an 0.5 percent annual growth rate in real medical price on top of TFP growth. If the aging and the faster real medical price growth continue until 2050, in the economy with the 2050 age structure, the extra tax burden will be 24 percent, which is much higher than the 16 percent in the case without the medical price growth. We also find that, given the age structure of 2050, if the annual growth rate of medical price is higher

Figure 4: Medical Cost



Source: National Health Insurance Annual Statistical Report, Department of Health, Executive Yuan, Taiwan.

than 2 percent on top of TFP growth, the labor income tax rate would be too high to sustain an equilibrium (see the bottom panel of Table 9).[26]

4.4 Deferring Retirement

The data shows that the average retirement age is 55 in Taiwan. It is younger than that in many developed countries. For example, the average retirement age in OECD countries in 2004-2009 was 64 for men. If the government introduces policies to encourage people to work longer and retire later, it can increase the labor supply and reduce the tax burden of the working-age population.

To discuss the effects of deferring retirement, we slightly modify the model and change the calibration accordingly, because there exists an additional type of agents who are facing the old generation's medical expenditure shocks but still working. The details are provided in Appendix B. The aged economy with 2050 age structure is considered. We investigate scenarios in which the average retirement age is deferred to age 60, 65, 70, and 75. There is no extra medical price growth in the experiments. The results are reported in Table 10.

Compared with the scenario of the retirement age at 55, deferring retirement moderates the sharp decline in labor supply caused by population aging. For example, if the retirement age is deferred to age 60, the labor supply in the economy with the 2050 age structure will be 0.22. Furthermore, the labor supply will return to 87 percent of that in the benchmark ($\frac{26}{30}$) if people work, on average, until age 75.

The results of these experiments suggest that the pressure on the government budget due to population aging could be partially reduced by maintaining the labor supply. For example, if the average retirement age is deferred to 75, the additional labor tax burden for financing the NHI will be 8 percent in the aged economy with the 2050 age structure instead of 16 percent in the case of retiring at 55.

Deferring retirement alleviates the tax burden, and thereby increasing an individual's welfare. However, because the retirement age is extended, people on average have to work longer. This lowers an individual's welfare. Our results indicate that the tax effect dominates, i.e., people are better off in the scenario with deferring retirement.[27]

[26] When the medical price grows at 1% annually, the capital-output ratio in the scenario of "Aging 2050" is even lower than that in "Aging 2030". This reflects the fact that savings are crowded out by fast medical price inflation.

[27] The model assumes that the disutility of working for the old is the same as that for the young. Therefore, the welfare gain and increases in labor supply here could be over-estimated.

Table 10: Experiments – Deferring Retirement

	Retirement Age	τ_n	$\Delta\tau_n$	Labor	$\frac{X}{Y}$	$\frac{K}{Y}$	Welfare change
Aging 2050	60	26.47%	12.17%	0.22	0.13	2.07	9.36%
Aging 2050	65	24.82%	10.52%	0.24	0.12	2.05	13.66%
Aging 2050	70	23.60%	9.30%	0.25	0.11	2.03	16.37%
Aging 2050	75	22.72%	8.42%	0.26	0.11	2.02	18.15%

Note: Compared with the case of retirement age 55, welfare change in the table is measured by consumption equivalent variation.

Table 11: Experiments – Financing NHI by Different Methods

	τ_n	τ_c	τ_k	Labor	$\frac{X}{Y}$	$\frac{K}{Y}$	Welfare change
By labor income tax							
Aging 2050	29.93%	5.00%	0.00%	0.19	0.14	2.13	-
By consumption tax							
Aging 2050	14.30%	12.50%	0.00%	0.21	0.13	2.19	17.76%
By capital income tax							
Aging 2050	14.30%	5.00%	21.24%	0.21	0.15	1.88	2.34%
$\underline{c}$ **reduced to 10% of the benchmark**							
Aging 2050	25.36%	5.00%	0.00%	0.20	0.13	2.21	-3.82%

Note: Compared with the first row in the table, welfare change is measured by consumption equivalent variation.

