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Analyzing Defined Contribution Pension Reform in Korea Using a General Equilibrium Model†

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Korea's National Pension Fund (NPF) is projected to be in deficit by the 2040s and exhausted by the 2050s. Increasing contribution rates may be unaffordable, prompting consideration of structural reforms, particularly shifting from a defined benefit (DB) to a defined contribution (DC) system. The DC system links benefits to contributions and investment returns, ensuring financial stability but raising concerns about income adequacy and redistribution. This study uses an overlapping generations model with heterogeneous agents to assess these reforms. By 2070, demographic changes will make the DB system unsustainable without substantial government subsidies, adversely affecting taxes, income, and savings. Conversely, the DC system would remain balanced without subsidies, resulting in lower interest rates, higher wages, and better economic output. The model shows that the DB system would require an annual subsidy of 11.3% of GDP at a 9% contribution rate by 2070, while the DC system would be self-sufficient. Even with lower returns, the DC system could be more efficient and equitable with partial subsidies, improving economic outcomes and reducing inequality.

Key Word: Defined Benefit, Defined Contribution, Pay-as-you-go, Public Pension, General Equilibrium, OLG, Aging
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I. Introduction

The finances of the National Pension Fund (NPF) are deteriorating, with projections indicating a deficit by the 2040s and complete exhaustion by the 2050s. The media and experts frequently advocate for raising the contribution rate as a solution. However, the required increase to stabilize the fund's finances may exceed what individuals can afford, rendering this approach insufficient. Consequently, there is a growing call for structural reforms rather than mere parametric adjustments. Among the various proposals for structural reform, the shift to a defined contribution (DC) pension system has gained traction. Unlike the current defined benefit (DB) system, where benefits are largely decoupled from contributions, the DC system ensures financial stability by aligning benefits with contributions and investment returns.

Despite the potential advantages of the DC system, public skepticism persists. Concerns include the possibility that, if implemented at the current contribution rate, the DC system may result in a lower income replacement rate, thereby jeopardizing the adequacy of retirement income. Additionally, the DC system could lack the redistributive function inherent in the DB system. Unfortunately, there is a paucity of research on the economic impacts of possible DC pension reforms in Korea. The prevalent fiscal projection model used by the Korean government is inadequate for addressing these concerns, as it does not track individual behaviors and is homogeneous in its categorization of individuals by gender, age, and contribution period. This model also fails to consider endogenous changes in macroeconomic variables such as interest rates and wages. To overcome these limitations, this study employs a stationary general equilibrium analysis using an overlapping generations model with heterogeneous agents to examine the endogenous economic responses of various age and income groups to changes in the pension system and the economic environment.

According to Future Population Projections (2021), the working-age to retirement-age ratio is expected to decline from 79.2:20.8 in 2022 to 48.7:51.3 by 2070. Maintaining the DB pension system under these demographic conditions is theoretically unsustainable without significant financial support from the government. Potential consequences include higher tax burdens, reduced after-tax income, lower savings, increased interest rates, lower wage rates, and diminished GDP. Additionally, a reduced labor force per capita may lower firms' capital demand, causing interest rates to fall, wage rates to rise, and aggregate output to decline. The correlation between the population structure and savings lifecycle may weaken, reducing the aggregate supply of capital. Even if households maintain their savings behavior, the aggregate supply of capital may decline due to an increased population in lower-saving age groups. Conversely, declining mortality may lead households to increase savings, resulting in lower interest rates, higher wage rates, and higher aggregate output.

The DC system, in contrast, maintains a financial balance without government intervention. This ensures that some funds are invested domestically, potentially lowering interest rates, raising wage rates, and increasing gross product relative to the DB system. While the aging population and declining mortality rates affect both systems somewhat similarly, the DC system amplifies the initial interest rate changes. For instance, a capital demand shock in the DC system leads to declining interest rates and fund returns, reducing pension benefits and prompting households to save more. Similarly, supply shocks to capital may cause households to reduce savings in response to rising interest rates and increasing pension benefits, eventually amplifying the effect. Declining mortality can further increase household savings under the DC system as pension benefits decrease due to the DC benefit formula. However, excessively low interest rates and high wage rates could worsen inequality, benefiting working-age individuals more than retirees.

The macroeconomic impacts on the DB and DC pension systems by 2070 differ significantly in direction and magnitude. Given the unprecedented rate of aging in Korea, an empirical analysis would be limited. Thus, this study employs a structural general equilibrium model, calibrated to the Korean economy, to assess the potential outcomes of changes to the National Pension system.

The model, adapted from Lee *et al.* (2019), analyzes households in a lifecycle framework, distinguishing between working and retirement ages. Working-age individuals supply inelastic labor and make consumption and savings decisions subject to productivity shocks, while retirees base their decisions on National Pension and Basic Pension benefits. Firms operate using a Cobb-Douglas production function, combining capital and labor. The government balances its budget through various taxes and finances pension deficits, with the consumption tax serving as the baseline due to its age neutrality and minimal labor market distortions. For the DC system analysis, the model includes a minimum foreign investment share, with foreign interest rates setting the lower bound for domestic rates.

Reflecting realistic macroeconomic conditions is challenging. The total amount of pension contributions is “mature,” but the distribution of contribution periods is mature only up to age 40 as of 2022, as the expansion of the National Pension Scheme to cover the entire population was only recently implemented in 1998. Full maturity of total benefits will not be achieved until all 41-year-olds in 2022 have died, diverging from a stationary equilibrium. To address this, the study estimates an exogenous labor supply and pension contribution function, fitting contribution period distribution data for individuals up to age 40 and employment rate data for those at older ages. The contribution rate is adjusted to match the 2022 ratio of total contributions to GDP, and the income replacement rate coefficient is adjusted accordingly.

The model predicts that in 2070, maintaining the DB system would require an annual government subsidy amount equivalent to 11.3% of GDP at a 9% contribution rate, or 8.8% of GDP even if the rate is increased to 18%. In contrast, the DC system would achieve fiscal balance without government support.

The comparative analysis shows that at the same contribution rate, the DC system without foreign returns (0% foreign return) may lower retirement living standards compared to the DB system due to lower interest rates and higher wage rates. However, if only a portion of the DB subsidy is redirected to supplement the universal pension as part of the Basic Pension under the DC system, it can provide greater economic benefits and a better income redistribution in retirement.

Even under conservative assumptions regarding the fund rate of return, a defined contribution (DC) system with fiscal subsidies can achieve greater efficiency. This efficiency is evident in the higher gross product and total after-tax income associated with the DC system. When a certain amount of the DC funds is invested domestically, both gross output and total after-tax income surpass those of the defined benefit (DB) system even without fiscal support, although addressing inequality remains a challenge. A modest increase in the universal pension benefit can significantly narrow the income gap between working-age and retirement-age individuals. This adjustment prompts households to reduce their savings, subsequently lowering wage rates and raising interest rates, which in turn elevates pension levels. Furthermore, increasing the contribution rate from 9% to 18% enhances the average pension benefit level under the DC system, thereby reducing the need for additional financial support.

Additionally, for a given contribution rate, the DC system can offer higher long-term pension benefits compared to the unfunded pay-as-you-go (PAYGO) system, provided the fund rate of return exceeds the nominal growth rate, known as the "Aaron (1966) condition." This relationship holds true even in realistically quantified models. As the population continues to age, the disparity between the DC and PAYGO systems will widen due to a smaller working-age population supporting a larger number of retirees. This underscores the long-term advantages of transitioning to a DC system in terms of sustainability and economic outcomes.

This study relates to previous Korean research on the income redistribution effects of the National Pension. Kim (2002) examines the impact of the National Pension's introduction of the Gini coefficient using Daewoo panel data. Kang *et al.* (2008) find that the 2007 reform of the National Pension reduced pension benefits, leading to a higher Gini coefficient. Yuh and Yang (2011) demonstrate a significant income redistribution effect of the National Pension through analyses of expected return ratios that account for survival rates by income decile. Lee *et al.* (2016), Choi (2016), Choi and Han (2017), and Choi (2021b) also investigate the income redistribution effect of the return ratio.

This study is also related to macroeconomic analyses of the National Pension, such as those by Jeon (1997), Kim (2003), Jeon and Yoo (2004), Nam (2008), and Kim (2018). Notably, Shin *et al.* (2010), Kim (2011), Oh (2012), Moon and Lee (2013), Choi *et al.* (2015), Kwon (2016), Hong *et al.* (2016), Hong (2018), Lee *et al.* (2019), Kim and Lee (2019), Lim and Kim (2021), Choi (2021a), Woo (2021), and Yoon *et al.* (2022) have analyzed the relationship between the National Pension system and future demographic trends using a variety of different macroeconomic models. This study closely references Lee *et al.* (2019), which offers detailed insights into old-age income and redistribution effects through model construction and quantification. Of course, Kwon (2016) and Woo (2021) include the endogenous labor supply, unlike Lee *et al.* (2019), and offer useful tools for analyzing the transition path of a pension reform. However, they do not address the distribution of contribution periods, resulting in lower specificity regarding the distribution of retirement income. Therefore, the model by Lee *et al.* (2019) was chosen.

Additionally, while there are discussions of DC pension systems within a macroeconomic context in Heo (2007), Park and Heo (2008), Park (2009), and Heo (2016), research on social inequality related to DC public pensions is scarce. To the best of my knowledge, this is the first study in Korea to analyze the long-term macroeconomic and distributional impacts of reforming from a DB to a DC pension system using a heterogeneous agent general equilibrium model in a future demographic context.

Section 2 outlines the overlapping generations general equilibrium model, Section 3 details the calibration methodology, Section 4 explains the theoretical framework, Section 5 presents the experimental results, and Section 6 concludes the paper.

II. Model

The overlapping generations model used in this study is primarily based on the work of Lee, Han, and Hong (2019). For more details, please refer to their paper.

Consider a general equilibrium model consisting of overlapping generations of households, representative firms, and the government. Households are utility maximizers, firms are profit maximizers, and the public sector (including the general government and the National Pension Service) adjusts tax rates to satisfy budget constraints. We analyze this through a stationary equilibrium model where individual household states (and thus decisions) can change over time, but the macro distribution remains invariant. For simplicity, we assume the labor supply to be inelastic.

A. *Household Problem*

The household utility maximization problem in the overlapping generations model assumes a lifecycle framework. A continuum of heterogeneous households is economically active at each age $i \in \{1, \cdots, I\}$. Households are given with exogenous and independent mortality probabilities γ_i at age $i+1$ before reaching the final age of $i+I$, where $\gamma_I = 1$ is given for the final age.

A household enters the labor market at age $i=1$ to earn labor income y_i^l and can work until age $i = i_R - 1$ Ages $i \in \{1, \cdots, i_R - 1\}$ are called the "working age." Labor income $y_i^l = w\varepsilon_i xl$ is composed of labor productivity shock x, labor hours l (interpreted as the number of months in a year) given by an exogenous transition function, age-specific labor productivity ε_i, and wage w determined by the general equilibrium. A household pays capital income tax $\tau_k ra$ given asset a and capital income ra, and pays income tax $T(y_i)$ given gross income $y_i = (1-\tau_k)ra + y_i^l$.[1] Those whose working hours l exceed the lower limit $\underline{l}$ are recognized as enrolled in the National Pension and pay contributions of $\tau_{ss} \min(\kappa, w\varepsilon_i x)l$ to the National Pension Service; i.e., the lower value between the monthly labor income $wx\varepsilon_i$ and the upper limit of recognized income κ is applied along with working hours and the contribution rate τ_{ss}. The upper limit κ is defined as the product of a constant k and gross domestic product Y:

$$\kappa = k \times Y .$$

Given disposable income $(1-\tau_k)ra + y_i^l - 1_{[l>\underline{l}]}\tau_{ss} \min(\kappa, w\varepsilon_i x)l - T(y_i)$, a household

[1]This is interpreted as a corporate tax, allowing for double taxation.

decides upon saving $a' - a$ and consumption c and pays consumption tax $\tau_c c$, where saving is subject to the incomplete financial market constraint $a' \geq 0$. Each age is associated with a period utility function $u(c) = (c^{1-\sigma_u} - 1)/(1-\sigma_u)$, which is discounted over time by β. The progressive income tax is modeled using the formulation in Heathcote *et al.* (2017):

$$T(y_i) = \max[y_i - \lambda y_i^{1-\tau}, 0].$$

The distribution of future labor hours l' is determined by the current labor hours via the transition function $l' = \Lambda^i(l)$. Independent and heterogeneous labor productivity shocks follow an AR(1) process:

$$\ln(x') = \rho_x \ln(x) + v_{x'},\ v_x \sim N(0, \sigma_x^2).$$

Age $i \in \{i_R, \cdots, I\}$ is referred to as the "retirement age." During this period, a household does not generate any labor income but receives interest income ra, National Pension income ξ,[2] and the Basic Pension income $\hat{\varphi}$. Similar to the working age, the household pays both income tax and capital gains tax. Additionally, consumption taxes are incurred as the household makes saving and consumption decisions based on disposable income.

The household utility maximization problem at retirement age is represented by the Bellman equation:

$$V_R^i(a; B, n) = \max_{c,a'} \{u(c) + \beta(1-\gamma_i)(1+g_z)^{1-\sigma_u} V_R^{i+1}(a'; B, n)\}$$

$$s.t.$$

$$(1+\tau_c)c + a'(1+g_z) = a + (1-\tau_k)ra + \xi(B, n; A, \alpha) + \hat{\varphi}(a, B, n; A, \alpha) - T(y_i),$$

$$y_i = (1-\tau_k)ra,$$

$$T(y_i) = \max[y_i - \lambda y_i^{1-\tau}, 0],$$

$$a \geq 0,\ c \geq 0,\ n < i_R.$$

Here, g_z is the adjustment factor for growth via total factor productivity z. National Pension income $\xi(B, n; A, \alpha)$ is determined by the average monthly labor income during the months the household was enrolled (B), the contribution period (n), average monthly labor income of all enrolled members (A), and the income replacement rate[3] coefficient (α). The income formula of the current DB pension system, which will be used as a baseline system, is as follows:

[2]In the real world, national pensions are also subject to income tax, but the tax credit is large compared to that for labor income and is thus ignored here.

