Macroeconomic Impacts of Population Aging in Korea

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I. Introduction

The goal of this paper is to assess quantitatively macroeconomic impacts of population aging in Korea for the next fifty years. At the current pace of population aging, one of the fastest in history, the proportion of people aged 65 and above in Korea will increase from 7% in 2000 to 20% in 2025 and 35% in 2050. Most people will agree that such rapid changes can have substantial negative impacts on the Korean economy, from the national pension system to economic growth. But there is far less agreement on the magnitude of the impacts. In this paper, I provide another set of forecasts of the economy using the standard Auerbach-Kotlikoff (AK) model.

There are several reasons for using the AK model. First, an empirical analysis of historical data may not provide much information on what will happen in the next fifty years, because no country has yet fully experienced population aging of the magnitude we consider here. Even in Japan, one of the most aged society in the world, the current proportion of the elderly people is less than 20%. Thus, for the purposes of this paper, a computable general equilibrium (CGE) model such as the AK model seems more appropriate than an empirical model. Second, a general equilibrium approach guarantees consistency among endogenous variables. For example, in the AK model, savings and labor supply decisions of a household are affected by the interest and wage rates which at the same time are determined by savings and labor supply decisions of households. A partial equilibrium approach, commonly taken in many empirical analyses, cannot not allow for such simultaneity. Third, the AK model is a benchmark model: it is relatively simple and has been used by many countries including US, Japan and UK for the analysis of population aging. While the AK model involves many simplifying assumptions (such as assumptions of market clearing, no adjustment costs, and no uncertainty), these assumptions may not be so critical for the purposes of the paper. Also, being a benchmark model, the AK model can produce results that can be easily compared with those from other countries.

Previous studies in Korea that used the AK model have mainly focused on specific policy issues, such as the national pension system and health expenditures, rather than the issue of population aging itself. Consequently, in those studies population aging is considered only in association with other factors. However, one problem here is that, even with no population aging, those other factors could have substantial impacts on the economy. For example, the national pension system in Korea was first introduced in 1988 and, by the eligibility requirement, the first full pension payment will not be made until 2008. Simply due to this institutional change, the saving rate and the growth rate may decrease after 2008. Another example may be the convergence in the growth rate or the "catching-up" effect. According to the standard growth theory, the growth rate is expected to decrease gradually in Korea, as the economy matures and the level of capital stock rises. And this has nothing to do with population aging. For proper evaluation of macroeconomic impacts of population aging, one needs to abstract from these other factors. This paper differs from previous studies in that it uses the AK model to describe macroeconomic changes that can be attributed solely to population aging.

The paper proceeds as follows. Section II briefly summarizes population forecasts for Korea, 2005-2050, and Section III describes the AK model and the parameter values used in this paper. In section IV, simulation results for macroeconomic impacts of population aging in Korea are provided. In particular, in order to estimate the macroeconomic changes that can be attributed solely to population aging, this section first considers an economy with a uniform population distribution and no public pension system. This economy works as a benchmark and forms the basis of our analysis. For this benchmark case and the Korean economy, forecasts of key macroeconomic variables and the welfare implications are provided. Section V introduces into the model a public pension system that resembles the current one in Korea and repeats the same analysis as in section IV.

II. Trend of Population Aging

Population aging is a worldwide phenomenon although the degree and manifestation varies across countries. As Table 1 shows, the proportion of population aged 65 and above is expected to increase from 7% in 2000 to 16% in 2050 worldwide. In advanced economies, in particular, the proportion is already above 14% and will become as high as 26% by 2050. By standard of United Nations (UN), a country is considered an aging society if its elderly proportion (proportion of population aged 65 and older) marks over 7 percent while it is considered a super-aging society if the proportion marks over 14 percent. As a result of the increase in elderly population, the average age of population will also increase from 26.5 in 2000 to 36.2 in 2050 worldwide, and from 37.4 in 2000 to 46.4 in 2050 among advanced economies.

<Table 1> Population aging in the world

Also, international comparison shows that the pace of population aging is getting faster. As Table 2 shows, while it took more than 40 years for most advanced economies to move from "aging" to "super-aging", Korea is expected to achieve the same change in only 19 years. Consequently, macroeconomic impacts of population aging will be more drastic in recently developed economies like Korea.

<Table 2> Population aging in selected countries

In addition to the UN, the National Statistical Office (NSO) of Korea provides its own population projections for Korea.[1)] The total population growth rate and the age structure of population from the NSO's projections are shown in Figure 1 and Figure 2, respectively.

<Figure 1> Population growth rate: NSO projections

<Figure 2> Age structure of population: NSO projections

Figure 1 shows that the total population growth rate of Korea, already below 1% annually, will further decrease to a negative value by 2025. This fall in the population growth rate is mainly driven by a drop in the fertility rate, since the death rate is on a decreasing trend for all age groups. Figure 2 shows that, as a result of lower fertility rates and lower death rates combined, the proportion of the elderly population will rise from 7% in 2000 to 34% in 2050.

Upon constructing the same figures from UN projections, one can find that UN projections are slightly less pessimistic. For example, the UN predicts a drop in the total population growth rate to -0.3% (opposite to -1% in NSO projection) and an increase in the proportion of elderly people to less than 30% (opposite to 34% in NSO projection) by 2050. This difference between the UN and the NSO projections originates mainly from their different views on the fertility rate. Although the fertility rate (and the death rate) figures assumed in the projections are not published, one can recover the figures through simple induction. Apparently, the UN assumes that the gross fertility rate increases

1) The OECD also presents population projections for its member countries. However, the OECD figures are the same with the UN figures.

gradually from 1.51 in 2001 to 1.64 in 2013, 1.87 in 2020, and eventually to the replacement level of 2.10 in 2050. The NSO, on the other hand, assumes that the fertility rate remains below the replacement level throughout the projection period (1.51 in 2001 and 1.40 in 2050). With higher fertility rates assumed, the UN predicts less drastic changes in population size and structure.

The main reason for the UN to assume convergence of the fertility rate to the replacement level is theoretical. If the fertility rate remains below the replacement level long enough, labor will become so much scarce and valuable relative to other factors of production that there will eventually be a voluntary rise in the fertility rate. By the same logic, a fertility rate higher than the replacement level cannot last long, either. As long as the fertility rate is an endogenous variable with the long-run equilibrium value of 2.10, the UN's assumption may not be unrealstic. It is not clear, however, whether such convergence in the fertility rate will be observed within the next fifty years.

This paper uses the NSO projections instead of the UN projections. In our view, the NSO projection is better consistent with the recent trend in the fertility rate in Korea. Also, while the UN projections are published for every five years until 2050, the NSO projections are available for each year.

III. Model

The overlapping generation model that we use is essentially the same with the one developed by Auerbach and Kotlikoff (1987). The model assumes that the economy consists of heterogenous individuals. Each individual lives for a finite number of periods, and in each period the oldest generation dies out and a new generation enters the economy. In each period, individual consumers of different generations choose their optimal saving and labor supply. These individual decisions collectively determine the aggregate supply of capital and labor of the economy. Also, the firm sector is assumed to be perfectly competitive and so the interest and wage rates are set to equal the marginal productivity of the aggregate capital and labor, respectively. For simplicity, it is assumed that individuals have perfect foresight (no uncertainty).[2] This assumption is unrealistic but it greatly simplifies the computations involved. Also, it is assumed there is no bequest motive.

2) It is not impossible to develop a model with uncertainty. However, even such models can consider only the simplest forms of uncertainty. See, for example, Imrohoroglu, Imrohoroglu, and Joines (1999).

The only difference between our model and the traditional AK model is in the treatment of total labor productivity. The traditional AK model assumes no growth in total labor productivity on the grounds that constant growth in productivity will cause constant decrease in labor supply and thus is inconsistent with the existence of the steady state. However, most people will agree that such changes in labor productivity and labor supply are real and should be allowed in the model (Auerbach et al. (1989), Miles (1999), Kotlikoff et al. (2004)).[3] In this paper, we follow Auerbach et al. (1989) and Kotlikoff et al. (2004) and assume that "technical progress causes the time endowment of each successive generation to grow" at a constant rate.[4]

Detailed description of the model is the following.

1. Consumer Behavior

Each consumer is assumed to have a fixed lifetime of 60 years. Since we ignore individuals aged 20 or below, this assumption implies a biological life expectancy of 80 years. The goal of each consumer is to maximize his/her lifetime utility with respect to consumption and leisure. We assume perfect foresight as mentioned before, and thus the entire consumption and leisure schedule is determined in the first year of lifetime. As is commonly assumed, the utility function is time separable and of a nested constant elasticity of substitution (CES) form. Under these assumptions, the lifetime utility of an individual aged n at time t can be represented as follows:

$$
\begin{aligned}
U &= \sum_{i=n}^{60}(1+\theta)^{-(i-n)} \left(u[c_{i,t},(E-l_{i,t})]^{(1-1/\rho)}\right)/(1-1/\rho), \\
u[c_{i,t},(1-l_{i,t})] &= [c_{i,t}^{(1-1/\varepsilon)}+\alpha(E-l_{i,t})^{(1-1/\varepsilon)}]^{1/(1-1/\varepsilon)}, \quad i=1,\ldots,61
\end{aligned} \tag{1}
$$

where E = time endowment of an individual;

$c_{i,t}$ = consumption of an individual aged i at time t;

$1-l_{i,t}$ = leisure of an individual aged i at time t;

3) Upon comparing simulation results with and without productivity growth, we find that the GDP growth rate series obtained from the positive productivity growth case is similar to the one obtained from the no productivity growth case adjusted for an ex post productivity growth (see the appendix).

