Advances

Kyoung Mook Lim*

Public provision of health insurance and welfare

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Abstract: This paper examines the effects of expanding public health insurance benefits on individuals' welfare in a highly old-age dependent economy. On the one hand, such a policy would benefit the older generations in the population by improving their health status. On the other hand, an economy that has a high share of the elderly may sharply increase the tax rate that finances the public health insurance program, which is mainly financed by working-age generations. Due to the trade-off, the impact of the policy on average welfare is ambiguous. To quantify this effect, I examine the South Korean plan to expand its public health insurance despite the country's rapidly aging population. I build an overlapping-generations model and track the effect of the proposed public health insurance expansion on welfare over a transition path. The results suggest that the proposed expansion not only increases average welfare, but also the welfare of the working-age generations who would be more likely to resort to preventative medicine. However, such welfare gains can be lost if implementation of the policy were to be postponed to a later highly old-age dependent economy.

Keywords: aging population; publicly-provided health insurance; South Korea; transition path.

JEL Classification: C68, D91, H51, I13.

1 Introduction

Many countries have experienced the combination of rising life expectancy and declining birth rates, a phenomenon commonly known as "aging population." The United Nations (2012) recommends that these countries strengthen its public health insurance in order to meet on going health care needs. The report suggests

***Corresponding author: Kyoung Mook Lim,** Department of Economics, Washington College, Chestertown, MD 21620, USA, Tel.: +1-410-810-5002, e-mail: mlim2@washcoll.edu

there is a need for expanding public health insurance to fill the gap in private financing of health care services in many countries. However, the overall effect of increasing public health insurance benefits on welfare is not clear. On the one hand, such a policy would improve the welfare of the elderly who are heavy users of health care. On the other hand, the relative size of the working-age population continues to shrink following demographic trends. Thus, the tax rate required to finance public health insurance would have to rise. To give a quantitative answer to the above policy conundrum, this paper examines the effect of expanding public health insurance in South Korea.

South Korea has the fastest aging population among the OECD countries. Table 1 compares how many years it takes for the elderly to reach a certain threshold – as a share of the total population in selected OECD countries. While the populations of other developed nations are older, the pace of aging is much faster in South Korea. Since the 1990s, South Korea has experienced a rapid growth in total medical expenditures together with a rapid increase in old-age dependency. Figure 1 shows that shares of the elderly (60 years old and older) in the total adult (25 years and older) population increased from 14 percent in 1990 to 23 percent in 2010. According to a projection by the United Nations (2012), in South Korea, the population share of the elderly will reach close to 40 percent by 2050.[1] With the rise in old-age dependency, there has also been a rise in the medical expenditure devoted to the care of elderly population in South Korea. For instance, Lee (2011) shows that the share of spending on the elderly as a proportion of total health care expenditures increased from 24 percent in 2005 to 32 percent in 2010. Much of the increase in health expenditure comes from the care for age-related chronic illnesses, such as hypertension, diabetes, dementia, cataracts, and arthritis.

Table 1: Shares of elderly in total population over time in selected countries.

Country	Share of elderly and year			Elapsed number of years	
	7%	14%	20%	7→14%	14→20%
South Korea	2000	2018	2026	18	8
Japan	1970	1994	2006	24	12
France	1864	1979	2018	115	39
Germany	1932	1972	2009	40	37
US	1942	2015	2036	73	21

Source: KOSIS (2011).
Elderly is defined as 65 years or older.

1 The UN projection uses the total population as the denominator. The projected share in the adult population would be thus higher than 40 percent in 2050.

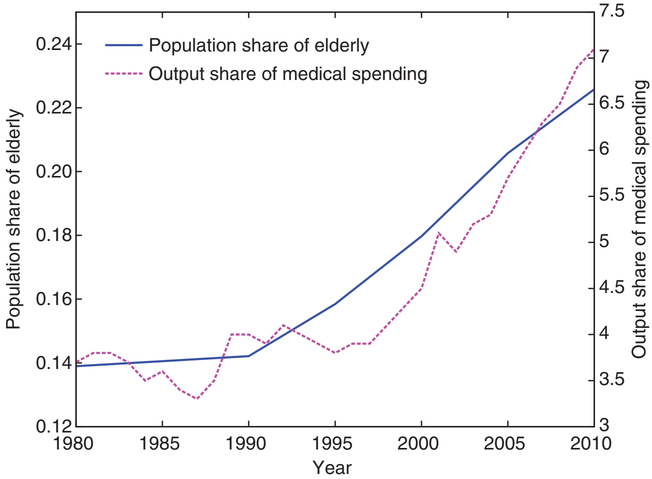

Figure 1: Population of the elderly to the total population in South Korea between 1980 and 2010.
Note: The population of the elderly is computed as the number of 60 and older divided by the number of 25 and older.
Source: Korean Statistical Information Service (2013).

What makes South Korea a suitable subject is that despite the pace of population aging, the government has put forward a plan to increase public health insurance benefits. The motivation behind the policy is to reduce the current level of out-of-pocket medical expenditure. Several studies find that many South Koreans are vulnerable to medical bankruptcy (Ruger and Kim 2007; Son, Shin, and Kim 2010). Some give up necessary medical treatments and consequently, face higher health risks (Kim 2008; Kim, Oh, and Jha 2014). It is, thus, not surprising that reducing medical expenditure shocks and improving access to health care have received widespread political support in South Korea. A concrete plan that is currently under development would raise the benefit rate from the mid-60 percent to 80 percent by 2016. However, achieving the target benefit rate by 2016 is doubtful, given that the same target was set in 2002 but was revised downward in 2006. If the government fails to meet the target again and postpones the time line, then implementation will have to take place in a higher old-age dependent environment.

There is a large empirical literature on the role of health insurance in health care utilization and health outcomes. McWilliams (2009) provides an extensive survey of the literature which finds that having greater health insurance benefits leads to greater medical utilization in the US.[2] These medical services include

2 Hoffman and Paradise (2008) also provides a survey of the literature which confirms the findings in McWilliams (2009).

various preventative and diagnostic services such as blood pressure checks, flu vaccination, and mammography.[3] Card, Dobkin, and Maestas (2009) find that Medicare eligibility at 65 increases the number of medical procedures done on the patient and as a result reduces the mortality rate by 1 percent. Decker and Rentier (2004) compare US seniors with Canadian seniors and find that at age 65 there is a reduction in self-reported morbidity by 4 percentage points for low-income US seniors who attain the Medicare coverage. A large study by the Institute of Medicine (2004) finds that the uninsured in the US face greater morbidity and mortality from various chronic illnesses (e.g. cardiovascular disease and diabetes).

Similarly in South Korea, relatively low public health insurance benefits has caused low income households to frequently give up visits to a physician (Kim, Ko, and Yang 2005) and medical services for treating chronic illnesses (Kim 2008). Kim, Oh, and Jha (2014) find that patients from the low socio-economic background suffer from higher in-hospital mortality even after controlling for their health status, because poor patients often give up expensive, yet life-saving medical services. These findings in South Korea suggest that a lack of health insurance results in a decrease in medical consumption and health outcomes.

In 2010, the public health insurance benefit rate in South Korea was 64 percent, which is far below the OECD average of 80 percent. Given the prevalence of insufficient medical consumption, an increase in the benefit rate in South Korea would result in substantial effects on macroeconomic variables. First, expanding public health insurance may result in an increase in labor productivity with health improvement. This factor may be more pronounced in South Korea given the nature of diminishing returns to health from medical consumption (Grossman 1972). Second, the policy change would reduce precautionary savings due to uninsurable health shocks, and thus aggregate saving. Such a reduction in aggregate saving may be larger in the context of aging population as there are more dissavers in the economy.

To understand the macroeconomic impact of the proposed policy, I build a general-equilibrium, overlapping generations (OLG) model with incomplete health insurance markets. The model includes universal public health insurance which covers a fraction of medical costs. The remaining medical cost is the coinsurance borne by households. Some households may not, however, commit to pay for coinsurance, instead they would give up medical consumption. Those who give up medical consumption will face a higher chance of adverse health shocks. Such endogenous medical consumption is akin to health investment where medical

3 For studies that report the impact of giving up diagnostic and preventative care on health in the US, see (Baker et al. 2001; Institute of Medicine 2002, 2004; Baker et al. 2006; Schoen et al. 2008).

consumption partially mitigates idiosyncratic health shocks. I estimate the health shock process using the Korean Welfare Panel Study (KOWEPS), which asks the survey respondent about giving up medical consumption due to financial pressure.

The welfare analysis of this paper relates to a number of macroeconomic studies that examine the effect of expanding public health insurance on welfare. A typical model in the literature considers the trade-off between the positive health effect and the negative tax effect. Theoretically, increasing the benefit rate not only reduces the magnitude of medical expenditure shocks, but also improves the health of individuals who would have otherwise given up on medical consumption. On the other hand, expanding public health insurance entails a tax hike, which reduces the disposable income of the working-age population. In addition to the trade-off, there are changes to the factor prices. An increase in public health insurance benefits reduces aggregate capital, which in turn increases the rate of return to capital, and decreases the wage rate. While the rising interest rate improves the welfare of the asset-rich, retired generation, the falling wage rate decreases the welfare of the working-age generation. Theoretically, the combined effect on average welfare is ambiguous.

The results of the paper show that implementing the policy change in South Korea in the contemporary demographic structure would result in a net welfare gain. However, deferring the policy implementation to a later older demographic structure would result in a net welfare loss. In a highly old-age dependent economy, the negative tax effect on welfare dominates the positive health effect. As a policy experiment, I conduct two sets of demographic structures: a contemporary demography, and an aged demography in the future. I apply the same policy change on each demographic structure and track the policy impact on welfare. The results show that, in the contemporary demographic structure, there would be an increase in average welfare at the onset of the transition dynamics. But the policy change in the aged demographic structure would decrease average welfare even at the onset.

Several papers in the macroeconomics health literature find that in the current US context the effect of expanding public health insurance benefits on average welfare is positive (Jeske and Kitao 2009; Hsu and Lee 2012; Pashchenko and Porapakkarm 2013; Kopecky and Koreshkova 2014). Although these papers consider different policy changes, they all find that the positive health insurance effect outweighs the negative tax effect. In contrast, Attanasio, Kitao, and Violante (2010) find that in an economy with high old-age dependency, the positive health insurance effect falls short of the negative tax effect on welfare. These findings confirm the findings of the current research that expanding public health insurance becomes a net welfare loss if the policy is implemented in a high old-age dependency. However, in all these papers, health shocks are the equivalent of exogenous medical expenditure shocks that are independent of previous medical consumption history. This paper improves the welfare analysis by allowing medical consumption to interact with future health status.

Within the macroeconomics health literature, there are several papers that examine the effect on welfare of expanding public health insurance, while allowing for endogenous medical consumption. Jung and Tran (2009) examine the effect on welfare of introducing a universal medical voucher in the US, and show that the positive effect of the policy outweighs the negative effect of an increase in tax. Similarly, Prados (2012) shows that expanding public health insurance in the US would improve average welfare. However, Feng (2009) shows that expanding public health insurance is welfare improving, only if the reform is able to contain the moral hazard effect.

One key distinction from the literature is that this paper captures the interaction between a lack of health insurance and health status by incorporating the health shock process from a panel data set, which includes the risk of giving up necessary medical services due to financial reasons. The feature of the model implies that this paper is able to capture the effect of (a lack of) medical consumption on wealth. Data permitting, this particular modeling feature can be an integral part of welfare analysis for aging economies such as China and Turkey who have considered expanding its public health insurance. What we glean from the South Korea case may offer an evaluation of the policy change across similarly situated countries.

The second contribution to the literature is that the current analysis uses the time path iteration method that tracks not only average welfare but also lifetime welfare by birth cohort over the transition path. Thus, this paper is unique in its ability to incorporate the welfare consequences of a lack of medical care and describe how welfare evolves over the transition path.

