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WELFARE IMPLICATIONS OF AN AGING POPULATION IN KOREA

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This paper examines macroeconomic impacts of population aging in Korea using a computable general equilibrium (CGE) model of Auerbach-Kotlikoff (AK) type. The conventional AK model is extended in order to incorporate open economy features and endogenous fertility choices. By applying this model to the current demographic structure of Korea, we obtain the following results. First, welfare implications of population aging are rather complicated, since there are both winners and losers. While current and future young generations will be harmed by population aging, current elderly generations benefit from the trend. Second, policy responses to population aging should be considered with great caution. Fertility promoting policies, for instance, may entail substantial redistribution of resources among individuals from current and future generations. Third, opening up the domestic capital market may be less controversial but a more effective policy response. By reducing fluctuations in the interest and wage rates caused by population aging, capital market integration can moderate welfare variations among different generations.

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I. INTRODUCTION

The goal of this paper is to assess quantitatively macroeconomic impacts of population aging in Korea. 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 percent in 2000 to 20 percent in 2025 and to 37 percent in 2050. Most people will agree that such rapid changes can have substantial impacts on many aspects of the Korean economy, from the national pension system to economic growth. But there is far less agreement on the magnitude and channels of the impacts. In this paper, I provide another set of forecasts of the impacts using a computable general equilibrium (CGE) model of Auerbach- Kotlikoff (AK) type.

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 percent. Thus, for the purposes of this paper, a computable general equilibrium (CGE) model such as the AK model is more appropriate than an empirical model. Second, a general equilibrium approach guarantees consistency among endogenous variables. For example, in the AK model, saving decision of a household is affected by the interest which at the same time is determined by household savings. A partial equilibrium approach, commonly taken in many empirical analyses, can allow for such simultaneity. Third, the AK model is a benchmark model: it is relatively simple and has been used by many countries, including U.S., Japan and U.K., for the analysis of population aging. While the AK model involves many simplifying assumptions (e.g., assumptions of market clearing, no adjustment costs, no uncertainty, etc.), these assumptions may not be critically problematic 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 [e.g., Jun

(1999) and Hong (2003)]. Consequently, in those studies population aging is considered only in association with other factors. However, even with no population aging, those other factors could exert substantial influence 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 savings rate and the growth rate may decrease after 2008. Another example may be the convergence in the growth rate or the "catching-up" effect. Even under the standard growth theory with no demographic changes, the growth rate in Korea is expected to decrease gradually as the economy matures and the level of per-capita capital stock rises. 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.

Also, this paper extends the conventional AK model in two ways that enable it to address policy measures to moderate impacts of population aging. As will be shown, population aging affects people's welfare mainly through increases in the capital/labor ratio. Therefore, in order to reduce the impacts, one should either decrease the supply of capital or increase the supply of labor. This paper considers (1) opening up of the capital market and (2) fertility promoting subsidies as policy measures for reducing capital and increasing labor, respectively.[1] It is relatively straightforward to implement capital market integration in the AK model. The second policy experiment can be examined when fertility decisions are endogenized in the model. This paper follows Barro and Becker (1989) and incorporates fertility decisions in the standard AK model.

The paper proceeds as follows. Section II briefly discusses population forecasts for Korea from 2005 to 2050, and Section III describes the AK model and the parameter values used in this paper. In Section IV, calibration results for macroeconomic impacts of population aging in

[1] An immigration policy is not separately examined, because immigration and capital market integration have similar welfare implications. In principle, capital can flow out (capital market integration) or labor can flow in (immigration) to achieve the capital/labor ratio that is consistent with the international interest rate. Clearly, immigration and capital market integration can have different implications for GDP: GDP will be greater when there is immigration.

Korea are provided. In particular, this section compares between the Korean economy and an imaginary economy with a uniform population distribution. This imaginary economy works as a benchmark in estimating macroeconomic changes that can be attributed solely to population aging. Section V considers two policy experiments (i.e., opening up of the capital market and provision of fertility promoting subsidies).

II. POPULATION FORECASTS

The National Statistical Office (NSO) of Korea provides population projections for years up to 2050.[2] According to NSO forecasts, the total population growth rate of Korea, already below 1 percent annually, will further decrease to reach 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. As a result of lower fertility rates and lower death rates combined, the proportion of the elderly population will rise from 7 percent in 2000 to 34 percent in 2050.

Upon constructing the same figures from UN's projections for Korean population, one can find that the UN's projections are less pessimistic. For example, the UN predicts a drop in the total population growth rate to -0.3 percent (opposite to -1 percent in NSO projection) and an increase in the proportion of elderly people to less than 30 percent (opposite to 34 percent 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 gradually from 1.51 in 2001 to 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

[2] The OECD also provides population projections for its member countries. We find, however, that the OECD figures are the same with the UN figures.

in population size and age structure.

The reason why the UN assumes convergence of the fertility rate to the replacement level is mainly 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.[3] By the same logic, a fertility rate higher than the replacement level cannot last long, either. To the extent that the fertility rate is an endogenous variable that mean-reverts to the long-run replacement level, the UN's assumption may not be unrealistic.

Since fertility decisions are fully endogenized in our model, we can provide our own series of population forecasts. As will be shown later, our forecasts are closer to the UN projections than to the NSO projections, because we set parameter values, such that the fertility rate eventually converges to the replacement level, as in the UN's assumptions. This setup is required for the existence of a non-degenerate steady state.

Some may criticize that, since our population forecasts are substantially different from the NSO projections, our model does not really represent the Korean economy. Note, however, that the NSO projections are purely based on past trends and incorporate no economic reasoning. As mentioned above, the UN assumes gradual increase in the fertility rate and provides population projections that are more in line with our own forecasts. Also, we find that main qualitative statements of this paper hold the same even if we exogenously impose the NSO projections and change parameter values to generate a fertility rate consistent with the NSO projections.

III. MODEL

As in the conventional AK model, we assume that the economy consists of heterogeneous 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. For simplicity, it is assumed that

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[3] A higher value of labor may also imply greater child-raising costs to the extent that raising children requires a part of parents' time resources available for work. Scarce labor will promote fertility only if the opportunity costs of raising children do not increase too much as the wage rate increases.

individuals have perfect foresight (no uncertainty).[4] This assumption is unrealistic, but it greatly simplifies the computations involved. Since there is no uncertainty, individuals make their optimal lifetime savings and fertility choices in the first period of life. These individual choices collectively determine the aggregate supply of capital and labor of the economy. Also, the firm sector is assumed to be perfectly competitive so that the interest and wage rates are set to equal the marginal productivity of aggregate capital and labor, respectively. We also assume that technical progress causes the time endowment of each successive generation to grow at a constant rate, following Auerbach et al. (1989) and Kotlikoff et al. (2004).[5,6]

In order to incorporate the fertility decision problem in the standard AK model, we follow Barro and Becker (1989) and assume that altruistic parents derive utility not only from their own consumption, but also from consumption by their children. Unlike Barro and Becker (1989), however, parental altruism is assumed to extend only to the first generation of descendants and only to the periods before the descendants become economically independent. This assumption is made in order to maintain the life-cycle feature of the model. If parental altruism extends to all generations of descendants, the entire path of the economy will be determined solely by current parents. Detailed description of the model is as follows.

1. Consumer Behavior

Each consumer is assumed to have a fixed economic lifetime of 50 years. Since we ignore economic decisions of individuals aged 30 or below, this assumption corresponds to a biological life expectancy of 80

[4] Although it is not impossible to develop a model with uncertainty, only the simplest forms of uncertainty can be considered in practice. See, for example, Imrohoroglu, Imrohoroglu, and Joines (1999).

[5] 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 a steady state, since demand for leisure would continue to increase across cohorts.

[6] 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 from the no productivity growth case, after ex post adjustment for the productivity growth.

years. The goal of consumers are to maximize their lifetime utility with respect to themselves and their children. As is commonly assumed, the utility function is time separable and of a Constant Relative Risk Aversion (CRRA) form. More specifically, lifetime utility of a parent aged n (<=50) at time t is represented as follows:

$$U = \sum_{i=0}^{50-n}(1+\theta)^{-i} * [u(c_{n+i,t+i}) + a_{n+i} * (N_{n+i,t+i})^{-\varepsilon} * N_{n+i,t+i}u(ck_{n+i,t+i})]$$
$$u(X) = X^{(1-1/\rho)}/(1-1/\rho)\,, \qquad (1)$$

where $c_{n+i,t+i}$ = consumption of this individual at the age of $n+i$ (at time $t+i$);
$ck_{n+i,t+i}$ = consumption of a child of this individual at the age of $n+i$;
$N_{n+i,t+i}$ = number of children of this individual at the age of $n+i$;
a_{n+i} = a parameter of parental altruism at the age of $n+i$;
ε = another parameter of parental altruism ($0<\varepsilon<1$)
θ = time discount rate;
$1/\rho$ = degree of relative risk aversion.