4) Miles (1999) makes the standard assumption of labor-augmenting technological change that the amount of effective labor increases at a constant rate. However, this assumption is not compatible with reaching a steady state, since leisure demand would continue to increase across cohorts.

θ = subjective discount rate;
$1/\rho$ = degree of relative risk aversion;
ε = degree of substitution between consumption and leisure;
α = importance of leisure relative to consumption.

Leisure is given by $E-l_{i,t}$ since the amount of time endowment for each period is defined as E. Although constant over an individual's life, E increases at a constant rate across cohorts. For the budget constraint, we assume the following asset accumulation process:

$$A_{i+1,\,t+1} = A_{i,\,t}(1+r_t) + w_t l_{i,\,t} h_{i,\,t} - c_{i,\,t} \tag{2}$$

where $A_{i,t}$ = asset of an individual aged i at time t;
w_t = wage rate at time t;
$h_{i,t}$ = effective unit of labor endowment of an individual aged i at time t;
$l_{i,t}$ = labor supply of an individual aged i at time t;
$c_{i,t}$ = consumption of an individual aged i at time t;
r_t = interest rate at time t.

When expanded, equation (2) implies the following lifetime budget constraint:

$$\begin{aligned} & c_{n,\,t} + \frac{c_{n+1,\,t+1}}{(1+r_t)} + \frac{c_{n+2,\,t+2}}{(1+r_t)(1+r_{t+1})} + \ldots + \frac{c_{60,\,t+60-n}}{(1+r_t)(1+r_{t+1})\ldots(1+r_{t+59-n})} \\ & = A_{n,\,t} + w_t l_{n,\,t} h_{n,\,t} + \frac{w_{t+1} l_{n+1,\,t+1} h_{n+1,\,t+1}}{(1+r_t)} + \,.. \\ & + \frac{w_{t+60-n} l_{60,\,t+60-n} h_{60,\,t+60-n}}{(1+r_t)(1+r_{t+1})\ldots(1+r_{t+59-n})} \end{aligned} \tag{3}$$

We assume that each individual is born with zero asset, i.e., $A_{1,t}$ = 0 for all t. Optimization of equation (1) under the budget constraint can be summarized by the following two first-order conditions:

$$\begin{aligned} & (E_t - l_{i,\,t}) = (w_t h_{i,\,t}/\alpha)^{-\varepsilon} c_{i,\,t} \equiv (\mu_{i,\,t}/\alpha)^{-\varepsilon} \\ & \frac{c_{i,\,t}}{c_{i-1,\,t-1}} = [(1+r_t)/(1+\theta)]^{\rho}([1+\alpha^{\varepsilon}(\mu_{i,\,t})^{1-\varepsilon}]/[1+\alpha^{\varepsilon}(\mu_{i-1,\,t-1})^{1-\varepsilon}])^{(\varepsilon-\rho)/(1-\varepsilon)} \end{aligned} \tag{4}$$

The first condition in equation (4) describes the optimal relationship between contemporaneous consumption and leisure, while the second one describes the optimal evolution of consumption over time. By combining equations (3) and (4), one can obtain the optimal consumption and leisure schedule for the entire lifetime. Also, given the individual optimal schedule, the aggregate labor and capital of the economy can be computed simply by summing the products of the individual choices and the number of people in the corresponding age group.

2. Firm Behavior

We assume that the firm sector is perfectly competitive and the production technology is given by a Cobb-Douglas function. This means that the interest and wage rates are determined as follows:

$$\begin{aligned} r_t &= \beta A(K_t/L_t)^{\beta-1} \\ w_t &= (1-\beta)A(K_t/L_t)^{\beta} \end{aligned} \tag{5}$$

where r_t = interest rate at time t;
w_t = wage rate at time t;
β = exponent of capital in production function;
A = total factor productivity;
K_t = aggregate capital at time t;
L_t = aggregate labor at time t.

3. Solution of the Model

(1) Methodology

Since we assume perfect foresight by individual agents, it is relatively straightforward to solve the model. First, we set a time horizon of 150 years (from 2001 to 2150) and assume that the population follows the NSO projection until 2050. Thereafter the population evolves by the assumption that every individual remains alive until the age of 60: i.e., people aged y (y<60) in year 2050+x (x<100) all survive to become people aged y+1 in year 2050+x+1, until they reach 60 and die out. Also, after 2050, the number of age 1 population is assumed to remain constant at the 2050 level.[5] The length of the time horizon

5) As a result, the distribution of the population will become uniform in the long run (starting from 2110 to be exact), with the number of people in each age group equal to the number of age 1 population in 2050.

is set to be longer than the projection periods (50 years), because people alive in 2050 or later years will make their choices over life in a forward-looking way. Fortunately, Auerbach and Kotlikoff (1987) report that for most simulations the steady state is reached in less than 150 years. Following Auerbach and Kotlikoff, we assume that the time horizon of 150 years is long enough to be consistent with forward-looking choices of every individual.

Second, in order to obtain the initial asset holdings in 2001, we assume that the cross-sectional distribution of asset holdings by age group in 2001 was the same as the over-lifetime distribution of asset holdings of age 1 population in 2001 adjusted for productivity gap between generations. In particular, we start with an arbitrary intial guess for the asset holdings of each cohort and obtain the optimal lifetime asset accumulation of the age 1 population in 2001. After substituting the initial guess with the resulting lifetime profile of age 1 population, we compute the optimal lifetime choices again. This procedure is repeated until the fixed point of the asset distribution is achieved. Intial asset holdings are obtained this way because, as mentioned in introduction, we are interested in measuring impacts of population aging on the economy in separation from other factors. In order to prevent our simulation results from reflecting factors other than population aging (for example, the catching-up effect), we need to determine initial asset holdings endogenously as just described.

Third, we assume an arbitrary initial guess for the interest and wage rate series for the entire 150 years. Given the interest and wage rates and initial asset holdings, the optimal consumption and labor supply schedules for each individual can be fully determined by the budget constraint in equation (3) and the first-order conditions in equation (4). One restriction here is that there exists an upper bound on the level of leisure that an individual can choose (1 in our definition). Also, every individual should retire at a fixed age and the amount of leisure after retirement should be always equal to 1. In order to meet both the first-order conditions and these restrictions on leisure choice, we define a shadow wage of labor. Whenever the labor supply becomes negative (or leisure becomes greater than 1), the shadow wage is set through iterations to a value where the first-order condition between consumption and leisure in equation (4) generates 0 labor supply as the optimal choice. Similarly, the shadow wage is set such that the optimal leisure choice is 1 for retired people. Under our functional and parameter assumptions to be described later, labor supply never exceeds 1 (or leisure never becomes negative).

Finally, given the individual choices, the aggregate labor and capital stock for each year are computed to produce a new series of the interest and wage rates for the entire time horizon. With the new series of the interest and wage rates, consumer's optimization produces new labor and capital supply. These steps are repeated until the fixed point for the interest rate (or/and the wage rate) is reached.

(2) Parameterization of the Model

We also follow the standard in choosing the parameter values of the model. Ideally, the parameter values need to be chosen to best represent the Korean economy. Since there are few background studies on these values in Korea, however, we are forced to cite the values from other countries' experiences. For consumer preferences, we assume α = 2 (importance of leisure relative to consumption), ε = 0.8 (degree of substitution between consumption and leisure), θ = 0.015 (subjective discount rate), $1/\rho$ = 2 (degree of relative risk aversion). All these values are close to the ones used by Auerbach and Kotlikoff (1987) and Miles (1999).[6] For the age-specific (not time related) labor endowment, we assume the following:

$$h_i = 0.05*(i+19) - 0.0006*(i+19)^2 \tag{6}$$

where h_i is labor endowment at age i (i = 1, 2, ... 60) over an individual's life. This representation is the same with the one in Miles (1999). In addition to equation (6), we assume aggregate (time related) productivity growth of 0.02: i.e., E_t in equation (1) grows at the rate of 0.02. The value of E_t for the age 1 population in 2001 is normalized to 1. Main conclusions of our experiment are not sensitive to reasonable modifications to the labor endowment. The parameters A and β in the production function are set to be 1 and 1/3, respectively. As mentioned above, population projections are provided by the NSO. Under this setup, convergence is achieved fairly quickly.

IV. Macroeconomic Impacts of Population Aging

1. Benchmark Distribution of Population

6) David Miles, Modelling the Impact of Demographic Change upon the Economy, *The Economic Journal*, January 1999.

For proper evaluation of population aging, one needs to have a benchmark distribution of population which does not exhibit any aging trend. Our benchmark in this paper is the uniform distribution where every cohort has the same size. The uniform distribution is a natural choice, since it is the distribution limit for populations with constant age-specific death rates and the fertility rate of 2.0. An intermediate between the benchmark distribution and the actual distribution (NSO projection) will be the case where the number of age 1 population is constant every year and the age-specific death rates are the same as those in the NSO projection. In our presentation of simulation results below, we compare the NSO projection with the benchmark distribution and the intermediate case.