The paper is organized as follows: Section 2 presents the model economy in a steady state and in transition to a new steady state. Section 3 provides a background on the Korean health care system and calibrates the model to the Korean economy. Section 4 presents the baseline results, and the results after several modifications to the model. Section 5 concludes. Appendix 6 describes the computational algorithm used in this paper. I have also provided a technical appendix that provides details on the estimation of the health transition probability.

2 A Life-cycle model of endogenous health outcomes

To quantify the effect of medical consumption on welfare, I build a life-cycle model with endogenous health outcomes. The life-cycle can be described as having two parts: first, individuals supply labor in the labor force, and second, they retire from work. Throughout the life-cycle, they face idiosyncratic health shocks, which affect their labor endowment when they are in the labor force, and mortality when in retirement. By consuming medical services, individuals can reduce the likelihood of bad health shocks in the next period.

I consider the current policy proposal in South Korea which intends to increase the benefit rate from the mid-60 percent to 80 percent. In other words, this policy reduces out-of-pocket medical spending. Consequently, the policy would increase total medical consumption, which in turn produces two conflicting effects on average welfare. On the one hand, it would increase welfare by improving health outcomes, especially for those who, in the absence of the policy reform, would give up medical consumption for financial reasons. On the other hand, the policy change entails an increase in the tax rate for working-age generations.[4] To measure the magnitude of these effects on welfare, I build the following overlapping-generations model.

2.1 Model economy

Demographics: Time is discrete. And it is denoted by t=0, 1, …, ∞. Each period corresponds to 5 calendar years. An agent's age consists of a maximum of 12 periods with each period denoted by s=1, …, 12. Individuals work during the first seven periods, and then retire for the remaining five periods. In each period, a new generation of individuals (s=1) enter the economy with zero asset holdings, and the oldest generation (s=12) exits the economy after exhausting all their wealth. The share of each generation is denoted by $\mu(s)$ with $\sum_{s=1}^{12}\mu(s)=1.$ The size of each cohort is equal to the population share of the cohort, so that the population mass is 1.

Preferences: Preferences are defined over the consumption of a composite non-medical good c and health status h. Health status can be "good" h_g or "bad" h_b. Bad health corresponds to utility loss due to morbidity: thus utility from good health is higher than that from bad health, holding age constant. In particular, individual preferences are represented by a constant elasticity of substitution (CES) utility function of the following form

$$u(c_t, h_t)=u(c, h)=\left[(1-\lambda)^{1/\nu}c^{\frac{\nu-1}{\nu}}+\lambda^{1/\nu}h^{\frac{\nu-1}{\nu}}\right]^{\frac{\nu}{\nu-1}}, \tag{1}$$

4 The tax rate could decrease if the health gains to the working-age population is substantially high. Then the policy change may increase labor supply and broaden the tax base.

where $0<\lambda<1$ is the weight of health status in utility. ν is the elasticity of substitution between c and h. I consider health status and consumption to be gross complements ($0<\nu<1$). Such complementarity between health and consumption suggests that the marginal utility of consumption increases with improved health status (Finkelstein, Luttmer, and Notowidigdo 2013).

However, complementarity between consumption and health status is not the only specifications used in the literature. For instance, Hall and Jones (2007) argue that the marginal utility of consumption can theoretically increase with deteriorating health.[5] They take an agnostic stance that health and consumption are separable and additive. Such a specification is adopted by Kashiwase (2009) and Ozkan (2011). Because the choice of utility function matters for welfare analysis, I also consider a separable, additive utility function

$$u(c_t, h_t)=\xi+\frac{c_t^{1-\sigma_c}}{1-\sigma_c}+\frac{h_t^{1-\sigma_h}}{1-\sigma_h}, \tag{2}$$

where ξ represents the value of being alive a life-year,[6] σ_c and σ_h describe the curvature of utility function with respect to consumption and health, respectively. Note that this separable and additive utility function implies that the marginal utility of consumption is independent of health status.

Health and mortality: There are two shock processes in the model: health and mortality shocks. Health status h follows a 2-state Markov process, which is defined by either good (h_g) or bad (h_b). Health status is a function of the individual's age, past health status, and past medical consumption, which is assumed to be binary. Binary medical consumption means that an individual can either commit to medical consumption or give up medical consumption. I consider medical consumption broadly, including preventative and curative care. As a result, individuals in both good or bad health can purchase medical care. The concrete implication of medical consumption today is that it reduces the likelihood of bad health shocks in the future.[7]

I first describe the health shock process h_{t+1}^{s+1} for an individual who is in age s and consumes medical services at time t in the following transition matrix

$$\Theta_{\mathbb{I}_{m_t}=1}(h'|h)=\text{Prob}\{h_{t+1}^{s+1}=h'|h_t^s=h\}=\begin{pmatrix} p_{gg}^s & p_{gb}^s \\ p_{bg}^s & p_{bb}^s \end{pmatrix}, \tag{3}$$

5 They use the example of having a ready-made meal and nursing care services for those in bad health.

6 Adding the constant avoids the issue of choosing death over low consumption.

7 The model considers medical consumption to be a homogenous medical service, which guarantees net positive health benefits. For the positive effect of preventative medicine on health, see US Preventive Services Task Force (2014).

where $\mathbb{I}_{m_t}=1$ indicates that the individual has consumed medical services at time t. For instance, in the above expression, p^s_{bg} represents the probability of an individual aged s having bad health status in period t and good health status in period t+1, conditional on medical consumption in period t.

The transition matrix for those who give up medical consumption is

$$\Theta_{\mathbb{I}_{m_t}=0}(h'|h)=\text{Prob}\{h^{s+1}_{t+1}=h'|h^s_t=h\}=\begin{pmatrix} q^s_{gg} & q^s_{gb} \\ q^s_{bg} & q^s_{bb} \end{pmatrix}, \tag{4}$$

where $\mathbb{I}_{m_t}=0$ indicates that the individual has given up medical consumption at time t. The transition probability is less favorable for those who give up medical consumption ($p^s_{bg}>q^s_{bg}$, $p^s_{gg}>q^s_{gg}$).

The mortality shock process $\chi(s, h)$ applies to the retired generations who are in bad health status. The probability of dying increases with age and it equals 1 if s=12. The asset holdings of the deceased are treated as accidental bequests, equally distributed to the rest of the population.

Firms: There are two perfectly competitive sectors, medical (m) and non-medical (n) sectors with a Cobb-Douglas production function

$$Y^i_t=Z^i L^{i\,1-\alpha}_t K^{i\alpha}_t,\ \ i=\{m, n\}, \tag{5}$$

where K^i_t represents the capital stock in sector i and period t, L^i_t is labor, and Z^i is the time-invariant total factor productivity in sector i. The share of capital α is the same across sectors.

Firms rent labor and capital from households. Factor markets are competitive, hence factors of production are compensated at their marginal product

$$r_t=\alpha Z^n\left(\frac{L^n_t}{K^n_t}\right)^{1-\alpha}-\delta=\alpha Z^m\left(\frac{L^m_t}{K^m_t}\right)^{1-\alpha}P^m-\delta \tag{6}$$

$$w_t=(1-\alpha)Z^n\left(\frac{K^n_t}{L^n_t}\right)^{\alpha}=(1-\alpha)Z^m\left(\frac{K^m_t}{L^m_t}\right)^{\alpha}P^m, \tag{7}$$

where r_t is the rate of return on capital, w_t the wage rate, and δ the capital depreciation rate. The price of the non-medical commodity is normalized to one, P^m the relative price of medical services.

Perfect factor mobility ensures equality of the marginal rates of transformation and the capital-labor ratios across sectors

$$\frac{K^n_t}{L^n_t}=k^n_t=\frac{K^m_t}{L^m_t}=k^m_t.$$

Given Equations (6) and (7), the relative price of medical service is the ratio of the TFPs

$$P^m = \frac{Z^n}{Z^m}. \tag{8}$$

The model assumes that the capital share α is the same across sectors. The relative price of medical services is thus time-invariant. However, if the capital share in the medical sector is to be higher than in the non-medical sector, we expect the relative price of medical services to change over the transition path.[8]

Public health insurance: All individuals have access to publicly provided health insurance, that is fully-funded by a payroll tax. The health insurance program is fully specified by η the benefit rate. Agents consuming medical services pay $1-\eta$ the coinsurance rate of medical services. The health insurance program is managed under a balanced budget rule; therefore, there exists a unique equilibrium payroll tax τ that covers the outlays

$$\tau = \frac{\eta_t P^m M_t}{w_t L_t}, \tag{9}$$

where M is the aggregate medical demand, L the aggregate labor supply.

Aggregate resource constraints: The sum of the resources used in both sectors makes up the aggregate capital K_t and the labor supply L_t. The aggregate resource constraints are

$$K_t^n + K_t^m = K_t,$$
$$L_t^n + L_t^m = L_t.$$

Medical services can only be consumed and non-medical output can be either consumed or invested

$$P^m M_t = Y_t^m,$$
$$K_{t+1} = Y_t^n - N_t + (1-\delta) K_t,$$

where N_t represents the aggregate consumption of non-medical goods.

2.2 The individual's problem

Individuals maximize their expected lifetime utility

$$\max \mathbb{E}_t \left[\sum_{s=1}^{12} \beta^{t+s-1} \Pi(1-\chi(s, h)) u(c_{t+s}, h_{t+s}) \right], \tag{10}$$

8 Acemoglu and Guerrieri (2008) suggest that capital deepening would result in an increase in the price of capital-intensive goods.

where β is the time discount factor, and $\Pi(1-\chi(s, h))$ is the accumulated probability of survival. Individuals draw utility from health status h and consumption of non-medical goods c.

The state space for individuals is in three dimensions: age, asset, and health status ($x=\{s, k, h\}$). Individuals' choice variables are consumption c, savings k' and medical consumption $\mathbb{I}_m$. The recursive formulation of the individual's problem is

$$V(x)=\max_{c,\mathbb{I}_m,k'} u(c, h)+\beta(1-\chi(s, h))\mathbb{E}[V(x')] \tag{11}$$

subject to

$$\begin{aligned} &k'=(1+r)k+(1-\tau)l(h)\mathbb{I}_w(s)e(s)w+b-c-\omega,\\ &\omega=(1-\eta)P^m\mathbb{I}_m\pi(s, h),\\ &k\geq 0, \end{aligned} \tag{12}$$

where $\mathbb{I}_w(s)$ is the indicator function which takes the value of one if the individual is of working age, and zero if the individual is retired; $e(s)$ is an age-specific efficiency parameter, which captures returns to experience; $l(h)$ is a shift parameter that governs the relative labor endowment in bad health relative to good health; ω represents the out-of-pocket medical spending. When the individual gives up medical services, the indicator function takes the value of zero $\mathbb{I}_m=0$, otherwise one. $\pi(s, h)$ represents the cost of medical consumption, which varies by age and health status. The cost increases with age ($\pi(s', h)>\pi(s, h)$ for $s'>s$). Also the cost is higher in bad health status ($\pi(s, h=h_b)>\pi(s, h=h_g)$). The details of the solution algorithm are in Appendix 6.1.