We assume that each individual makes the fertility choice in the first year of lifetime (biological age of 31), and once made, the choice is irrevocable. The parameter a for parental altruism is time independent but allowed to change over age. Both a and ε are from Barro and Becker (1989). We ignore leisure / labor choice by assuming that total time available for work is exogenously given. While time endowment for each period is constant over an individual's life, it increases at a constant rate across cohorts.

For the budget constraint, we assume the following asset accumulation process:

$$A_{n+1,t+1} = A_{n,t}(1+r_t) + w_t l_{n,t} h_{n,t} + c_{n,t} - N_{n,t}(ck_{n,t} + B_{n,t})\,, \qquad (2)$$

where $A_{n,t}$ = asset of an individual aged n at time t;
r_t = interest rate at time t.
w_t = wage rate at time t;

$l_{n,t}$ = time endowment available for work of an individual aged n at time t;
$h_{n,t}$ = effective unit of labor endowment of an individual aged n at time t;
$c_{n,t}$ = consumption of an individual aged n at time t;
$N_{n,t}$ = number of children of an individual aged n at time t;
$ck_{n,t}$ = consumption of a child of an individual aged n at time t;
$B_{n,t}$ = costs of raising a child of an individual aged n at time t.

We also assume that each individual retires after working for 30 years (i.e., $l_{n,t}$ = 0 for n > 30) and that parents care about their children only until they are 30 years old, at which time descendants become economically independent and need no more parental care (i.e., $ck_{n,t} = B_{n,t} = 0$ for $n > 30$). The assumption of $ck_{n,t} = 0$ for $n > 30$ can be regarded as being equivalent to the assumption of $a_n = 0$ for $n > 30$. Under these assumptions, equation (2) can be expanded to imply the following lifetime budget constraint:

$$
\begin{aligned}
& c_{n,t} + N_{n,t}ck_{n,t} + N_{n,t}B_{n,t} \\
& + \frac{c_{n+1,t+1} + N_{n+1,t+1} + ck_{n+1,t+1} + N_{n+1,t+1} + B_{n+1,t+1}}{(1+r_{t+1})} \\
& + \frac{c_{n+2,t+2} + N_{n+2,t+2} + ck_{n+2,t+2} + N_{n+2,t+2} + B_{n+2,t+2}}{(1+r_{t+1})(1+r_{t+2})} + \ldots \\
& + \frac{c_{30,t-n+30} + N_{30,t-n+30} + ck_{30,t-n+30} + N_{30,t-n+30} + B_{30,t-n+30}}{(1+r_{t+1})(1+r_{t+2})\ldots(1+r_{t-n+30})} \\
& + \frac{c_{31,t-n+31}}{(1+r_{t+1})(1+r_{t+2})\ldots(1+r_{t-n+31})} + \frac{c_{32,t-n+32}}{(1+r_{t+1})(1+r_{t+2})\ldots(1+r_{t-n+32})} \\
& \ldots + \frac{c_{50,t-n+50}}{(1+r_{t+1})(1+r_{t+2})\ldots(1+r_{t-n+50})} \\
& + A_{n,t}(1+r_t) + w_t l_{n,t} h_{n,t} + \frac{w_{t+1} l_{n+1,t+1} h_{n+1,t+1}}{(1+r_{t+1})} + \ldots \\
& + \frac{w_{t-n+301} l_{30,t-n+30} h_{30,t-n+30}}{(1+r_{t+1})(1+r_{t+2})\ldots(1+r_{t-n+30})}. \qquad (3)
\end{aligned}
$$

Since we assume no bequests, $A_{1,t} = 0$.

Optimization of Equation (1) under the budget constraint (3) can be summarized by the following first-order conditions:

$$\frac{c_{n,t+1}}{c_{n,t}} = \left(\frac{1+r_{t+1}}{1+\theta}\right)^{\rho}, \tag{4}$$

$$\frac{ck_{n,t}}{c_{n,t}} = (\alpha_n N_{n,t}^{-\varepsilon})^{\rho}, \tag{5}$$

$$\begin{aligned}\frac{a * N_n^{-\varepsilon}}{1-1/\rho} &= [ck_{1,t-n+1}^{(1-1/\rho)} + ck_{2,t-n+2}^{(1-1/\rho)}(1+\theta)^{-1+\cdots} + ck_{30,t-n+30}^{(1-1/\rho)}(1+\theta)^{-29}] \\ &= c_{1,t-n+1}^{-1/\rho}[ck_{1,t-n+1} + \frac{ck_{2,t-n+2}}{(1+r_{t-n+2})} + \ldots + \frac{ck_{30,t-n+30}}{(1+r_{t-n+2})\ldots(1+r_{t-n+30})} \\ &+ B_{1,t-n+1} + \frac{B_{2,t-n+2}}{(1+r_{t-n+2})} + \ldots + \frac{B_{30,t-n+30}}{(1+r_{t-n+2})\ldots(1+r_{t-n+30})}.\end{aligned} \tag{6}$$

Equation (4) is the standard Euler Equation for the evolution of consumption over time. Equation (5) describes the optimal relationship between a parent's consumption and a child's consumption within the same period. As expected, $ck_{n,t}$ increases under greater parental altruism (higher a_n or lower ε). Also, $ck_{n,t}$ is proportional to $c_{n,t}$ (for given values of $N_{n,t}$) and is inversely related with $N_{n,t}$ (for given values of $c_{n,t}$). Equation (6) is the first-order condition with respect to the number of children, $N_{n,t}$. Since we assume that the number of children is constant over a parent's lifetime ($N_{n,t} = N_n$), the marginal benefit of having another child (LHS of Equation (6)) is equal to the sum of utility derived from a child's consumption over a parent's lifetime. The marginal cost of having another child (RHS of Equation (6)) is equal to the sum of a child's consumption and raising costs over a parent's lifetime. Note that while Equations (4) and (5) hold true for all n, Equation (6) is valid only for $n = 1$ because we assume that fertility decisions made in the first period are irrevocable.

By combining Equations (3) through (6), one can obtain the optimal consumption (for a parent and children) and fertility schedule for the entire lifetime.

2. Aggregation

Given the individual optimal schedule, aggregate values for the economy can be computed simply by summing the products of the individual choices and the number of people in the corresponding age group. In particular, aggregate capital and labor supply and aggregate consumption expenditure are given as follows:

$$K_t = \sum_{i=1}^{50} A_{i,t} * P_{i,t}$$
$$L_t = \sum_{i=1}^{50} l_{i,t} * h_{i,t} * P_{i,t}$$
$$C_t = \sum_{i=1}^{50} (c_{i,t} + N_{i,t}(ck_{i,t} + B_{i,t})) * P_{i,t} , \qquad (7)$$

where K_t = aggregate capital at time t;

L_t = aggregate labor at time t;

C_t = aggregate consumption expenditure at time t;

$P_{i,t}$ = number of individuals aged i at time t;

$A_{i,t}$ = asset of an individual aged i at time t;

$l_{i,t}$ = time endowment available for work of an individual aged i at time t;

$h_{i,t}$ = effective unit of labor endowment of an individual aged i at time t;

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

$N_{i,t}$ = number of children of an individual aged i at time t;

$ck_{i,t}$ = consumption of a child of an individual aged i at time t;

$B_{i,t}$ = costs of raising a child of an individual aged i at time t.

3. 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:

$$r_t = \beta(K_t / L_t)^{\beta-1}$$
$$w_t = (1-\beta)(K_t / L_t)^{\beta}\ , \qquad (8)$$

where r_t = interest rate at time t;
w_t = wage rate at time t;
β = exponent of capital in production function;
K_t = aggregate capital at time t (given from equation (7));
L_t = aggregate labor at time t (given from equation (7)).

4. 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 300 years (from 2001 to 2300). The time horizon is set to be longer than a typical projection period, because people alive in the last year of the projection period will make their choices over life in a forward-looking way. In order to allow for such choices, we need to have forecasts of the economy for latter years as well. In our setup, the steady state is reached in less than 300 years, making our choice of time horizon consistent with forward-looking behavior of every individual.[7]

Second, we assume that the population exactly follows the NSO projection until 2030, and thereafter, diverges from it according to the fertility rate endogenously derived from our model. For instance, ignoring age-specific mortality rate, newborns in 2001 (given by the product of the number of age 1 population and the number of each age 1 individual's children in 2001) grow up to constitute the age 1 population in 2031, the

[7] Auerbach and Kotlikoff (1987) report that for most simulations a steady state is reached in less than 150 years. It takes longer in our model to reach a steady state, because endogenously determined fertility rates make it difficult for the population distribution to stay constant. In a steady state, the number of new parents (age 1 cohort) should be constant over time. Since the number of new parents is equal to the number of newborns 30 years back, it is required (in addition to the replacement level fertility rate) that the number of new parents 30 years back should also be equal to the steady state level.

age 2 population in 2032, and so on. Similarly, newborns in 2002 become the age 1 population in 2032, the age 2 population in 2033, and so on. Through this procedure, we can obtain fully endogenized population forecasts for years 2080 and later. For years 2051 through 2079, which neither NSO forecasts nor our full endogenous forecasts are available, we assume that people aged y ($20<y<50$) in year $2050+x$ ($0<x<30$) all survive to become people aged $y+1$ in year $2050+x+1$, until they reach 50 and die out.