[3]The income replacement rate (%) is defined as $100 \times \xi / (12 \times B)$.

$$\xi(B,n;A,\alpha)=\begin{cases}\alpha(A+B)\cdot(1+0.05\times 1_{[n\geq 10]}(n+20)) & \text{if } n\geq 10\\ \alpha(A+B)\cdot 0.5 & \text{o.w.}\end{cases}.^{4}$$

A and B are combined at a ratio of 1:1, implying an income redistribution function. The formula for the A value is

$$A\equiv\frac{w\times\sum_{i=1}^{i_R-1}\mu_i\varepsilon_i\int xl1_{[l\rangle\underline{l}]}\psi^i(l,x)}{12\times\sum_{i=1}^{i_R-1}\mu_i\int l1_{[l\rangle\underline{l}]}\psi^i(l)}.$$

The Basic Pension $\hat{\varphi}(a,B,n;A,\alpha)$ is also affected by the same four inputs as the National Pension income because it is affected by the amount of National Pension income. Additionally, it is influenced by asset a, as the Basic Pension can only be received when the combined income from interest and the National Pension is less than $\overline{y}$, which represents the lower 70% income level of retirement age. The following formulas hold for the Basic Pension:

$$\hat{\varphi}(a,B,n;A,\alpha)=\min\{\varphi,\max\{\overline{y}-(y_i+\xi(B,n;A,\alpha)),0\}\},$$

$$\varphi(B,n;A,\alpha)=\begin{cases}\overline{\varphi} & \text{if } \xi(B,n;A,\alpha)\leq 1.5\overline{\varphi}\\ \max\{\varphi_1,\varphi_2\} & \text{if } 1.5\overline{\varphi}<\xi(B,n;A,\alpha)\end{cases},$$

$$\varphi_1=\max[\overline{\varphi}-(2/3)INC_A(n;A,\alpha),0]+0.5\overline{\varphi},$$

$$\varphi_2=\max\{2.5\overline{\varphi}-\xi(B,n;A,\alpha),0\},$$

$$INC_A(n;A,\alpha)=\xi(A,n;A,\alpha).$$

When National Pension income ξ is less than or equal to 1.5 times base pension $\overline{\varphi}$, the potential Basic Pension φ is $\varphi=\overline{\varphi}$. If ξ increases to more than 1.5 times $\overline{\varphi}$, φ decreases as much as ξ increases $(\xi+\varphi=2.5\overline{\varphi})$ until it reaches $\overline{\varphi}+(2/3)INC_A$, where INC_A is the National Pension income when $B=A$. φ is fixed at $\varphi=\varphi_1$ if ξ increases further and φ decreases to reach lower bound φ_1.[5] For ξ values that are even greater, φ is adjusted so the total retirement income $y_i+\xi+\varphi$ does not exceed $\overline{y}$.

The working-age utility maximization problem can be expressed as a Bellman equation:

[4]The original National Pension Regulation refers to the first 20 years of contributions as "full old-age pension" and the second 10 years or more but less than 20 years as "reduced old-age pension," but because the benefit amount is linear, the same formula can be used.

[5]https://basicpension.mohw.go.kr/menu.es?mid=a10103010000.

$$V^i(l,a,x,B,n) = \max_{c,a'}\{u(c) + \beta(1-\gamma_i)(1+g_z)^{1-\sigma_u} E_{(x',l')|(x,l)} V^{i+1}(l',a',x',B',n)\}$$

$$s.t.$$

$$(1+\tau_c)c + a'(1+g_z) = a + (1-\tau_k)ra + y_i{}^l - 1_{[l>\underline{l}]}\tau_{ss}\min(\kappa, w\varepsilon_i x)l - T(y_i),$$

$$y_i = (1-\tau_k)ra + y_i{}^l,$$

$$y_i{}^l = w\varepsilon_i xl,$$

$$n' = \begin{cases} n+1 & \text{if } l > \underline{l} \\ n & \text{if } l = \underline{l} \end{cases},$$

$$B' = \begin{cases} \dfrac{B \times 12n + \min(\kappa, w\varepsilon_i x)l}{12n'} & \text{if } l > \underline{l} \\ \text{B} & \text{if } l = \underline{l} \end{cases},$$

$$\log x' = \rho_x \log x + v_x, \quad v_x \sim N(0, \ \sigma_x{}^2),$$

$$a \ge 0, \quad c \ge 0, \quad n \le i.$$

For each age i, if $l > \underline{l}$, l is recognized as a contribution period, included in the calculation of n', and, together with the lower limit of $wx\varepsilon_i$ and the upper limit κ, reflected in the calculation of the average monthly labor income B'. Age $i = 1$ takes $a = n = B = 0$ as the initial condition.

The model does not include all specific provisions of the National Pension and the Basic Pension. For example, the model does not account for pension reductions due to early receipt or increases due to deferred pensions, nor does it specifically address income taxes or tax credits on pensions. However, we believe that we have captured the essential elements of our research topic.

B. *Firm Problem*

Homogeneous firms use capital inputs K, labor inputs N, total factor productivity z, and the capital income share θ to generate gross domestic product Y through Cobb-Douglas production technology:[6]

$$Y = zK^{\theta}N^{1-\theta}.$$

Firms face depreciation rate δ, interest rate r, and wage rate w when solving the following problem:

[6]Total factor productivity z grows by $(1+g)^{1-\theta}$ every year.

$$\max_{K,N}\{zK^{\theta}N^{1-\theta}-(r+\delta)K-wN\}.$$

The optimal conditions are:

$$w=(1-\theta)zN^{-\theta}K^{\theta},$$
$$r+\delta=\theta zN^{1-\theta}K^{\theta-1}.$$

The wage rate and the interest rate are the marginal product of labor and capital, respectively. As the relative size of capital to labor K/N decreases, capital becomes scarcer and labor becomes more abundant, causing w to decrease and r to increase. Conversely, if K/N increases, the opposite occurs.

From these formulas, we can show that the income share of total output is also unchanged:

$$\theta Y=RK,$$
$$(1-\theta)Y=wN.$$

Thus, if N is exogenously given, the only reason labor income could rise is that aggregate output rises.

C. *Public Sector*

The public sector is divided into two sectors: the National Pension Service and the general government. The contribution revenue of the National Pension Service, given population μ_i and age I, is as follows:

$$T_p=\sum_{i-1}^{i_R-1}\mu_i\int(\tau_{ss}\cdot 1_{[l>\underline{l}]}\min(\kappa,w\varepsilon_i x)l)d\psi^i(l,a,x,B,n).$$

Here, $\psi^i(l,a,x,B,n)$ is the density function of age i, and T_p is the result of integrating contribution revenue over the working-age population. National Pension payments $\aleph$ are expressed as:

$$\aleph=\sum_{i=i_R}^{I}\mu_i\int\xi(B,n;A,\alpha)d\psi^i(a,B,n).$$

These payments are initially covered by contribution revenue T_p, and the shortfall is covered by government subsidy G_p according to

$$G_p=\aleph-T_p.$$

The government raises revenue T through consumption, capital, income, and death taxes, as follows:

$$T = \sum_{i=1}^{I} \mu_i \int [\tau_c c + T(y_i) + \frac{\gamma_{i-1}}{1-\gamma_{i-1}} a] d\psi^i (l,a,x,B,n) + \tau_k rK \ ,$$

with $\gamma_0 = 0$. This revenue T is comprised of the government subsidy for the National Pension G_p, government consumption G, and the total Basic Pension amount Φ:

$$T = G + \Phi + G_p \ ,$$

$$\Phi = \sum_{i=i_R}^{I} \mu_i \int \hat{\varphi}(a,B,n;A,\alpha) d\psi^i (a,B,n) \ ,$$

$$G = \bar{g} \times \sum_{i=1}^{I} \mu_i \ .$$

Government spending is assumed to be a constant, $\bar{g}$, multiplied by the population. The government can consider consumption tax rates, income tax levels, and corporate tax rates to achieve a fiscal balance. In this study, we focus on adjusting the consumption tax rate τ_c.

D. *Market Clearing*

At each age i, the aggregate labor supply is expressed as

$$N_i = \mu_i \int \varepsilon_i x l d\psi^i \ .$$

The labor market clearing condition is that labor demand and supply must be equal:

$$N = \sum_{i=1}^{i_R - 1} N_i \ .$$

For the capital market, we assume a small open economy in which domestic investors can freely invest abroad. This reflects a realistic economic environment where domestic interest rates are not excessively lowered due to the availability of overseas investment opportunities. Additionally, we assume that foreigners cannot invest in the country due to capital restrictions. This setup reflects the supply and demand dynamics in the domestic capital market without embracing the characteristics of a complete small open economy. K^* is defined as the capital level for which the overseas interest rate r^* equals the domestic after-tax interest rate, as follows:

$$r^* = (1-\tau_k) \times (z\theta K^{*\theta-1} N^{1-\theta} - \delta) \ ,$$

$$K^* \equiv [\frac{z\theta}{r^* / (1-\tau_k) + \delta}]^{1/(1-\theta)} N \ .$$

The capital market clearing conditions, which require the supply and demand of capital to match, are expressed as follows:

$$K = \min[\sum_{i=1}^{I} \mu_i \int a d\psi^i , K^*].$$

This means that the foreign interest rate r^* is the lower bound on the domestic after-tax interest rate $(1-\tau_k)r$. Households will choose to invest domestically when the domestic interest rate is higher than the foreign interest rate.

E. *Definition of Stationary Equilibrium*

The conditions for stationary equilibrium in this model are as follows:

1. Households are utility maximizers.
2. Firms are profit maximizers.
3. Public sector budget constraints are satisfied.
4. The capital and labor markets clear.
5. The macro distribution is dynamically consistent.

In this study, we modify one of the original equilibrium conditions, in this case dynamic consistency. While the original equilibrium condition states that if economic agents act rationally in anticipation of the future population structure through exogenous mortality, the macroeconomic distribution should not change in the next period, the exogenous mortality and population structure of this model are not dynamically consistent in a strict sense. Given that one of the most critical elements of this study is the population structure (μ_i) of an aging society in 2070, it had to be extracted exogenously from data rather than being derived from exogenous mortality (γ_i). However, dynamic consistency is still maintained by interpreting μ_i as the age-specific weights that make up the aggregate variables, and redefining dynamic consistency as the macroeconomic distribution not changing over time as a result of economic agents accepting this as true and acting on it. While the model is not fully consistent with the rational expectations hypothesis and may be unconventional to experts, we believe that this equilibrium is sufficient to capture the macroeconomic effects central to the subject of this study, as in Lee *et al.* (2019).

This study is limited by the exclusion of an analysis of the transition path of pension reform from the DB to the DC system. Specifically, it does not consider the already promised pension benefits in the DB system at the time of the DC reform. Therefore, it does not accurately analyze the economic phenomena that will actually occur in 2070. Instead, it is confined to analyzing the long-term effects of each pension system within the context of an aging society in 2070, leaving the analysis of the transition path for future research.

F. *Definition of the DC Pension System*

Let's modify the DB pension system defined above into a DC system. A collective defined contribution (CDC) pension system insures survivorship by contracting within a cohort to receive a pension until death. If we reform to a CDC, we change the B value dynamics and the calculation of the pension income ξ as follows:

$$B' = B(1+\tilde{r})/(1-\gamma_{i-1}) + \tau_{ss}\min(\kappa, w\varepsilon_i x)l\,,$$

$$\xi(B) = \frac{B(1+\tilde{r})/(1-\gamma_{i_R-1})}{1+\frac{1-\gamma_{i_R}}{1+\tilde{r}}+\cdots+(1-\gamma_{i_R})\times\cdots\times(1-\gamma_{I-1})(1+\tilde{r})^{-(I-i_R)}}\,,$$

$$1+\tilde{r} \equiv \frac{1+\hat{r}}{1+g_z}\,,$$

where $\hat{r}$ is the fund rate of return. This formula can be interpreted such that the funds of deceased members are transferred to the funds of survivors within a cohort, with the cohort's accumulated balance continuing to be capitalized and earning interest even after retirement until it is exhausted. An individual's pension benefit in such a DC pension system is no longer directly dependent on the contribution period n or the A value, which is determined by the income of others. In this study, we limit our discussion of "DC" to these cohort-specific CDC schemes.

In the DC, let the amount of capital invested at each age (or cohort) be F_i. The formula for this variable until retirement then becomes

$$F_i = \frac{\mu_i}{(1-\gamma_{i-1})(1+g_z)} \times \sum_{j=1}^{i-1}[(1+\tilde{r})^{i-1-j}\tau_{ss}\int y_i{}^l 1_{[l>\underline{l}]}d\psi^i(l,a,x,B,n) \times \prod_{m=0}^{i-1-j}\gamma_m{}^{-1}]$$

$$(2 \leq 1 < i_R)\,,$$

$$F_1 = 0\,,$$

$$\overline{B} \equiv \sum_{j=1}^{i_R-2}[(1+\tilde{r})^{i-1-j}\tau_{ss}\int y_i{}^l 1_{[l>\underline{l}]}d\psi^i(l,a,x,B,n) \times \prod_{m=1}^{i-1-j}\gamma_m{}^{-1}]\,,$$

$$F_i = \frac{\mu_i}{(1-\gamma_{i-1})(1+g_z)}\sum_{j=1}^{i-1}\{\overline{B}\frac{1+\tilde{r}}{1-\gamma_{i_R-1}}(1+\hat{r})^{I-i_R}\prod_{j=i_R}^{i-1}\gamma_j{}^{-1} - \xi(\overline{B})\sum_{j=i_R}^{i}(1+\tilde{r})^{j-i_R}\prod_{m=i_R-1}^{j-1}\frac{\gamma_{i_R-1}}{\gamma_j}\}$$

$$(i_R \leq i \leq I)\,.$$

The specific derivation of these expressions is described in the Appendix. $\overline{B}$ is the cohort average of the fund at retirement in stationary equilibrium.[7] If we define

[7]Therefore, for convenience, we also assume $INC_A(n;A,a) = INC_A(\overline{B})$ for all n.

the foreign investment ratio of the total DC funds F as $1-\omega$,[8] the following new capital market clearing conditions hold:

$$F = \sum_{i=1}^{I} F_i ,$$
$$\hat{r} = \omega r + (1-\omega) r^*$$
$$K = \min[\sum_{i=1}^{I} \mu_i \int a d\psi^i + \omega F, K^*] .$$

One of the important features of the DC is that there is always an investment fund, as you receive pension benefits only to the extent that you pay contributions and earn investment returns, regardless of economic changes. For this reason, unlike the DB, the government in the DC case does not need to fund the National Pension Service and only needs to cover government consumption and Basic Pension expenditures. This creates a new government budget formula:

$$T = G + \Phi .$$

If population μ_i and mortality γ_i are consistent in equilibrium, then the following equations hold:

$$Ex = \sum_{i=i_R}^{I} \mu_i \int \xi(B) d\psi^i(B) ,$$
$$\mathrm{Re}v = \tau_{ss} w \sum_{i=1}^{I_R - 1} \mu_i \int y_i^l 1_{[l > \underline{l}]} d\psi^i(l) ,$$
$$Ex + (1+g_\mu)(1+g_z)F = F(1+\hat{r}) + \mathrm{Re}v ,$$
$$Ex - \mathrm{Re}v \approx F \times (\hat{r} - g_\mu - g_z) .$$

In other words, if $\gamma_i = \mu_{i+1} / [\mu_i \times (1+g_\mu)]$ is true for the population growth rate g_μ, the primary deficit of pension (left-hand side) is equal to real interest (right-hand side), resulting in a fiscal balance. For simplicity, we will interpret the average of the residual term g_μ in this equation, $\gamma_i = \mu_{i+1} / [\mu_i \times (1+g_\mu)]$, as the population growth rate.