2.3 Steady state equilibrium

Definition: Let $X=\{1, \ldots, 12\}\times\mathbb{R}_+\times\{h_g, h_b\}$. A recursive equilibrium is a probability distribution Γ of households over X, a value function V: $X\rightarrow\mathbb{R}$, a policy function g: $X\rightarrow\{0, 1\}\times\mathbb{R}_+$, a tax rate τ, and an amount of accidental bequest b such that:

1. The value and policy functions solve the individual optimization problem Equation (11) given the factor prices, tax rate, and accidental bequest;
2. The labor and capital markets clear;

$$K=\int_X k\, d\Gamma, \tag{13}$$

$$L=\int_X l\, d\Gamma; \tag{14}$$

3. The outlays for public health insurance are equal to the revenues raised by the payroll tax;

$$\tau wL=\eta P^m M; \tag{15}$$

4. The goods market clears;

$$Y=C+K'+P^m M-(1-\delta)K, \tag{16}$$

where

$$C=\int_X g_c \, d\Gamma, \tag{17}$$

$$K'=\int_X g_k \, d\Gamma, \tag{18}$$

$$M=\int_X P^m g_m m \, d\Gamma; \tag{19}$$

5. Γ is the probability density function over X of a randomly drawn individual from the living population. The law of motion for Γ is

$$\Gamma_s^{t+1}=\int(1-\chi(s-1, h_{s-1}))\Gamma_{s-1}dx. \tag{20}$$

2.4 Transition path

The economy is initially in a steady state. Then I introduce a policy change that increases public health insurance benefits. To measure the policy's impact on welfare over the life-cycle, I track the transition path which is the movement of the model economy from the initial state to a new steady state. The economy takes a maximum of T periods to converge to the new steady state. I use the time path iterations (TPI) algorithm by Nishiyama and Smetters (2007) who compute the transition path in a stochastic general-equilibrium OLG framework. The TPI method assumes that all individuals share a common belief in the future distribution of population over the state space Γ. In the following, I describe the model on the transition path. The solution algorithm for the transition path is in Appendix 7.

The model on the transition path operates similarly as it does in a steady state equilibrium. In each period, a generation of individuals enters the economy as the oldest generation exits the economy. The population size is 1, which is the sum of each generation's population share. Individuals' preference is described by the CES utility function (Equation 1) in the baseline. There are two sectors: the non-medical sector n and medical sector m. They operate under the Cobb-Douglas production (Equation 5). The health shock process and mortality risks are conditional on medical consumption. The publicly provided health insurance system covers a fraction of medical expenditure η which is financed by the payroll tax rate τ. The main difference arises from the fact that the model economy is changing period by period. The steady state economy contains a single set of factor prices and other macroeconomic variables, whereas the transition path contains T sets of factor prices and macroeconomic variables.

What produces a unique transition path is the assumption that individuals at time t share a common belief in the future distribution of population in terms of age, health status, and asset holdings Γ

$$\Gamma^{e}_{t+i} = \Omega^{i}(\Gamma_{t}) \ \forall t \ i \geq 1,$$

where the shared belief Ω^i gives all individuals the same expected distribution Γ^{e}_{t+i} in i periods. With the knowledge of $\Gamma^{e}_{t=1,\ldots,T}$, one can calculate the corresponding set of factor prices and tax rates over the transition path. Using this information, individuals compute their policy rule $k'=g(s, k, h|\Omega)$ which yields the optimal intertemporal consumption/saving decision. Given that the convergence to the new steady state occurs within T periods, the shared-belief on Γ allows the economy to move on a unique transition path.

The solution to an individual's problem on the transition path is similar to that in the steady state. To solve the optimal saving and medical consumption decision, I use the backward induction methods for each birth cohort. The solution on the transition path involves S sets of factor prices and tax rates, whereas the steady state solution involves only one set of factor prices and tax rate. In the recursive form, the individual's problem on the transition path is

$$V(x) = \max_{c, \mathbb{I}_m, k'} u(c, h) + \beta(1-\chi(s, h)) \ \mathbb{E}[V(x')] \tag{21}$$

subject to

$$\begin{aligned} &k' = (1+r(\Gamma_t))k + (1-\tau(\Gamma_t))l(h)\mathbb{I}_w(s)e(s)w(\Gamma_t) + b(\Gamma_t) - c - \omega, \\ &\omega = (1-\eta_t)P^m \mathbb{I}_m \pi(s, h), \\ &k \geq 0, \end{aligned} \tag{22}$$

where the factor prices, accidental bequest, and tax rate depend on the distribution of population in the state space Γ.

3 Calibration

In what follows, I provide a background on the South Korean health care system, and the calibration of the model. Section 3.1 describes some notable features of the South Korean health care system, and discusses the proposed plan to increase public health insurance benefits. Section 3.2 presents the parametrization of the model.

3.1 Health care in South Korea

Public health insurance in South Korea covers a comprehensive array of health care services to all its citizens. Its benefit rate, which is defined by the share of public spending in total health spending, has increased from 35 percent in 1989 to 64 percent in 2010. However, the benefit rate is still considered to be one of the lowest among the OECD countries. As a result, many South Koreans have been vulnerable to medical bankruptcy (Ruger and Kim 2007), and to the risk of giving up medical treatment due to financial constraints (Kim 2008).

The risk of giving up medical consumption is especially prevalent among the poor. Kim, Oh, and Jha (2014) suggest that those of low socioeconomic status in South Korea may skip expensive medical services and thus suffer a higher within-hospital mortality rate due to cerebrovascular diseases, gastrointestinal bleeding, and pneumonia. Kim, Ko, and Yang (2005) show that in response to an increase in out-of-pocket medical expenditures, low income households would reduce their visits to a physician by three times more than their high-income counterparts. The literature shows that the lack of health insurance benefits in South Korea has become a barrier to sufficient medical consumption, which in turn negatively affects health outcomes.

On the financing structure, the National Health Insurance Corporation (NHIC) collects social contributions via payroll taxation and reimburses doctors and hospitals for the provision of health care services. To balance the budget, the NHIC sets the social contribution rate, and collects them as proportional payroll taxation. The NHIC also runs the Medical Aid Programme, a means- and asset-tested assistance program which targets poor and disabled households.[9]

Private health insurance in South Korea is supplementary as an additional layer of protection on top of public health insurance. It pays for a large fraction of co-payments as well as some uninsured medical services. In 2008, private health insurance represented about 4.4 percent of total health spending, and outlays for car accidents represented about half of the total private health insurance outlays (Jones 2010).[10]

Health care provision in South Korea is dominated by the private sector (90 percent of provision), whereas the public sector specializes in psychiatric care,

9 I have excluded the Medical Aid Programme from the analysis for two reasons. First, the recipients represent a small fraction of the population (3.3 percent in 2010) of which are also disabled. Second, the proposed policy would not affect the medical cost schedule of the recipients.

10 I have excluded private health insurance from the analysis as it plays a marginal role in health care financing.

as well as primary care in rural areas. For covered services, patients pay a fraction of the cost as copayment, and physicians are reimbursed by the NHIC on a fee-for-service basis. For non-covered services, patients pay either directly out-of-pocket or indirectly through private health insurance. Non-covered services include screening services such as sonograms and PET scans. Some of these services are considered either preventative or essential diagnostic services. The combination of low benefits and high co-payments have created a barrier in access to health care.

To reduce the barrier to health care, most major political parties in South Korea have supported the notion of increasing the public health insurance benefit rate. Since 2000, both conservative and progressive parties while in power have introduced various plans to increase the benefit rate to between 70 and 80 percent. However, there has been a lack of consensus on the speed of expansion especially in the face of NHIC's budget deficit. For example, in 2001, when the NHIC faced a deficit of 4 trillion Korean won (approximately $US 4 billion), the government rolled back benefits for certain medical services. For example, in 2001, non-surgical dental scaling was delisted. In 2002, President Rho's center-left government proposed to increase the benefit rate to 80 percent by 2008. This target was revised in 2005 downward to achieving 71.5 percent by 2008, and revised again in 2006 to achieving 72 percent by 2017, and 85 percent by 2030.

The current conservative government intends to increase the benefit rate. In 2013, the Park administration proposed a policy change that would reduce out-of-pocket expenditure for four major illnesses (cancer, heart disease, stroke, rare (orphan) diseases). This proposal also includes coverage for associated imaging services (CT scan, MRI, PET scan), chemotherapy, and other related services, which had not been covered. These reforms are part of a broader policy objective to increase the benefit rate to around 80 percent by 2016. However, the government may again slow the pace of expansion in the future, given the expected increase in the tax rate, which is unpopular among the public (Kwon 2009). I examine the consequences of postponing the expansion for welfare in the face of the rapidly aging population of South Korea.

3.2 Parametrization

To solve the model numerically, I calibrate the model to the Korean economy. Table 2 summarizes the parameters used in the model, and what follows discusses the parametrization in detail.

Demographics: Each period in the model corresponds to 5 calendar years. The birth age in the model $s=1$ corresponds to biological ages between 25 and 29.

Table 2: Parameters.

Parameter	Description	Values	Source
α	Capital share	0.3	Young (1995)
β	Discount factor	$0.9=0.98^5$	Baseline
d	Mortality parameter	0.002	Baseline
δ	Depreciation rate	$0.23=1-(1-0.05)^5$	Pyo, Rhee, and Ha (2006)
P^m	Relative price of medical care	1.103	Pyo, Rhee, and Ha (2006)
$\pi(s, h)$	Cost of medical expenditure	See text	KOWEPS (2006–2010)
p_{gg} and p_{gb}	Health transition probability	See text	KOWEPS (2006, 2007)
q_{gg} and q_{gb}	Health transition probability	See text	KOWEPS (2006, 2007)
ν	Elasticity of substitution	0.5	Baseline
λ	Health weight in utility	0.6	Baseline
$l(h=h_b)$	Labor supply in bad health	0.75	Baseline

Sources: Korean Statistical Information Service (KOSIS, 2013), Korea Welfare Panel Study (KOWEPS).
The relative price of medical care is the ratio of labor productivity in the health sector and economy-wide. The relative labor supply in good health is 1.

The retirement age in the model $s=8$ corresponds to biological ages between 60 and 64. The terminal age $s=12$ corresponds to ages between 80 and 84.

The share of the retired in the total population in the baseline is 36 percent. This reflects high old-age dependency in South Korea around 2030, according to a projection by the United Nations (2012). To attain this old-age dependency ratio, I set the population growth rate at 0.67 percent, which reflects the average population growth rate between 1991 and 2010, a period in which the old-age dependency ratio increased sharply. The baseline model assumes considerable delay in implementing the policy change as observed since 2001.

As policy experiments, I consider three other demographic structures which reflect the old-age dependency rates in 2010–2015, 2015–2020, and 2030–2035. The first two are the contemporary demographic structures where the dependency rates are 23 percent, and 26 percent, respectively. The third demographic structure is the oldest one where the dependency rate is 38 percent.

Preferences: In the baseline, I set the time discount factor β equals 0.9. This is the equivalent of a 5-year discount factor at an annual rate of 0.98.

In the baseline utility function Equation (1), there are two parameters to be calibrated. I target the share of medical spending in output at 0.07, which corresponds to the 2010 level in the national accounts. To achieve the target, I set the weight of health in utility λ at 0.6. In the baseline, I set the elasticity of substitution ν to be 0.5, which means that health status and consumption are gross complements. To check the model's sensitivity, I examine alternative values to these parameters in Section 4.6.

For the separable utility function in Equation (2), there are three parameters to be calibrated. Again, I target the share of medical spending in output at 0.07 by setting the value of the life-year parameter ξ equals to 9.[11] And I set the risk aversion coefficients for consumption σ_c and health status σ_h equal to 2. However, these values do not have to be identical. Hall and Jones (2007) set the value of σ_h lower than that of σ_c to explain the rise in health spending as a share of GDP. Kashiwase (2009) pins the share of the uninsured in total production by fixing the values of σ_c and σ_h to be 3.7.

The value of health status is taken from the quality-of-life weights in Nyman et al. (2007). They use the time trade-off methods which ask the survey correspondents, "how many of 10 years of life in the current health status would you trade to live in full health?" The results are mapped with the self-reported health status to calculate the quality-of-life (QOL) weights on a scale of 0 to 1. I take the average of the QOL weights for "excellent" and "very good," and "good" as good health status in the model. And I take the average of the QOL weights for "fair" and "poor" as bad health status in the model.