Third, we set up initial asset holdings and initial fertility rate for each age group in 2001. For initial asset holdings in 2001, we assume that the cross-sectional distribution of asset 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 initial 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 in separation from other factors. In order to prevent our simulation results from reflecting factors other than population aging (e.g., the catching-up effect), we need to determine initial asset holdings endogenously as just described. For initial fertility rates, we use actual population data from 1972 through 2000 and compute the ratio of the number of newborns to the number of people with biological age 31 for each year.[8] In our model, this series should correspond to fertility rates of people with model age 30 through 2 in 2001. Initial fertility rates for population aged 31 (biological age 61) or above are not necessary, because we assume that these people do not care about their children any more, and thus, their remaining life choices are independent of their children.

Fourth, we assume an arbitrary initial guess for the interest and wage rate series for the entire 300 years. Given the interest and wage rates,

[8] This series turn out to be very similar to total fertility rate series provided by the NSO.

initial asset holdings, and initial fertility rates, optimal consumption and fertility schedules for each individual can be fully determined by the budget constraint in Equation (3) and the first-order conditions in Equations (4) through (6).

Finally, given the individual choices, the aggregate labor and capital stock for each year are computed as in Equation (7) to produce a new series of interest and wage rates for the entire time horizon. With the new interest and wage rates plugged in, consumer's optimization problems produce new labor and capital supply. These steps are repeated until the fixed point for the interest rate (and/or the wage rate) is reached.

(2) Parameterization of the Model

Consumer preferences are parameterized to maintain consistency with the restrictions implied by first-order conditions and to secure the existence of the steady state. We assume $\rho = 1.5$, because while most previous studies assume $\rho < 1$, equation (6) implies that ρ should be greater than 1. This restriction does not appear in other studies that ignore optimal fertility choices. Small changes in ρ, when accompanied by accommodating changes in other parameters, do not change the main results. Since most previous studies do not consider endogenous fertility decisions, it is hard to find references for the magnitude of parental altruism a_n and ε. We assume $a_n = 0.5$ (for $n \leq 30$) because, according to equation (5), consumption of a child is a^{ρ} times consumption of a parent in the steady state ($N = 1$). Given our assumption of $\rho = 1.5$, $a_n = 0.5$ implies that a child consumes about 35 percent of what an adult consumes. Consumption equivalence scale by OECD assigns a value of 1 to the household head and 0.5 to each child. "OECD-Modified Equivalence Scale," by EUROSTAT, assigns a value of 1 to the household head and 0.3 to each child. Our choice of ρ and a_n is consistent with this scale. Also, $a_n = 0$ for n > 30 because, as mentioned before, parents are assumed to care about their children only when they are economically dependent. Another parameter of parental altruism ε is determined in order to secure the existence of a steady state. We find that, given the assumed values of all the other parameters, the steady state fertility rate ($N = 1$) is achieved when $\varepsilon = 0.5132$. For the subjective discount rate, we assume $\theta = 0.015$.

Parameter $B_{n,t}$, costs of raising a child, is set to be inversely proportional to the (productivity adjusted) market wage rate. The coefficient of inverse proportion is 0.2, which in our simulation implies that $B_{n,t}$, is about 10.5 percent of total consumption of a household. Household Income and Expenditure Survey, by the NSO, shows that in years 2003 through 2006, a household's expenditure on education was about 11 percent of total consumption expenditure.

Perhaps a more conventional assumption about child rearing costs would be that $B_{n,t}$ and the wage rate are positively (not negatively) correlated, since an important part of $B_{n,t}$ is time resources devoted to raising a child. The reason we assume an inverse relationship here is because otherwise we cannot generate fertility series that are consistent with the actual trend in Korea. As will be shown later, age structure of Korea's population is still relatively young and the wage rate is relatively low compared to the steady state. At the same time, the current fertility rate in Korea is substantially lower than the steady state level (replacement fertility rate). In order to generate a gradual increase in the fertility rate and in the wage rate, we need to assume an inverse relationship between child rearing costs and the wage rate.[9] One economic interpretation for this assumption may be that educational costs can go down as labor becomes more scarce. It is likely that educational expenditures are high in Korea, because the labor market is so competitive. As labor becomes more scarce in the future, it may cost less to raise a child to survive in the labor market. It is for similar reasons that the UN population projection assumes gradual increase in the fertility rate toward the replacement level.[10]

[9] One problem with this setup is that it cannot explain the high fertility rate of the 1970s and the 1980s when the wage rate was even lower. Apparently, among the two opposing roles that the wage rate plays in fertility decisions (wage as the opportunity cost of time vs. wage as an inverse proxy for labor market competitiveness), the first may have been more important in those years. In order to explain actual fertility rates of those years, one will have to assume different functional forms for $B_{n,t}$ for each year. As described above, we simply take past fertility rates as given and impose the series on our model as an initial condition.

[10] Low wage rates may depress fertility for another reason. If people care about their children's consumption even after the children become adults, and if the current wage signifies how much their children will earn as adults, people may want to have fewer children when their wages are low. Upon extending our model to incorporate this channel, we find that none of our main patterns

For the age-specific (not time related) labor endowment, we assume the following:

$$h_i = 3 + 0.15 * i - 0.0025 * i^2 , \tag{9}$$

where h_i is labor endowment at age i (i = 1, 2, ... 50) over an individual's life. This representation is similar to the one in Miles (1999). In addition to Equation (9), we assume aggregate (time related) productivity growth of 0.02 as in Auerbach et al. (1989)(i.e., l_t in Equation (2) grows across generations at the rate of 0.02). The value of l_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 parameter β in the production function are set to be 1/3. This value also is commonly used in previous studies (e.g., Miles (1999), Auerbach and Kotlikoff (1987)).

Under this parameterization, convergence is achieved fairly quickly.

IV. MACROECONOMIC IMPACTS OF POPULATION AGING

For proper evaluation of population aging, one needs to have a reference distribution of population against which other distributions are compared. Our reference in this paper is a uniform distribution where every cohort has the same size, and thus, no aging trend exists. The uniform distribution is a natural choice, since it is the only distribution that is consistent with a non-degenerate steady state. In this section, we contrast our simulation results under the baseline scenario explained above to those under the no-aging scenario. By comparing the two scenarios, one can clarify macroeconomic changes that are solely attributable to population aging.

Also, while our entire time horizon is 300 years, we only report our simulation results for the first 150 years. In the second 150 years, most variables exhibit gradual convergence to the steady state with relatively small fluctuations.

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change substantially.

1. Macroeconomic Variables

Age structure of population

[Figure 1] Age structure of population: old-age dependency ratio

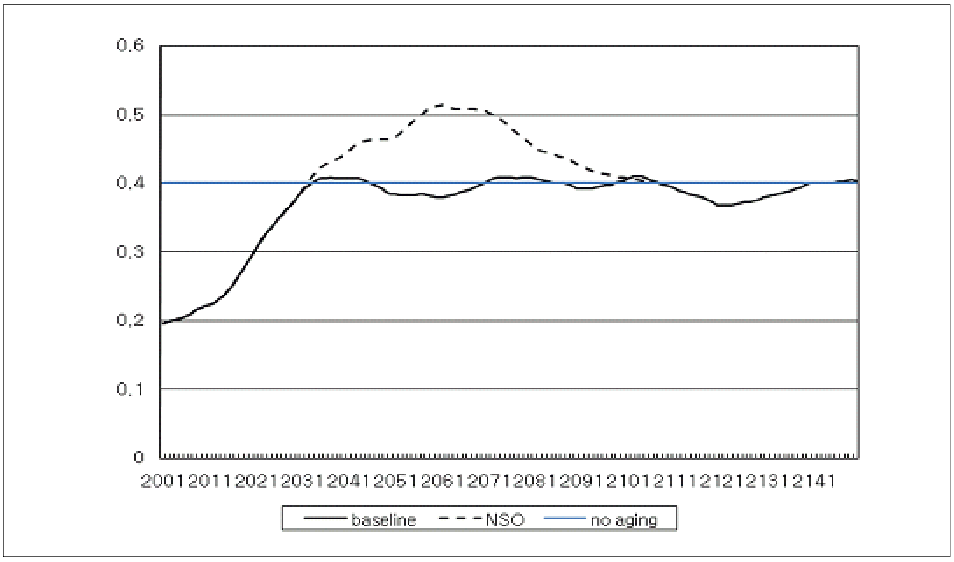


Figure 1 shows how the age structure of population evolves under our baseline scenario. As expected, the proportion of elderly people (aged 31 or above) gradually increases during the next couple of decades before it reaches about 40 percent in 2030. Since the steady state value of the old-age dependency ratio is 40 percent in our setup,[11] Figure 1 demonstrates that present population of Korea is rather young compared with the steady state and will remain so at least for the next couple of decades. Also shown in Figure 1 is the old-age dependency ratio under the NSO population projection. As explained above, the NSO projection assumes an exogenous fertility rate series that, while more closely representing current trends in Korea, are substantially lower than those in the UN projection or our endogenously derived series. Figure 1 shows that the two forecast series start to split in 2031 when the first newborns in our model grow to join the labor force. NSO forecasts imply a higher

[11] The old-age dependency ratio in Figure 1 is defined as the proportion of retired people (aged 31-50) in total population. This ratio should be 0.4 under a uniform distribution.

dependency ratio thereafter up to 2080, and a lower dependency ratio after that. Overall, fluctuations in the age structure of population are less volatile in our endogenous population series.