4.5 Financing NHI by Different Methods

In all experiments discussed in the previous sections, we focus on financing NHI by labor income tax. This sub-section further discusses possible alternatives: taxing on consumption, taxing on capital income, or reducing social welfare (the minimum level of consumption). The results are summarized in Table 11.

In the experiment that finances NHI by collecting consumption tax, consumption tax has to increase by 7.5 percent (from 5 percent to 12.5 percent) due to population aging. Since not only the young but also the old pay the consumption tax, the distortion on labor supply is not as large as that in the case of taxing on labor income. An individual's welfare is also improved. Similar results are found in the experiment that finances NHI by capital income tax. However, taxing on capital income lowers savings and the capital-output ratio in the economy.[28]

Finally, we conduct an experiment that finances NHI by adjusting the minimum level of consumption. Suppose that $\underline{c}$ is only 10 percent of that in the benchmark. In addition, the government will adjust labor income tax in order to maintain a balanced budget. The results are reported in the last row of Table 11. Compared with the case that NHI is totally financed by labor income tax, the labor income tax here is about 5 percent lower. However, because now the minimum level of consumption guaranteed by the government is much lower, people have to save more for their uncertain future and are worse off.

4.6 Sensitivity Tests

The utility parameter μ is set to be 2 and the corresponding risk aversion is 1.5. This subsection tests whether the results are sensitive to the setting of μ. Values between 1 and 3 are tested. For each μ, the discount factor β and the labor parameter ϕ are re-calibrated accordingly in order to ensure that the capital-output ratio is equal to 2 and the average labor hour is 0.30 in the benchmark. The results are summarized in Table 12. As Table 12 shows, the effects of population aging are similar under various values of μ: a higher labor income tax rate has to be imposed in order to finance the additional NHI cost due to population aging.

[28]In the calibration, given that the depreciation rate is 4%, we choose $\beta = 0.803$ so that the capital-output ratio is equal to 2. The lower time discount factor implies that people are relatively impatient. Besides, in our welfare analysis, the measure of consumption equivalent variation is based on a new-born agent's (ex-ante) expected lifetime utility. Thus, taxing on consumption significantly alleviates the young's tax burden and thereby results in a larger welfare improvement. We also conduct an experiment with $\delta = 10\%$ and choose $\beta = 0.85$ (more patient) so that the capital-output ratio is 2. When the additional NHI cost is financed by the consumption tax, the welfare improvement becomes lower (14.8%).

Table 12: Sensitivity Tests for Risk Aversion

	β	ϕ	Labor	K/Y	τ_n	$\Delta\tau_n$
$\mu = 1.01$ **(risk aversion** $\gamma = 1.0$**)**						
Benchmark	0.803	0.485	0.30	2.00	14.30%	0.00%
Aging 2030	0.803	0.485	0.23	2.04	24.03%	9.73%
Aging 2050	0.803	0.485	0.19	2.13	29.72%	15.42%
$\mu = 2$ **(risk aversion** $\gamma = 1.5$**)**						
Benchmark	0.803	0.487	0.30	2.00	14.30%	0.00%
Aging 2030	0.803	0.487	0.24	2.10	21.41%	7.11%
Aging 2050	0.803	0.487	0.19	2.13	29.93%	15.63%
$\mu = 3$ **(risk aversion** $\gamma = 2.0$**)**						
Benchmark	0.800	0.487	0.30	2.00	14.30%	0.00%
Aging 2030	0.800	0.487	0.24	2.16	20.01%	5.71%
Aging 2050	0.800	0.487	0.19	2.12	30.53%	16.23%

5 Concluding Remarks

Population aging is a global trend. This paper employs a dynamic general equilibrium model to investigate the impacts of population aging on financing a NHI program. In particular, we focus on the additional tax burden required in response to the fast population aging expected in the NICs. We specifically select Taiwan as an example because it has both a NHI system and a fast-aging population. More importantly, the household level data are available and have been used for empirical studies in the literature.

Given the population projection in Taiwan, the results indicate that labor supply will decline significantly. The cost of NHI per capita will increase by 39 percent if the economy has the age structure of 2030 and an additional 7 percentage points of labor tax will be required, compared with the benchmark in the 2000s. The NHI cost will further increase by 61 percent if the age structure of 2050 is employed. In this case, an additional 16 percentage points of labor tax will be required.