Mortality shock: The mortality shock process $\chi(s, h)$ follows an exponential form

$$\chi(s\geq 8, h=h_b)=e^{sd}-1. \tag{23}$$

where I target the mortality rate of the most elderly group (80–84 years old) at 7.5 percent by setting the mortality hazard rate d at 0.002. The mortality shock applies to the elderly in bad health only.

Health transition: The health transition depends on age, past health status, and the past occurrence of giving up medical consumption. I estimate the health transition matrix using the first two waves of KOWEPS (2006–2007). KOWEPS includes questionnaires on economic hardship including: "insufficient medical fund," "skipped meals," "no heating in winter." I use the insufficient medical fund questionnaire to control for giving up medical consumption, which are less likely to be discretionary.

11 As in Hall and Jones (2007), I add a positive constant terms to ensure that utility does not drop below zero. Without the constant term, individuals may prefer death over low consumption. This issue is not applicable to the baseline CES utility function, because the values of c and h are always above zero.

I build a logistical regression model to estimate the health transition

$$\ln\left(\frac{P^i_{g,t}}{1-P^i_{g,t}}\right)=\alpha+\beta_1 s^i_t+\beta_2(s^2)^i_t+\beta_3 P^i_{g,t-1}+\gamma m^i_{0,t-1}, \tag{24}$$

where the dependent variable is the odds of having good health. The independent variables are age s, health status in the previous period $P^i_{g,t-1}$, and giving up medical consumption in the previous period $m^i_{0,t-1}$.

Table 3 shows the point estimates, the standard errors, and the marginal effects. The point estimates are all significant at the 1 percent level. Among the control variables, the strongest influence that determines the current health status is health status in the previous period. Also, giving up medical consumption has a substantial negative effect on future health status. For example, for a 50-year-old who gave up medical consumption, the transition probability from good health to good health is 78%, whereas the same transition would improve by 13% for those who did not give up medical consumption. This gap caused by lack of medical consumption widens in older age.

The baseline estimation does not include the controls suggested by the literature. This would result in the overestimation of the insufficient medical consumption variable. In the technical appendix, I show that a more extensive specification reduces the estimated coefficient. In Section 4.6, I check for the model's sensitivity to an alternative health shock process.

Relative labor supply when in bad health: In the baseline model, I calibrate the impact of bad health on labor endowment such that individuals in bad

Table 3: Estimation of health transition to good health.

Variable	Coefficient	Marginal effect
Age	−0.12***	−0.02
	(0.02)	
Age squared	0.00***	0.00
	(0.00)	
Previous health	1.95***	0.37
	(0.08)	
Insufficient med	−0.93***	−0.18
	(0.13)	

I use the first two waves of the Korea Welfare Panel Study (2006, 2007). The sample size is 5684 which includes those who are between 25 and 84, and without disability.
Superscripts on the coefficients denote the level of statistical significance from a two-tailed test: *** denotes the 1% level.

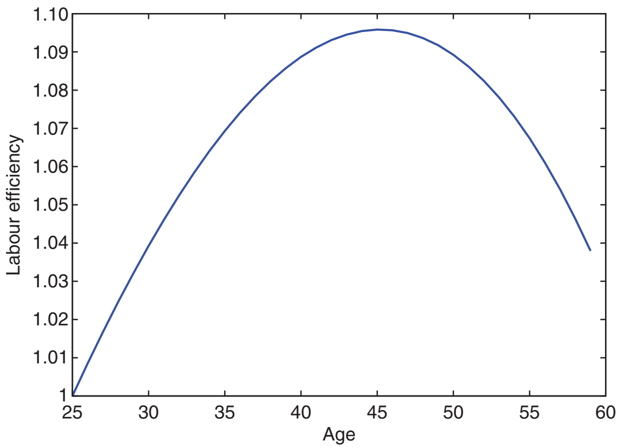

Figure 2: Labor efficiency over life-cycle.
Source: Estimation of Equation (2) using the data from the Korean Welfare Panel Study [wave 1 (2006) – wave 5 (2010)].

health lose 25 percent of their labor endowment (i.e. $h(h=h_g)=1$, $l(h=h_b)=0.75$). Research suggests that a percentage point reduction in labor productivity due to illness can be as low as 6 percent (Chirikos and Nestel 1985), and as high as 42 percent (Mitchell and Burkhauser 1990).[12] Because of the wide range of variability, I conduct a sensitivity analysis on alternative parameter values for labor endowment due to a bad health shock.

Labor efficiency over the life-cycle: I estimate the labor efficiency parameter $e(s)$ using the following empirical specification

$$e(s)=\ln \text{wage}_t^i=\varrho_1 s_t^i+\varrho_1 s_t^{2i}+\varrho_1 s_t^{3i} \tag{25}$$

where $\ln \text{wage}_t^i$ is the log of wage income of the head of a household, and s_t^i the age of the head of the household. Figure 2 shows that the life-cycle labor efficiency follows a hump-shape pattern over working-age years.

12 The literature on health and earnings outcomes (Strauss and Thomas 1998; Currie and Madrian 1999) suggests that this parameter value varies by types of illness, gender, and race. For example, in terms of wage, Mitchell and Burkhauser (1990) find that having arthritis reduces wages by 28 percent for men and 42 percent for women, and Berkovec and Stern (1991) find that having poor health reduces wage by 17 percent. In terms of labor supply, Mitchell and Burkhauser (1990) find that having arthritis reduces work hours by 42 percent for men and 37 percent for women. Chirikos and Nestel (1985) find that having poor health decreases work hours by 13 percent for White men, 21 percent for Black men, 6 percent for White women, and 27 percent for Black women.

Cost of medical consumption: I estimate the cost of the medical consumption parameter $\pi(s, h)$ according to

$$\pi(s, h)=q_t^i=\rho_1 s_t^i+\rho_2 h_{gt}^i, \tag{26}$$

where q_t^i is the medical expenditure of a household i normalized by the average income at time t, s_t^i the age of the head of household, h_{gt}^i is the dummy variable whether the household head is in good health status or in bad health status. Table 4 shows that the cost of medical expenditure increases with age and decreases with good health status.

Firms: In the production function, I set the capital income share α at 0.3 as in Young (1995). I set the capital depreciation rate δ to be 0.23. This is equivalent to a 5-year depreciation rate at an annual rate of 0.05. The relative price of medical services P^m is estimated to be 1.103 based on sector-specific productivity in Pyo, Rhee, and Ha (2006).

4 Quantitative analysis

In this section, I report the results concerning the effect on welfare of increasing the health insurance benefit rate in South Korea. First, I compare the lifetime health status between the model and the data. Second, I compare the steady states that are characterized by different benefit rates: one that reflects the 2010 level at 64 percent and the other that reflects the projected level at 80 percent. Third, I track the change in welfare along the transition path between the steady states. Lastly, I extend my analysis to using alternative demographic projections and employing an alternative utility function.

Table 4: Estimation of the cost of medical expenditure over the life-cycle.

Variable	Coefficient
Age	0.0017***
	(0.000)
Good health	−0.072***
	(0.010)

I use the Korea Welfare Panel Study (2006, 2008–2010). The 2007 wave does not include a questionnaire on the expenditure information specific to medical services. The sample size is 7430, which includes those who are of age between 25 and 84, without disability.
***Statistically significant at the 1% level.

4.1 Baseline results

There are two health outcomes possible in the model: good or bad health status. Figure 3 shows the share of population in good health over age in the model and the data. The middle dotted line represents the average probability of having a good health status in the KOWEPS (2007) data. The solid line represents the share of good health over age in the baseline model before the policy change. It shows that the share of the population in good health declines over age both in the data and the model. However, there is a notable discrepancy at the end of the life-cycle where the share of good health is underestimated by the model. This is largely driven by the modeling choice of the terminal age at 84. Knowing that death is certain between ages 80 and 84, in the model individuals between ages 75 and 79 completely disengage from preventative medicine, and this results in a sudden decrease in their share of good health at the end.

4.2 Welfare analysis

Given that the model matches the life-cycle health status, in what follows, I present the policy experiments examining the effect on welfare of expanding public health insurance benefits. In all experiments, the state of the economy is initially in a steady state, which is then disturbed by an increase in the benefit

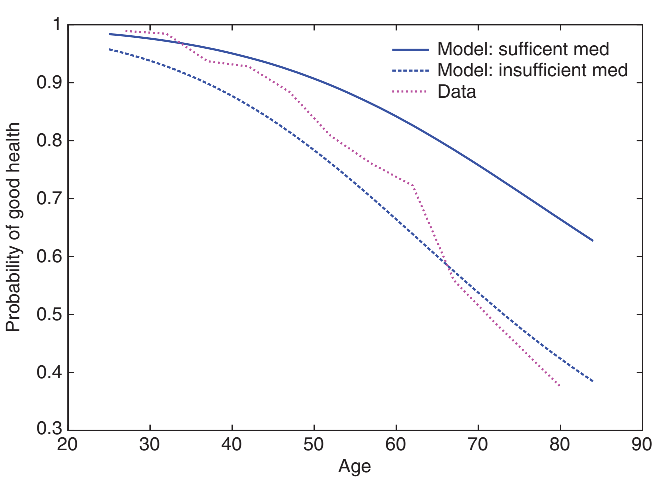

Figure 3: Transition probability from good health to good health: Model versus data. Source: Korean Welfare Panel Study [wave 2 (2007)].

Table 5: Macroeconomic impact of health insurance benefits, initial steady state vs. new steady state.

	Initial state (η=0.64)	New state (η=0.80)
Output *Y*	100	99.4
Capital *K*	100	97.6
Labor *L*	100	100.1
Medical spending *M*	100	125.8
w	100	99.3
r	100	105.8
τ	100	157.3
μ_{h_b}	8.5%	7.4%
C.E.	–	1.3%

w and r are the equilibrium wage and interest rate; τ is the equilibrium tax rate; μ_{h_b} represents the share of bad health in the population; C.E. is the consumption equivalence measure. The share of the elderly in the population is 36 percent.

rate from 64 percent to 80 percent. The economy eventually reaches a new steady state.

Table 5 shows that the aggregate medical spending also rises as the demand for medical services rises. To finance the increased medical outlays, the government increases the medical tax rate by 57 percent. Lastly, the policy change decreases the population share of individuals in bad health μ_{h_b} by 1.1 percentage points, this is a direct improvement in health for those individuals who had given up medical consumption before the policy change.

Table 5 shows the changes in macroeconomic variables in response to the policy change. The policy change decreases the aggregate capital by 2.4 percent, because individuals save less against future medical expenditure shocks. The policy change increases the aggregate labor by 0.1 percent, because some working-age individuals no longer give up medical consumption and improve their labor supply. The changes in aggregate capital and aggregate labor reduce the level of output by 0.6 percent.[13] The co-movements of the aggregate capital and labor result in an increase in the return to capital and a decrease in the wage rate. the general equilibrium effects of the policy also do not favor the working-age generations as the wage rate falls. An increase in the interest rate favors the

13 The changes in these macroeconomic variables suggest that expanding public health insurance in the context of aging population may reduce economic growth, despite the labor productivity gains with health improvement (Bloom, Canning, and Sevilla 2004; Li, Zhang, and Zhang 2007; Aisa and Pueyo 2013).

middle-age, and retired generations who are relatively asset rich. It is not clear whether the general equilibrium effect increases average welfare.

Table 5 shows in the bottom row that the consumption equivalence is positive 1.3 percent in the new steady state. It means that households in the new steady state would require additional 1.3 percent of consumption in order to be as well off as in the initial steady state. This finding is congruent with the findings by Attanasio, Kitao, and Violante (2010) that in a high old-age dependent economy, expanding public health insurance benefits decreases average welfare.