G. *Growth Adjustments*

The endogenous variables in this study are considered as per capita variables because they are essentially adjusted for population growth. This means that the endogenously determined variables, other than the interest rate variables $(r, \hat{r}, r^*, \tilde{r})$, are interpreted as increasing by $(1+g_z)$ per year in the model. The exogenous population variable μ_i is interpreted as increasing by $(1+g_\mu)$, and labor N is taken as labor per capita and is assumed to remain unchanged.

[8]The reason for assuming a minimum share of foreign investment is to avoid analyzing a full small open economy in the first analysis and to reflect the effects of supply and demand in the domestic capital market.

III. Calibration

There are several challenges with regard to making a reasonable projection of the macroeconomic environment surrounding the National Pension in 2070. As of 2022, the National Pension's total contribution amount is already mature, but the contribution period is only mature from age 18 to age 40. It will take another 24 years for all contribution periods to reach maturity, and an additional 35 years after that for the total benefit to mature. From a stationary equilibrium perspective, in 2022, working-age people are paying contributions in the mature stage, and up to the age of 40, are engaged in consumption and savings activities with a view to a mature pension benefit. However, individuals over 40 and under 64 are engaged in savings activities with a view to an immature pension benefit. Additionally, individuals at retirement age are receiving benefits in the immature stage and their saving choices and total pension benefits are also thus immature. Therefore, it is difficult accurately to project the situation in 2070 by simply quantifying the stationary equilibrium model based on the situation in 2022. The different stages of maturity for various age groups make it challenging to capture the long-term dynamics and effects on the pension system.

To address this problem, we employed the following strategy. First, we estimated an exogenous function Λ of hours worked and the contribution period by fitting to the 2022 contribution period distribution data only up to age 40. For individuals over 40, we used employment rate data to identify the maturity stage of the contribution period. Simply applying the function Λ of the maturity stage to 2022 data would overestimate the total amount of National Pension benefits and, consequently, government support. Therefore, we assumed that the National Pension finances do not affect the government budget only when fitting to the 2022 data. On the other hand, because the contribution revenue as a percentage of GDP is already mature in 2022 and serves as an important measure of the overall size of the pension, it is necessary to fit it accurately. While the actual contribution rate is 9%, we adjust τ_{ss} to match the total contribution revenue. Additionally, keeping α fixed at 1.2 and adjusting τ_{ss} would introduce bias into the actual payroll as a percentage of GDP. Thus, α is adjusted so that its ratio to 1.2 equals the ratio of τ_{ss} to 9%. As a result, these estimates provide a good representation of the economic incentives for those under 40 in 2022 and of the current and future financial situation of the National Pension Service.[9]

Here's how we quantify this. First, the baseline model assumes the current DB system and population structure μ_i and mortality rate γ_i of 2022. Some exogenously determined parameters of the model, primarily referring to Lee *et al.* (2019), are as follows: $\sigma_u = 1.5$, $\rho_x = 0.92$, $\sigma_x = 0.05$, $\theta = 0.36$, $\delta = 0.08$, and $\tau_1 = 0.0365$. Age $i = 1$ corresponds to 20 years old, $i = i_R$ is 65 years old, and $i = I$ is set to 98 years old. The difference between Lee *et al.* (2019) and this study is that we set the present year to 2022 instead of 2016 and the future year to 2070 instead of 2040 for an aging society by extracting population μ_i and mortality rates

[9]In the model, those over age 40 may have a lower incentive to save due to higher pension benefits than in 2022, which may introduce an estimation bias.

γ_i directly from Future Population Projections (2021). For convenience, we adjusted the population in 2022 such that it sums to 1. Labor Productivity by age ε_i was extracted from the Korean Labor Panel (2019)[10] by dividing the average income by the average working status for each age. ε_i is later adjusted so that $N = 1$ using the explicit derivation of the labor hours distribution from Λ. In anticipation of targeting $K/N = 3$, we adjust z in advance so that $Y = 1$.[11] Based on a 2022 corporate tax revenue-to-GDP ratio of 4.79%, we set $\tau_k = 0.3992$.[12]

For the exogenous labor-hour transfer function Λ, similar to Lee *et al*. (2019), the states are $1 \in \{1/3,\ 2/3,\ 1\}$ with $\underline{l} = 1/3$. The working age is divided into three bins (20-34, 35-49, and 50-64) and therefore we estimate three 3×3 matrices and the initial labor distribution. Given that the national pension is only mature until the age of 40, we fit the distribution data of the age 32 and age 40 contribution periods of 2022 provided by the Ministry of Health and Welfare. To identify the labor supply after age 40, we estimate the transfer function Λ by fitting its distribution of working hours to a combination of the employment rate data by age group from the Economic Activities Census and the average working status by age from the Korean Labor Panel (2019). Figures 1, 2, and 3 show that these targets are well met, indicating high explanatory power. In the model, retirees have an average contribution period of 23.5 years, which is more mature than the average contribution period of 59-year-olds in 2022, which is 13.9 years. If we assume that all employed people over the age of 20 contribute, the average contribution period from the Economic Activity Survey (2019) is 31.7 years, indicating that the model's contribution period is much lower than the ideal contribution period. The contribution period distribution across all ages in the model and data is presented in the Appendix.

(Unit: Density)

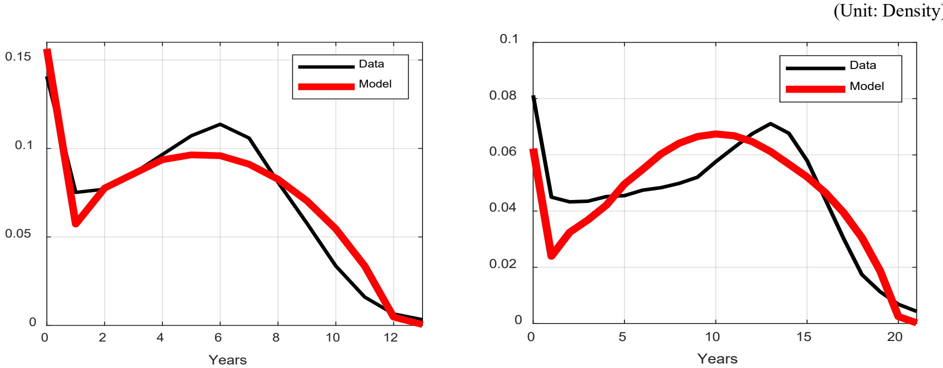

FIGURE 1. MODEL TO DATA COMPARISON OF THE AGE 32 (LEFT) AND AGE 40 (RIGHT) CONTRIBUTION PERIOD DENSITY LEVELS

Source: Author's figure based on 2022 population data by age×contribution period from the Ministry of Health and Welfare.

[10]We chose 2019 because it is the last year without the impact of COVID-19 and it is possible that the labor environment after 2019 has not recovered from the impact of COVID-19.

[11] $z = 1/K^{\theta}N^{1-\theta}$

[12] $\tau_k = 4.79(\%)/(\theta - \delta K/Y)$

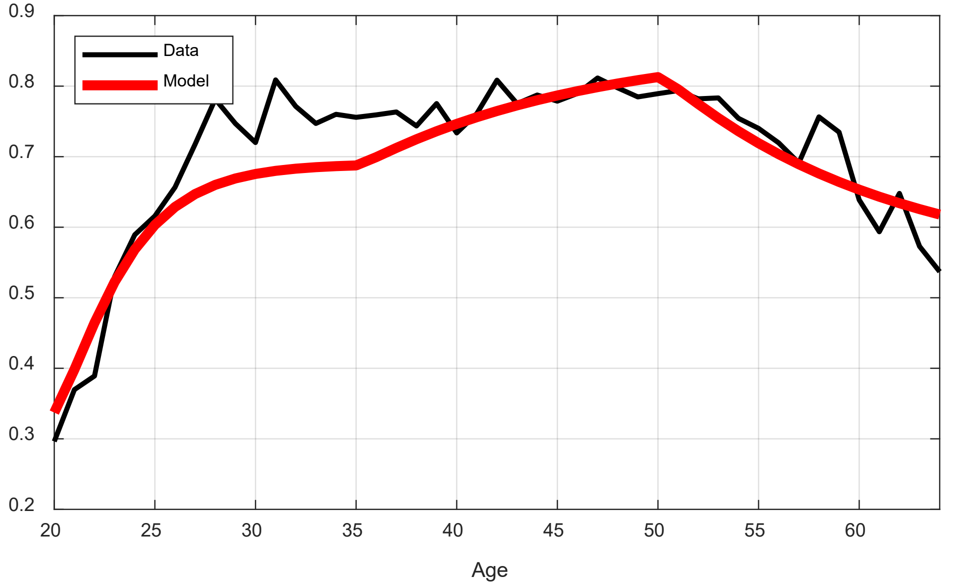

FIGURE 2. EMPLOYMENT RATE DATA VS MODEL

Source: Author's figure based on labor hours data from the Korea Labor Panel (2019).

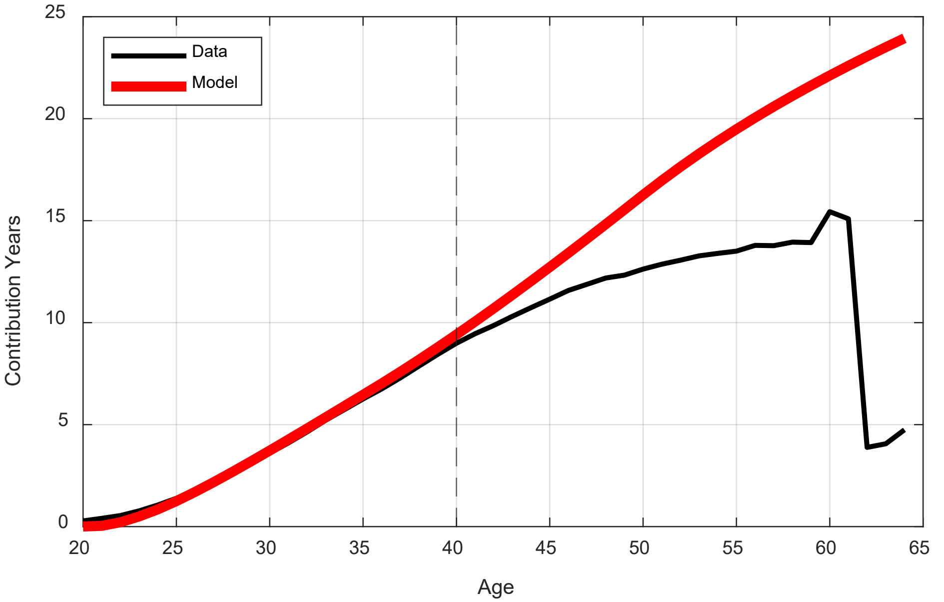

FIGURE 3. MODEL TO DATA COMPARISON OF LABOR HOURS

Source: Author's figure based on 2022 population data by age×contribution period of the Ministry of Health and Welfare.

The following parameters were estimated by solving the model. β, following Lee *et al.* (2019), is calibrated so that $K/Y=3$. λ_l is set to match the 2022 income tax revenue to GDP ratio 5.96%. τ_c is adjusted so that the consumption tax revenue ratio is 3.78%, and $\overline{\varphi}$ is set to achieve the Basic Pension expenditure ratio of 0.75%. The upper limit of monthly contribution κ is based on an average of 13.5% of members falling within the upper limit. The contribution rate was 9% in 2022, but because the size of the National Pension system as a share of GDP is critical to the results of this study, we estimated $\widehat{\tau_{ss}}$ to match the 2022 contribution to GDP ratio of 2.59%. To simulate a future contribution rate of 18%, we double the contribution rate to $\tau_{ss}=2*\widehat{\tau_{ss}}$. The income replacement rate coefficient was adjusted to $\alpha=1.2*\widehat{\tau_{ss}}/0.09$.

In that the National Pension Fund had not yet been exhausted in 2022, we assume that the fund M was as large as 42% of GDP solely for the purpose of quantifying the model to match the 2022 economic environment. Consequently, we modify the capital market clearing condition as follows:

$$K=\min[\sum_{i=1}^{I}\mu_i\int ad\psi^i+\omega M, K^*].$$

Here, $1-\omega=0.506$ represents the current proportion of foreign investments, which is also used in the experiments for the DC system. The derivation of this figure is detailed in the Appendix.

Because the National Pension Fund remains in surplus until 2022, we assume that the National Pension Service's finances do not affect the government budget constraint to reflect this accurately. Thus, the government budget constraint is modified only in the estimation phase, as follows:

$$T=G+\Phi.$$

For the baseline fund rate of return, the foreign interest rate is set to $r^*=0$ to compare DB and DC under similar circumstances. Later, we adjust r^* to analyze the impact of foreign interest rates on DC.