As will be shown later (Figures 10 and 13), the optimal number of children for the age 1 cohort in 2001 is about 0.87 under our baseline scenario. Since we assume asexual reproduction, 0.87 in our model corresponds to a female fertility rate of 1.74 in real world. This is substantially larger than the actual fertility rate of 1.3 in 2001. We allow this discrepancy to remain, for a couple of reasons. First of all, our fertility rate series are derived under the restriction that the rate should converge to 1 in the long run. If one changes some of the parameter values to obtain a lower fertility rate for 2001, the long-run restriction will be violated. In our view, this suggests in part that current child-raising costs in Korea are too high to be consistent with the existence of a steady state. In principle, one may assume more complicated, time-varying functional forms for child-raising costs to generate both a lower short-run fertility rate and the long-run fertility rate of 1. We do not opt for such approach, because it is too arbitrary. Second, Korea's exceptionally low fertility rate in recent years is partly attributable to the continuing rise in the average marriage rate and the average birth rate. Such changes will tend to lower the observed total fertility rate, even if lifetime fertility of an individual is unchanged.[12] Since the age at birth is fixed in our model, our estimated fertility rate may well be higher than the observed fertility rates of recent years.

Fortunately, we find that, despite the differences in the demographic trend implied by the NSO projection and our own forecasts, main patterns in macroeconomic variables are qualitatively similar under both forecasts. For instance, the interest rate exhibits a strong downward trend under both series, even though the trend is more pronounced for the NSO forecasts. Movements in *per capita* GDP and welfare distribution over generations also turn out to be similar in both cases, again with each pattern more pronounced under the NSO forecasts. For internal consistency of the paper, it is clearly better to use our endogenously

[12] Suppose that each individual lives for 2 periods. If old people gave birth in the first period of their lives and current young people decide to delay fertility to the second period, the observed fertility rate in the current period will be zero.

determined forecasts. When we exogenously impose the NSO forecasts, the link between fertility rates and the subsequent population evolution cannot be enforced any more. For these reasons, we report below only the simulation results derived from our baseline model, unless otherwise stated.

Interest rate

[Figure 2] Interest rate

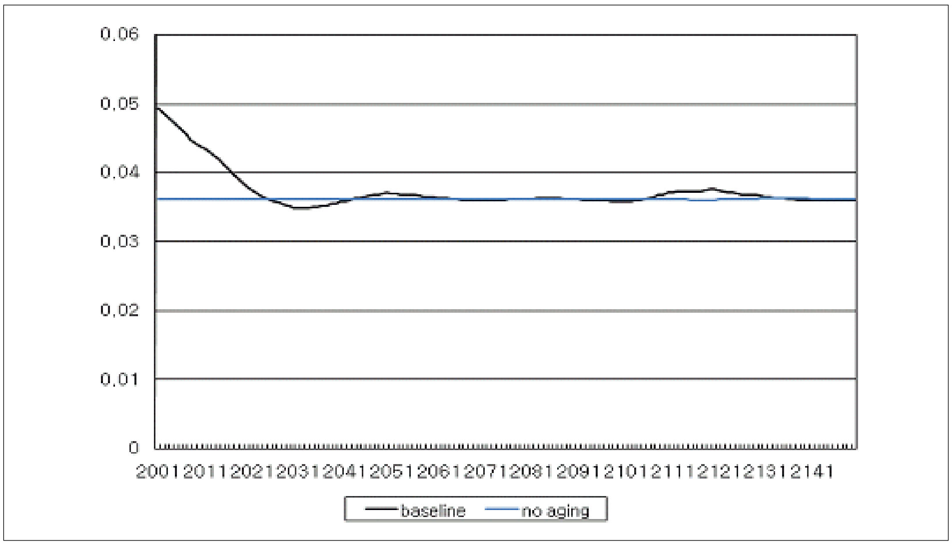


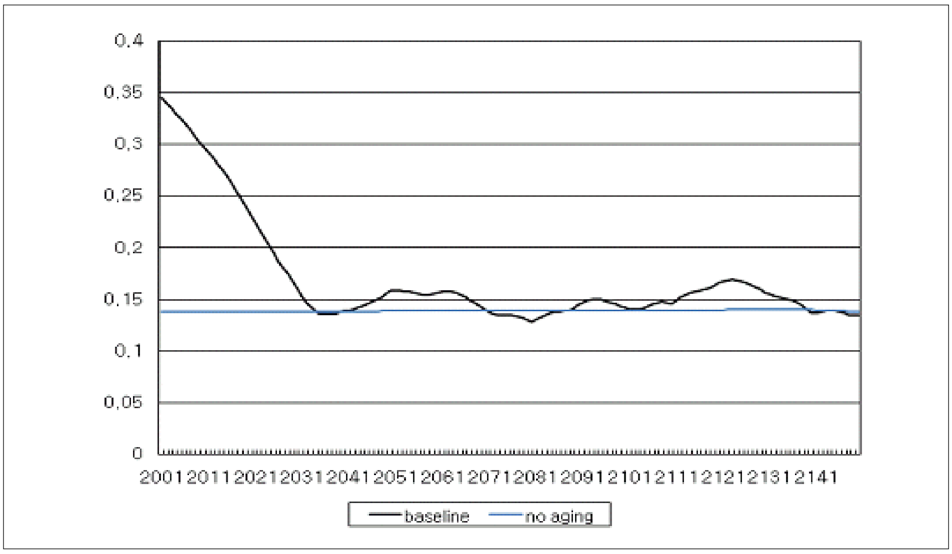
Figure 2 shows that the interest rate in Korea will remain higher than the steady state value of 3.6 percent, for the next couple of decades. The reason for this is the relatively young age structure of Korea's population. With most of its population belonging to the working age group, Korea is still a labor abundant economy that can generate a high rate of return to capital.

When the large group of working age people retires, however, Korea will turn into a capital abundant economy. Since retired people are wealthy, a greater proportion of the elderly population implies a greater aggregate capital stock. This explains why the interest rate falls below the no-aging scenario level after 2025.

Another thing to note in Figure 2 is that the computed real interest rate for 2001, about 4.9 percent, seems to be lower than the actual interest rate in Korea. The low value of the interest rate may originate from unrealistic assumptions of the model or unreasonable parameter values. We believe, however, that the main reason for this is related to our treatment of the initial capital stock. As explained above, initial asset holdings in our model are endogenously determined. Considering historical background of the Korean economy, 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 probably still distant from the steady state. Initial asset holdings assumed in our model do not take into account such Korea specific features. Thus, the interest rate obtained from our model may well be lower than actual.

Saving rate

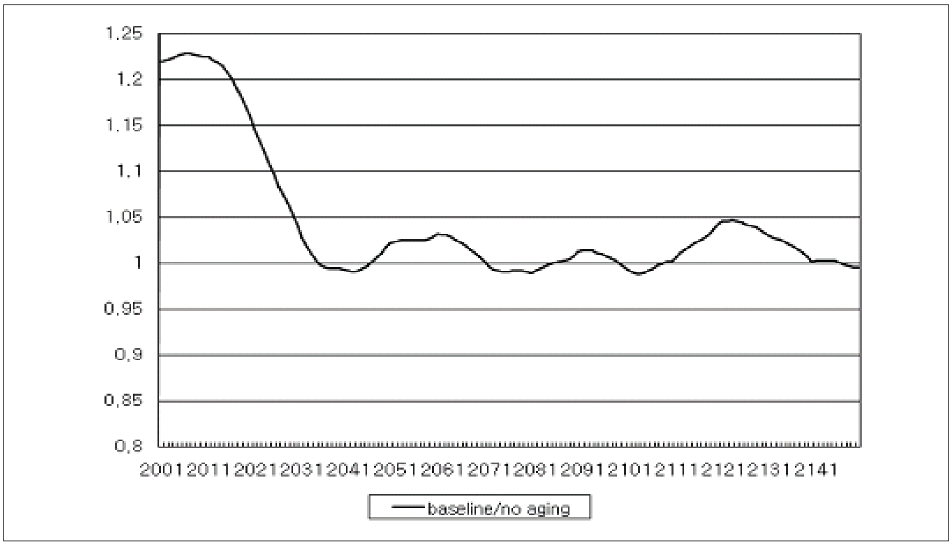
[Figure 3] Saving rate



The aggregate saving rate series is presented in Figure 3. Under the no-aging scenario with uniform population distribution, the saving rate stays constant at about 13.8 percent. Under the baseline scenario, on the other hand, the saving rate is about 34 percent in 2001 and is expected to remain higher than that of the no-aging scenario for a substantial period of time. Again, the reason for this is that the population of Korea, although aging rapidly, is still relatively young and will remain so for a while. Eventually, the saving rate will become equal to the steady state rate of 13.8 percent, since in our setup the population distribution converges to a uniform distribution in the long run.