The net negative effect on welfare suggests that the negative tax effect dominates the net health effect in the highly old-age dependent economy. Despite the improvement in health of some individuals in the economy, the policy change decreases the consumption possibility of all working-age generations by sharply increasing the tax rate. This net decline in average welfare would prescribe against deferring the policy change on the ground that it does more harm than good.

However, the welfare analysis requires more than a simple comparison of steady states, because such comparison misses the short-run effect on welfare that occurs immediately after the policy change. Most of those who are affected by the policy are those who experience the policy change during their lifetime. So, I shift my focus to the transition between the steady states, especially to the onset where most actions take place.

Figure 4 shows the policy impact on the macroeconomic variables over time. Time is represented by the number of model periods. The vertical axis represents the percentage change from the initial state value. Figures in each row are in the same scale. Most variables converge to their new steady state level within 5 periods (25 years). The exceptions are that aggregate capital and interest rate converge to the new steady state in about 11 periods (55 years), almost a full life-cycle in calendar time. Such a slow convergence is expected given the impact of an unanticipated policy change as each birth cohort born before the changes revises their optimal saving behavior with respect to their remaining life.

The policy change immediately increases aggregate medical spending by users of medical services. This implies immediate health benefits for the retired generations, but later health benefits for the working-age generations. The policy change benefits some of the working-age generations by reducing their chance of negative health shocks. Figure 4 Panel (B) shows that aggregate labor is increased by 0.1 percent, as negative health shocks become less frequent among the working-age generations. The gains in aggregate labor could be made larger by specifying a larger loss in labor endowment from a negative health shock. I will discuss the implication for such a case under sensitive analysis in Section 4.6.

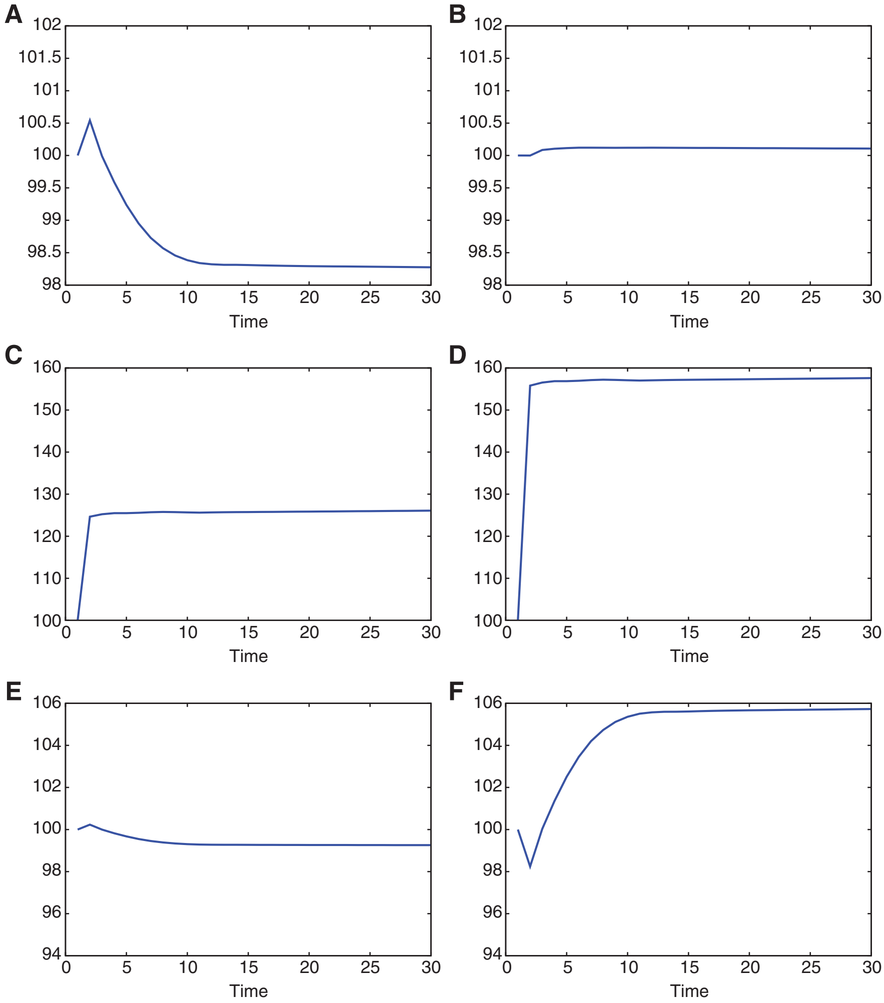

Figure 4: Macro variables over the transition path.
(A) Aggregate capital. (B) Aggregate labor. (C) Aggregate medical spending. (D) Tax rate.
(E) Wage rate. (F) Interest rate.
The transition dynamics is in terms of percentage change from the initial steady state value.
Each time period in the horizontal axis represents 5 calendar years.

Contrary to skewed health benefits for the retired generations, the welfare losses from the policy change are concentrated among the working-age generations. Immediately after the policy change, the payroll tax rate increases by 57 percent, reducing the working-age generations' labor income. This suggests that the negative tax effect on welfare would be at its full force at the onset of the transition path in the form of a sharp increase in the tax rate.

Over the transition path, on average, the welfare losses of the young would exceed the welfare gains of the old. Figure 5A shows that the average welfare declines monotonically in the first 10 periods, and then plateaus to a new level of welfare, which is about 0.6 percent lower than the pre-reform level. This indicates

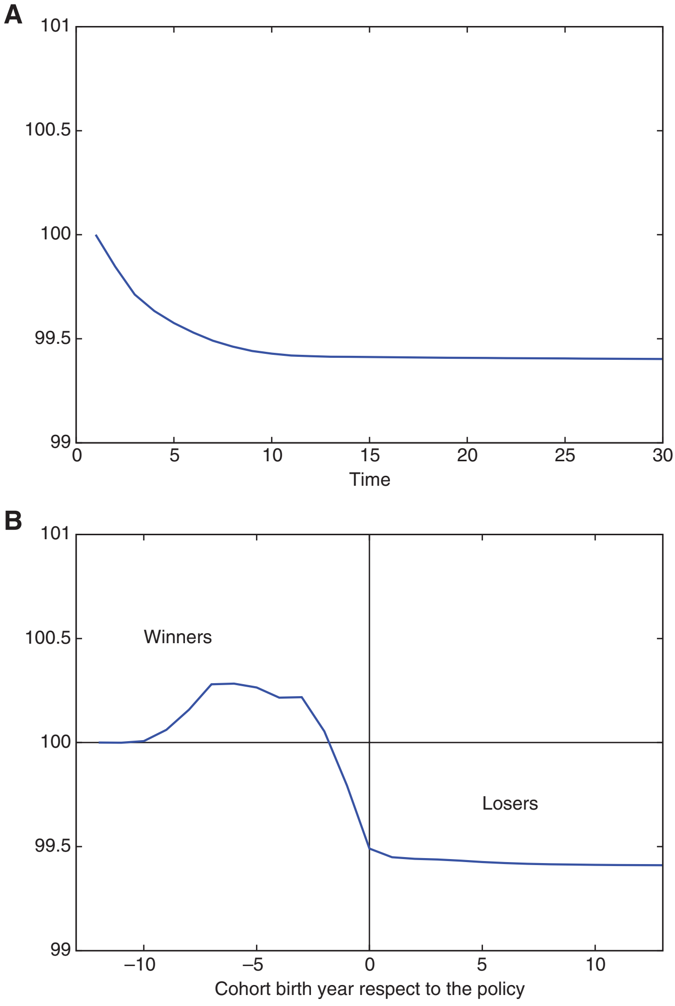

Figure 5: Welfare over the transition path.
(A) Average welfare. (B) Lifetime welfare by cohort.
Each time period in the horizontal axis represents 5 calendar years.

that from the onset the average welfare is dominated by the negative tax effect. However, the positive effect is strongest also at the onset, but gradually diminishes over time, suggesting that the welfare benefits accrue to those who were relatively old at the time of the policy change. As these "beneficiary cohorts" exit the economy, the welfare gains of the policy change subsides over time, whereas the welfare losses occasioned by higher tax rates remain in full force throughout the transition path.

I now turn to the impact of the policy on lifetime welfare by birth cohort. Figure 5B shows lifetime welfare by birth cohort with respect to pre-reform average welfare. The horizontal axis represents the birth year of each cohort from the policy change. For instance, the generation born 5 periods before the policy change is denoted by "–5" and these individuals would live 5 periods under the pre-reform benefit rate and 7 periods under the post-reform benefit rate. If a cohort's lifetime welfare is above 100 (the horizontal line in the middle), they experience net-gains in welfare, whereas if a cohort's lifetime welfare is below 100, they experience net-loss in welfare.

Those who are born at least two periods prior, gain from the policy change. In particular, the welfare gains for the retired generations is as high as 0.3 percent of the pre-reform level. In contrast, those in the early stages of the life-cycle at the policy change could lose up to 0.6 percent of their lifetime welfare. Interestingly, some winners include cohorts who are within working-age but close to the retirement age, which means that their positive health effect dominates their negative tax effect.

So far, I have discussed the positive health effect and the negative tax effect on welfare. However, this welfare analysis cannot be seen as simply measuring the conflicting effects between a tax hike and greater health insurance benefits. The reason is that, along the transition path, both the rate of return to capital and the wage rate also change. These changes influence saving and medical consumption decisions. Moreover, the changes in these factor prices (the general-equilibrium effects) have a direct influence on the welfare of individuals from different age groups with different levels of wealth. While the increase in the rate of return to capital increases the welfare of the retired generations, the decrease in the wage rate decreases the welfare of the working-age generations.

4.3 Alternative demographic structures

Old-age dependency matters for welfare analysis for two reasons. First, it affects the share of medical spending in output. High old-age dependency implies that there would be a relatively large share of output devoted to medical consumption.

This would increase the tax rate for working-age individuals. Second, it determines the size of the tax base in the economy. A high old-age dependency implies a smaller tax base with the concrete implication that any increase in the benefit rate would lead to a relatively large increase in the tax rate. Given that demographic trends tend to be deterministic in the short-run, it is easy to see that the longer it takes to implement the policy change, the greater is the negative effect on welfare. To quantify this mechanism, I consider several alternative demographic structures and check their welfare impact.

In the current model, I set the old-age dependency exogenously. In the baseline model, the population share of the elderly is 36 percent, which the UN predicts the old-age dependency would be by 2030. To assess the sensitivity of the results to alternatives, I consider three other population shares of the elderly: 22, 26, and 38 percent.[14] The population shares of the elderly at 22 and 26 percent represent contemporary "low" old-age dependency rates and the shares of 36 and 38 percent represent the projected "high" old-age dependency rates.[15] The policy experiment is otherwise the same in that the benefit rate increases from 64 percent to 80 percent.

Employing a different population projection makes a large difference in the share of medical spending in output. The reason is that the demand for medical services is concentrated around the retirement age. Figure 6A shows that the share of medical spending in output increases with the share of the elderly in the population. Between the lowest and highest age-dependencies, the difference in the increase in the output share of medical spending is about 3 percent. Because the demand for medical services is largely concentrated among the elderly, increasing the benefit rate under a high old-age dependency rate would cause a larger share of the population to consume medical services than it would under a low old-age dependency rate.

Figure 6B shows that the tax rate increases with old-age dependency. Between the lowest and highest old-age dependencies, the difference in the increase in tax rate is about 4 percent. Higher old-age dependency increases the demand for medical services and lowers the tax base, which in turn leads to a higher tax rate. The later the policy change takes place, the greater the negative tax effect on welfare.