<Figure 3> Age structure of population

Figure 3 shows how the age structure of population will evolve under different scenarios. As expected, the proportion of elderly people increases under both scenarios and the trend is more drastic under the aging scenario (NSO projection). Note, however, that the present population of Korea is rather young and will remain so at least for the next 10 to 15 years: most of the population is between 1 and 30 years old (between 21 and 50 in biological age) for years 2001 and 2011.

2. Simulation Results

(1) Individual Choices

Before obtaining macroeconomic forecasts, we examine how individual choices over life are made in our model. The model would not be reliable if individual choices obtained from it were unrealistic. Figure 4 shows individual choices made by age 1 population in 2001 under the benchmark case (uniform distribution). Similar patterns are observed for other cohorts and/or under different scenarios. First, the labor supply schedule shows that an individual works for about a third of his time until retirement. To be sure, both labor supply and leisure will be greater for future generations because of the aggregate productivity growth we assume. The pattern of labor supply peaking at mid ages where age-specific labor productivity is highest holds for all generations.

Individual savings and asset accumulation exhibit traditional life-cycle patterns. The saving rate is negative at the beginning of life and after retirement, and positive for most of the working period. Consequently, the amount of asset holding peaks right before retirement. Since we assume no bequests, asset holding drops to zero at the end of life. The absolute magnitude of asset is irrelevant in the figure, as we use normalized variables in the model (for example, time endowment for age 1 population in 2001 is set to 1).

<Figure 4> Individual choices: age 1 cohort under the benchmark distribution

(2) Macroeconomic Variables

Now we examine forecasts of key macroeconomic variables computed from our model.

Saving rate

The aggregate saving rate series is presented in Figure 5. In the benchmark case with the uniform population distribution, the saving rate stays constant at about 11%. Under the two scenarios we consider, the saving rate is about 24% in 2001 and is expected to remain higher than that of the benchmark case for a substantial period of time. The reason for this is that the population of Korea, although aging rapidly, is still young and will remain so for some time. Eventually, however, the saving rate becomes equal to the benchmark rate of 11%, since in our setup the population distribution converges to the uniform distribution in the long run under both scenarios.

Comparison between the two scenarios shows that, as expected, the saving rate is consistently lower for the aging scenario.

<Figure 5> Saving rate

Interest rate

The interest rate is about 4.5% under the uniform population distribution. It is higher under both scenarios we consider for the next 30 years. Again, the reason for this is the relatively young age structure of Korea's population. With most of the population in the working age group, Korea is still a labor abundant economy.

Between the two scenarios, the aging scenario has a greater proportion of the elderly people and thus a higher ratio of aggregate capital to labor. This implies that the interest rate will be lower under the aging scenario. The interest rate series in Figure 6 is consistent with this expectation for most periods. For the first few years, however, the interest rate is higher under the aging scenario. This can be explained by differences in the amount of initial asset holdings between the two scenarios. In our model, initial asset holdings in 2001 are determined endogenously in accordance with lifetime asset accumulation patterns of the age 1 cohort in 2001. The age 1 individuals in 2001 under the aging scenario determine their labor supply and savings decisions based on their expectation of higher wages and lower interest rates (compared with the series under the no-aging scenario). Under the parameter values we assume, the optimal response to higher wages and lower interest rates is to accumulate less capital through life. Thus, cohorts in 2001 are set to start with a less amount of assets under the aging scenario.7) This explains the interest rate pattern in Figure 6.

<Figure 6> Interest rate

Another thing to mention about Figure 6 is that the real interest rate for 2001 under the NSO projection, about 5.7%, seems to be lower than the actual value. This discrepancy may originate from unrealistic assumptions of the model or unreasonable parameter values. We suspect, however, that the seemingly low value of the interest rate is fully justifiable. As explained above, our model assumes endogenously determined intial asset holdings. Considering the current state of Korea, these values are likely to be greater than actual asset holdings in 2001. The Korean economy, having started with a very low level of capital stock after the Korean War, is still distant from the steady state. Initial asset holdings assumed in our model do not take into account this Korea specific feature. Thus, the interest rate obtained from our model may well be lower than actual.

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7) It also turns out that the total labor supply in 2001 is greater under the aging scenario. Under the aging scenario, while young generations supply less labor, old generations supply more labor in 2001. The net effect is a greater supply of labor.

Per capita GDP

Per capita GDP is one of the most important variables to consider in evaluating macroeconomic impacts of population aging. Figure 7 shows how per capita GDP in Korea will change in the future. For presentational convenience, per capita GDP under the two scenarios are represented by a ratio to that of the benchmark case. The ratio is greater than 1 under both scenarios throughout our projection period (2001 through 2050), i.e., per capita GDP under the two scenarios is greater than that of the benchmark case. This result indicates that Korea's population, while rapidly aging, is still relatively young and thus that Korea will enjoy its young age structure for the time being.

Eventually, however, per capita GDP (as a ratio to the benchmark level) will become lower than 1 under the aging scenario, as young age groups that currently comprise the majority of Korea's population move to elderly age groups. An increase in the proportion of the elderly decreases per capita GDP through two channels: because of the trend growth in productivity, old generations have lower labor productivity than young generations; even without the productivity growth, old (retired) people have smaller income than young people. As can be expected from this argument, per capita GDP is consistently higher under the no-aging scenario than under the aging scenario.

<Figure 7> Per capita GDP: as a ratio to the benchmark level

Also, Figure 7 shows that under the no-aging scenario per capita GDP is always greater than 1. This suggests that a fertility increase can reduce the long-run negative impacts of population aging on per capita GDP. Since the number of new entries to the labor market is constant under the no-aging scenario, the population distribution converges to the uniform distribution and pre capita GDP becomes 1 in the long run.

Per capita GDP growth

While per capita GDP remains high compared to the benchmark value, the growth rate of per capita GDP will soon drop. In Figure 8, the growth rate under both scenarios is shown to fall rather sharply from above the benchmark line in 2001 to below the benchmark line a few years thereafter. This result is consistent with the pattern observed in Figure 7 that the level of per capita

GDP approaches the benchmark level from above.

In our model, population aging reduces per capita GDP growth mainly through many channels. One is the convergence effect generated by a trend increase in the capital/labor ratio. Clearly, the current level of the capital/labor ratio of Korea is lower than the steady state value. Even if we ignore specific historical factors such as the Korean War, the current age structure of population makes Korea a labor abundant country. As the population ages and the capital/labor ratio increases, the law of decreasing marginal productivity sets in and consequently the growth rate decreases. The second is a shift in the steady state caused by lower savings. Population aging decreases the saving rate (Figure 5), and a decrease in the saving rate implies a decrease in the steady state level of the capital/labor ratio. Given current capital/labor ratio, this change in the steady state causes a fall in the growth rate. In addition, population aging lowers the proportion of workers. This implies a smaller labor supply from a given number of people.

The growth rate series in Figure 8 is also quantitatively reasonable. The estimated growth rate of 2% for 2001 (under the aging scenario) is lower than the actual growth rate of 3.5% for the period of 1997 through 2003. However, as explained above, the initial capital stock assumed in our model is likely to be greater than the actual capital stock in 2001. With a greater than actual level of the initial capital stock, it is natural to underestimate the growth rate.[8)]

<Figure 8> Per capita GDP growth rate

(3) Welfare Analysis

A decrease in per capita GDP growth as shown in Figure 8 is often regarded as one of the most important negative consequences of population aging. However, a lower growth in per capita GDP does not necessarily mean that individual agents are worse off. For example, as shown in Figures 7 and 8, the growth rate of per capita GDP may decrease even when the level of per capita GDP remains high. Also, even when the level of per capita GDP decreases, lifetime utility of individuals may actually increase. If intergenerational transfer is large enough to equalize the distribution of resources across all generations

8) When the initial capital stock is lowered by 30%, the capital/output ratio decreases from 3.8 to 3.0 and the per capita GDP growth rate increases from 2.0% to 2.6%.

(including future generations yet to be born), per capita GDP will be an accurate indicator of individual welfare. However, as long as intergenerational transfer is incomplete, an aggregate indicator such as per capita GDP cannot provide a full description of individual welfare of different generations.

In this section, we examine welfare implications of population aging by explicitly computing the wealth equivalent of lifetime utility for each generation. See Auerbach and Kotlikoff (1987) for details. In order to control for level differences among different generations caused by aggregate productivity growth, lifetime utility is represented by a ratio to that of the benchmark case.

Figure 9 shows lifetime utility of the age 1 cohort from each period under the two scenarios. Under both scenarios, the welfare level of age 1 individuals is below 1 for the first few decades. The reason for this is that, because of the current young age structure of Korea's population, labor remains abundant (capital remains scarce) and the wage rate remains low (the interest rate remains high) for substantially long periods of time. Since age 1 individuals enter the labor market with no capital asset by assumption, they are more affected by the low wage rate than by the high interest rate. However, the magnitude of these welfare differences do not appear to be substantial. A similar explanation can be applied to Figure 10 which shows lifetime utility of each cohort alive in 2001. Abundant labor supply in present Korea keeps the wage rate low and the interest rate high. As a result, working-age individuals who rely mainly on labor income suffer while elderly people who rely mainly on interest income benefit.