IV. Theory

The main focus of this study is the effect of each pension system on the economy under the 2070 demographic environment (population structure and mortality). Before reviewing the results of the analysis, we provide a theoretical discussion of the macroeconomic consequences of changes in the demographic environment and corresponding increases in contribution rates for both the DB and DC systems within the overlapping generations model.

As mentioned earlier, in our model, population structure μ_i is not determined by mortality rate γ_i; instead, each is exogenously inputted using data from the

Prospective Population Projections dataset (2021). Therefore, it is necessary to clearly distinguish the roles of the population structure and mortality in the model. In the model, households are unaware of the population structure but assume that their mortality rate is γ_i. Thus, utility-maximizing households are informed with regard to prices, macro variables, and mortality, but not μ_i. Moreover, mortality affects benefit levels and the death tax revenue in DC systems, as shown in the model's equations. The population structure μ_i is used as a weight to aggregate individual variables to form aggregate variables, mainly affecting market clearing and government budget constraints.

We begin by summarizing the theoretical discussion of the macroeconomic effects changes in the population structure, declines in mortality rates, and increases in contribution rates in each pension system.

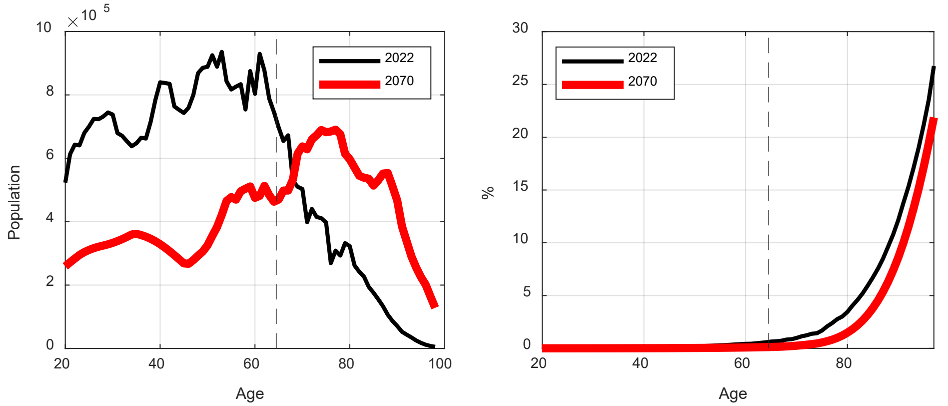

FIGURE 4. CHANGES IN POPULATION STRUCTURE (LEFT) AND MORTALITY (RIGHT)

Note: The vertical dashed line indicates the age of retirement.

Source: Author's illustration based on Future Population Projections (2021).

TABLE 1. 2022 VS 2070: POPULATION, POPULATION STRUCTURE, LABOR, AND MORTALITY RATES

		All ages	Ages 20-64	Ages 65-98
2022	Model Population	1.000	0.792	0.208
	Population Density	1.000	0.792	0.208
	N / μ_i	1.000	1.262	0.000
	Mortality	0.031	0.002	0.072
2070	Model Population	0.770	0.375	0.395
	Population Density	1.000	0.487	0.513
	N / μ_i	0.597	1.227	0.000
	Mortality	0.021	0.000	0.049

Note: Mortality rates weigh each age equally; N / μ_i is labor per capita, which is total labor divided by the population of each age group.

A. *Impact of the Aging Population Structure*

The most significant difference between the population structures of 2070 and 2022 is the much higher dependency ratio of the elderly. As shown in Table 1, the share of retirement-age adults is projected to increase from 20.8% in 2022 to 51.3% in 2070, representing a 146.6% increase. Conversely, the share of working-age people eligible for pensions will decrease, resulting in less contribution revenue for the pension funds. The share of working-age people is expected to drop from 79.2% in 2022 to 48.7% in 2070, a decrease of 38.5%.

The macroeconomic effects of the demographic transition to 2070 include a decrease in the labor supply per capita. As the labor supply per capita falls, firms with Cobb-Douglas function production technology will reduce their demand for complementary capital in production. Consequently, in equilibrium, capital per capita falls, the interest rate falls, the wage rate rises, and aggregate output rises. The primary economic phenomenon that occurs when the wage rate rises is that the consumption and income gap between the working-age and retirement-age groups widens. Although the level of pension benefits at retirement age also increases as the wage rate rises, inequality worsens because the working-age population gains more from wages.

A second macroeconomic effect of the 2070 population structure is a potential decline in the correlation between lifecycle savings and the weighting of the population structure. While savings typically peak in the life cycle just before retirement, Figure 4 shows that in 2022, the population has a relatively high proportion of people nearing retirement. In contrast, by 2070, the highest proportion will be in their mid-70s, a period when savings have significantly declined. This suggests that even if people maintain the same savings patterns throughout their lives, the demographic shift alone can reduce total savings per capita. In response to this capital supply shock, aggregate capital decreases, interest rates increase, wage rates decrease, and aggregate output decreases. If a demand shock for capital occurs simultaneously with the decline in the per capita labor supply, the decline in aggregate output is theoretically certain, but the final directions of changes in interest rates and wage rates are uncertain.

While the first two shocks can occur in both the DB and DC cases, it is only in the DB case that the aging population structure leads to a deficit in the pension fund and a higher tax burden. This occurs because the pension benefit of the current extreme DB system in Korea responds to the overall income level of the population, as shown in the benefit formula, and does not respond to demographic changes. Because the contribution rate and the level of benefits applied to members are separate, a higher dependency ratio of the elderly may simply increase the proportion of people receiving benefits, worsening the finances. In such a situation, if the contribution rate is not high enough, the total contributions will be insufficient to cover the total benefits each year. Consequently, in the long run, the economy will need continuous injections of general government funds to achieve equilibrium with the same population structure as in 2070. Higher taxes would reduce households' after-tax income, potentially leading to lower savings, which in turn could lead to higher interest rates, lower wage rates, and decreased output.

Assuming that the government's proposal to increase tax rates to close the funding deficit in the DB system passes, the fiscal balance would have to be achieved through three main sources: income taxes, corporate taxes, and consumption taxes. Increasing income taxes to finance pension deficits tends to reduce inequality within the working-age group due to the progressive nature of income taxes. However, because the largest portion of income taxes is levied on working-age incomes, this approach reduces the disparity in disposable income between working-age and retirement-age individuals, potentially improving inequality measures such as the Gini coefficient.

Another feature of higher income taxes is that interest income can also be subject to income tax, which can reduce overall savings and thus investment. This can cause interest rates to rise and the economy to contract. Wage rates will also decline along with gross domestic product, reducing pensions but reducing overall inequality as well.

On the other hand, corporate taxes can depress the economy by lowering after-tax interest income, which discourages saving and investment. Given that corporate taxes are purely targeted at capital income, their depressive effect may be stronger than that of income taxes if the same revenue is targeted. As a result, capital may decrease, raising the marginal product of capital. This, in turn, lowers wages, which generally lowers consumption overall.

Compared to the features of income and corporate taxes, consumption taxes are neutral for the population as a whole, as everyone is taxed at a single rate, and if labor supply is inelastic, tax distortions are minimized. Unlike income taxes, consumption taxes do not directly shift the burden to the working-age population, and the tax burden is relatively high for the retired population. To remain neutral on the age concentration of the effects and labor distortions, we use consumption taxes as the main source of revenue in this study.[13] Regardless of the chosen revenue source, households' after-tax income falls, leading to reduced savings, which has a contractionary effect on the economy, although the intensity of this effect may vary depending on the type of tax selected.

Whereas DB faces a serious problem of rising tax rates, DC remains financially stable even if the elderly dependency ratio rises, as shown in Figure 4. This arises because individuals only receive benefits equivalent to contributions and investment returns. As a result, some of the funds are invested domestically, which is why interest rates can be lower in the DC case even under conditions identical to those of the DB case. Therefore, DC can have higher total capital, lower interest rates, higher wage rates, and higher gross product than DB.

B. *Impact of Lower Mortality*

Declining mortality gives households an incentive to increase savings at most ages as life expectancy increases. As shown in Table 1, the decline in mortality is more pronounced in the retirement-age group than in the working-age group. Consequently, the retirement-age group may save more to self-insure against longer lifespans. As overall savings rise, the interest rates fall, and the wage rate rises, increasing wages

[13]Of course, effective tax rates vary by age, which should be interpreted with some caution. For example, Kim (2020) shows that the proportion of tax-exempt consumption is higher among the older and the elderly, so an increase in consumption taxes could narrow the gap between the working and retirement age groups.

for working-age individuals. This can exacerbate inequality measures by further widening the income gap between working-age and retirement-age individuals.

C. *Effect of Reduced Savings as DC Benefits Decline*

In general, households tend to increase their savings in response to an expected decrease in future pension benefits. However, while DB does not adjust benefit levels in response to factors other than income levels, the benefit levels of DC can change elastically with interest rates, making the equilibrium outcome responsive to various external shocks. When interest rates rise, the pension fund grows, leading to higher benefit levels, which subsequently reduces savings and further increases interest rates. Conversely, a decrease in interest rates has an amplifying effect in the opposite direction, causing interest rates to fall further.

If we express this in a partial equilibrium of the capital market, the slope of the capital supply curve of DC is steeper than that of DB. The total supply curve of DC is divided into the capital supply of households and the supply of funds through the DC fund. The total amount of the DC fund in this case slopes upward relative to the interest rate because the fund also grows as the rate of return $\hat{r}$ (proportional to the interest rate) rises. With regard to the supply of household capital, some incentives may be upwardly sloping, as in DB, but there is also an incentive for households to save less as pension benefits increase when interest rates rise. As a result, the capital supply curve for DC is likely to be counterclockwise steeper than the DB capital supply curve. From the perspective of a general equilibrium analysis, both the DB and DC capital supply curves may be steeper than the slopes in partial equilibrium because when interest rates fall, wages necessarily rise, increasing the income level of households. However, the capital supply curve is still steeper in the DC case than in the DB case because households have an incentive to reduce their capital supply further as interest rates rise.

In such a situation, a demographic demand shock that reduces labor per capita will cause interest rates to fall more in DC than in DB. However, equilibrium per capita capital will fall less in the DC case, resulting in a smaller decline in aggregate output, as shown in Figure 5. This outcome is primarily due to households increasing

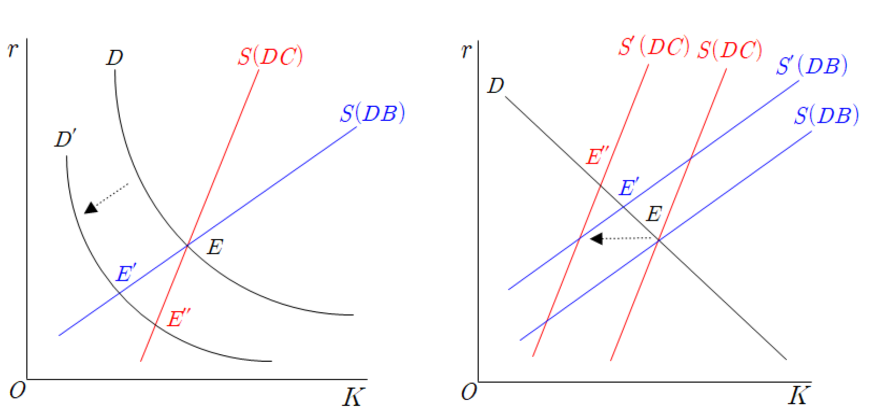

FIGURE 5. DB VS DC RESULTS FOR DEMAND SHOCKS (LEFT) AND SUPPLY SHOCKS (RIGHT) OF CAPITAL

their savings in response to lower interest rates as pension benefits are reduced. Conversely, if there is a supply shock due to a decline in the correlation between capital and the population structure, the same shock may cause interest rates to rise more and aggregate output to fall more in DC than in DB. This is due to the savings response effect, as shown in Figure 5.

Mortality is also a factor that affects benefit levels in DC, meaning that a decline in mortality may have different impacts on DC and DB. Like DB, DC benefits from the savings boost that comes from longer life expectancy. However, lower mortality directly reduces the level of benefits under the DC benefit formula. Because the contractual terms of DC dictate that the funds originally belonging to deceased individuals are passed on to the survivors, the later the population in the cohort dies, the lower the benefit level. The resulting rise in savings can boost the economy, lower interest rates, and increase wage rates, potentially leading to a rise in inequality indices.

D. *Effect of Contribution Rate Increases*

It is possible for DB to remain in place and for the contribution rate to rise as the system's finances deteriorate toward 2070. Another possibility is that the DC reform would occur only after an 18% increase in the contribution rate as DB remains in place. Alternatively, the DC reform may occur when the contribution rate is 9%, but the rate would need to be raised due to an insufficient income replacement rate. Therefore, let's briefly discuss the implications of having a contribution rate higher than 9% in each pension system.

A simple interpretation of increasing contribution rates in the DB case within this model is that, instead of financing the pension deficit with consumption taxes, it is financed with a single-rate labor income tax. An increase in the contribution rate would reduce saving among the working-age population, which is the main saving age group, leading to reductions in gross domestic product and wage rates. This redistributive effect increases the after-tax income of the retirement-age group while decreasing the after-tax income of the working-age group, thus improving the inequality index. However, if the increase in the contribution rate replaces corporate or income taxes rather than consumption taxes, it may actually increase savings. The final equilibrium capital gains or losses may depend on the choice of tax adjusted to achieve a fiscal balance.

On the other hand, the DC case does not have the same substitution effect on tax revenues compared to DB. An increase in the contribution rate in the DC case increases the amount of funds directly invested in Korea but also increases pension benefits, which creates an incentive for households to save less. Additionally, working-age individuals who make higher contributions due to the increased contribution rate will have lower after-tax incomes, similar to the DB case, and thus have an incentive to save less. Essentially, the relative magnitudes of these three effects determine whether capital is ultimately increased or decreased. If the increase in pension funds invested domestically is not substantial, the working-age group is likely to be the worse off due to lower wage rates, which could lead to an improvement in inequality measures.