Our results also show that if a high TFP growth, as observed in Taiwan and many NICs, continually sustains and grows faster than the medical price inflation for decades, the tax burden due to population aging can be largely reduced. If the TFP grows at a rate of 1 percent on top of medical price growth and the population aging continues until 2030, the tax rate in the economy can be maintained as it was in the 2000s. However, the current data suggest that real medical costs grow faster than TFP. If the real medical price growth rate is 0.5 percent on top of TFP, the tax burden will be largely raised in the future. Moreover, the NHI will be unsustainable by only collecting the labor income tax if the annual growth rate of medical price on top of TFP is more than 2 percent.

This study shows that the impacts of population aging on an economy are significant, particularly with regard to the tax burden on the working-age population. We focus on the NHI program because social security or public pension systems are usually not well-established in the NICs. If those old-age-oriented social programs were also implemented, fast population aging would result in a much higher tax burden in the near future. Some NICs, such as Asia Tigers, have a relatively short period of time to prepare for population aging. It is important for these countries to design appropriate policies right away in response to the population aging anticipated in the next two decades.

This paper also investigates a scenario with deferring retirement. If the government introduces policies that successfully encourage later retirement, the tax burden on the working-age population will be reduced. The exercise suggests that the tax burden can be partially reduced if the average retirement age can be significantly postponed. This also improve people's welfare.

There are other possible policies to reduce the influence of population aging. For example, the government may encourage international immigration of the working-age population or inspire fertility, so that the proportion of the working-age population becomes larger. Besides, an aging society faces other problems, such as providing professional medical services and long-term care, financing a social security program, and taking care of the elderly who live alone. These important issues are left for future research.

References

1. Aiyagari, S. Rao (1994), "Uninsured Idiosyncratic Risk and Aggregate Saving," *Quarterly Journal of Economics*, 109:3, 659–684.

2. Attanasio, Orazio (1999), "Consumption," In: Taylor, J.B., Woodford, M. (Eds.), *Handbook of Macroeconomics* 1B. Elsevier, Amsterdam, 741–812.

3. Attanasio, Orazio, Sagiri Kitao, and Giovanni L. Violante (2007), "Global Demographics Trends and Social Security Reform," *Journal of Monetary Economics* 54, 144-198.

4. Attanasio, Orazio, Sagiri Kitao, and Giovanni L. Violante (2011), "Financing Medicare: A

General Equilibrium Analysis," In J. B. Shoven (ed.), *Demography and the Economy*, NBER book, University of Chicago Press, 333 – 366.

5. Bewley, Truman F. (1986), "Stationary Monetary Equilibrium with A Continuum of Independently Fluctuating Consumers," In: Hildenbrand, W., Mas-Colell, A.(Eds.), *Contributions to Mathematical Economics in Honor of Gerard Debreu*. North-Holland, Amsterdam, 79–102.

6. Castañeda, Ana, Javier Díaz-Giménez, and José-Víctor Ríos-Rull (2003), "Accounting for the US Earnings and Wealth Inequality," *Journal of Political Economy* 111(4), 818–857.

7. Chatterjee, Satyajit, Dean Corbae, Makoto Nakajima, and José-Víctor Ríos-Rull (2007), "A Quantitative Theory of Unsecured Consumer Credit with Risk of Default," *Econometrica* 75:6, 1525–1589.

8. Cheng, Shou-Hsia and Tung-Liang Chiang (1997), "The Effect of Universal Health Insurance on Health Care Utilization in Taiwan: Results from A Natural Experiment," *Journal of American Medical Association* 278 (2), 89–93.

9. Chou, Shin-Yi, Jin-Tan Liu, and James K. Hammitt (2003), "National Health Insurance and Precautionary Saving: Evidence from Taiwan," *Journal of Public Economics* 87, 1873–1894.

10. Chou, Shin-Yi, Jin-Tan Liu, and Cliff J. Huang (2004), "Health Insurance and Savings over the Life Cycle- A Semiparametric Smooth Coefficient Estimation," *Journal of Applied Econometrics* 19(3), 295-322.