Per capita (per adult) GDP

[Figure 4] *Per capita* GDP: as a ratio to the no-aging scenario

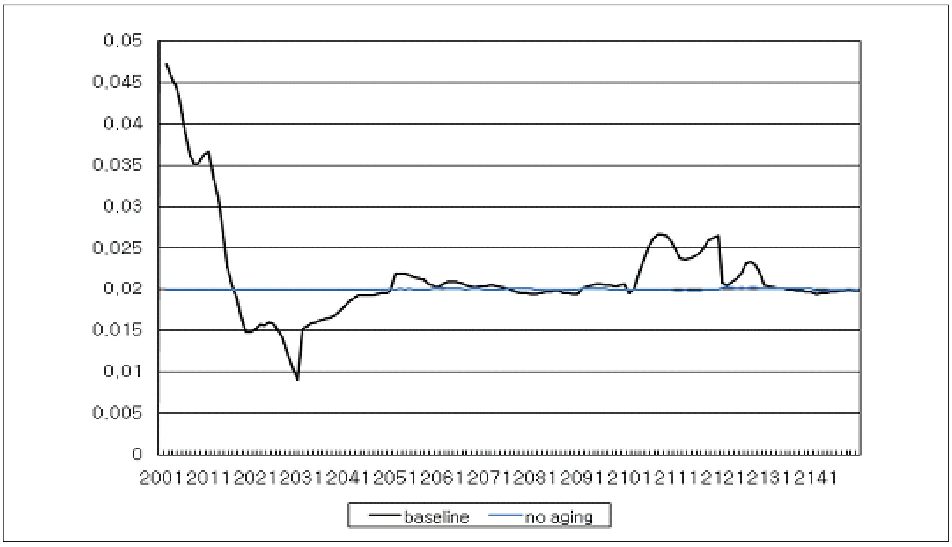


Per capita GDP is one of the most commonly considered variables in evaluating macroeconomic impacts of population aging. Figure 4 shows how *per capita* (per adult) GDP in Korea will evolve in the future. We do not count children in computing *per capita* GDP, in order to maintain consistency with previous studies where fertility is not endogenized and thus the existence of children is largely ignored. For presentational convenience, *per capita* GDP is shown as a ratio to the no-aging scenario. According to the ratio, *per capita* GDP under the baseline scenario will remain greater than that of the no-aging scenario until 2030. This result indicates that Korea’s population, while rapidly aging, is still relatively young, and thus, Korea will continue to enjoy its young age structure for the next few decades, at least in terms of *per capita* GDP.

After that, however, *per capita* GDP (as a ratio to the no-aging scenario) stays lower than 1 for a while, as young age groups that currently comprise the majority of Korea's population move to elderly age groups. An increase in the proportion of elderly people decreases *per capita* GDP through two channels: old generations are less productive than young generations because of the trend growth in labor productivity (time endowment) across generations; even without the productivity growth, old people normally have smaller income than young people because old people have little or no wage income.

GDP growth

[Figure 5] GDP growth rate



While *per capita* GDP will remain high compared to the no-aging scenario, the growth rate of GDP will soon drop. In Figure 5, the growth rate is shown to fall rather sharply under the baseline scenario, from 4.7 percent in 2001 to the steady state growth rate of 2 percent in about 2015. This result is driven by both a decrease in population growth and a decrease in *per capita* GDP growth. A slowdown in *per capita* GDP growth can be inferred from Figure 4 where the level of *per capita* GDP is shown to approach the no-aging scenario from above.

In our model, population aging reduces *per capita* GDP growth 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 3), 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 the same number of people.

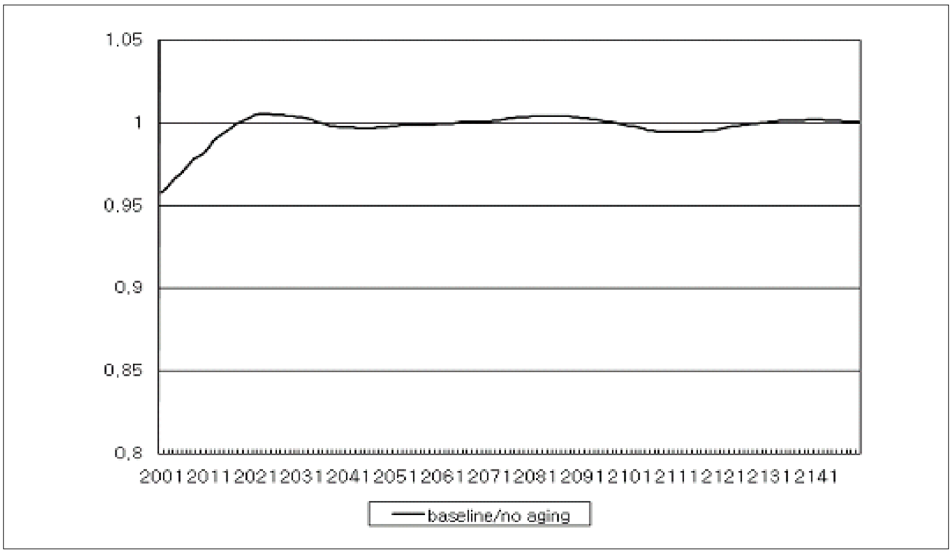
2. Welfare Analysis

A decrease in GDP growth as shown in Figure 5 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. If inter-generational transfer is extensive enough to equalize the distribution of resources across all generations (including future generations yet to be born), *per capita* GDP will be an accurate indicator of individual welfare. However, as long as inter-generational 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 shown as a ratio to the no-aging scenario case.

Figure 6 shows lifetime utility of the age 1 cohort from each period. It is clear from the figure that the welfare level of age 1 individuals is below 1 for the first 10 to 15 periods. 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 the next couple of decades. Since age 1 individuals enter the labor market with no capital, their lifetime welfare is negatively affected when the wage rate remains low during their working periods. Figure 6 also shows that, starting in around 2015, the welfare level of the age 1 cohort becomes greater under the baseline scenario than under the no-aging scenario. By 2015, the baby boomers will have shifted to older groups and the relative supply of capital will have accordingly increased. The increase in the capital/labor ratio will have the effect of raising labor productivity.

[Figure 6] Welfare of age 1 cohort from each period: as a ratio to the no-aging scenario

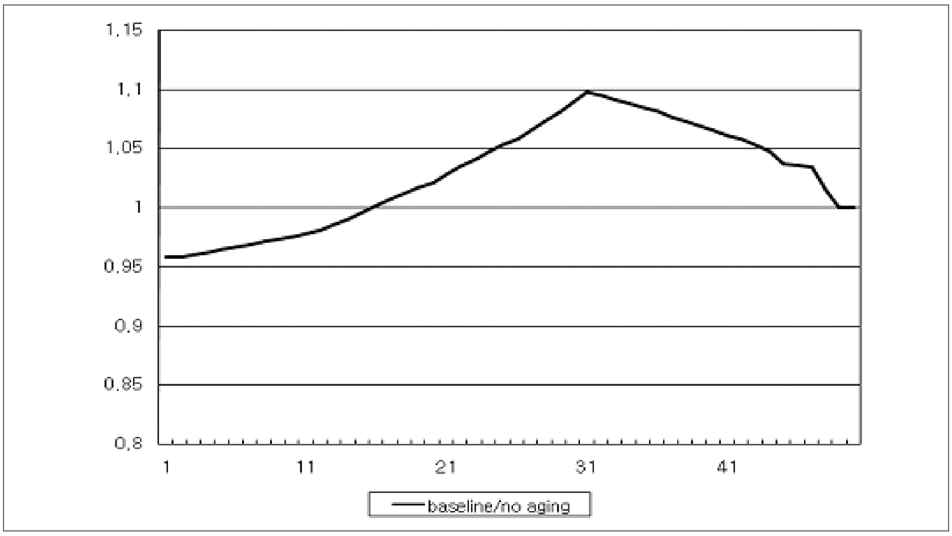


A similar explanation can be applied to Figure 7 which shows lifetime utility of each cohort alive in 2001. Abundant labor supply in present Korea keeps the wage rate low and the interest rate high. As a result, young individuals who rely mainly on labor income suffer, while elderly people who have large accumulation of assets benefit.