TABLE 2. DB GENERAL EQUILIBRIUM EFFECT DIAGRAM

Shock	Channel	Result
Pension Deficit↑ →	Taxes↑→ [After-tax Income↓ Savings↓ Interest Rate↑]	Capital↓ Interest Rate↑ Wage Rate↓ Gross Product↓
Labor↓ →	Capital Demand↓→ Interest Rate↓	Capital↓ Interest Rate↓ Wage Rate↑ Gross Product↓
Savings × Population Structure↓ →	Capital Supply↓→ Interest Rate↑	Capital↓ Interest Rate↑ Wage Rate↓ Gross Product↓
Mortality↓ →	Savings↑→ Interest Rate↓	Capital↑ Interest Rate↓ Wage Rate↑ Gross Product↑
Contribution Rate↑ →	[After-tax Income↓ Savings↓ Interest Rate↑] Deficit↓ → Taxes↓→ [After-Tax Income↑ Savings↑ Interest Rate↓]	Capital (↓) Interest Rate (↑) Wage Rate (↓) Gross Product (↓)

Note: Parentheses indicate ambivalent results. Single arrows indicate an effect. Double arrows indicate a strong effect.

TABLE 3. DC GENERAL EQUILIBRIUM EFFECT DIAGRAM

Shock	Channel	Result
Funds Investment↑ →	Capital Supply↑ → Interest Rate↓→ [Benefit↓ Savings↑ Interest Rate↓]	Capital↑↑ Interest Rate↓↓ Wage Rate↑↑ Gross Product↑↑
Labor↓ →	Capital Demand↓ → Interest Rate↓→ [Benefit↓ Savings↑ Interest Rate↓]	Capital (↓) Interest Rate↓↓ Wage Rate↑↑ Gross Product↓
Savings × Population Structure↓ →	Capital Supply↓ → Interest Rate↑→ [Benefit↑ Savings↓ Interest Rate↑]	Capital↓↓ Interest Rate↑↑ Wage Rate↓↓ Gross Product ↓↓
Mortality↓ →	Savings↑ → Interest Rate↓→ [Benefit↓ Savings↑ Interest Rate↓] [Benefit↓ Savings↑ Interest Rate↓]	Capital↑↑ Interest Rate↓↓ Wage Rate↑↑ Gross Product↑↑
Contribution Rate↑ →	[After-tax Income↓ Savings↓ Interest Rate↑] → [Benefit↑ Savings↓ Interest Rate↑] [Benefit↑ Savings↓ Interest Rate↑] Funds↑ → Interest Rate↓→ [Benefit↓ Savings↑ Interest Rate↓]	Capital (↓) Interest Rate (↑) Wage Rate (↓) Gross Product (↓)

Note: Parentheses indicate ambivalent results. Single arrows indicate an effect. Double arrows indicate a strong effect.

However, rather than focusing on the effect of increasing the contribution rate, this study examines on the impact of changing the pension system at a given contribution rate. Regarding the effect of an increase in the contribution rate in the DB case, see Lee *et al.* (2019).

E. *Summary*

Tables 2 and 3 summarize this discussion. The main difference between the two pension systems is that the capital supply curve is more counterclockwise in the DC than in the DB case. This is due to the effect of the saving response to changes in pension benefits, making the interest rate more elastic to any shock. Additionally, it is evident that the directions of pension benefits and wage rates are always opposite in the DC case. This occurs because the interest rate and wage rate are negatively correlated according to the firm's optimization formula, while pension benefits and interest rates are positively correlated through the pension formula and the household's savings response. Therefore, for any shock, the gains of working-age and retirement-age individuals move in opposite directions, leading to corresponding changes in the Gini coefficients.

V. Counterfactual Experiment Results

This section highlights the challenges in maintaining the DB pension system over the long term in the 2070 demographic environment and suggests that a DC reform could be a viable solution. We also propose a supplementary reform of the Basic Pension system as a way to address the issues associated with the DC reform. In this section, we assume that the government primarily adjusts the consumption tax rate to achieve a fiscal balance. This section assumes that $g_z = 0$.

A. *Results of the Demographic Environment Change*

1. DB Pension System

a) Pension fund deficit results

Table 4 shows the projected deficit for DB in 2070. If the current demographic environment (population structure and mortality) continues as it is today (2022) with a 9% contribution rate, the underlying fiscal deficit of the National Pension Fund is only 0.8% of GDP each year. Doubling the contribution rate to address this would result in a fiscal surplus of 1.8% of GDP annually. Currently, proposals to increase the contribution rate to 13% or 15% are frequently discussed in the media, suggesting that such an increase would be sufficient to balance the fund. However, if the demographic environment projected for 2070 persists, a 9% contribution rate will

TABLE 4. IMPACT OF AGING ON DB DEFICITS

(Unit: % of GDP)

Contribution Rate	Population structure	Pension Deficit	Contribution Income	Pension Spending
9	2022	0.80	2.59	3.39
	2070	11.35	2.57	13.92
	Difference	10.55	-0.02	10.53
18	2022	-1.79	5.18	3.39
	2070	8.78	5.14	13.92
	Difference	10.57	-0.04	10.53

Note: Author's creation based on the model.

b) Household Analysis

TABLE 5. IMPACT OF AGING ON THE DB SYSTEM

Population Structure	2022	2070	2070	2022
Mortality	2022	2070	2022	2070
Pension Systems	DB	DB	DB	DB
Contribution rate	9%	9%	9%	9%
Gross Product	0.983	0.683	0.651	1.019
Capital (demand)	2.864	2.598	2.278	3.160
Consumption	0.544	0.369	0.370	0.537
Disposable Income	0.661	0.515	0.502	0.675
After-tax Income	0.617	0.331	0.336	0.619
Labor	1.000	0.597	0.597	1.000
K/N	2.864	4.348	3.814	3.160
Interest Rate	0.044	0.015	0.023	0.036
Wage Rate	0.629	0.731	0.698	0.652
Gini Consumption	0.232	0.264	0.274	0.226
Gini Disposable Income	0.344	0.408	0.404	0.345

Note: Normalized to per capita population.

result in a deficit of 11.4% of GDP each year. Even increasing the contribution rate to 18% to address this situation would still result in an annual deficit of 8.8%. To sustain the pension system in a state of stationary equilibrium, the government would have to raise taxes to cover the deficit, imposing a significant burden on the public.

To examine the effects of the population structure and mortality on households' economic activity separately, we substitute them into the model one by one. For convenience, only some of the results for the 9% contribution rate are presented here. First, the results of the experiment in which only the 2070 demographic structure is substituted into DB are as follows. As shown in Table 5, there is a demand shock for capital that reduces labor per capita by about 40%. This is accompanied by a decline in the supply of capital due to the weakened correlation between the population ratio and savings over the life cycle, resulting in a decline in output as well. However, as the decline in capital per capita does not match the decline in labor, K/N is higher than before. Consequently, the equilibrium state is characterized by a lower interest rate and a higher wage rate. The decline in the interest rate indicates that the effect of the demand shock was greater than the supply shock. As the wage rate rises, the disposable income of working-age people increases. However, their consumption and after-tax income levels (equivalent to disposable income minus consumption tax) fall because consumption taxes must be higher to cover the pension deficit. For retirees, the higher wage rate raises pension levels, but consumption, disposable income, and after-tax income all decline. As a result, retirees are more adversely affected, leading to higher Gini coefficients for all ages.

An experiment in which only the 2070 decline in mortality is considered under DB results in the following outcomes. All age groups in the household increase their savings in anticipation of living longer, leading to a rise in aggregate output, a decline in interest rates, and a rise in wage rates. Pension benefits rise in turn, raising everyone's disposable income. However, capital tax revenue decreases because the stronger impact of the fall in interest rates outweighs the increase in aggregate capital. Additionally, tax revenue declines due to a reduction in death tax revenue caused by the lower mortality rate. This leads to an increased consumption tax burden, which reduces overall consumption. The negative impact is greater for the working-age group, as shown by the improvement in the all-age consumption Gini coefficient.

Substituting both the population structure and mortality of 2070 shows that the impact of the population structure is more pronounced for most variables. In particular, Table 5 shows that capital declines in the lower mortality scenario, in contrast to the results for the higher mortality scenario. However, Figure 6 shows that saving does not change much, suggesting that the decline in capital is more attributable to the reduced correlation between the population structure and lifecycle than a decline in overall lifecycle savings levels.

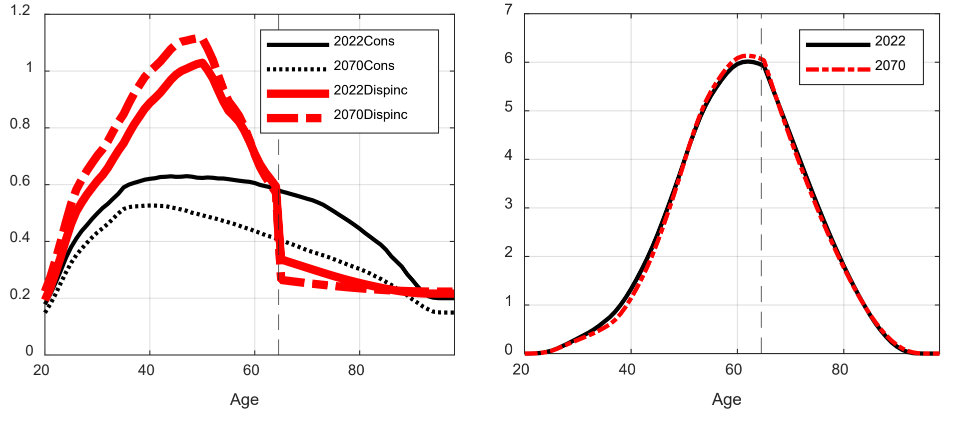

FIGURE 6. DB CONTRIBUTION RATE 9%: LIFECYCLE OF CONSUMPTION AND DISPOSABLE INCOME (LEFT) AND ASSETS (RIGHT)

Note: Vertical dashed line indicates the age of retirement.

2. DC Pension System

TABLE 6. IMPACT OF AGING ON THE DC SYSTEM

Population Structure	2022	2070	2070	2022
Mortality	2022	2070	2022	2070
Pension System	DC	DC	DC	DC
Contribution Rate	9%	9%	9%	9%
Gross Product	1.053	0.750	0.747	1.100
Capital (demand)	3.461	3.376	3.333	3.908
Capital (household)	3.006	3.648	2.860	3.462
Consumption	0.548	0.411	0.424	0.533
Disposable Income	0.667	0.466	0.477	0.680
After-tax Income	0.624	0.360	0.379	0.622
Labor	1.000	0.597	0.597	1.000
K/N	3.461	5.651	5.578	3.908
Interest Rate	0.030	0.000	0.001	0.021
Wage Rate	0.674	0.804	0.800	0.704
Gini Consumption	0.231	0.288	0.310	0.224
Gini Disposable Income	0.370	0.544	0.517	0.381

Note: Normalized to per capita population.

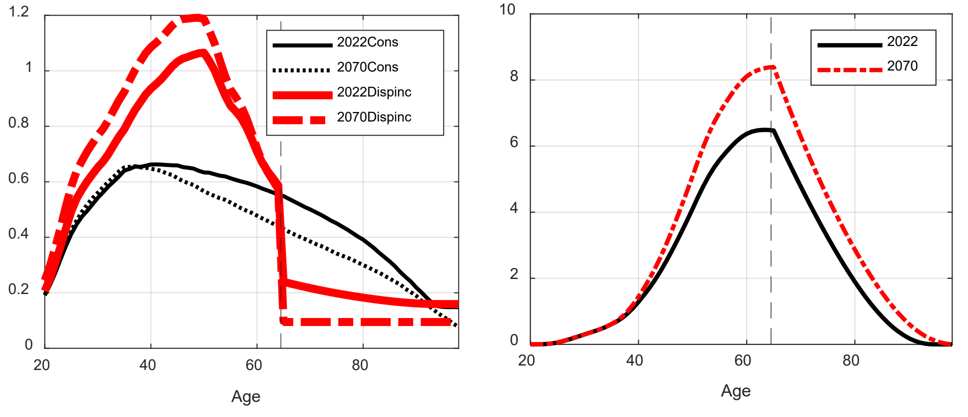

FIGURE 7. DC CONTRIBUTION RATE 9%: LIFECYCLE OF CONSUMPTION AND DISPOSABLE INCOME (LEFT) AND ASSETS (RIGHT)

Note: The vertical dashed line indicates the time of retirement.

For the DC case, let's keep the mortality rate at 2022 but change the population structure to that of 2070. By definition, a financial burden associated with DC does not exist, as each cohort only receives benefits equivalent to the exact amount of contributions and investment returns. Hence, there are no concerns about depleting the fund. However, as shown in Table 6, the interest rate is lowered due to a capital demand shock that reduces labor per capita, and the impact of a capital supply shock is relatively small. Unlike the DB case, in the DC case, the level of pension benefits is lowered primarily due to lower interest rates. Households respond by increasing their savings such that total capital per capita does not decrease as much as in the DB case.[14] As a result, gross output per capita is still lower, although not as much as labor per capita. In this situation, the working-age group benefits relatively more from the higher wage rate, while the retirement-age group loses more due to the lower interest rate, which reduces pension benefits. Consequently, inequality measures such as consumption and the disposable income Gini coefficient worsen.

If only mortality is changed from 2022 to 2070, DC is more affected than DB. In the DB case, despite the fact that pension benefits are fixed, households will increase their savings in anticipation of a higher survival rate. However, in the DC case, the benefit level directly decreases due to the additional decrease in mortality. As a result, households start increasing their savings from a younger age to prepare for their old age. As shown in Table 6, the labor income of working-age individuals increases as savings rise and wage rates increase. Gross output increases compared to the 2022 environment, but consumption and after-tax income decrease. This is due to lower mortality reducing death tax revenue and lower capital tax revenue from decreased lower interest rates, increasing the consumption tax burden. This trend affects all age groups. However, the working-age population shows a stronger tendency to consume less and save more, resulting in a lower all-age consumption Gini coefficient.

When both the population structure and mortality rates of 2070 are applied to DC, gross output falls as in the demographic change scenario, but capital demand rises as in the mortality decline scenario. However, it can be concluded that the overall impact of the population structure is stronger than that of mortality, similar to the DB case.

B. *Comparison of DB and DC in 2070*

Let's directly compare the DB and DC cases under the 2070 population structure and mortality rates. As shown in Table 7, disposable income in DB is higher than in DC at a 9% contribution rate and similar to DC at an 18% contribution rate. However, DC results in higher after-tax income and consumption levels. This can be interpreted as the DB system having a higher consumption tax due to a larger fiscal deficit, resulting in lower after-tax income and consumption levels. Additionally, the DC system benefits from increased total output, as its funds can be partially invested domestically rather than being exhausted.