11. Chow, Gregory and An-loh Lin (2002), "Accounting for Economic Growth in Taiwan and Mainland China: A comparative Analysis," *Journal of Comparative Economics* 30:3, 507-530.

12. De Nardi, Mariacristina, Eric French, and John Bailey Jones (2010), "Why Do the Elderly Save? The Role of Medical Expenses," *Journal of Political Economy* 118:1, 39-75.

13. Dormont, Brigitte, Michel Grignon, and H*é*l*è*ne Huber (2006), "Health Expenditure Growth: Reassessing the Threat of Ageing," *Health Economics* 15, 947-963.

14. Fare, Rolf, Shawna Grosskopf, and Wen-Fu Lee (2001), "Productivity and Technical Change: the Case of Taiwan," *Applied Economics* 33:15, 1911-1925.

15. Heathcote, Jonathan (2005), "Fiscal Policy with Heterogeneous Agents and Incomplete Markets," *Review of Economic Studies* 72(1), 161-188.

16. Heathcote, Jonathan, Kjetil Storesletten, and Giovanni L. Violante (2008), "Insurance and Opportunities: A Welfare Analysis of Labor Market Risk," *Journal of Monetary Economics* 55, 501-525.

17. Hubbard, R. Glenn, Jonathan Skinner, and Stephen P. Zeldes (1995), "Precautionary Saving and Social Insurance," *Journal of Political Economy* 103, 360–399.

18. Huggett, Mark (1993), "The Risk-free Rate in Heterogeneous-agent Incomplete-insurance Economies," *Journal of Economic Dynamics and Control* 17, 953–969.

19. İmrohoroğlu, Ayse (1989), "Cost of Business Cycles with Indivisibilities and Liquidity Constraints," *Journal of Political Economy* 97, 1364–1383.

20. Jeske, Karsten and Sagiri Kitao (2009), "U.S. Tax Policy and Health Insurance Demand: Can a Regressive Policy Improve Welfare?" *Journal of Monetary Economics* 56, 210–221.

21. Kotlikoff, Laurence J. (1989), "Health Expenditures and Precautionary Savings," in L. J. Kotlikoff (ed.), *What Determines Savings?* Cambridge, Mass: MIT Press.

22. Liang, Chi-Yuan (2002), "The International Comparison of Total Factor Productivity Changes," *World Economy* 25:8, 1169-1195.

23. Livshits, Igor, James MacGee, and Michele Tertilt (2007), "Consumer bankruptcy: A fresh start," *American Economic Review* 97:1, 402–418.

24. Maddison, Angus (1989), "The World Economy in the 20th Century," *OECD Development Centre*, Paris.

25. Palumbo, Michael G. (1999), "Uncertain Medical Expenses and Precautionary Saving near the End of the Life Cycle," *Review of Economic Studies* 66, 395–421.

26. Scholz, John Karl, Ananth Seshadri, and Surachai Khitatrakun (2006), "Are Americans Saving 'Optimally' for Retirement?" *Journal of Political Economy* 114, 607–643.

27. Uwe, E. Reinhardt (2003), "Does the Aging of the Population Really Drive the Demand for Health Care?" *Health Affairs* 22:6, 27-39.

28. Werblow, Andreas, Stefan Felder, and Peter Zweifel (2007), "Population Ageing and Health Care Expenditure: A School of 'Red Herrings'," *Health Economics* 16, 1109-1126.

Appendix

A. Health Insurance and Demographics in Taiwan

A1. National Health Insurance

The NHI was introduced in Taiwan in 1995. It was expanded from the following three public health insurance programs: Labor Insurance, Government Employees' Insurance, and Farmers' Health Insurance. In 1994, 57 percent of total population was covered by the existing insurance programs; the remaining 43 percent included children, students, elderly, and non-working adults in the households whose heads were not in the public sector (Cheng and Chiang, 1997). The coverage rate of the NHI soon increased to 97 percent in 1998 (Chou et al. 2003).

Before the NHI was introduced, around 85 percent of the hospitals and 70 percent of the clinics had contracted with the above three insurance programs. After 1995, the Bureau of National Health Insurance became a monopsony for medical care services, and the contracted medical care institutions increased to around 96.5 percent of total hospitals and 89.5 percent of total clinics in 1997 (Chou et al. 2003).