A general conclusion to be derived from Figures 6 and 7 is that individuals belonging to an age cohort that constitutes a large portion 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. On the other hand, future generations that enter the labor market at the time current workers (baby boomers) retire can enjoy a higher welfare level than is possible under the no-aging scenario.[13]

[Figure 7] Welfare of each cohort in the present period: as a ratio to the no-aging scenario



V. POLICY EXPERIMENTS

As shown in the previous section, population aging affects people's welfare mainly through changes in the capital/labor ratio. This implies that, in order to moderate the impacts of population aging, one needs to either decrease the supply of capital or increase the supply of labor. This section considers two policy experiments that may achieve such changes.

1. Capital Market Integration

The first policy experiment we consider is capital market integration. While international capital flows have already become an important

[13] To be sure, the pattern in Figure 6 will not hold if the assumption of no inter-generational transfers is modified. If there are resource transfers from the young to the old (such as a national pension system), these future generations may also be adversely affected.

source of finance in Korea, it is also clear that capital market integration is still far from complete. This sub-section examines how capital market integration will change macroeconomic consequences of population aging.

Interest rate

In order to implement gradual integration of capital markets, we assume that the interest rate converges to the world interest rate by year 2025.[14] The world interest rate is assumed to be fixed at 3.6 percent, which is the steady state value under our baseline closed-economy setup.[15] For years before 2025, the domestic interest rate is assumed to be given by the average of the closed-economy interest rate series (in Figure 3) and 3.6 percent. After 2025, the domestic interest rate is equal to 3.6 percent.

Saving rate

The pattern of the national saving rate is similar as before. We find that, with or without capital market integration, the saving rate is expected to decrease gradually from about 34 percent in 2001 to about 15 percent in 2030 (not shown in a graph due to space limitations). However, there also exist some important discrepancies between the two scenarios. In particular, the saving rate is somewhat more volatile under the open-economy scenario (the open-economy saving rate exceeds the closed-economy rate until 2030 and falls behind the closed-economy rate afterwards). This discrepancy between the two scenarios mainly reflects the discrepancy between GDP and GNP. Under integrated capital markets, labor abundant economies, such as Korea, prior to 2030 will experience capital inflows, with GDP exceeding GNP as a result. Since national saving is defined as GDP minus consumption, the saving rate in such

[14] We do not assume an instantaneous capital market integration because, under that assumption, the interest rate will be equalized across all countries and individual welfare will be affected by the global aging trend only.

[15] We assume a constant world interest rate based on the fact that long-run data for the U.S. economy are well consistent with the steady state. In particular, the real interest rate has remained about the same in the U.S. over the past 50 years (Mankiw (2006)).

economies will be greater than it would have been without capital inflows.[16] Similarly, capital abundant economies, such as Korea, after 2030 will experience capital outflows, with GDP falling behind GNP as a result.

Per capita (per adult) GDP and GDP growth

[Figure 8] *Per capita* GDP under capital market integration: as a ratio to the baseline scenario

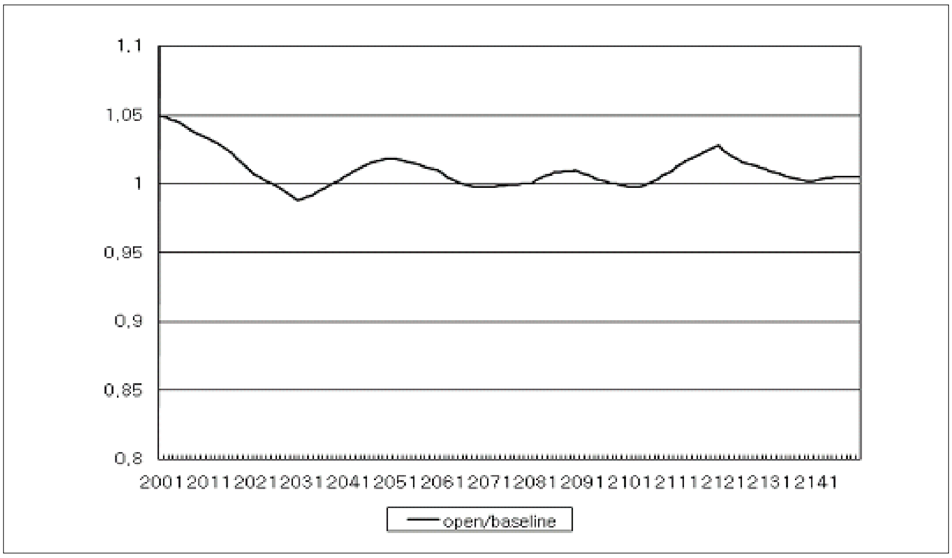


Figure 8 shows the impact of capital market integration on *per capita* GDP. The GNP series under the open-economy scenario turns out to be very similar to the GDP series and thus are not reported separately.

As Figure 8 shows, *per capita* GDP is increased as a result of capital market integration and the positive effect is expected to persist until 2025. The underlying source of this effect is abundant labor force that attracts foreign capital. When workers are matched with more capital, their production increases.

In the subsequent 10 years, Korea turns into a labor-scarce, capital-exporting economy and as a result GDP is negatively affected by capital

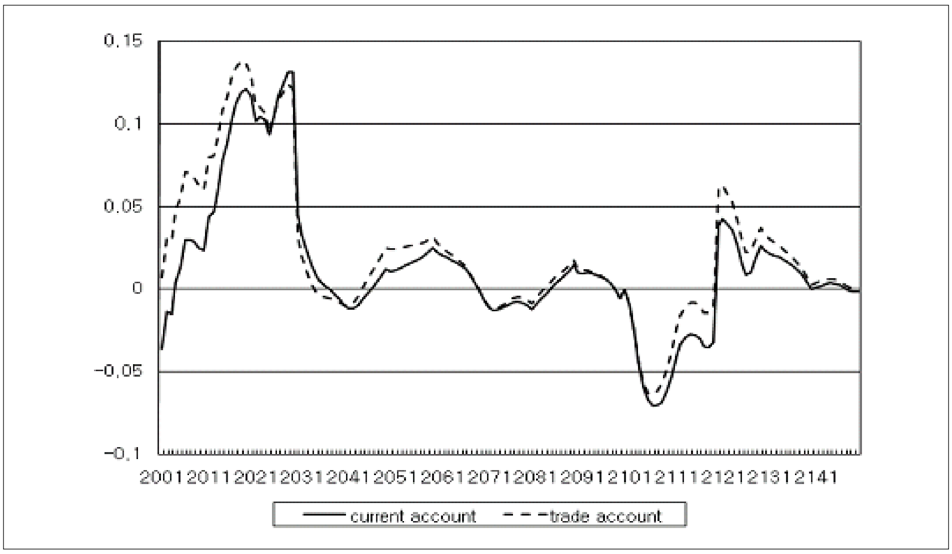
[16] This argument may not hold if consumption differs greatly between the two scenarios. It turns out, however, that GNP and consumption under the open-economy scenario are close to GDP (or GNP) and consumption from the closed-economy scenario.

market integration. The negative effect, however, appears to be short lasting compared to the positive effect.

Fluctuations in GDP growth are broadly the same as before (Figure 5), and thus, not shown in a separate graph. One interesting difference is that, like the saving rate, the GDP growth rate is more volatile under the open-economy scenario. One may expect that economic integration among countries will moderate the impact of demographic changes on GDP growth. Such expectation will be correct if labor is mobile across countries, with labor force moving from labor abundant countries to capital abundant countries. When only capital is mobile, however, economic integration magnifies fluctuations in GDP growth caused by demographic changes.

External balance

[Figure 9] External balance / GDP



The trade and current account balances as a ratio to GDP are reported in Figure 9. The figure shows that Korea will experience trade and current account surplus during the next three decades, for which period according to Figure 1 the proportion of elderly population continues to increase. When capital markets are fully integrated, investment becomes perfectly proportional to changes in labor force, and thus, investment in an economy with aging population becomes small and may even be negative. In our computation, this fall in investment is even greater than the fall in saving.

Korea's population is still young, in the sense that the interest rate is greater than the steady state or the world interest rate. Accordingly, Korea's net foreign asset and net factor income are currently negative. As Korea continues to make net foreign investments (net exports), however, net foreign asset and net factor income will turn positive by 2025. Net factor income is shown by the gap between the current account and the trade account in Figure 9.