<Figure 9> Welfare of age 1 cohort from each period: as a ratio to the benchmark level

<Figure 10> Welfare of each cohort in the present period: as a ratio to the benchmark level

Figure 9 also shows that, starting in around 2030, the welfare level of the age 1 cohort will become lower under the aging scenario compared to the benchmark case. By 2030, the baby boomers will shift to older groups and as a result the relative supply of capital will increase. This will have the effect of raising labor productivity by increasing the amount of capital that can be combined with labor.

A general conclusion derived from Figures 9 and 10 is that individuals belonging to an age cohort that constitutes a large proportion of population tend to be in a disadvantageous position throughout life. A baby boomer suffers from low wages during his working periods, because ample labor supply from other baby boomers decreases the wage rate. Similarly, after retirement, competition among baby boomers decreases the interest rate. Another point to make is that, in contrast to common perception, economic impacts of population aging on future generations may not be limited to adverse effects. As Figure 9 shows, future generations that enter the labor market at the time current young people (baby boomers) retire can enjoy a higher welfare level than is possible under the benchmark case. To be sure, the pattern in Figure 9 will not hold when the assumption of no intergenerational transfers is modified. If there are resource transfers from the young to the old (such as a national pension system), future generations may be adversely affected.

Finally, we note that welfare differences across generations are always smaller under the no-aging scenario. Welfare differences in our model are generated by fluctuations in the relative supply of labor and capital. Thus, the no-aging scenario that makes the population more evenly distributed across ages is more equalizing.

3. Simulation Results with the Pension System

Our model economy considered above does not have the government sector. Now we allow for the government in the form of a national pension system. Although macroeconomic impacts of the national pension system in Korea are not evident yet, it will become more important in the future as the population ages.

In implementing the national pension system of Korea, we assume that both the contribution rate and the replacement rate are fixed at current levels. The contribution rate is 0.09 (9 percent of labor income each working period) and the replacement rate is 0.6 (60 percent of the mean income over the lifetime of the insured people), currently. As a result, unlike the pure pay-as-you-go system where pension contributions and payments are equal each period, the pension system in our model may record either a deficit or a surplus in each period depending on the demographic structure of the time. This assumption is consistent with the current pension system of Korea.

One problem with this implementation is that the current pension system of Korea is not sustainable in the long run. As population continues to age, a pension system with constant contribution and replacement rates, particularly those with a low contribution rate and a high replacement rate like the one in Korea, will become eventually unsustainable. Also, from the viewpoint of our model, unsustainability of the pension system implies that the pension debt accumulates until the capital stock eventually turns to a negative value. A steady state cannot exist in such economies. The only solution to these problems is to balance the pension budget by either increasing the contribution rate or lowering the replacement rate. It is unclear, however, exactly how the pension reform will be done. In this paper, we assume that the current pension system (with the current contribution and replacement rates) remains unchanged until the pension fund is fully exhausted, at which time the pension system is abolished altogether. Under this scenario, some future generations will only make contributions without receiving any pension benefits. Actual pension reforms are likely to be more gradual than this. So our simulation results should be regarded as an exaggerated manifestation of impacts of the pension system.

We pay particular attention to Korea specific features of the national pension system. Korea's national pension system was first introduced in 1988, and it requires at least 20 years of contribution for eligibility. When assuming the retirement age of 60, this means that people who were aged over 41 in 1988 did not have the incentive to join the pension system.[9] Or equivalently, in year 2001 (the starting year for our simulation) people aged over 54 are not part of the pension system. In order to reflect this, our model considers two distinct maximization problems, one for pension members and the other for non-members, until year 2027 when theoretically everyone becomes a member. Also, we extend our projection period back to 1988. Assuming that the introduction of the pension system in 1988 was unexpected, we can obtain initial asset holdings for 1988 in the same way as before from a model without the pension system.

Since individual savings and labor supply decisions over life are basically the same as before, we only describe how the macroeconomic variables are affected by the existence of the pension system.

(1) Macroeconomic Variables

9) For people aged over 41 in 1988, the maximum number of contributions that can be made before the retirement age is 19.

Saving rate

The aggregate saving rate under the existence of the pension system is shown in Figure 11. A comparison of Figure 5 and Figure 11 indicates that, for both scenarios of population distribution, the national pension system has the effect of lowering the aggregate saving rate for the next few decades. This is consistent with the theoretical prediction that a pay-as-you-go pension system depresses savings in an OLG model with no bequests (Blanchard and Fischer (1989)).

However, the saving rate in Figure 11 temporarily exceeds that in Figure 5 starting in around 2050, at which time the series exhibits a structural break. The reason for this is that, in our simulation, the pension fund is exhausted (and thus the pension system is abolished) around that time. Young individuals at that time, having paid pension payments only to serve the elderly population, will be left with only a small amount of assets and no expectation of pension benefits. In order to secure consumption after retirement, they need to save a greater portion of their income. This higher propensity to save by the young can explain the temporarily high saving rate as shown in Figure 11. Figure 12 confirms that the pension fund, after peaking in around 2020 (as a ratio to GDP), is exhausted in around 2050.[10]

<Figure 11> Saving rate

<Figure 12> Pension funds

Also, Figures 11 and 12 show that the structural break will occur sooner under the benchmark case than under the two scenarios. The national pension system can be sustained longer under the two scenarios because the current population of Korea is younger than the uniform population distribution.

Interest rate

A comparison between Figures 13 and 6 shows that, under the existence of the pension system, the interest rate starts lower in 2001 but becomes greater in

10) The amount of funds that the national pension system currently has is about 20% of GDP. In our simulation, as Figure 12 shows, the ratio for 2001 is about 70%. The discrepancy may reflects the existence of non-members of the pension scheme and underreporting of income.

around 2015. The interest rate for the next decade is lower in Figure 13 because, as mentioned before, the economy accumulates more pension funds while not making full pension payments. The interest rate in Figure 13 becomes higher starting in around 2015 as negative impacts of the pension system on individual savings become more evident.

<Figure 13> Interest rate

Per capita GDP

We saw in Figure 7 that per capita GDP for the next few decades will be greater under the two scenarios than under the benchmark case. It was also shown that, in the longer run, per capita GDP will become smaller relative to the benchmark case because young age groups that currently comprise the majority of Korea's population will move to older groups. Figure 14 shows that these patterns do not change when the pension system is introduced.

In addition to these long-run patterns, one can observe severe short-run fluctuations in per capita GDP series in around 2045. These fluctuations, however, mainly reflect differences in the timing of the structural break (abolition of the pension system) between the benchmark case and the two scenarios, and thus are not of critical importance.

<Figure 14> Per capita GDP

<Figure 15> Per capita GDP growth

Per capita GDP growth

Per capita GDP growth rate series in Figure 15 also exhibit volatile short-run fluctuations. Overall patterns, however, are basically the same as before (Figure 8). In particular, the per capita GDP growth rate under the aging scenario is expected to remain below the benchmark line for the next few decades, regardless of the existence of the national pension system.

(2) Welfare Analysis

Intergenerational welfare distributions are substantially affected by the pension system. A comparison of Figures 9 and 16 shows that the pension system can benefit newborns that enter the labor market within the next ten years or so. In general, as Figure 9 shows, the young age structure of population in Korea is disadvantageous for newborns. Under the current pension scheme of Korea, however, the pension fund is expected to last longer with a young age structure (see Figure 12). Thus, some future generations, while receiving no pension payments under the benchmark case, may retire before the abolition of the pension system under the two scenarios we consider. Figure 16 also shows that this gain comes at the cost of a lower welfare level for the remaining newborns. Among current generations, as Figure 17 shows, working-age people tend to have lower welfare levels than elderly people. The magnitude of intergenerational welfare differences is roughly the same as in Figure 10. One main difference between Figures 10 and 17 is the welfare level of people aged below 10. While the young age structure of Korea tends to work against this age group's interests (Figure 10), the pension system can offset this effect. The complicated curvature in Figure 17 merely reflects differences in the timing of the abolition of the pension system, and thus is nor critically important.

<Figure 16> Welfare of age 1 cohort from each period: as a ratio to the benchmark value

<Figure 17> Welfare of each cohort in the present period: as a ratio to the benchmark value

<Figure 18> Welfare of age 1 cohort from each period: as a ratio to the value under no pensions

<Figure 19> Welfare of each cohort in the present period: as a ratio to the under with no pensions

In order to show more directly how individual welfare is affected by the pension system, Figures 18 and 19 report the welfare level of each individual as a ratio to the value under no pension system. Thus, values greater than 1 in Figures 18 and 19 indicate a welfare gain from the pension system. Figures 18 and 19 show that the current pension system has the effect of increasing the welfare of current middle-age population at the cost of current and future newborns.[11)] In our simulation results, the national pension system is abolished in around 2050, before most future generations retire. This implies that, while current middle-age people benefit from the low contribution rate and the high replacement rate, newborns only make payments without receiving any benefits. Figure 18 also shows that, even for those newborns that enter the labor market within the next ten years, the absolute level of welfare is lower under the pension system.

To summarize welfare implications of Figures 16 through 19, the clear winner of the pension system is current generations. Also, future generations that enter the labor market during next 10 or 20 years will be adversely affected by both population aging and the pension system.