The premium for Taiwan's NHI depends mainly on labor income: 5.17 percent of registered labor income, in general. The premium can be interpreted as a labor income tax. In each category, the insurance premium is shared by employees, employers, and the government. In general, both private and public employers are required to pay 60 percent of the premium for their employees; employees pay 30 percent; and the government pays the remaining 10 percent.[29] However, it is possible for employers, especially the private ones, to transfer the cost of the insurance premium to employees so that the total labor costs remain unchanged. People without labor income pay 60 percent of the average premium, and the remaining proportion is subsidized by the government.

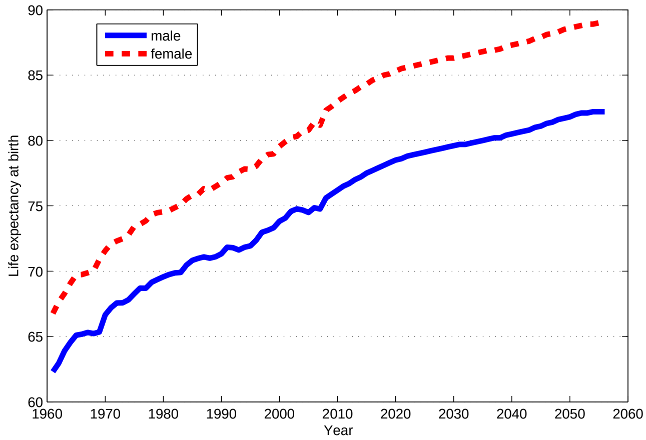
A2. Demographics

Taiwan has experienced rapid demographic changes in the past decades because of a sharp decline in fertility and an increase in survival probabilities. As a result, life expectancy at birth, rose to 75 years for males and 81 years for females in 2007 (Figure 5). In addition, the ratio of old age increased from below 5 percent to more than 10 percent during 1961-2007.

As reported in Table 13, the total fertility rate in 2007 was only 1.1. It is far below the replacement rate, and it is unable to sustain a zero population growth in the near future. Therefore, according to the government population projections (made by the Council for Economic Planning

[29]Source: Bureau of National Health Insurance of Taiwan.

Figure 5: Life Expectancy at Birth



Note: 1961-2007 are actual data; 2008-2056 are population projections. Source: Projections of the Population of Taiwan, Republic of China 2008 to 2056, Council for Economic Planning and Development, Executive Yuan, Taiwan.

and Development, Executive Yuan, Taiwan), the population growth rate in Taiwan will be close to zero in 2026. After that, Taiwan will experience a negative population growth.[30]

The projection also suggests that, in 2036, one-half of the total population in Taiwan will be older than age 50. The proportion of children (age 0-14) will be as low as 10 percent. The young-age dependency ratio will decline to 19 percent. In contrast, the proportion of the population aged 65 and above will increase to 38 percent. The old-age dependency ratio will increase to 72 percent in 2056. This trend implies that Taiwan will rapidly become a super-aged society in the next half century.

A3. Medical Cost of the Elderly

Old individuals are more likely to have chronic diseases, such as hypertension, cataracts, diabetes mellitus, and heart diseases. These diseases are more expensive than others and usually need long-term care. Therefore, an aging population will sharply increase the demand for medical resources.

In Table 14, the first column presents the fraction of medical costs designated for the population aged 65 and above as a percentage of total medical costs in Taiwan. The second reports the

[30] In the report, five population projections are provided: low, medium, high, ideal, and achieving the replacement rate. This paper is based on the medium projection. It is also used in the calibration.

Table 13: Population Projections for Taiwan

	TFR	Population Growth (‰)	Median Age	Age Structure (%)			Dependency Ratio (%)	
				(1) 0-14	(2) 15-64	(3) 65^{+}	(1)/(2)	(3)/(2)
2007	1.11	3.4	35.7	17.6	72.2	10.2	24.3	14.1
2010	1.11	3.3	37.3	15.8	73.4	10.8	21.6	14.7
2030	1.14	-1.9	48.5	11.1	64.6	24.3	17.2	37.6
2040	1.13	-6.4	52.9	9.7	59.6	30.7	16.3	51.5
2050	1.06	-10.2	56.6	8.3	54.4	37.3	15.3	68.6

Note: 2007 numbers are actual data; others are population projections. Source: Projections of the Population of Taiwan, Republic of China 2008 to 2056, Council for Economic Planning and Development, Executive Yuan, Taiwan.