Fertility

[Figure 10] Fertility under capital market integration

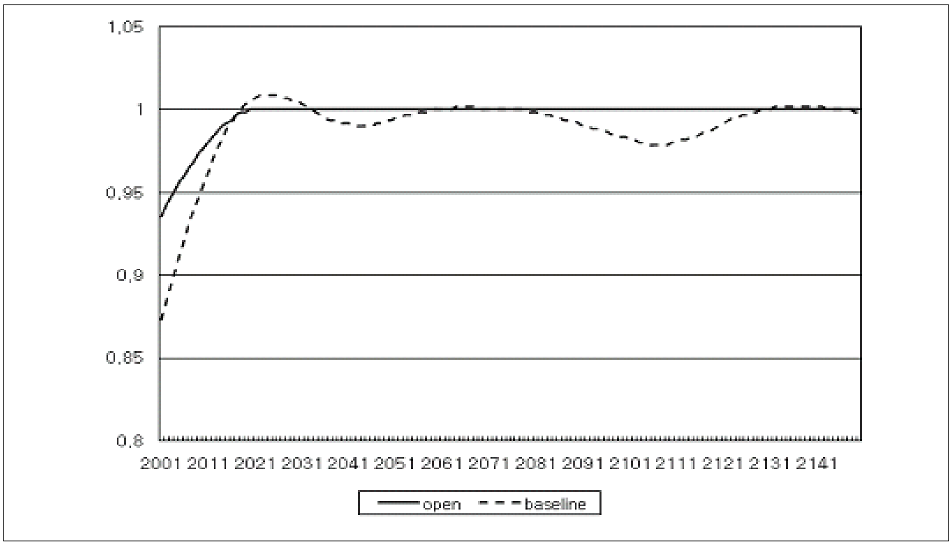
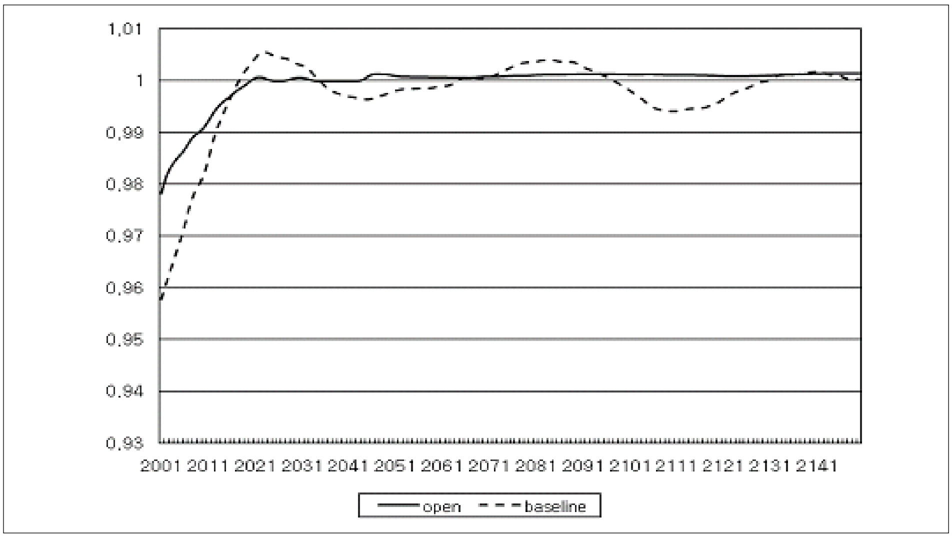


Figure 10 shows that economic integration may promote fertility. The underlying reason for this is fairly simple in our model. Capital market integration brings about an increase in the wage rate of a labor abundant economy like Korea. The increase in the wage rate in turn implies a decrease in child-raising costs, since child-raising costs, *B*, are assumed to be inversely proportional to the wage rate. In short, a less tight labor market promotes fertility.

Welfare implications

[Figure 11] Welfare of age 1 cohort from each period under capital market integration: as a ratio to the no-aging scenario



[Figure 12] Welfare of each cohort in the present period under capital market integration: as a ratio to the no-aging scenario

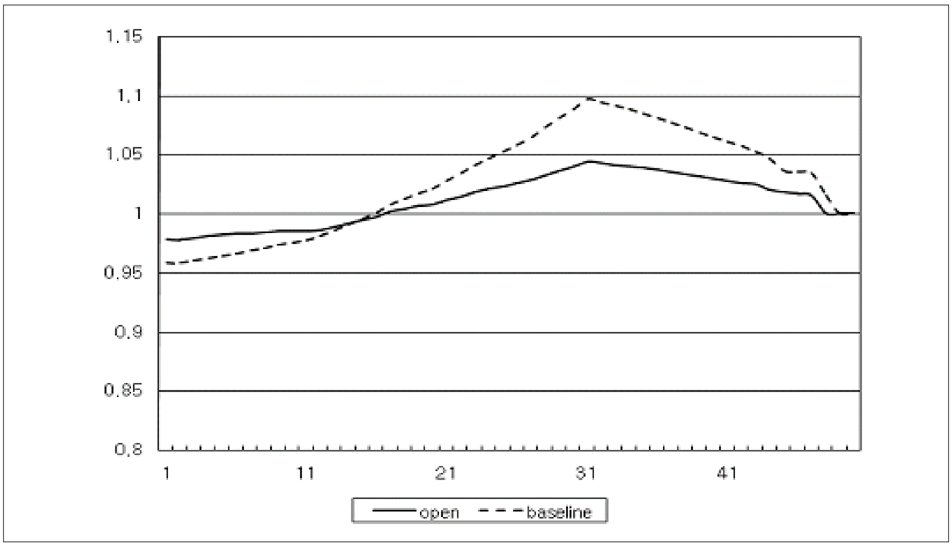


Figure 11 shows lifetime utility of the age 1 cohort from each period under capital market integration as a ratio to the no-aging scenario with a uniform population distribution. The baseline scenario from Figure 6 is also shown for comparison. It is clear from the figure that capital market integration has the effect of moderating welfare variations among generations caused by population aging. As mentioned before, population aging is in essence a problem of inter-generational redistribution. Capital market integration can moderate the problem of population aging through reducing over-time fluctuations in the interest rate and the wage rate. Similarly, Figure 12 shows that welfare differences among current cohorts are reduced as a result of capital market integration. This result provides another rationale for economic integration of countries.

2. Fertility Promoting Policy

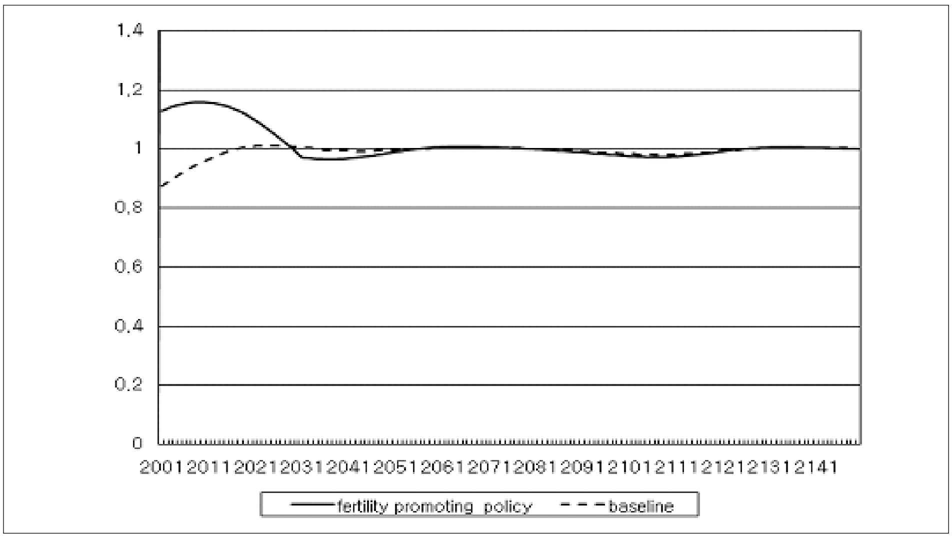
Korea’s total fertility rate is currently one of the lowest in the world. In order to promote fertility, the Korean government is considering various policy measures. It is not clear, however, whether such measures are effective or desirable. Government subsidies large enough to affect people’s fertility decisions will require equally large tax payments by individuals. Also, more children may imply more child rearing costs for families; government subsidies will cover only a portion of the total costs. This section examines macroeconomic implications of fertility promoting policies using our AK model.

In our model, the key exogenous variable that affects fertility decisions is child rearing costs, B. In order to examine economic impacts of fertility promoting policies, we consider government subsidies that cover 20 percent of total child rearing costs for newborn children. Also, since fertility changes have long lasting impacts, we assume that aforementioned government subsidies exist only for 30 years starting in 2001. Otherwise, full impacts of the government policy cannot be contained within our projection period. We assume that the government subsidies are financed through taxes on labor income. For each period, the labor income tax rate is determined endogenously such that the tax revenue raised is equal to the government subsidies needed. We assume that tax burdens are shared by all working age individuals in proportion to their labor income. Our model achieves the balance between government subsidies and tax revenue through iterations: for given initial series of the number of children and child rearing costs (or the wage rate), the amount of subsidies needed is computed; by dividing the amount of subsidies by total labor income, the required tax rate is determined; given the tax rate, the model produces new series of the number of children and child rearing costs; this process is repeated until the fixed point of the tax rate is achieved.