14 The population share of the elderly at 22 percent is equivalent to the 2010 demographic structure. The population share of elderly at 26 and 38 percent are attained by setting the average population growth rate to that of the periods between 1951 and 1989, and 2005-2010, respectively.

15 According to the 2010 United Nations World Population data, South Korea will reach the population share of the elderly at 38 percent between 2030 and 2035.

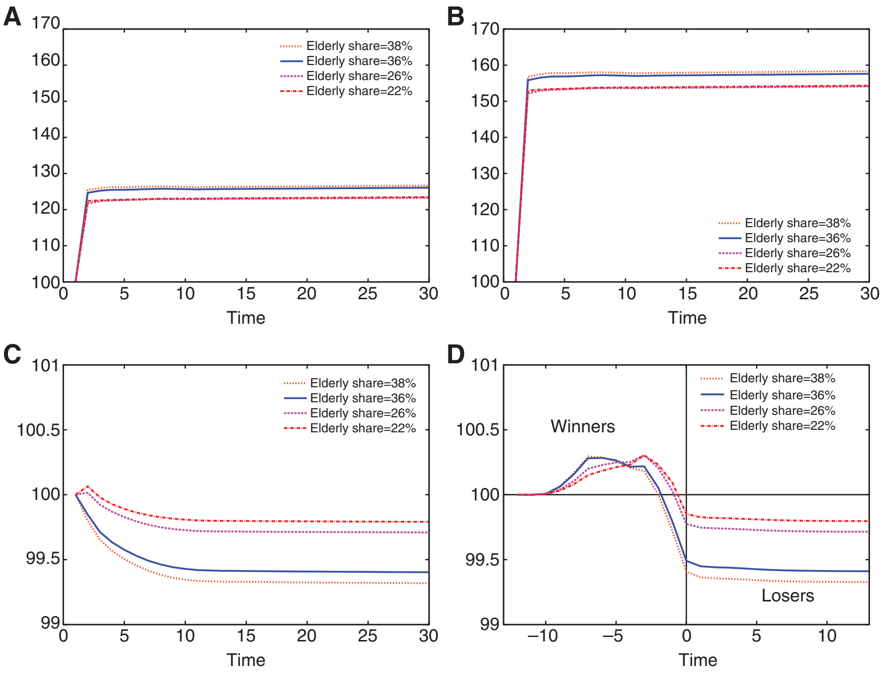

Figure 6: Comparing the impact of policy change based on various demographic structures. (A) Share of medical spending in output. (B) Tax rate. (C) Average welfare. (D) Lifetime welfare by cohort.
Each time period in the horizontal axis represents 5 calendar years.

As a result of these mechanisms, the welfare analysis is also sensitive to the old-age dependency rate used in the analysis. Figure 6C shows that average welfare increases at the onset of policy change for the contemporary demographic structures, while the long-run effect on welfare is negative for all demographic structures due to higher tax rates. Figure 6D shows that under the contemporary demographic structures almost all cohorts born before the policy change would gain from it. The key difference between the current and projected demographic structures is that the welfare gains are concentrated among different birth cohorts. For example, retirees are the primary beneficiaries in the case of high old-age dependency, while the working-age generations are the primary beneficiaries in the case of contemporary old-age dependency. The tax rate and factor prices change and these changes account for the differences in the welfare profiles by birth cohort. Specifically, a milder tax increase in the low old-age dependency economy reduces the negative tax effect on welfare for the working-age generations. Moreover, these cohorts also experience welfare gains from engaging in preventative medicine early in their lives, whereas the generations that retired before the policy change missed such opportunities. These findings suggest that the timing of policy implementation matters considerably not only for the retired generations but also for the working-age generations.

The findings show that implementing the proposed expansion in the contemporary demographic structures may lead to welfare improvement for a vast portion of the population. The positive health effects would dominate the negative tax effects, as there would be a milder tax increase. With the current rate of population aging in South Korea, postponing the policy change would amount to greater welfare losses. One limitation of this analysis is that the model does not allow for population aging along the transition path. To care for an aging population, individuals would forego additional consumption in order to pay higher taxes in the future. This may dampen the positive gains to average welfare in the case of demographic structures. However, even accounting for population aging, it would not change the notion that welfare losses would be greater if policy implementation were postponed.

4.4 Alternative utility function

The choice of utility function matters for medical consumption across asset holdings. If an individual gives up medical consumption, their discounted expected marginal utility of any improvement in health must be less than the marginal utility of consumption today. With the separable utility function, the marginal utility of better health (from bad to good) is constant across consumption levels, whereas with the CES utility function, it would rise with consumption when health and consumption of non-health goods are gross complements – as I have assumed in the baseline model. In other words, medical consumption in the CES utility function is considered to be more desirable for those who hold relatively high wealth. Given that medical consumption is mainly concentrated among the wealthy, with a CES utility function, it would mean that all else being equal, there would be a greater demand for medical services than with a separable utility function.

Figure 7A shows that increasing the benefit rate with a separable utility function increases the share of medical spending in output, which leads to a higher tax rate (Figure 7B). However, these increases are smaller than those found using the baseline CES utility function. Figure 7A shows that the increase in the share of medical spending in output is lower in the separable utility case by about 5 percentage points. Figure 7A shows that the tax rate is lower in the separable utility case by about 6 percentage points. These results suggest that using the separable utility function produces a smaller positive health effect on welfare. However,

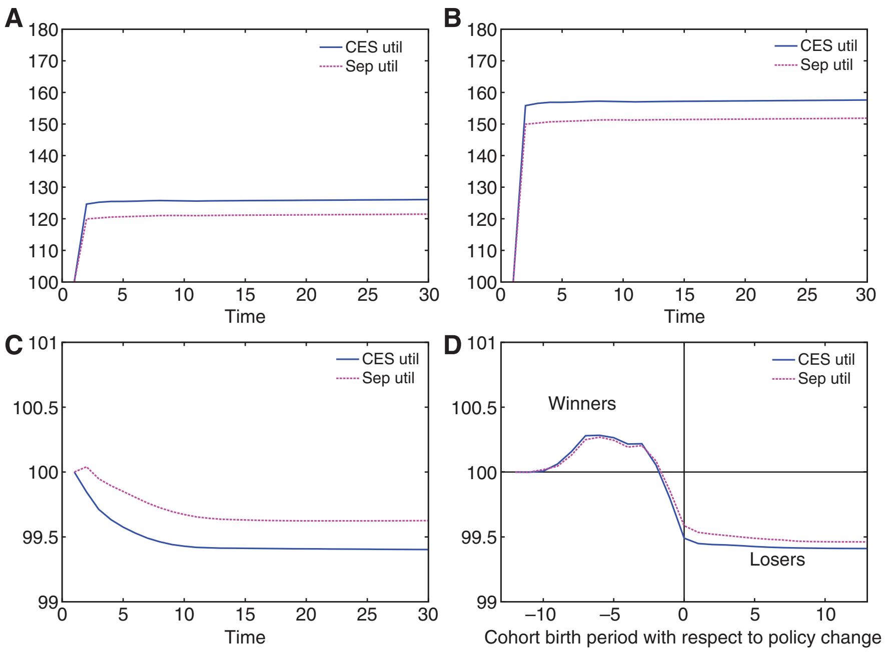

Figure 7: Comparing the impact of policy change on medical spending and tax rate between a CES utility function and a separable utility function.
(A) Share of medical spending in output. (B) Tax rate. (C) Average welfare. (D) Lifetime welfare by birth cohort.
Each time period in the horizontal axis represents 5 calendar years. The separable utility model includes the same parametrization. The population share of the elderly is set at 36 percent.

there is also a smaller negative tax effect on welfare under the separable utility function specification.

Figure 7C compares average welfare over time between the two alternative utility specifications of the utility functions. The long-run effect on average welfare of policy change is negative in both utility specifications. While the short-run effect on average welfare is also negative across utility specifications, the magnitude of welfare loss in the separable utility specification is smaller in the short-run. This is largely driven by a smaller negative tax effect. Figure 7D shows that the welfare loss of those who entered the economy 1–2 periods before the policy change is smaller in the separable utility specification. Overall, the model with separable utility function also shows that policy change in a high old-age dependency economy would result in net-loss in average welfare. This result suggests that the choice of utility function by itself may not affect the welfare analysis, and high old-age dependency ratio may be a more important consideration.

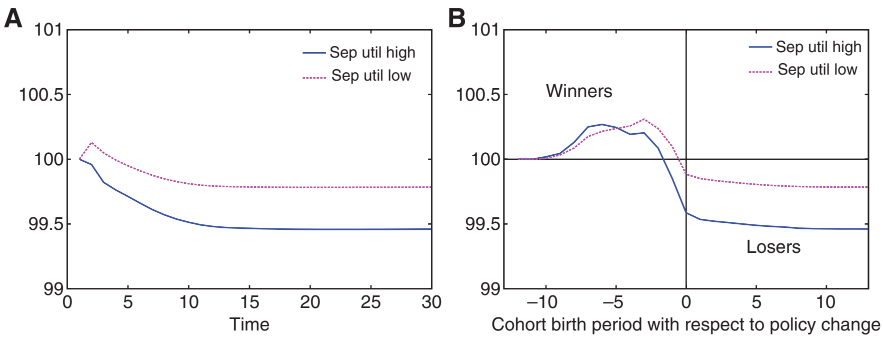

Figure 8: Comparing the impact of policy change on various demographic structures under a separable utility function.
(A) Average welfare. (B) Lifetime welfare by birth cohort.
Each time period in the horizontal axis represents 5 calendar years.

To verify whether old-age dependency also matters for the separable utility specification, I compare the effects on welfare of the policy change in the alternative demographic structures. I use two demographic structures: one is the baseline case, which corresponds to "high" old-age dependency ratio with the population share of the elderly at 36 percent. The other one corresponds to a "low" old-age dependency ratio with the population share of the elderly at 26 percent. Figure 8A shows that increasing the benefit rate increases average welfare at the onset of policy change for the low old-age dependency case. Figure 8B shows that the short-run welfare gains accrue to the working-age generations, because the policy change offers them a positive health effect in their lifetime, but also a milder tax hike.

Overall, the choice of utility function does not change the impact on welfare where policy change is made. What seems to matter the most is the timing of the change. By implementing the policy change in a low old-age dependency environment, I show that the short-run effect on average welfare is positive. A deferment of policy implementation to a later high old-age dependency rate would mean that the negative tax effect would dominate the positive health effect on welfare. These results are robust across alternative utility specifications.

4.5 Alternative retirement age

In the following experiment, I raise the retirement age and examine the effect of the same policy change on welfare.[16] In many countries including South Korea,

16 I thank an anonymous referee for suggesting this experiment.

there has been proposals to increase the official retirement age and the eligibility age for age-related social programs such as Medicare, Social Security in the US. The proponents argue that financing a public health insurance has become more difficult due to the rising old-age dependency ratio. Raising the retirement age would broaden the tax base for social programs, and increase the labor supply.

This experiment assumes that the retirement age is raised to a new level before increasing public health insurance benefits. I consider two sets of retirement age: age 65 s=9 and age 70 s=10. The policy change is the same that the benefit rate increases from 64 percent to 80 percent. To avoid any confusion, please note that the policy change occurs at the initial state at a higher retirement age.