V. Conclusion

Using the AK model, this paper examined macroeconomic impacts that population aging may have on the Korean economy for the next few decades. Our simulation results can be summarized as follows. First, despite the aging trend, Korea's population is still young and will remain so at least for the next couple of decades. Most macroeconomic variables, including the saving rate and the interest rate, will be under the influence of the young age structure for the time being. One exception may be the growth rate: per capita GDP growth will soon drop below the steady state level as the benefit from the young age structure diminishes. Second, in contrast to common belief, some of future generations may actually benefit from the current trend of population aging. Future generations that enter the labor market after current baby boomers retire will be able to have their labor force combined with the abundant capital stock provided by current baby boomers. The resultant high capital/labor ratio will increase labor productivity of those future generations. Third, introduction of the pension system into the model does not substantially change long-run macroeconomic trends. However, the pension system has important distributional implications: the current pension system in Korea benefit current middle-age people at the cost of current and future young generations. We suspect that many of the results derived here can also be expected under more realistic models.

There is no simple cure for the problem of population aging. As shown above, population aging is essentially a problem of intergenerational resource

11) Since people aged 37 and above in 2001 are outside the pension system, their welfare level is little affected by the pension system as in Figure 19.

distribution. A consensus is hard to reach on distributional issues. Also, changes in the age structure of population occur very slowly. We saw above that, while the current pace of population aging in Korea is one of the fastest in history, Korea's population will remain relatively young at least for the next couple of decades. Similarly, even if the fertility rate is raised now, it will take many decades before the current trend of population aging is reversed.

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<Table 1> Population aging in the world

	2000				2050			
	proportion(%)			average age	proportion(%)			average age
	0-14	15-64	65+		0-14	15-64	65+	
World	30.1	63.0	6.9	26.5	20.1	64.0	15.9	36.2
Advanced	18.4	67.3	14.3	37.4	15.8	58.3	25.9	46.4
Developing	33.0	61.9	5.1	24.3	20.8	64.9	14.3	35.0
Africa	42.6	54.2	3.2	18.4	27.8	65.4	6.8	27.4
Asia	30.4	63.7	5.9	26.2	18.6	64.6	16.8	38.3
Europe	17.5	67.8	14.7	37.7	14.7	57.4	27.9	49.5
Sth America	30.8	63.6	5.6	24.4	18.0	63.7	18.3	37.8
Nth America	21.5	66.2	12.3	35.6	17.7	61.8	20.5	41.0
Oceania	25.8	69.4	4.8	30.9	18.1	62.8	19.1	39.1

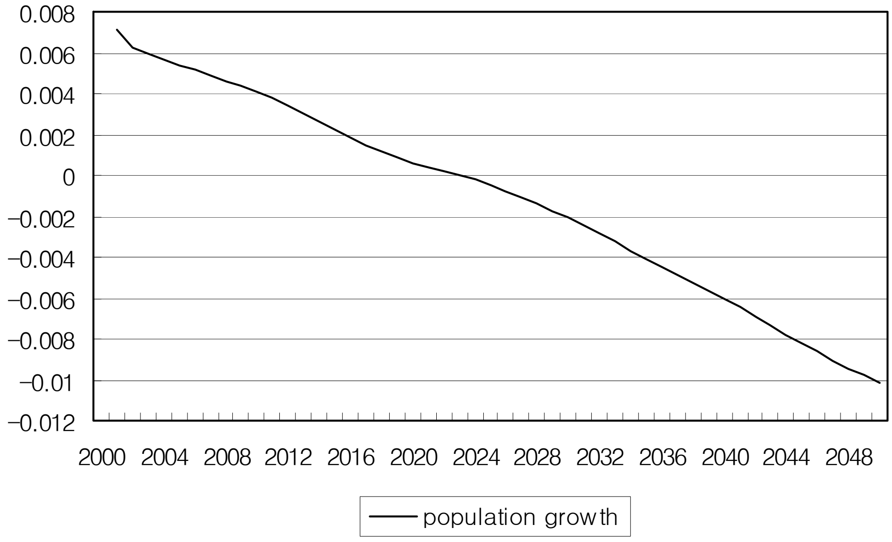
Source: UN, 『World Population Prospects』, 2002

<Table 2> Population aging in selected countries

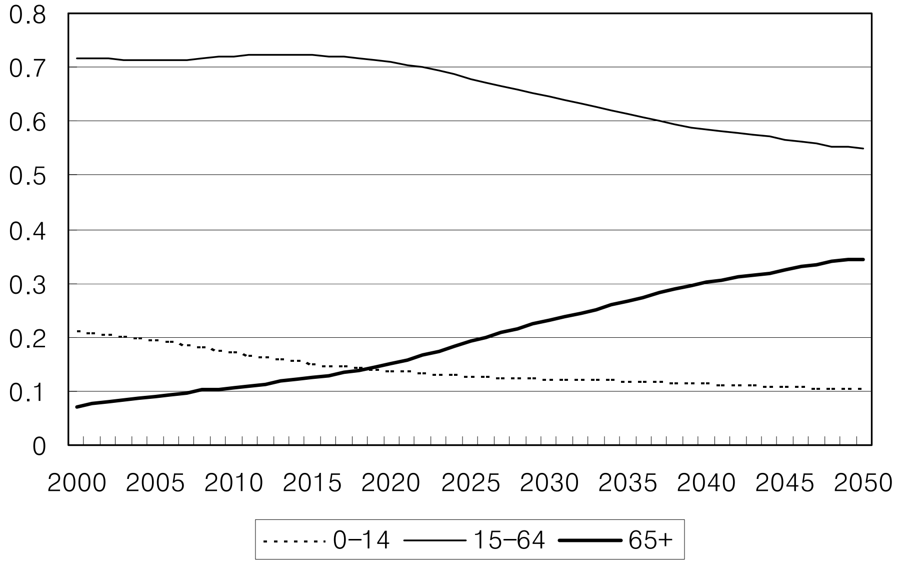
	year			number of years	
	7%	14%	20%	7%→14%	14%→20%
Korea	**2000**	**2019**	**2026**	**19**	**7**
Japan	1970	1994	2006	24	12
France	1864	1979	2020	115	41
Germany	1932	1972	2012	40	40
UK	1929	1976	2021	47	45
Italy	1927	1988	2007	61	19
US	1942	2013	2028	71	15
Sweden	1887	1972	2012	85	40

Source: UN, 『The Sex and Age Distribution of World Population』, 2002

<Figure 1> Population growth rate: NSO projections

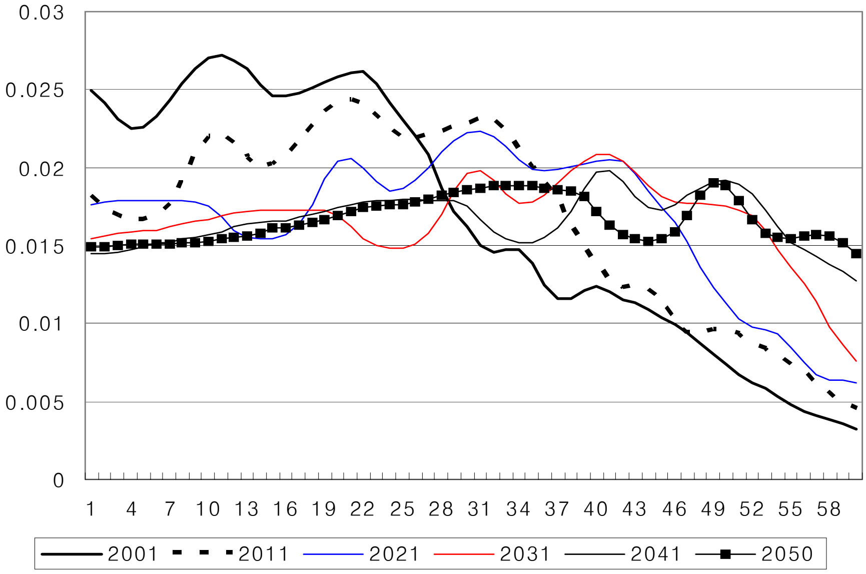


<Figure 2> Age structure of population: NSO projections

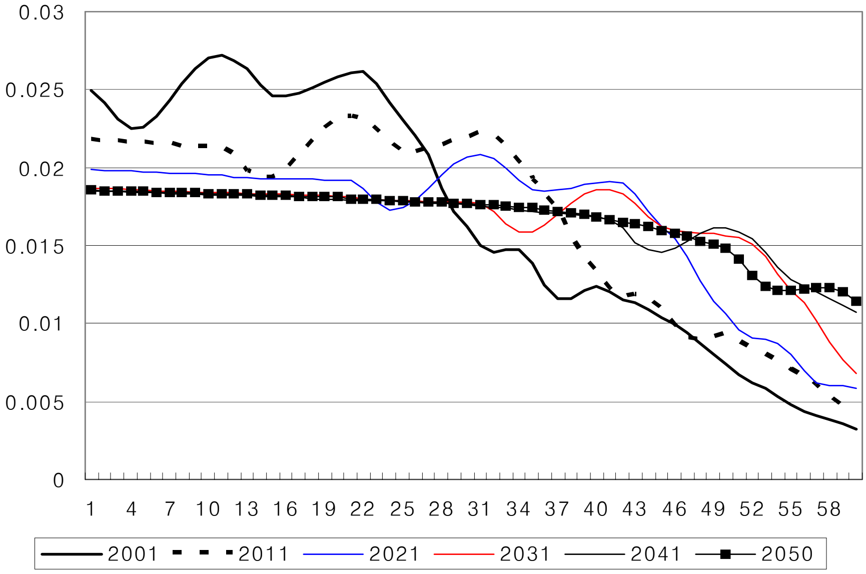


<Figure 3> Age structure of population

NSO projection (aging scenario)