Computation results from this policy experiments are as follows.

Fertility

[Figure 13] Fertility under fertility promoting policy



According to our model, government subsidies that cover 20 percent of total child rearing costs increase the fertility rate from 0.87 to 1.13 in the first year (Figure 13). The model also predicts that the number of children increases by about 15 percent in 2030 and by about 18 percent permanently. A permanent increase in the number of children is possible because, while the fertility rate drops back to the original level, the size of population is permanently larger.

Per capita (per adult) GDP

[Figure 14] *Per capita* GDP under fertility promoting policy: as a ratio to the baseline scenario

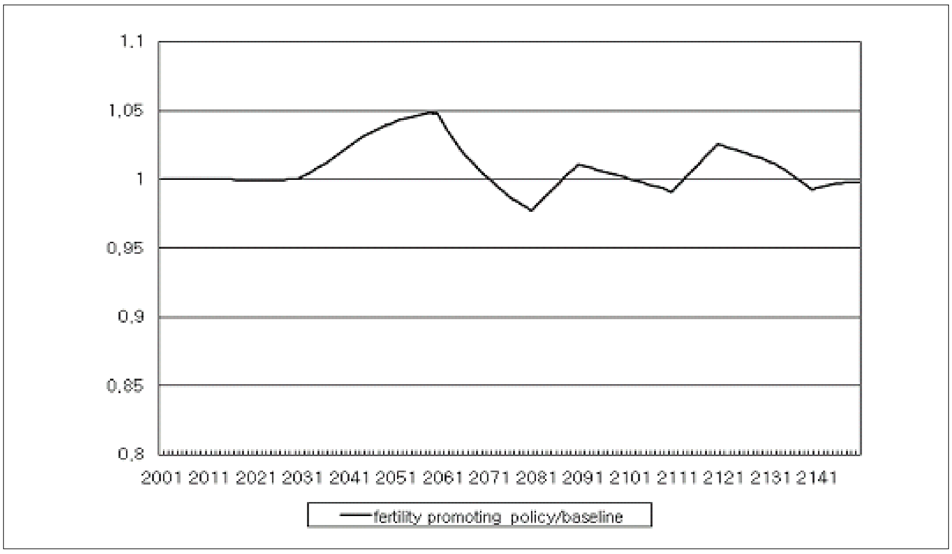


Figure 14 shows that the impact of fertility promoting policies on GDP is long-lagged. Even if the policy successfully increases the number of children today, it is not until 30 years later that those children grow up to join the labor market and contribute to GDP. GDP shows little change until then. In principle, our simulation could have even shown that GDP will actually decrease during this "build-up" period, because a larger number of children may demand greater child rearing costs and greater total consumption by children. This is not the case in our model, because as it turns out, the increase in the number of children caused by the subsidies is largely offset by a cut in per child consumption. Note however that, if we choose to count in the number of children in computing *per capita* GDP, even Figure 14 should imply that the fertility promoting subsidies initially decrease *per capita* GDP.

Welfare implications

Figure 15 shows lifetime utility of the age 1 cohort from each period under the fertility promoting policy, as a ratio to the no-aging scenario.

Compared to the baseline, the welfare level of those people who give births to children, during the next 30 years, are better off, while their children who will start working, with a lag of 30 years, are worse off. Under our assumption that the policy exists for 30 years, individuals aged 1 in 2001 receive government subsidies for the entire time they raise their children. Their tax payments are much smaller than the subsidies in the present value, because we assume that tax burdens are shared by all working age individuals. Similarly, individuals aged 1 in any year between 2002 and 2030 become net beneficiaries of the policy. However, we find that the magnitude of lifetime consumption of an adult (as measured by the present discounted value) decreases for all of these cohorts. While these people increase the number of children in response to government subsidies and manage to enjoy a greater level of lifetime welfare, they reduce their own consumption. New born children become worse off for aforementioned reasons. Generations that constitute a large proportion of population tend to be in a disadvantageous position throughout life.

[Figure 15] Welfare of age 1 cohort from each period: as a ratio to the no-aging scenario

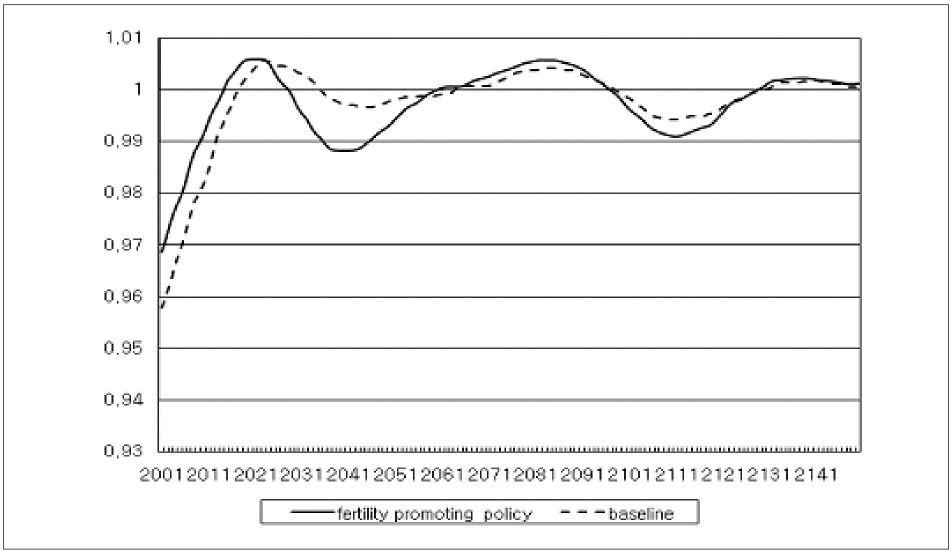
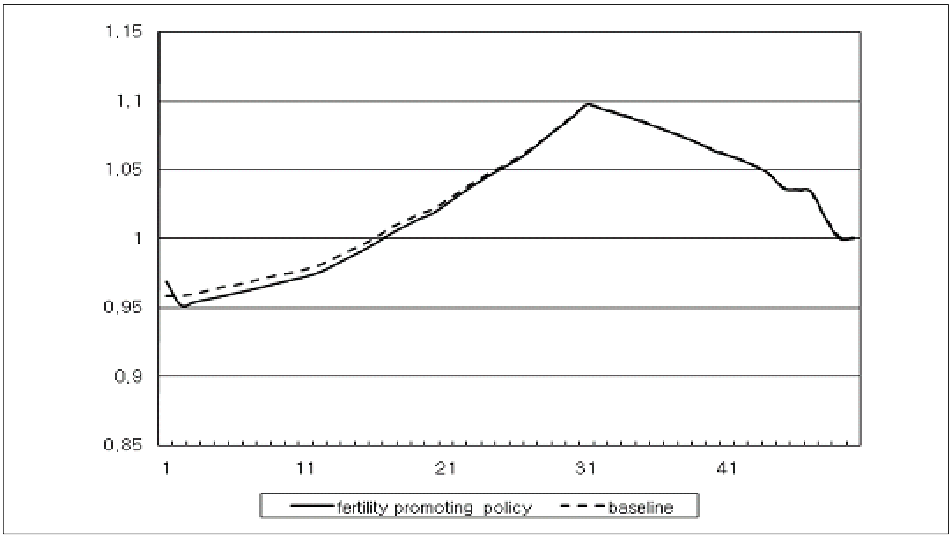


Figure 16 shows lifetime utility of each cohort alive in 2001. In Figure 16, individuals aged 2 through 30 are shown to be worse off under the fertility promoting policy, compared to the baseline. Note that these individuals are assumed to pay taxes (because they are in their working ages) without receiving any subsidies (because they have made their fertility choices earlier in their lives).

[Figure 16] Welfare of each cohort in the present period: as a ratio to the no-aging scenario



These results suggest that fertility promoting policies need to be considered with great caution. First, it will take several decades before higher fertility brings about an increase in GDP. Second, such policy measures may cause substantial redistribution of resources among generations, depending on who pays the tax. Third, it is not clear whether fertility promoting policies will increase the welfare level of current cohorts on average, while such policies will likely reduce the welfare level of newborns.

VI. CONCLUSION

This paper provides a quantitative prediction of macroeconomic impacts of population aging in Korea, using an AK type CGE model. Computation results from the model can be summarized as follows. First, in terms of GDP, Korea has been and still is benefiting from its relatively young age structure of population. The benefit, however, will gradually diminish. Second, welfare implications of population aging are more complicated, since there are both winners and losers. While current and future young generations will be harmed by population aging, current elderly generations will benefit from the trend. Third, policy responses to population aging should be considered with great caution. Fertility promoting policies, for instance, may entail substantial redistribution of resources among individuals from current and future generations. Fourth, a less controversial but effective policy response to the aging problem may be opening up the domestic capital market. By reducing fluctuations in the interest and wage rates caused by population aging, capital market integration can moderate welfare variations among different generations.

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