Figure 8 shows that disposable income is higher in DC than in DB for the working-age population and lower for the retirement-age population.[15] In Table 7, the Gini coefficient of disposable income at all ages is absolutely higher for DC. Similarly, other indicators show that DC does not provide sufficient retirement income

[14]After-tax income decreases by 46% in the DB system and 39% in the DC system, while capital supply decreases by 20% in the DB system and only 5% in the DC system. This large double differential is driven by the difference in the slopes of the capital supply curves.

[15]While the higher disposable income of DC in the working-age group may make it appear as if DC has higher aggregate disposable income, the higher retirement population proportion is such that the DC case ends up with lower aggregate disposable income.

TABLE 7. DB VS DC IN 2070

Pension System	DB	DC	DB	DC
Contribution Rate	9%	9%	18%	18%
Gross Product	0.683	0.750	0.658	0.750
Capital (demand)	2.598	3.376	2.342	3.376
Capital (household)	2.598	3.648	2.342	2.513
Consumption	0.369	0.411	0.352	0.402
Disposable Income	0.515	0.466	0.488	0.488
After-tax Income	0.331	0.360	0.326	0.368
Labor	0.597	0.597	0.597	0.597
K/N	4.348	5.651	3.921	5.651
Interest Rate	0.015	0.000	0.021	0.000
Wage Rate	0.731	0.804	0.705	0.804
Income Replacement Rate	0.142	0.048	0.142	0.095
Pension Return Ratio (beta)	0.988	0.332	0.494	0.332
Gross Return Ratio (beta)	0.108	0.063	0.105	0.097
Gini Consumption	0.264	0.288	0.248	0.280
Gini After-tax	0.408	0.544	0.390	0.456
Consumption (work)	0.444	0.529	0.415	0.514
Disposable Income (work)	0.806	0.858	0.750	0.818
After-tax Income (work)	0.585	0.721	0.559	0.665
Gini Consumption (work)	0.227	0.223	0.215	0.220
Gini Disposable (work)	0.303	0.305	0.293	0.295
Consumption (ret)	0.298	0.299	0.292	0.296
After-tax Income (ret)	0.239	0.095	0.239	0.175
Disposable Income (ret)	0.091	0.018	0.106	0.086
Gini Consumption (ret)	0.252	0.266	0.240	0.253
Gini Disposable (ret)	0.152	0.044	0.153	0.104

Note: "Return Ratio" is the present value ratio of benefits to contributions. "Pension" only considers the National Pension, "Gross" considers the government fiscal sector as well, and "(beta)" uses a discount rate of $1/\beta - 1$ to calculate the present value; Values are normalized to per capita figures. Here, "(work)" denotes working age and "(ret)" denotes retirement age. Except for the Gini coefficient and population, variables with "(work)" and "(ret)" are normalized to their respective population ratios.

compared to DB. As shown in Table 7, the income replacement rate is significantly lower in DC, and the gross return ratio,[16] whose present values are calculated through the discount rate of $1/\beta - 1$[17] and mortality, is also lower in DC. Additionally, the average disposable income and after-tax income at retirement age are both lower in

[16]The gross return ratio is the return ratio, which is the present value ratio of benefits to contributions, taking into account the government fiscal sector (i.e., taxes, Basic Pension).

[17] $1/\beta - 1 = 0.0318$

the DC case. This occurs because DC benefits are more elastic with respect to interest rates. While working-age people benefit from the increase in capital (and subsequently output) and wage rates in DC, it does not lead to an equivalent increase in pension benefits as in the DB scenario. Furthermore, the decline in interest rates results in a decline in DC benefits at retirement age, increasing income inequality across all ages. Although consumption at retirement age is slightly higher in DC, the consumption gap with the working-age population is larger in DC, resulting in a higher all-age consumption Gini coefficient.

When the contribution rate increases to 18%, the difference between DB and DC remains qualitatively similar, with DB offering higher retirement disposable and after-tax incomes. However, the gap in the Gini coefficients of disposable income between the two schemes narrows. As the contribution rate rises, pension benefits rise in the DC case, which reduces savings, wage rates, and gross product, thereby reducing the income gaps between retirement and working ages. Although the

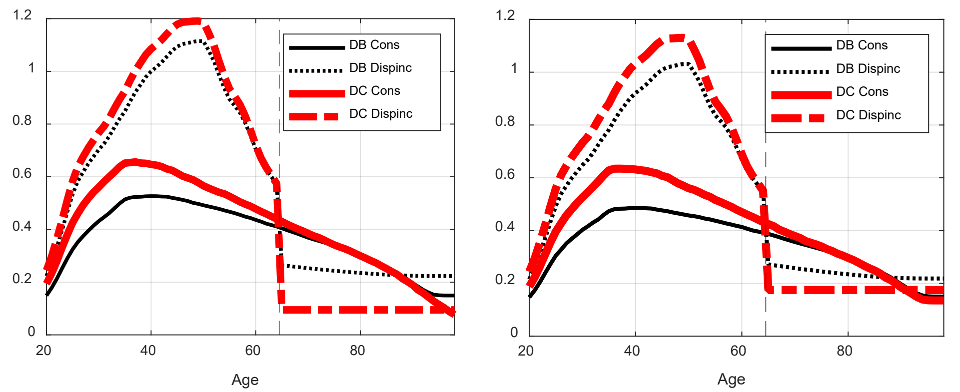

FIGURE 8. COMPARISON OF DB-DC LIFECYCLES IN 2070: 9% (LEFT) AND 18% (RIGHT) CONTRIBUTION RATES

Note: The vertical dashed line indicates the age of retirement.

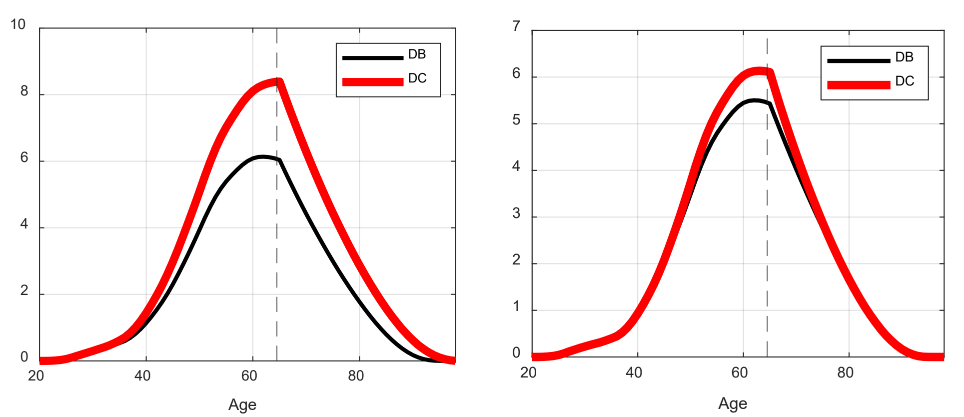

FIGURE 9. COMPARISON OF DB-DC ASSET LIFECYCLES IN 2070: 9% (LEFT) AND 18% (RIGHT) CONTRIBUTION RATES

Note: The vertical dashed line indicates the age of retirement.

disposable income Gini coefficient is lower in DB as the contribution rate increases, the improvement is more significant in DC. On the other hand, the gap in consumption Gini coefficients between the two pension systems widens. While an increase in the contribution rate also reduces the consumption of working-age people in the DC case, for DB, the economic contraction affects working-age people more, leading to a greater improvement in consumption inequality in DB.

One of the weaknesses often cited in relation to DC systems is the inability of these systems to redistribute income in life in later, though this is only partially true. Admittedly, the DC case, in contrast to the Korean DB system that equally weighs the A and B values in the benefit, are based on the concept that individuals contribute and receive only as much as they invest. This suggests that DC would have higher income inequality in retirement. However, the Gini coefficient of retirement disposable income is actually lower for the DC than the DB case. Although the Gini coefficient of retirement disposable income for DC increases when the contribution rate rises to 18%, it is still lower than that of DB.

The reason for this lower inequality in retirement disposable income in the DC case is that everyone's benefit level is very low in the DC system, as shown in Figure 8.[18] Of course, raising the contribution rate until the level of retirement disposable income in DC is similar to that in DB could make the Gini coefficient of retirement disposable income in the DC case higher, but the feasibility of this approach is doubtful given the common notion that an 18% contribution rate is already too burdensome for households in Korea. Thus, while it is plausible that DC reforms could widen the social gap between the working- and retirement-age groups, leading to greater overall inequality than in the DB case, it is important to examine further whether inequality within the retirement-age group itself will worsen.

C. *Analyzing the Universal Pension Policy under DC*

As we have seen, one of the main problems with the DC system is not the redistribution of income in retirement but rather the generally low level of retirement income. We find that DC could be worse than DB in terms of the income replacement rate, return ratio, disposable income at retirement age, and after-tax income at retirement age. We also find that the Gini coefficient of consumption in retirement age is higher in DC, primarily because pension benefits are too low in DC, causing households to rely more on savings for consumption. As a solution to these problems, we propose expanding government fiscal support for retirement-age individuals. For simplicity, we assume a universal pension that provides the same amount of transfer payments to all retirement-age groups.[19] The Basic Pension is assumed to be reduced based on the sum of the National Pension and the universal pension. We also consider this universal pension when calculating the income replacement rates.

Unlike the DB case, the DC case is not financially problematic; however, the

[18]The higher Gini coefficient of retirement consumption for the DC system is also due to the fact that retirement age income is so low that they rely primarily on savings for consumption, while savings inequality is higher than that of the pension benefit.

[19]How to implement these subsidies in the real world through the Basic Pension system is left for future research.

DC system's pension benefits are highly sensitive to decreases in interest rates. Additionally, the increase in savings in preparation for such situations can further decrease pension benefits through additional decreases in interest rates. Although it is inevitable that interest rates and pension benefit levels will fall due to the initial decline in the labor force per capita, we suggest expanding the universal pension to mitigate the phenomenon of households increasing their savings even more to prepare for their own retirement, which in turn lowers the level of benefits. The reason this study proposes this solution instead of increasing the contribution rate further to 18% is to emphasize the need for structural reform by making a direct comparison with the current DB pension system in an equalized environment. We have already shown that a government transfer of 9-11% of GDP to the pension each year would be necessary to maintain the DB in the 2070 demographic environment. If such policy is feasible, it may be realistic as well to provide a smaller fraction of this transfer as a universal pension under the DC system. Model experiments can be used to determine the amount of the additional universal pension benefit needed to achieve the welfare effects of the DB system.

To determine whether DC is better than DB, we will use the following criteria, referred to as the "key indicators:" (1) the average standard of living at working age (consumption and after-tax income), (2) the average standard of living at retirement age (consumption, after-tax income, income replacement rate, and gross return ratio), and (3) inequality within the retirement-age group (consumption and disposable income Gini coefficients). Because this analysis relies on consumption tax as the main source of government revenue, average disposable income that does not consider consumption tax is not a good measure of welfare. Moreover, given that after-tax income can be negative in reality, we will consider disposable income instead of after-tax income for the Gini coefficient. We also exclude the inequality index within the working-age group to focus on the pension and welfare of the retirement-age group. However, readers are free to use their own criteria to compare pension systems.

For the 2070 demographic environment and the given contribution rate, we experimented on the DC system by a adding universal pension amounting to only a fraction of the 100% of the government transfer needed to maintain the DB system.[20] The results of the key indicators in Table 8, Table 9, Figure 10, and Figure 11 show that at a contribution rate of 9% in 2070, DC needs less than 90% of the government transfer required to maintain DB to improve the key indicators compared to DB. At an 18% contribution rate, a subsidy of less than 60% is sufficient to improve the key indicators.[21]

The primary reason why DC is more efficient overall than DB after accounting for government subsidies is that the total output and after-tax income are inherently higher in the DC case. Even without the supplemental universal pension, total output and after-tax income are higher in DC than in DB, meaning that the main issue with DC remains redistribution. As we have seen, there is an amplifying effect between interest rates, pension benefits, and household savings in the DC case, which can lead to a larger income gap between working and retirement ages than in the DB

[20]Therefore, for the same weight (%), the subsidy is larger at a 9% contribution rate than at an 18% contribution rate.

[21]Consumption and disposable income Gini coefficients, working-age consumption and disposable income Gini coefficients worsen.

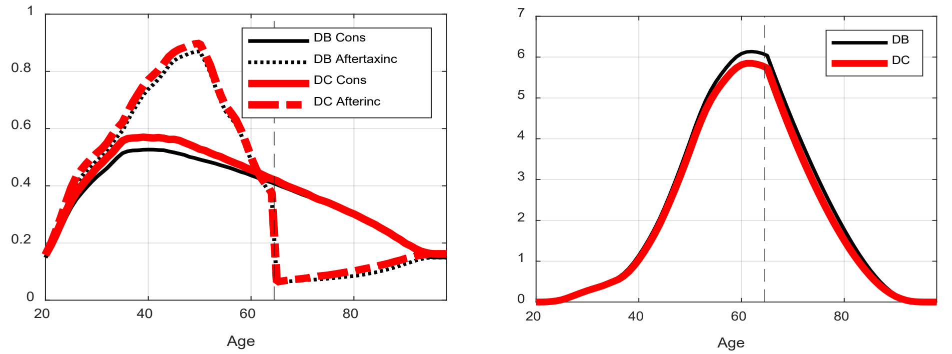

FIGURE 10. DB VS DC (90% SUPPLEMENTAL) AFTER-TAX INCOME-CONSUMPTION (LEFT) AND SAVINGS (RIGHT): 9% CONTRIBUTION RATE

Note: The vertical dashed line indicates the age of retirement.