Raising the retirement age increases the size of labor force and broadens the tax base. These effects mitigates the negative tax effect of increasing the benefit rate on welfare. Figure 9A show that the increase in medical spending as a share of output is smaller at higher retirement ages. Accordingly, Figure 9B shows that

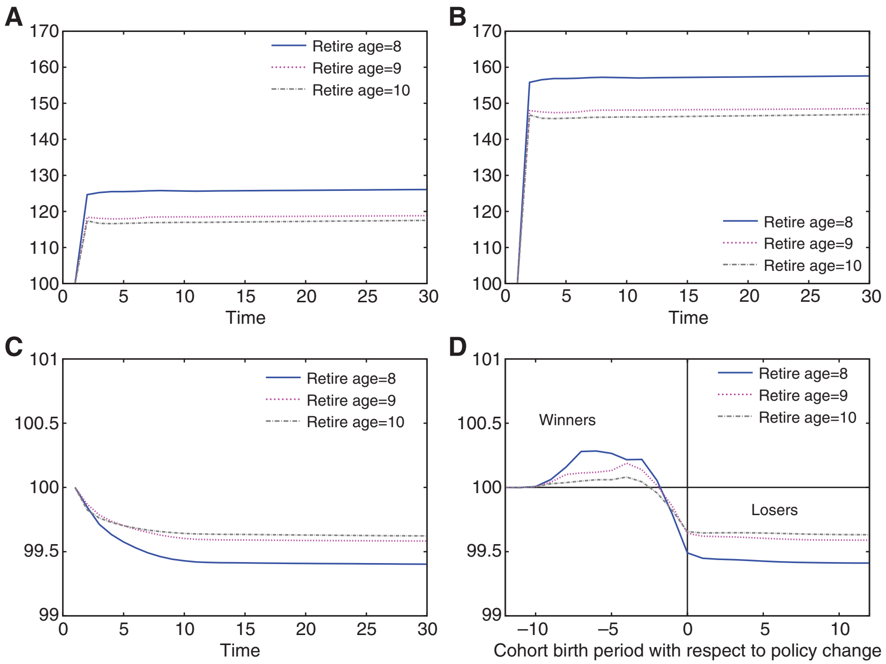

Figure 9: Comparing the impact of policy change across several retirement ages.
(A) Share of medical spending in output. (B) Tax rate. (C) Average welfare. (D) Lifetime welfare by birth cohort.
Each time period in the horizontal axis represents 5 calendar years. The higher retirement ages includes the same parametrization. The population share of the elderly is set at 36 percent.

the increase in the tax rate is also smaller at higher retirement ages. Raising the retirement age increases the importance of medical consumption in ages 60 and 65, because bad health can be costly not only in terms of health outcomes, but also for labor income earnings. This finding is congruent with the theory of the demand for health capital (Grossman 1972).

Raising the retirement age results in a smaller loss in average welfare. Figure 9C shows that average welfare is about 0.2 percentage points higher at higher retirement ages than in the baseline. Figure 9D shows that, at higher retirement ages, the policy change reduces the welfare gains and losses between the winners and losers. There are two implications for welfare analysis. One, the welfare losses and gains are smaller because the tax hike has been diffused over a wider part of the population. Two, the longer working-age years now have made health investment more attractive, and in turn, induce individuals not to give up medical consumption even before the policy change. The results suggest that raising the retirement age can alleviate the welfare losses associated with expanding public health insurance benefits.

4.6 Sensitivity analysis

While the model matches the health status of the data by calibrating certain key parameters, the parametrization, nevertheless, involves setting the values of two parameters rather arbitrarily: the relative labor endowment in bad health $l(h_b)$, and the parameter for the elasticity of substitution between health and consumption of non-health goods ν. In addition, the estimation of health transition probability used in the model includes an overestimation of the "insufficient medicine" variable. These parameter values may affect the model results to be greatly different from the baseline. In what follows, I explore the sensitivity of the model to using some alternative parameter values for the labor endowment loss, the elasticity of substitution, and the insufficient medicine variable.

Theoretically, increasing the endowment loss (reducing the value of $l(h_b)$) results in an ambiguous effect on average welfare. On one hand, the health effect becomes more beneficial to some of the working-age generations who had given up medical services before the policy change. On the other hand, the policy change may yield smaller welfare gains, as the demand for medical for medical services would be already high even before the policy change.

The literature suggests that the degree of labor endowment loss due to a health shock ranges between 5 and 50 percent (Currie and Madrian 1999). The baseline sets the labor endowment loss in bad health at 25 percent ($l(h_b)$=0.75).

Table 6: Sensitivity analysis.

	% change in K/Y	% change in L	% change in M/Y
A			
$l(h_b)$=0.00	0.0	0.0	+14.9
$l(h_b)$=0.5	−2.0	+0.3	+24.2
$l(h_b)$=0.75*	−1.7	+0.1	+25.8
$l(h_b)$=0.85	−1.5	+0.1	+30.0
B			
ν=0.3	−2.4	+0.1	+28.8
ν=0.5*	−1.7	+0.1	+25.8
ν=1	−1.0	+0.1	+27.1
C			
Baseline health*	−1.7	+0.1	+25.8
Low health	−1.4	+0.1	+34.9

*denotes the baseline where I set the parameter for the relative labor endowment in bad health at 0.75, and the parameter for the elasticity of substitution at 0.5. Low health denotes the model results of using the health transition probability of the extended specification as in the technical appendix.

I check for the sensitivity of the model to changing the value for labor endowment loss. I also consider an "extreme case" of complete labor endowment loss $l(h_b)=0$.

Table 6 shows that the macroeconomic variables behave similarly as the baseline when using alternative parameters for labor endowment loss except for the extreme case. In the extreme case, individuals are less likely to give up medical services even before the policy change. Thus, increasing the benefit rate results in a relatively small effect on the economy. Figure 10A shows that the results from using the range of parameter values from the literature deviate less than 0.02 percentage points from the baseline. However, when using the extreme case of $l(h_b)=0$, the deviation amounts to about positive 0.2 percentage points. In terms of lifetime welfare, Figure 10B shows that using the extreme case reduces the welfare gains for the retired and middle-age generations as well as the losses for the young working-age generations. This suggests that worsening labor endowment in bad health mitigates the moral hazard effect of increasing the benefit rate.[17]

I check for the sensitivity of the results with respect to the elasticity of substitution, which is important for individuals' medical consumption decisions. In the baseline, I set the parameter value at 0.5. I consider two alternative values: $\nu=0.3$ and $\nu=1$. By setting ν at 0.3, I increase complementarity between health

17 I thank an anonymous referee for pointing out the non-monotonicity.

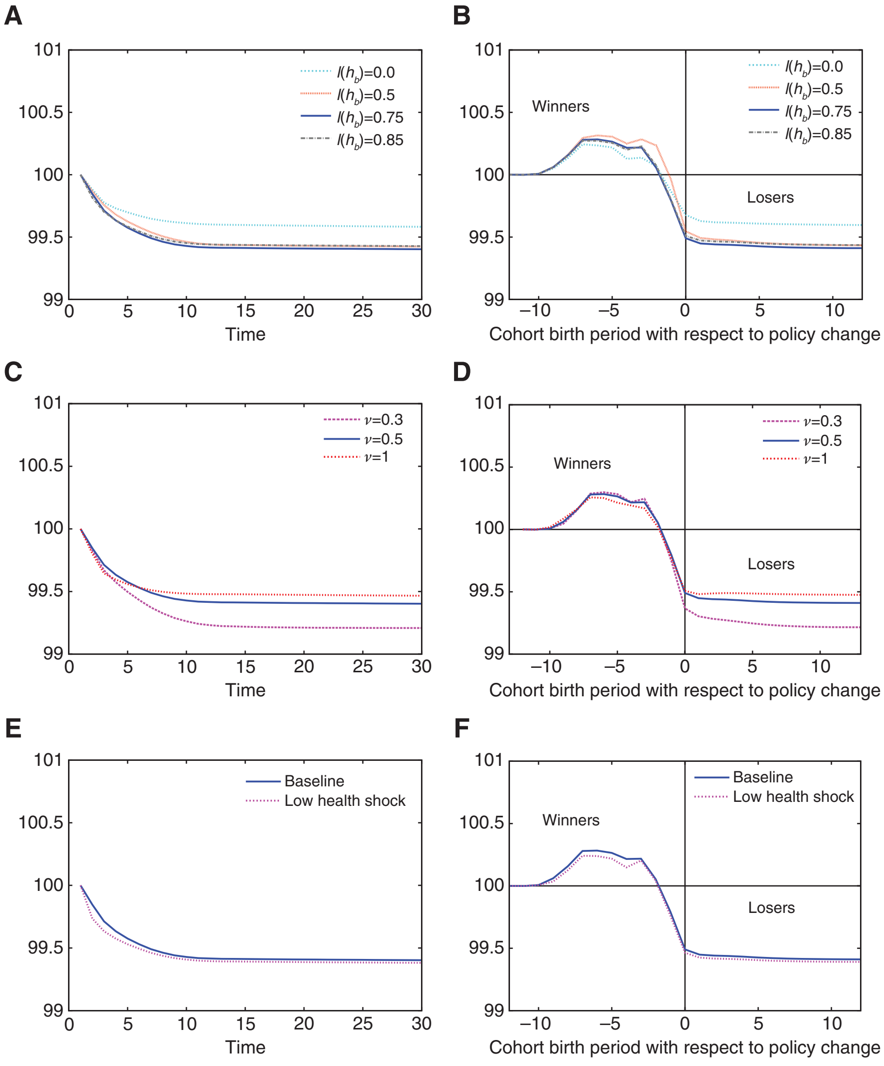

Figure 10: Sensitivity analysis on welfare.
(A) Average welfare: labor endowment loss. (B) Lifetime welfare by birth cohort: labor endowment loss. (C) Average welfare: elasticity of substitution. (D) Lifetime welfare by birth cohort: elasticity of substitution. (E) Average welfare: health shock process. (F) Lifetime welfare by birth cohort: health shock process.
Each time period in the horizontal axis represents 5 calendar years. The baseline parametrization sets $l(h_b$=0.75, and ν=0.5. The population share of the elderly is set at 36 percent.

and the consumption of non-health goods, such that the marginal utility of consumption increases with health improvement. This makes medical consumption more attractive. Table 6 Panel B shows in the third column that by decreasing the elasticity of substitution from ν=0.5 to ν=0.3, there is a slightly larger increase in the share of medical spending in output. However, the individual's medical consumption decision does not solely depend on the elasticity of substitution, but also depends on asset holdings. Increasing the elasticity of substitution reduces the decline in aggregate capital saving, and thus lowers the magnitude of the decline in income. Given that medical consumption is a normal good, individuals are on average able to purchase more medical services in the case of ν=1. Table 6 Panel B shows that increasing the elasticity of substitution from ν=0.5 to ν=1 reduces the decline in the capital-output ratio, while it increases the rise in the share of medical spending in output.

Figure 10C shows the effects on average welfare for alternative elasticities of substitution between health and consumption of non-medical goods. It shows that the decline in average welfare in the case of ν=0.3 is greater by about 0.2 percentage points than the baseline. Such a large decline in average welfare is driven largely by the negative tax effect on the working-age generations. Figure 10D shows that the lifetime welfare of the young working-age generations incurs a greater welfare-loss than in the baseline. This is largely driven by a higher tax hike in the case of ν=0.3.

The last sensitivity test is about health transition probability. Equation 24 estimates the health transition probability conditional on age, previous health status, and an occurrence of insufficient medicine. However, this specification is simplistic such that the effect of the insufficient medicine variable may be overestimated. The literature shows that those who are likely to give up medical consumption are also those who are of low socio-economic background and already paying a substantial portion of their income on medical services. Indeed, in the technical appendix, including the aforementioned controls (suggested by the literature) shows that the insufficient medicine variable in the baseline specification has been over estimated. The coefficient of interest in the extended specification is −0.79, whereas the coefficient in the baseline is −0.93.

I check for the sensitivity of the model to using the extended specification coefficient as in the technical appendix. I denote the results obtained by the extended specification as "Low health shock." Figure 10E shows that in terms of average welfare the deviation is less than 0.02 percentage points. There is a slight decrease in average welfare in the "Low health shock" case. In terms of lifetime welfare by birth cohort, Figure 10F shows that the welfare losses for the young working-age generations are almost identical, whereas the welfare gains for the retired and middle-age working age generations are slightly lower. The result suggests that using the “Low health shock” process diminishes the positive health effect on welfare.