Table 14: Medical Cost and Population of the Elderly

Year	Ratio of medical cost for the elderly among total (%)	Ratio of the elderly population among total (%)
1998	26.7	8.7
2001	29.4	9.0
2004	31.9	9.6
2007	33.2	10.2
2009	33.9	10.5

Source: National Health Annual Statistical Report, Department of Health, Executive Yuan, Taiwan.

ratio of the population aged 65 and above to the total insured population covered by the NHI. We observe that, first, the ratio of the insured elderly and the proportion of medical cost spent on them increased continuously. Second, in 1998-2009, the proportion of the elderly slightly increased 2 percentage points (from 8.7 to 10.5 percent). However, the medical costs for the elderly rose 7 percentage points (from 27 to 34 percent). The ratio of medical costs spent on the elderly grew faster than the ratio of the old population.

B. Deferring Retirement

B1. The Model

In the model in Section 2, there are only two types of individuals, young workers and old retirees, in terms of age and working status. To study the impacts of deferring retirement, an additional type, old workers is required.

Young Agent

An individual enters the economy as a young agent at age 21 and faces a probability ρ_o of becoming an old worker (i.e., facing a higher medical expenditure shock but still working). The agent solves the following maximization problem:

$$V_y\left(s\right) = \max_{c,n,a'} \left\{u\left(c,n\right) + \beta\left(1-\rho_o\right)E\left[V_y\left(s'\right)\right] + \beta\rho_o E\left[V_{ow}\left(a',z',x_o'\right)\right]\right\}$$

subject to (4), (5), (6), (7), and (8), where V_{ow} is the value for an old worker.

Old Worker

Since the retirement age is deferred, an old worker still makes a labor supply decision in each period and faces the income uncertainty as a young agent does. However, unlike the young agent, the old worker faces the higher medical expenditure uncertainty, x_o. The old worker faces a probability ρ_r of retirement. $\frac{1}{\rho_r}$ indicates the average years the old agent works after becoming old. An old worker's problem is given by:

$$V_{ow}\left(a,z,x_o\right) = \max_{c,n,a'} \left\{u\left(c,n\right) + \beta\left(1-\rho_r\right)\left(1-\rho_d\right)E\left[V_{ow}\left(a',z',x_o'\right)\right] + \beta\rho_r\left(1-\rho_d\right)E\left[V_{or}\left(a',z',x_o'\right)\right]\right\}$$

subject to

$$\begin{aligned}
&(1+\tau_c)c + a' = Wel_{ow} + T; \\
&Wel_{ow} \equiv (1-\tau_n)\, wzn + [1 + (1-\tau_k)\, r]\, (a+b) - [1-\omega]\, P_x x_o - P_{NHI}; \\
&P_{NHI} = \tau_{NHI}(wzn); \\
&T = \max\{0,\ (1+\tau_c)\underline{c} - Wel_o\}; \\
&a' \geq 0;\ 1 > n \geq 0.
\end{aligned}$$

Old Retiree

Once an old agent becomes retired, the problem that he/she solves is the same as that in the original model:

$$V_{or}\left(s_o\right) = \max_{c,a'} \left\{ u\left(c,0\right) + \beta\left(1-\rho_d\right) E\left[V_{or}\left(s_o'\right)\right] \right\}$$

subject to (10), (12), (11), (13), and (14), where V_{or} is the value for the retiree and ρ_d is the death probability.

B2. Calibration

Young agents and old workers face the income uncertainties reported in Table 3. Young agents are hit by the medical expenditure shocks reported in the first part of Table 5. Old workers and old retirees are hit by the medical shocks reported in the second part of Table 5. The price of medical expenditure is set to be 1. The definitions of ρ_o and ρ_d are the same as those in the original model. In addition, ρ_r pins down the average years that an old agent works after becoming old. Other parameters remain unchanged.