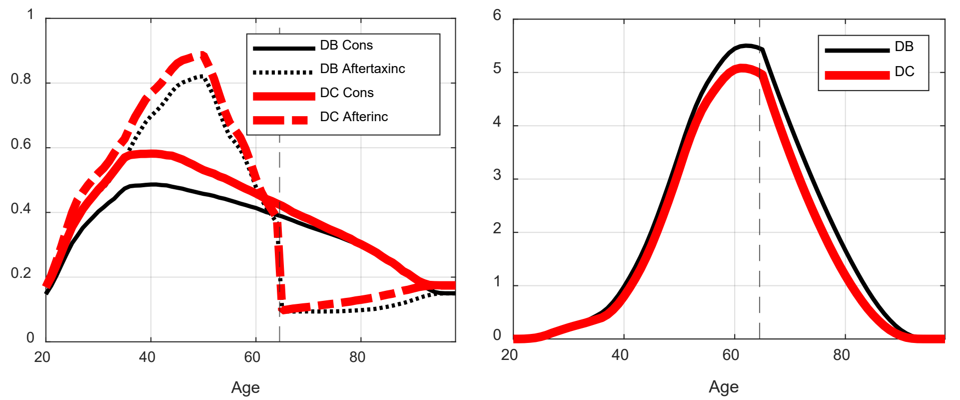

FIGURE 11. DB VS DC (60% SUPPLEMENTAL) AFTER-TAX INCOME - CONSUMPTION (LEFT) AND SAVINGS (RIGHT): 18% CONTRIBUTION RATE

Note: The vertical dashed line indicates the age of retirement

case. However, this amplifying effect also means that even a small government subsidy can significantly reduce the gap. Geometrically speaking, the capital supply curve of DC is steeper than that of DB, which means that it is possible to reduce the gap in living standards between the working-age and retirement-age groups by raising interest rates and lowering wage rates with less government transfer. If the contribution rate increases, although the after-tax income of the working-age group will decrease, the retirement-age group will need even less financial support through the universal pension due to the higher DC pension benefit.

The second reason is that when the fund rate of return is higher than the nominal growth rate (interpreted as nominal wage growth plus population growth rates) and the population structure is aging, the pay-as-you-go (PAYGO) system becomes very inefficient in the long run.[22] For example, if we assume that the same amount of

[22]The fact that funded system is better than the PAYGO system if the fund rate of return is higher than the sum of population growth and wage growth rates is called the Aaron (1966) condition.

government transfer goes to the DC economy as to the DB economy, the relative efficiency of each system for a given contribution rate is theoretically determined by the difference between the fund rate of return and the nominal growth rate. In this analysis, we assume that wage growth is $g_z = 0$ and assume as well a negative population growth rate $(g_\mu < 0)$ consistent with a larger population of several age groups than younger groups, with fund rates of return between 0% and 0.5% (depending on the size of the universal pension). Although the fund rate of return is affected by the assumption of 0% foreign interest rates, this analysis assumes a smaller gap between the fund rate of return and wage growth than in general pension projections, which is less favorable for the DC case.[23] In such a situation where the fund rate of return is greater than the nominal growth rate, the PAYGO system

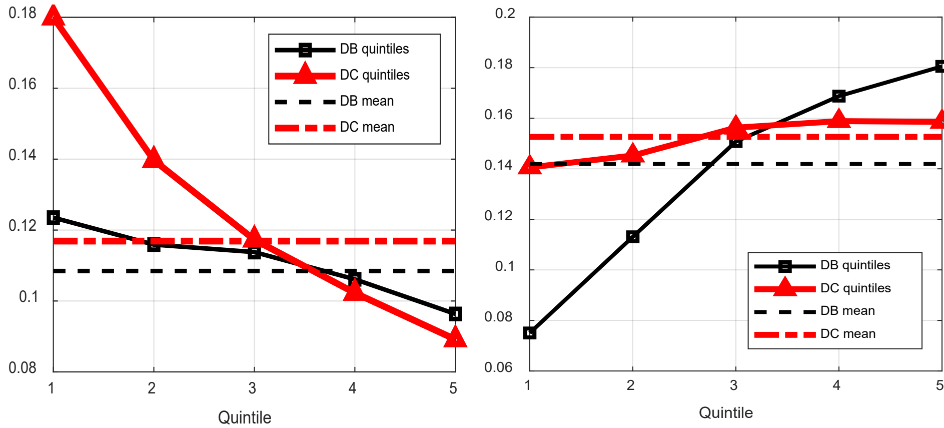

FIGURE 12. DB VS DC (90% SUPPLEMENTAL) GROSS RETURN RATIO (LEFT) AND INCOME REPLACEMENT RATE (RIGHT): 9% CONTRIBUTION RATE

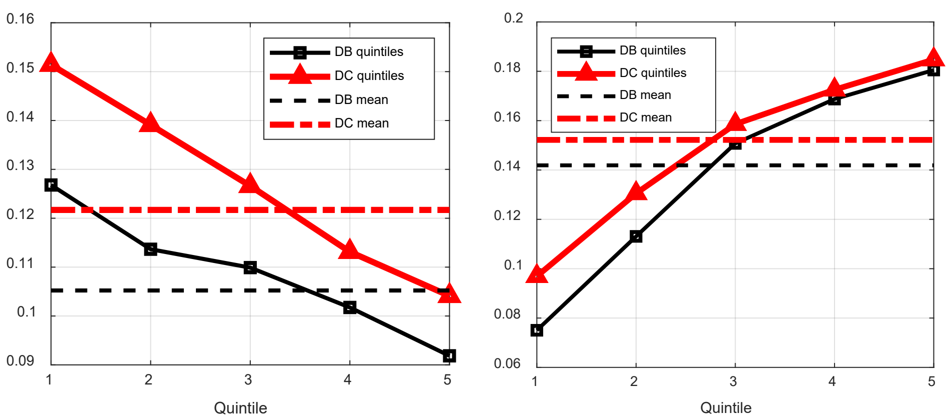

FIGURE 13. DB VS DC (60% SUPPLEMENTAL) RETURN RATIO (LEFT) AND INCOME REPLACEMENT RATE (RIGHT): 18% CONTRIBUTION RATE

[23]The Fifth Government Pension Projection assumes a long-term nominal wage growth rate of 3.7% and a fund rate of return of 4.5%.

becomes increasingly inefficient as the demographic structure ages. This inefficiency arises because a smaller number of working-age individuals must support a larger number of retirement-age individuals without benefiting from of high fund rate of return. A mathematical explanation of this phenomenon is provided in the Appendix.

Regarding inequality within the retirement-age group, we initially observe that the Gini coefficient of disposable income is already lower in the DC case without a government subsidy compared to the DB case. This occurs simply because DC has lower benefit levels. Conversely, the Gini coefficient for consumption at retirement age is higher in DC, which is interpreted as a result of the higher dependence of consumption on savings. Therefore, increasing the level of disposable income through the universal pension while lowering the Gini coefficient of disposable income can lower the Gini coefficient of consumption. An increase in the universal pension lowers the Gini coefficient of disposable income because it raises the living standard of everyone within the retirement age group by the same amount. It is likely that the Gini coefficient of consumption will also be reduced, unless an interest rate increase due to lower household saving leads to a very strong increase in the variance of pension benefits.

Furthermore, we analyzed the gross return ratio and income replacement rate of the combined universal and DC National Pension by lifecycle income quintiles, whose present values are calculated with the discount factor $1/\beta - 1$. The results show that the inequality in the gross return ratio improves, as indicated by the lower slope of the quintile figures for DC compared to DB, as shown in Figure 12. Similarly, the inequality in the income replacement rate improves, as the slope of the quintile figures for DC is also lower than that of DB, as shown in Figure 13.

TABLE 8. 2070 DC+UNIVERSAL PENSION, 9% CONTRIBUTION RATE

	DB	DC	DC Univ. 60%	DC Univ. 70%	DC Univ. 80%	DC Univ. 90%	DC Univ. 100%
Gross Product	0.683	0.750	0.739	0.728	0.718	0.708	0.698
Capital (demand)	2.598	3.376	3.239	3.107	2.984	2.868	2.765
Capital (household)	2.598	3.648	2.781	2.650	2.528	2.412	2.310
Consumption	0.369	0.411	0.395	0.392	0.389	0.386	0.382
Disposable Income	0.515	0.466	0.509	0.514	0.520	0.525	0.531
After-tax Income	0.331	0.360	0.353	0.352	0.351	0.349	0.347
Labor	0.597	0.597	0.597	0.597	0.597	0.597	0.597
K/N	4.348	5.651	5.422	5.200	4.994	4.800	4.628
Interest Rate	0.015	0.000	0.002	0.004	0.007	0.009	0.011
Wage Rate	0.731	0.804	0.792	0.780	0.769	0.758	0.748
Income Tax	0.040	0.043	0.043	0.042	0.041	0.041	0.040
Consumption Tax	0.183	0.106	0.156	0.162	0.169	0.176	0.184
Capital Tax	0.015	0.000	0.003	0.005	0.008	0.010	0.012
Death Tax	0.009	0.016	0.009	0.009	0.008	0.007	0.007
Government Spending	0.117	0.117	0.117	0.117	0.117	0.117	0.117
Pension Spending	0.095	0.035	0.035	0.036	0.036	0.036	0.037
Pension Contribution	0.018	0.019	0.019	0.019	0.018	0.018	0.018
Pension Fund	0.000	0.930	0.928	0.926	0.924	0.922	0.921
Basic Pension	0.017	0.014	0.012	0.012	0.013	0.013	0.013
Universal Pension	0.000	0.000	0.046	0.054	0.062	0.070	0.077
Income Replacement Rate	0.142	0.048	0.113	0.126	0.139	0.153	0.166
Pension Return Ratio (beta)	0.988	0.332	0.339	0.347	0.355	0.363	0.371
Gross Return Ratio (beta)	0.108	0.063	0.098	0.105	0.111	0.117	0.123
Pension Return Ratio	2.197	1.000	0.978	0.955	0.933	0.911	0.892
Gross Return Ratio	0.222	0.177	0.258	0.263	0.266	0.268	0.270
Gini Consumption	0.264	0.288	0.276	0.271	0.265	0.260	0.255
Gini Disposable	0.408	0.544	0.451	0.431	0.413	0.396	0.380
Gini Asset	0.577	0.546	0.593	0.601	0.609	0.617	0.624
Consumption (work)	0.444	0.529	0.501	0.492	0.483	0.474	0.466
Disposable (work)	0.806	0.858	0.849	0.840	0.832	0.823	0.816
After-tax (work)	0.585	0.721	0.652	0.637	0.622	0.607	0.592
Asset (work)	2.866	3.759	3.050	2.934	2.827	2.725	2.633
Income Tax (work)	0.081	0.089	0.088	0.086	0.085	0.084	0.083
Consumption Tax (work)	0.221	0.137	0.197	0.204	0.210	0.217	0.223
Gini Consumption (work)	0.227	0.223	0.223	0.222	0.221	0.220	0.220
Gini Disposable (work)	0.303	0.305	0.305	0.304	0.304	0.304	0.304
Gini Capital (work)	0.595	0.593	0.612	0.614	0.617	0.619	0.622
Consumption (ret)	0.298	0.299	0.296	0.298	0.300	0.302	0.304
Disposable (ret)	0.239	0.095	0.186	0.205	0.224	0.243	0.261
After-tax (ret)	0.091	0.018	0.070	0.082	0.094	0.105	0.115
Asset (ret)	2.343	3.541	2.526	2.381	2.244	2.116	2.004
Income Tax (ret)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Consumption Tax (ret)	0.148	0.077	0.116	0.123	0.131	0.138	0.146
Gini Consumption (ret)	0.252	0.266	0.248	0.242	0.236	0.231	0.226
Gini Disposable (ret)	0.152	0.044	0.045	0.047	0.048	0.050	0.051
Gini Asset (ret)	0.543	0.486	0.561	0.574	0.588	0.601	0.614
Population	0.770	0.770	0.770	0.770	0.770	0.770	0.770
Population (work)	0.375	0.375	0.375	0.375	0.375	0.375	0.375
Population (ret)	0.395	0.395	0.395	0.395	0.395	0.395	0.395

Note: "Return Ratio" is the present value ratio of benefits to contributions using the domestic interest rate as the discount rate. "Pension" only considers the National Pension, "Gross" considers government the fiscal sector as well, and "(beta)" takes uses the discount rate $1/\beta-1$ to calculate the present value; Normalized to per capita figures. Here, "(work)" denotes working age and "(ret)" denotes retirement age. Except for the Gini coefficients and population, variables in (work) and (ret) are normalized using their respective populations; "Univ. 30%," for example, means that 30% of the DB system's deficit amount of government transfer is used in the universal pension case.