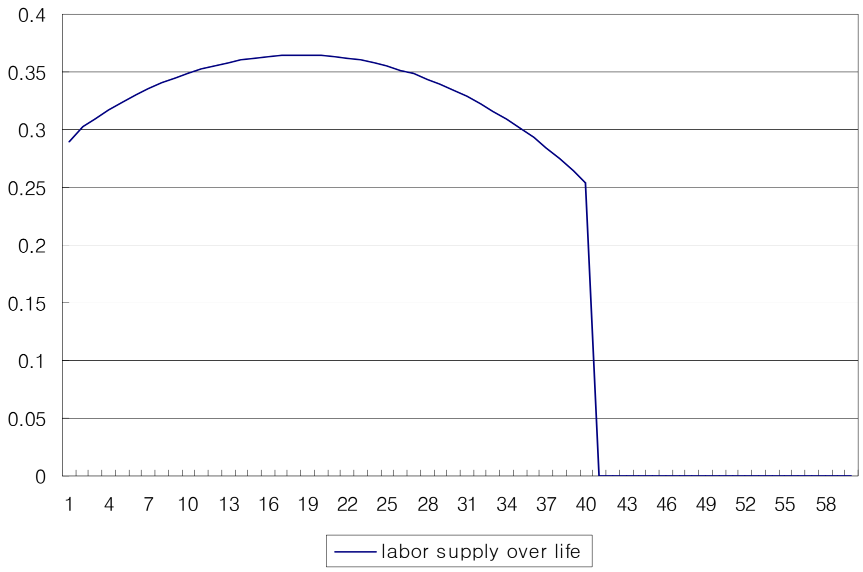


Intermediate case (no-aging scenario)