5 Conclusions

This paper has examined the effects of increasing public health insurance benefits on welfare in an economy marked by high old-age dependency. The policy change increases welfare by improving health outcomes and by providing protection against medical expenditure shocks, which are otherwise uninsurable. However, in the range of parameter values and utility function specification considered here, the policy change also increases the tax rate due to a sharp rise in the demand for medical services by a large elderly population. This trade-off makes increasing health insurance benefits a difficult task for a country with a large number of under-insured aging population. Such difficulty can be found in several industrialized countries like South Korea.

To capture this complex mechanism, I offer a life-cycle model with endogenous medical consumption and health outcomes, which captures the positive health effect on welfare. The results suggest that in an economy marked by high old-age dependency, the negative tax effect on working-age generations cannot be compensated by the positive health effect. However, the dominance of the tax effect is weakened in the less old-age dependent demographic structures. If the policy change were to take place sooner in a less old-age dependent environment, it can increase the average welfare.

I want to note that the results are based on conservative estimates on the positive effect of the policy change on health outcomes. First, the health transition process does not account for the long-term negative health consequences of “insufficient medicine.” Second, the health transition process does not account for catastrophic medical expenditure shocks. Through provision of public health insurance, an increase in preventive medicine may reduce the incidence of large medical expenditure shocks in the long-run by reducing likelihood of developing an acute illness, and delaying the incidence of a chronic illness. Third, I have excluded the positive effect of improving access to health care for the disabled and those with chronic illness who would have given up on medical services prior to the policy change. Moreover, individuals may develop disabilities because they had given up medical services in the past. The policy change may increase labor supply and the tax base by preventing the development of disabilities and chronic illnesses. These extensions of the current research are left for future research.

Another limitation of the model comes from future developments in the existing social welfare programs in South Korea. There are two consumption floor programs: the Basic Livelihood Security System and the Basic Old-age Pension System, which are asset- and income-tested. Although these programs have not been successful in providing a meaningful consumption floor to the vast majority of the elderly poor, a social welfare reform may help in reducing the risk of deferred medical treatment. In that case, the health effect on welfare of increasing the benefit rate may be smaller.

The paper also does not explore other types of taxation. For instance, future research may explore the effect on welfare of using a progressive labor income tax financing. Such a tax scheme would have potentially two effects. One, it would improve average welfare, as the losses in the marginal utility of high income earners would be dominated by the gains of low income earners. But progressive tax financing can also decrease average welfare, if the tax distortion of the labor supply is very large.

Finally, there are a few more limitations to the model. First, the model sets the retirement age exogenously, whereas the effective retirement age can vary according to health status. As health status improves, the effective retirement age can be raised, resulting in an increase in aggregate labor and a broader tax base. Second, the model lacks the distinction between acute care and long-term care for the elderly. Although the provision of long-term care in South Korea is relatively underdeveloped, there have been various policy initiatives to build long-term care facilities and to mandate a separate savings account for long-term health care. If such a policy change can be implemented concurrently, an increase in old-age dependency would not necessarily entail a large increase in the payroll tax rate. Third, the model assumes an unexpected policy change, whereas the policy announcement can occur prior to its implementation. This would change people's behavior in anticipation of the policy change. For instance, a number of individuals might withhold medical consumption before the effective date of the policy change. Fourth, the model assumes no change in future income due to technological advancement. Given that health as a normal good, an increase in income due to technological advancement would increase medical consumption. As observed in the welfare analysis, the net impact on average welfare is ambiguous – it depends on the magnitude of positive health effect, and a negative tax effect on welfare.

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Appendix

A.1 Algorithm: steady state

To solve the individual's problem in a steady state, I follow the algorithm provided in Chapter 10 of Heer and Maussner (2009), which relates to solving stochastic OLG models. The main idea of the algorithm is to find a steady state probability distribution Γ of households over the state space X with three dimensions age, health status, and asset holdings. To find the steady state distribution, the algorithm must satisfy the steady state equilibrium conditions provided in Section 2.3. I construct the following algorithm:

1. Parameterize the model to the South Korean economy and compute the aggregate employment L based on the ergodic distribution of health shocks in each working-age cohort,
2. Guess the initial condition of the economy: aggregate capital stock K, the share of each cohort in total population μ, and the tax rate τ,
3. Compute the competitive factor prices w and r,
4. Compute the household's policy function using backward induction,
5. For a newly born generation s=1 with zero asset holdings, apply the policy function forward until their terminal age s=12,
6. Aggregate the optimal savings, individual labor supply, and medical consumption to attain the aggregate capital K, aggregate labor L, and aggregate medical consumption M, respectively,
7. Update K, L, M and go back to Step 3 until convergence.

In step 1, I parameterize the model according to Section 3.2. Because health status is binary, the ergodic distribution of health shocks represents the steady-state distribution of good and bad health statuses for each cohort. I compute the ergodic distribution of good health statuses for each age s by solving the following

$$\text{ergo}(s)=\frac{1}{1+\dfrac{(1-p_{gg}(s))}{p_{bg}(s)}},$$

where $p_{gg}(s)$ represents the transition probability of age s having good health status in period t and good health status in period t+1, $p_{bg}(s)$ represents the transition probability of age s having bad health status in period t and good health status in period t+1. After calculating the ergodic distribution of good health status, I compute the initial aggregate labor L by summing every working-age population's individual labor supply based on their health status.

In Step 2, I guess the initial capital stock by solving the following

$$K=\left(\frac{\alpha}{\frac{1}{\beta}-1+\delta}\right)^{\frac{1}{1-\alpha}}L,$$

where α represents the capital share of output, β the time discount factor, and δ the capital depreciation rate. I set the initial share of each generation by setting the population growth rate provided by the data. I set the initial tax rate equal to 3 quarters of the benefit rate η.

In Step 3, I compute the factor prices using Equations (6) and (7).

In Step 4, I compute the household's policy function by backward induction. Since individuals in their terminal age consume all of their state space capital, we can certainly calculate the terminal period utility $V^{s=12}(k, h)$, which then can be used to find the value function for previous ages $V^s(k, h)$ for s=11, …, 1 with only one iteration. Moving backward from each state space grid point, I look for the optimal saving and medical consumption decisions by visiting every possible grid space for asset holdings and health status.

In Step 5, I apply the policy function for a new-born generation with zero asset holdings. As the generation becomes older and the next generations enter the economy, I construct the probability distribution of households.

In Step 6, I aggregate the optimal savings, medical consumption, and individual labor supply to calculate the aggregate capital stock, aggregate medical consumption, and aggregate labor, respectively.

In Step 7, I compare this new set of aggregate variables K, L, M with the previously determined set of aggregate variables. If the change in these aggregate variables exceeds the tolerance level of 0.0001 percent, I exit the program. Otherwise, I update the set of aggregate variables by a bisection method (taking the middle (average) value between the new and old sets of macro variables) and return to Step 3.

A.2 Algorithm: TPI

This section provides the algorithm for solving the transition path. I follow the time path iteration (TPI) method introduced by Nishiyama and Smetters (2007), which relates to finding a unique transition path for stochastic OLG models. To ensure a unique path, the TPI method assumes that all individuals have a shared belief in the future course of macroeconomic variables.

The main of this paper's algorithm is to find the unique transition path between two steady states that are characterized by public health insurance benefits. Time subscript t=1 represents the initial state and t=T represents the final state. At t=2, I introduce a policy change that increases the benefit rate from 64 percent (2010 level) to 80 percent. The policy change forces households to adjust their saving and medical consumption behaviors. Consequently, the economy enters a transition path from the initial steady state to the new steady state. The transition path contains a set of aggregate variables, factor prices, accidental bequests, and tax rates $\{K, L, M, w, r, b, \tau\}$. The economy converges to the new steady state within T periods. The following algorithm describes the transition process:

1. Parameterize the model to the South Korean economy,
2. Choose the maximum period of transition T,
3. Set the initial steady state and retrieve $\{K_1, L_1, M_1, w_1, r_1, b_1, \tau_1\}$,
4. Set the final steady state and retrieve $\{K_T, L_T, M_T, w_T, r_T, b_T, \tau_T\}$,
5. Given the retrieved variables, interpolate linearly to guess the intermediate values over T,
6. Solve the households' policy functions for S–1 generations by backward induction from t=T, T–1, …, 1,
7. Apply the policy functions forward for each newly-born generation from t=1–S to t=T,
8. In each time period, aggregate each household's optimal savings, medical consumption, and labor supply to attain the aggregate capital, aggregate medical consumption, and aggregate labor, respectively,
9. Update the aggregate variables and return to Step 6,
10. After finding a unique transition path, check to see whether the end of transition path exhibits convergence to the final steady state. If no convergence, return to Step 2 to increase T.

Several steps in this algorithm overlaps considerably with the steady state algorithm. For those parts, I simply refer them to the previous algorithm.

In Step 1, I parameterize the model according to Section 3.2. I adjust the calibration from 1-year to 5-year to represent one period. For example, I adjust the time discount factor and capital depreciation rate from the annual level to the 5-year equivalent level.

In Step 2, I set T the maximum transition time period to 3×S, which is three times the length of the life-cycle. This describes the maximum time it would take for the economy, after the policy change, to reach the new steady state. With the life-cycle of 12 periods, the maximum transition time period is 36 periods. Usually, the economy reaches the final steady state in less than 15 periods.

In Steps 3 and 4, I use the previous steady state algorithm to calculate the steady states that are characterized by the policy change. I compute the initial steady state with the benefit rate at 64 percent and the final steady state with the benefit rate at 80 percent. I store the two sets of macroeconomic variables $\{K_1, L_1, M_1, w_1, r_1, b_1, \tau_1\}$ and $\{K_T, L_T, M_T, w_T, r_T, b_T, \tau_T\}$, which define the beginning and the end of the transition path. I also store the density distribution of households Γ_1, which will be used to iterate forward the policy function in Step 7.

In Step 5, I guess the initial condition of the transition path to be a linear interpolation between the values from the initial and final steady states. These interpolated values set the initially shared belief on the factor prices and tax rate from $t=2$ to $t=T-1$. The initially guessed linear path will be replaced by a non-linear path after many iterations of Steps 6–9.

In Step 6, I apply backward inductions for terminal-aged individuals for $t=T, T-1, \ldots, 1$. Similar to the previous steady state algorithm, it is certain that the terminally-aged individuals' utility is known. But the key difference is that instead of iterating only once in the steady state backward induction, the backward induction here is done T times for each period. Another key difference is that households' decision rule in the steady state algorithm depends on a single set of factor prices and tax rate, whereas in the transition path, it depends on S sets of factor prices and tax rate. This is because individuals face in their lifetime, changing values of factor prices and tax rate.

In Step 7, I apply the policy function forward on a new-born generation in each period from $t=1-S$ to $t=T$. I begin forward iteration at $t=1-S$ not at $t=1$ in order to capture the effect of policy change on those individuals who experience the policy change in the middle of their life-cycle.

In Step 8, I sum up the optimal savings, medical consumption, and labor supply in each period to attain T sets of macroeconomic variables $\{K, L, M, w, r, \tau\}$ and density distribution of households Γ.

In Step 9, I compare the new and old transition paths by comparing the T sets of macroeconomic variables K, L, M in each period. If the change in these aggregate variables exceeds the tolerance level of 0.001 percent, I exit the program. Otherwise, I update the set of aggregate variables by taking the weighted average between the new and old sets of macro variables and return to Step 6.

In Step 10, I check for the convergence of the economy to the final steady state. If the macroeconomic variables near T do not show any sign of convergence to the final steady state, I return to Step 2 and increase T.

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