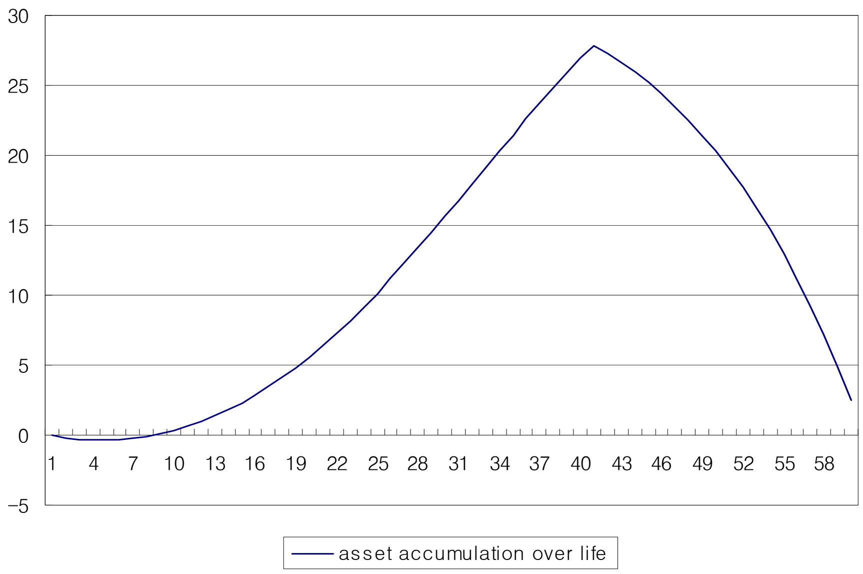


<Figure 4> Individual choices: age 1 cohort under the benchmark distribution

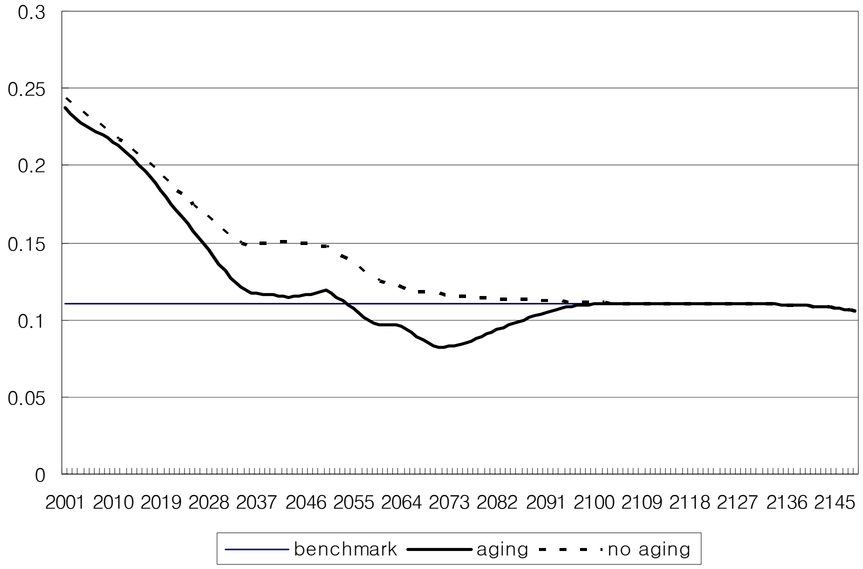
Labor supply



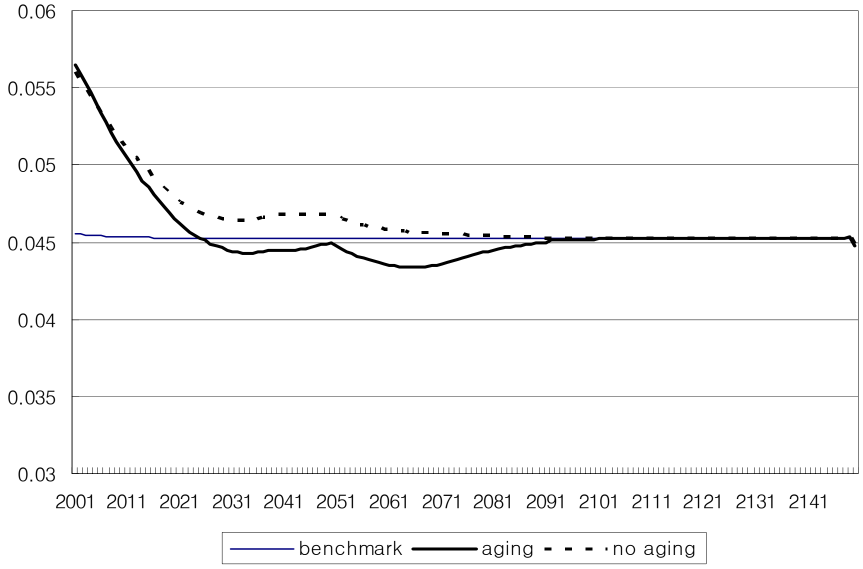
Asset accumulation



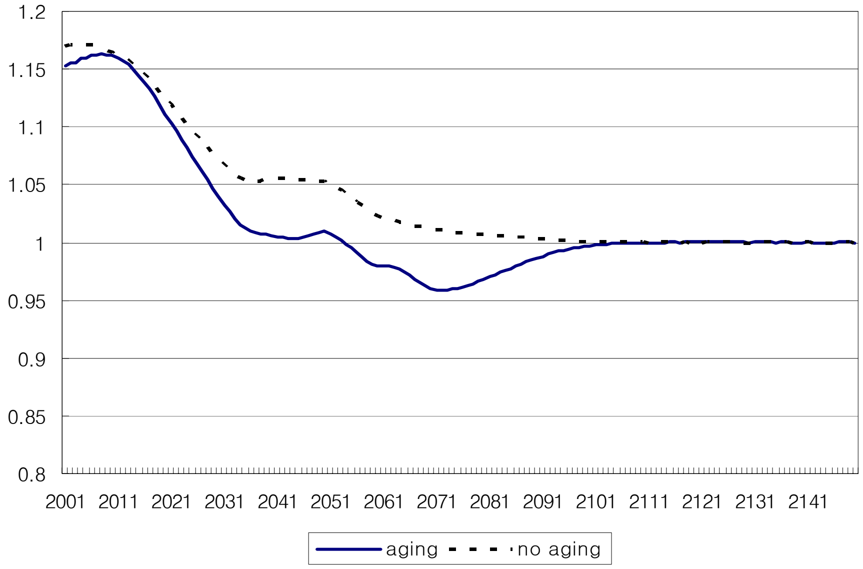
<Figure 5> Saving rate



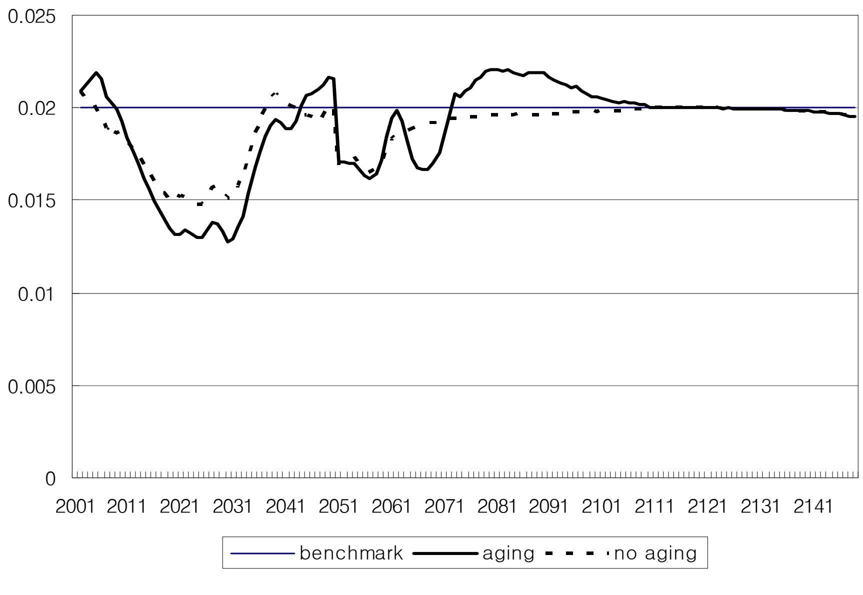
<Figure 6> Interest rate



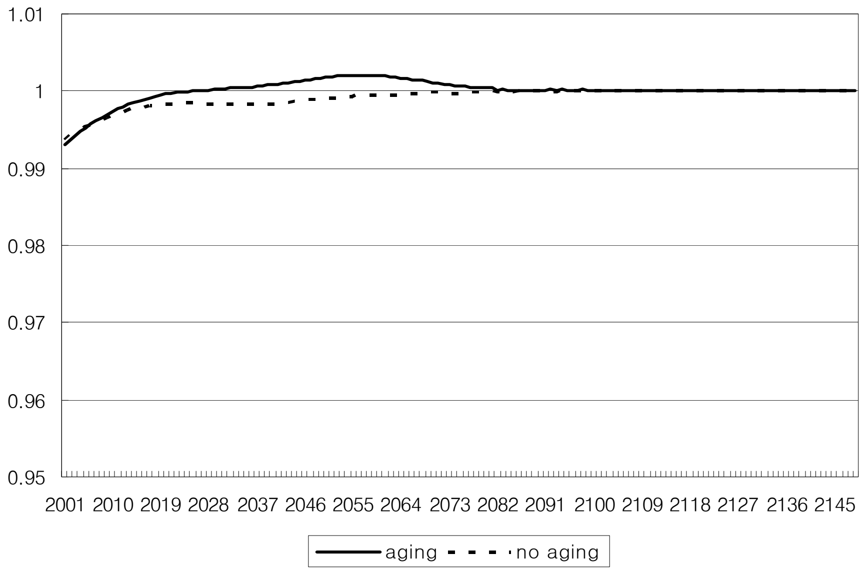
<Figure 7> Per capita GDP: as a ratio to the benchmark level



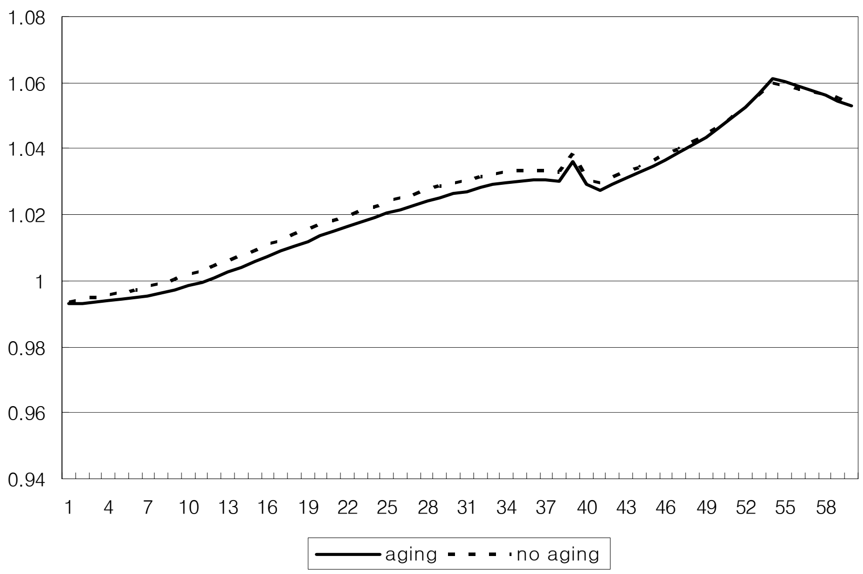
<Figure 8> Per capita GDP growth rate



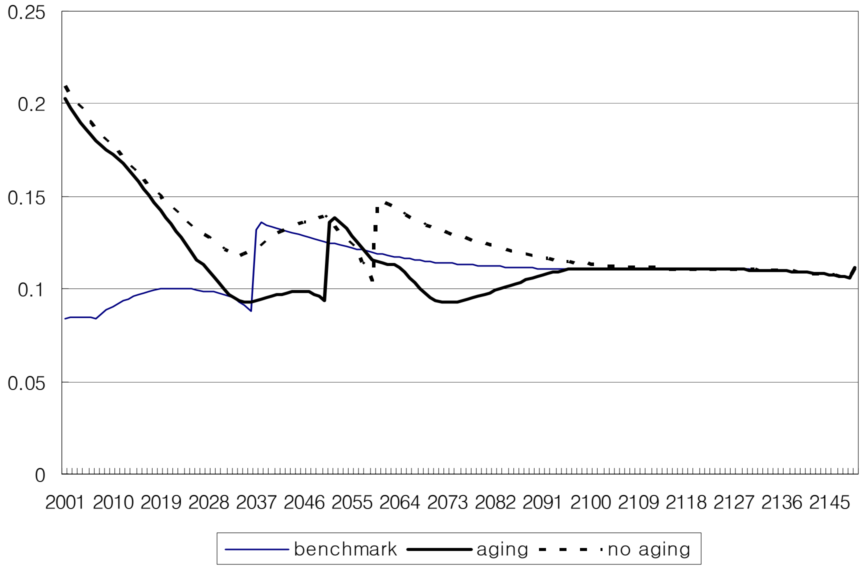
<Figure 9> Welfare of age 1 cohort from each period: as a ratio to the benchmark level



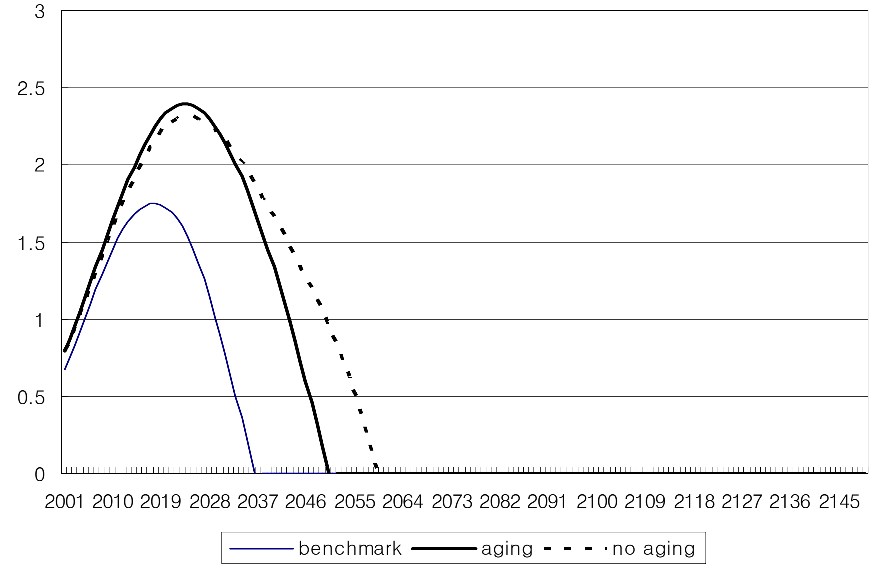
<Figure 10> Welfare of each cohort in the present period: as a ratio to the benchmark level



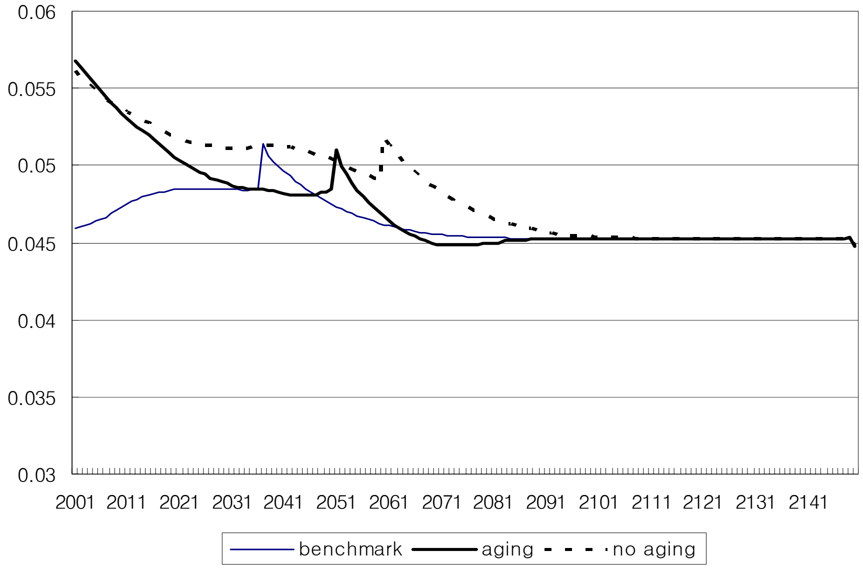
<Figure 11> Saving rate



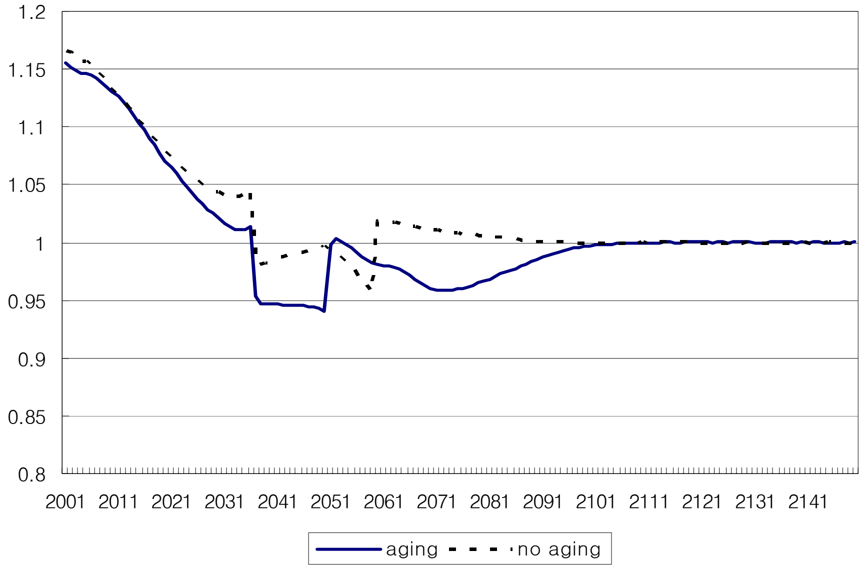
<Figure 12> Pension funds



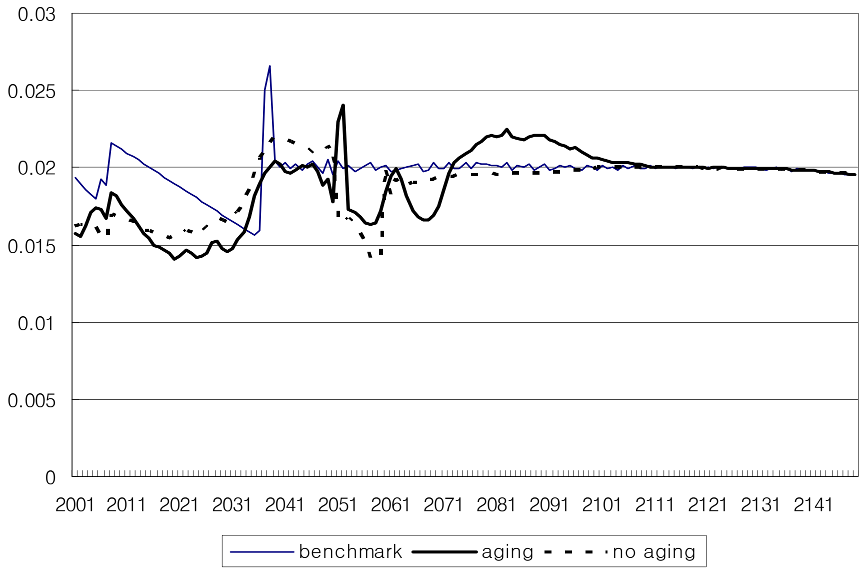
<Figure 13> Interest rate



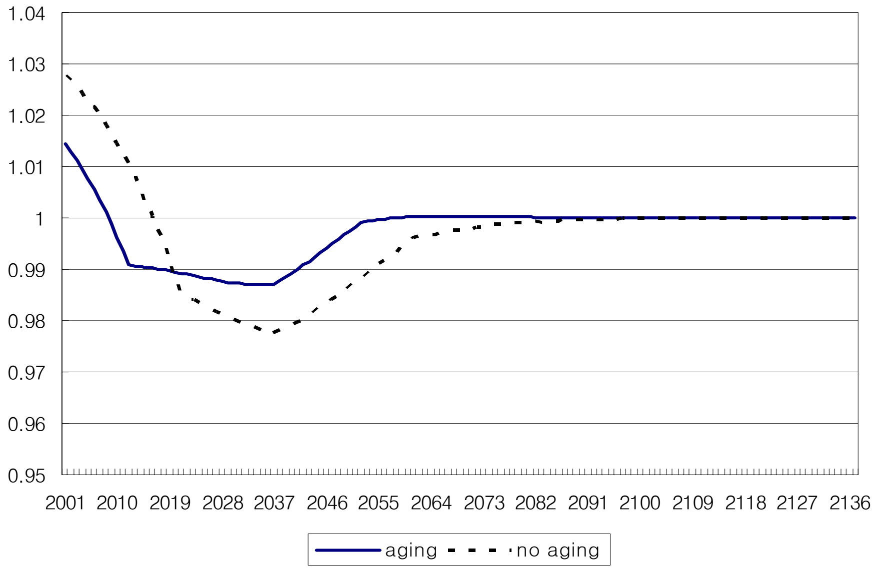
<Figure 14> Per capita GDP



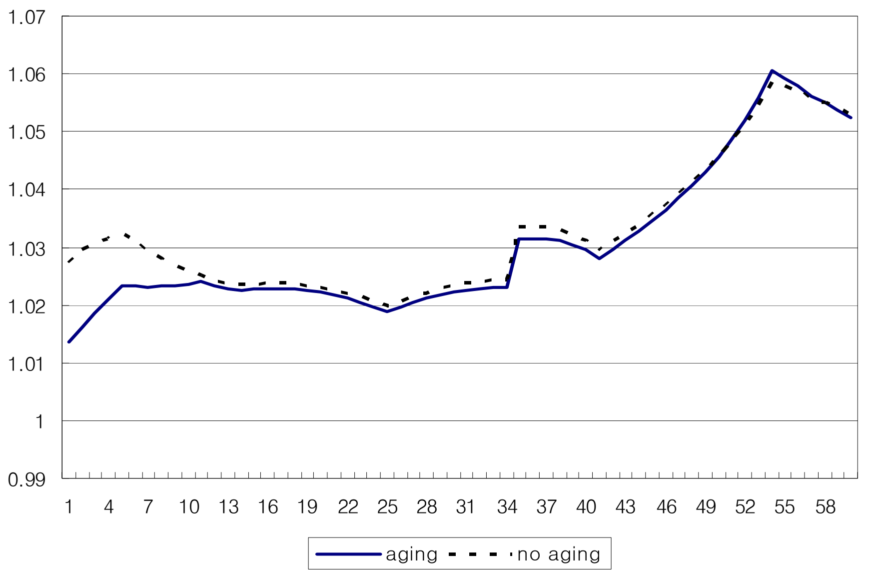
<Figure 15> Per capita GDP growth



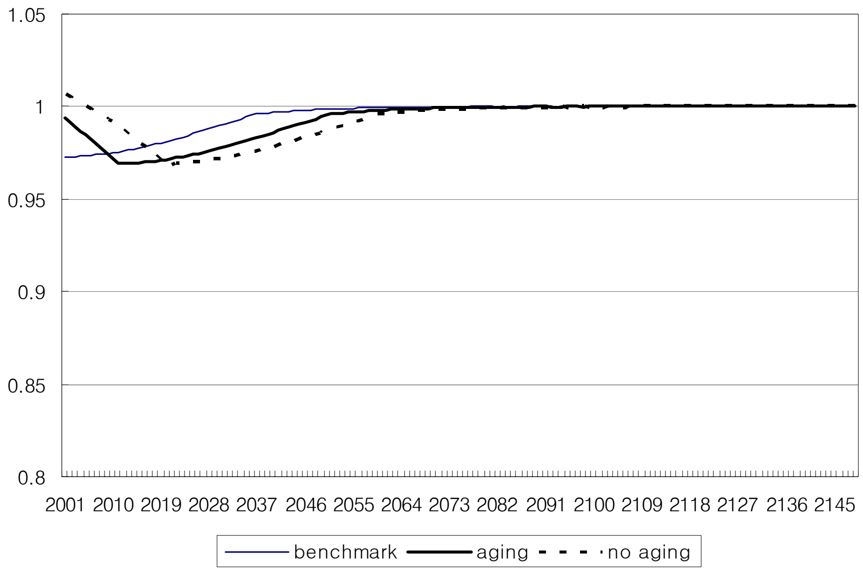
<Figure 16> Welfare of age 1 cohort from each period: as a ratio to the benchmark value



<Figure 17> Welfare of each cohort in the present period: as a ratio to the benchmark value



<Figure 18> Welfare of age 1 cohort from each period: as a ratio to the value under no pensions



<Figure 19> Welfare of each cohort in the present period: as a ratio to the value under no pensions