TABLE 9. 2070 DC+UNIVERSAL PENSION, 18% CONTRIBUTION RATE

	DB	DC	DC Univ. 20%	DC Univ. 30%	DC Univ. 40%	DC Univ. 50%	DC Univ. 60%
Gross Product	0.658	0.750	0.742	0.735	0.728	0.721	0.714
Capital (demand)	2.342	3.376	3.270	3.188	3.105	3.022	2.943
Capital (household)	2.342	2.513	2.353	2.273	2.191	2.110	2.032
Consumption	0.352	0.402	0.399	0.397	0.394	0.392	0.390
Disposable Income	0.488	0.488	0.496	0.499	0.503	0.506	0.510
After-tax Income	0.326	0.368	0.367	0.366	0.365	0.364	0.363
Labor	0.597	0.597	0.597	0.597	0.597	0.597	0.597
K/N	3.921	5.651	5.473	5.336	5.197	5.059	4.927
Interest Rate	0.021	0.000	0.002	0.003	0.004	0.006	0.007
Wage Rate	0.705	0.804	0.795	0.787	0.780	0.772	0.765
Income Tax	0.038	0.043	0.043	0.042	0.042	0.042	0.041
Consumption Tax	0.161	0.120	0.129	0.133	0.137	0.142	0.147
Capital Tax	0.020	0.000	0.002	0.004	0.005	0.007	0.009
Death Tax	0.008	0.008	0.007	0.007	0.006	0.006	0.006
Government Spending	0.117	0.117	0.117	0.117	0.117	0.117	0.117
Pension Spending	0.092	0.070	0.071	0.071	0.071	0.072	0.072
Pension Contribution	0.034	0.039	0.038	0.038	0.037	0.037	0.037
Pension Fund	0.000	1.860	1.857	1.854	1.851	1.849	1.846
Basic Pension	0.017	0.020	0.017	0.017	0.016	0.016	0.015
Universal Pension	0.000	0.000	0.012	0.017	0.023	0.029	0.035
Income Replacement Rate	0.142	0.095	0.113	0.122	0.132	0.142	0.152
Pension Return Ratio (beta)	0.494	0.332	0.337	0.342	0.347	0.352	0.358
Gross Return Ratio (beta)	0.105	0.097	0.104	0.108	0.113	0.117	0.122
Pension Return Ratio	0.960	1.000	0.983	0.969	0.955	0.940	0.926
Gross Return Ratio	0.192	0.272	0.281	0.284	0.287	0.289	0.291
Gini Consumption	0.248	0.280	0.276	0.273	0.270	0.266	0.262
Gini Disposable	0.390	0.456	0.437	0.426	0.414	0.403	0.391
Gini Asset	0.570	0.585	0.591	0.594	0.598	0.602	0.607
Consumption (work)	0.415	0.514	0.506	0.500	0.494	0.487	0.481
Disposable (work)	0.750	0.818	0.812	0.806	0.801	0.795	0.789
After-tax (work)	0.559	0.665	0.648	0.639	0.629	0.619	0.608
Asset (work)	2.542	2.755	2.617	2.546	2.472	2.400	2.328
Income Tax (work)	0.078	0.089	0.088	0.087	0.086	0.085	0.084
Consumption Tax (work)	0.191	0.154	0.163	0.168	0.172	0.177	0.181
Gini Consumption (work)	0.215	0.220	0.221	0.221	0.221	0.221	0.220
Gini Disposable (work)	0.293	0.295	0.295	0.294	0.294	0.294	0.294
Gini Capital (work)	0.594	0.607	0.607	0.608	0.608	0.609	0.611
Consumption (ret)	0.292	0.296	0.298	0.299	0.300	0.302	0.303
Disposable (ret)	0.239	0.175	0.196	0.208	0.220	0.233	0.245
After-tax (ret)	0.106	0.086	0.100	0.107	0.115	0.123	0.131
Asset (ret)	2.153	2.283	2.103	2.014	1.925	1.835	1.751
Income Tax (ret)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Consumption Tax (ret)	0.134	0.088	0.096	0.100	0.105	0.109	0.114
Gini Consumption (ret)	0.240	0.253	0.250	0.247	0.244	0.241	0.237
Gini Disposable (ret)	0.153	0.104	0.115	0.118	0.120	0.119	0.117
Gini Asset (ret)	0.532	0.547	0.557	0.563	0.570	0.579	0.587
Population	0.770	0.770	0.770	0.770	0.770	0.770	0.770
Population (work)	0.375	0.375	0.375	0.375	0.375	0.375	0.375
Population (ret)	0.395	0.395	0.395	0.395	0.395	0.395	0.395

Note: "Return Ratio" is the present value ratio of benefits to contributions using the domestic interest rate as the discount rate. "Pension" only considers the National Pension, "Gross" considers government fiscal sector as well, and "(beta)" takes uses discount rate $1/\beta - 1$ to calculate the present value; Normalized to per capita figures. Here, "(work)" denotes working age and "(ret)" denotes retirement age. Except for the Gini coefficients and population, variables in (work) and (ret) are normalized using their respective populations; "Univ. 30%," for example, means that 30% of the DB system's deficit amount of government transfer is used in the universal pension case.

VI. Conclusion

This study examines the challenges of continuing the DB pension system in the 2070 demographic environment and the effects of reforming to a DC pension system using a stationary general equilibrium model with overlapping generations. In so doing, we confine our analysis to long-term effects, abstracting from the transition path analysis of the DC reform.

First, if the DB system continues with the aging demographics projected for 2070, it will require 11.3% of GDP in government fiscal support each year at a 9% contribution rate and 8.8% of GDP if the contribution rate rises to 18%. Under the same demographic conditions in 2070, replacing the DB system with a DC system and assuming no net foreign income, would improve the gross product and the average living standard of the working-age group. However, it would also deteriorate the living standard of the elderly, leading to a widening gap between age groups compared to the DB system. If the DC system is supplemented by a universal pension, the average living standards of both working- and retirement-age groups, as well as inequality indicators within the retirement-age group, can be improved by using only a fraction of the financial support required for the DB pension system. Additionally, the DC pension could potentially improve further if there is positive net foreign income.

This study does not aim to identify the optimal pension system. Instead, we focus on demonstrating that parametric reforms that merely maintain the current DB pension system and double the contribution rate are fiscally inefficient in the long run. We propose a policy combining a DC system with a universal pension as a comparison. We do not discuss what contribution rates are optimal for the DC system, which could be an interesting topic for future research.

There may also be policies that are superior to the combination of DC and a universal pension within the stationary equilibrium framework. For example, exploring the effects of reducing the current DB pension system and replacing it with a universal pension could be an interesting research topic. Adding automatic stabilizers to the current DB pension system or incorporating a PAYGO flavor into the DC pension system through a notional defined contribution (NDC) system are also worthy of further study.

However, reality deviates significantly from stationary equilibrium, and a stationary equilibrium analysis alone does not capture the dynamic responses to population shocks. For example, along a transition path to stationary equilibrium, unexpected fertility declines or longevity shocks may deteriorate the return ratio of a PAYGO pension benefit, leaving some generations disproportionately worse off than others. The optimal pension system cannot be fully discussed without considering this dynamic perspective.

Even from this dynamic point of view, extreme DB systems like that of Korea have serious problems: they are not financially resilient to various shocks, and PAYGO pension systems without adequate funding cannot avoid lower pension return ratios. Conversely, even in a country with one of the lowest fertility rates in the world, DC pension systems ensure financial stability and a stable pension return ratio because reserves always exist. While the risk to old-age income in DC systems mainly comes from the fund rate of return, in reality, unlike in our model, the proportion of foreign investment is determined endogenously, which makes it possible to hedge against domestic shocks. Therefore, the analysis within this study's equilibrium framework may underestimate the benefits of the DC pension system.

APPENDIX

Assuming a fixed mortality rate, the budget constraint for the DC pension fund with growth adjusted for population and wage growth looks like

$$\alpha_t Ex_t + (1+g_z)(1+g_z)S_{t+1} = (1+r)S_t + \mathrm{Re}v_t \quad .$$

t : year

g_z : wage growth rate

g_μ : population growth rate

r : fund rate of return

Ex_t : DC yearly expenditure per capita (when the return ratio is 1)

$\mathrm{Re}v_t$: DC yearly contribution per capita

S_t : DC fund per capita

α_t : return ratio factor (in DC, by definition, $\alpha_t = 1$)

In this context, adjusting the growth rate means that the following equations hold in long-run equilibrium:

$$Ex_t = Ex_0 \times [(1+g_z)(1+g_\mu)]^t ,$$
$$\mathrm{Re}v_t = \mathrm{Re}v_0 \times [(1+g_z)(1+g_\mu)]^t ,$$
$$S_t = S_0 \times [(1+g_z)(1+g_\mu)]^t .$$

The long-run equilibrium equation without t is

$$\alpha Ex - \mathrm{Re}v = S[(1+r)-(1+g_z)(1+g_\mu)] \approx S(r - g_z - g_\mu) .$$

The pension fiscal deficit (left) is equal to the "real" interest rate (right) expressed as the difference between the fund rate of return (r) and the nominal growth rate $(g_z + g_\mu)$. Assuming that the contribution rate Is fixed and that $\mathrm{Re}v$ is fixed as well, the equation leads to the following conclusions.

Proposition 1. If $r > g_z + g_\mu$, the DC benefit is higher than in a fully unfunded PAYGO system; i.e., in DC plan $S > 0$, $\alpha Ex - \mathrm{Re}v > 0$, and $\alpha = 1$, whereas in an unfunded system, $\hat{S} = 0$ and $\hat{\alpha} = \frac{\mathrm{Re}v}{Ex} < 1$.

Proposition 2. If $r > g_z + g_\mu$, a larger $r - g_z - g_\mu$ means a larger the gap in pension benefits between the DC and the PAYGO system. We refer to this as the "real interest rate effect."

Finally, one aspect that is not obvious from the equations above is that as the aggregate fertility rate falls, not only does g_μ go down, generating the real interest rate effect, but the population structure ages as well, widening the pension benefit gap between the DC system and the PAYGO system. We refer to the latter as the "population structure effect."

TABLE A1. DC BENEFIT CALCULATION PROCEDURE

i	F_i (beginning of year fund)	$\tilde{F}_i$ (year-end account by cohort)
1	0	v_1
2	$\tilde{F}_1(1+g_z)^{-1}\mu_2/(1-\gamma_1)$	$v_1(1+\tilde{r})/(1-\gamma_1)+v_2$
3	$\tilde{F}_2(1+g_z)^{-1}\mu_3/(1-\gamma_2)$	$v_1(1+\tilde{r})^2/[(1-\gamma_1)(1-\gamma_2)]+v_2(1+\tilde{r})/(1-\gamma_2)+v_3$
$\vdots$	$\vdots$	$\vdots$
i_R-1	$\vdots$	$\bar{B}\equiv v_1(1+\tilde{r})^{n-1}/[(1-\gamma_1)\cdots(1-\gamma_{n-1})]+\cdots+v_{i_R-1}$
i_R	$\tilde{F}_{i_R-1}(1+g_z)^{-1}\mu_{i_R}/(1-\gamma_{i_R-1})$ $=\bar{B}(1+g_z)^{-1}\mu_{i_R}/(1-\gamma_{i_R-1})$	$\bar{B}(1+\tilde{r})/(1-\gamma_{i_R-1})-\xi=\tilde{B}-\xi$
i_R+1	$\vdots$	$\tilde{B}(1+\tilde{r})^{I-i_R}/[(1-\gamma_{i_R})\cdots(1-\gamma_{I-1})]-\xi(1+\tilde{r})^{I-i_R}/[(1-\gamma_{i_R})\cdots(1-\gamma_{I-1})]-\cdots-\xi$
$\vdots$	$\vdots$	$\vdots$
I	$\cdots$	$\tilde{B}(1+\tilde{r})^{I-i_R}/[(1-\gamma_{i_R})\cdots(1-\gamma_{I-1})]-\xi(1+\tilde{r})^{I-i_R}/[(1-\gamma_{i_R})\cdots(1-\gamma_{I-1})]-\cdots-\xi$

Note: v_i refers to the average contribution of age i; $\xi=\xi(\bar{B})$, $1+\tilde{r}=(1+\hat{r})/(1+g_z)$.

TABLE A2. INITIAL DISTRIBUTION OF LABOR HOURS

	$l=1$	$l=2$	$l=3$
Density	0.992	0.004	0.004

TABLE A3. TRANSITION FUNCTION FOR HOURS WORKED FOR AGES 20-34

	Future $l'=1$	Future $l'=2$	Future $l'=3$
Current $l=1$	0.842	0.132	0.026
Current $l=2$	0.041	0.513	0.446
Current $l=3$	0.121	0.042	0.837

TABLE A4. TRANSITION FUNCTION FOR HOURS WORKED FOR AGES 35-49

	Future $l'=1$	Future $l'=2$	Future $l'=3$
Current $l=1$	0.917	0.031	0.052
Current $l=2$	0.424	0.167	0.408
Current $l=3$	0.010	0.014	0.976

TABLE A5. TRANSITION FUNCTION FOR HOURS WORKED FOR AGES 50-64

	Future $l'=1$	Future $l'=2$	Future $l'=3$
Current $l=1$	0.927	0.058	0.015
Current $l=2$	0.627	0.254	0.118
Current $l=3$	0.024	0.044	0.933

TABLE A6. CALIBRATION RESULTS

	Variables	Value	Rationale
μ_i	Population density by age	-	National Statistics Future Population Projections (2021)
γ_i	Mortality rate by age	-	National Statistics Future Population Projections (2021)
β	Time discount rate	0.97	$K/Y=3$ (Lee *et al.*, 2019)
σ_u	CRRA factor	1.5	Literature Hong *et al.* (2016) Lee *et al.* (2019)
ρ_x	Autoregressive coefficients of AR(1) heterogeneous labor productivity shocks	0.92	Chang *et al.* (2018) Lee *et al.* (2019)
σ_x	Variance of AR(1) heterogeneous labor productivity shocks	0.05	Lee *et al.* (2019)
ε_i	Average labor productivity by age	-	Wages and working hours by age from the Korean Labor Panel (2019)
Λ^{20-34} Λ^{35-49} Λ^{50-64}	Labor time transition matrix	-	National Pension Enrollment Period Data (2022) by age provided by the Ministry of Health and Welfare; Working hours according to the Korea Labor Panel (2019)
θ	Capital gains share	0.36	Hong *et al.* (2016)
δ	Depreciation rate	0.08	Hong *et al.* (2016)
τ_l	Income tax progressivity	0.0365	Seok and You (2018)
λ_l	Income tax level factor	0.915	Tax revenue as a percentage of GDP in 2022 (5.96%)
τ_k	Corporate tax	0.399	Tax revenue as a percentage of GDP in 2022 (4.79%)
τ_c	VAT	0.068	Tax revenue as a percentage of GDP in 2022 (3.78%)
$\widehat{\tau_{ss}}$	Contribution rate for 2022	0.050	Contribution as a percentage of GDP in 2022 (2.59%)
k	Income Cap Constant	1.519	Capped contributors (13.5%)
α	Pension Income Replacement Coefficient	0.672	$1.2\times\widehat{\tau_{ss}}/0.09$
$\overline{\varphi}$	Basic Pension standard	0.053	Spending as a percentage of GDP in 2022 (0.75%)
z	Total Factor Productivity	0.673	$Y=1$
$\overline{g}$	Government spending as relative to population	0.152	Government budget constraint in the model

TABLE A7. NATIONAL PENSION FUND ALTERNATIVE INVESTMENT PORTFOLIO

Portfolio	Private Equity	Real Estate	Infrastructure	Total
Total (trillion won) End of Q2 ’23	65	49.5	39.4	153.9
International (%) Late ’22	78	86.5	79	-.
International Total (trillion won)	50.7	42.8	31.1	124.6 (13.0%)

Source: Author’s derivation of the percentage of international investments by referring to publicly available data at https://fund.nps.or.kr/.

TABLE A8. NATIONAL PENSION FUND PORTFOLIO

Portfolio	International				Domestic		
	Stocks	Bonds	Alternative Investment		Alternative Investment	Other	
Ratio	30.4%	7.2%	13.0%	50.6%	3.1%	46.3%	49.4%

Source: Author’s derivation of the percentage of foreign investments by referring to publicly available data at https://fund.nps.or.kr/.

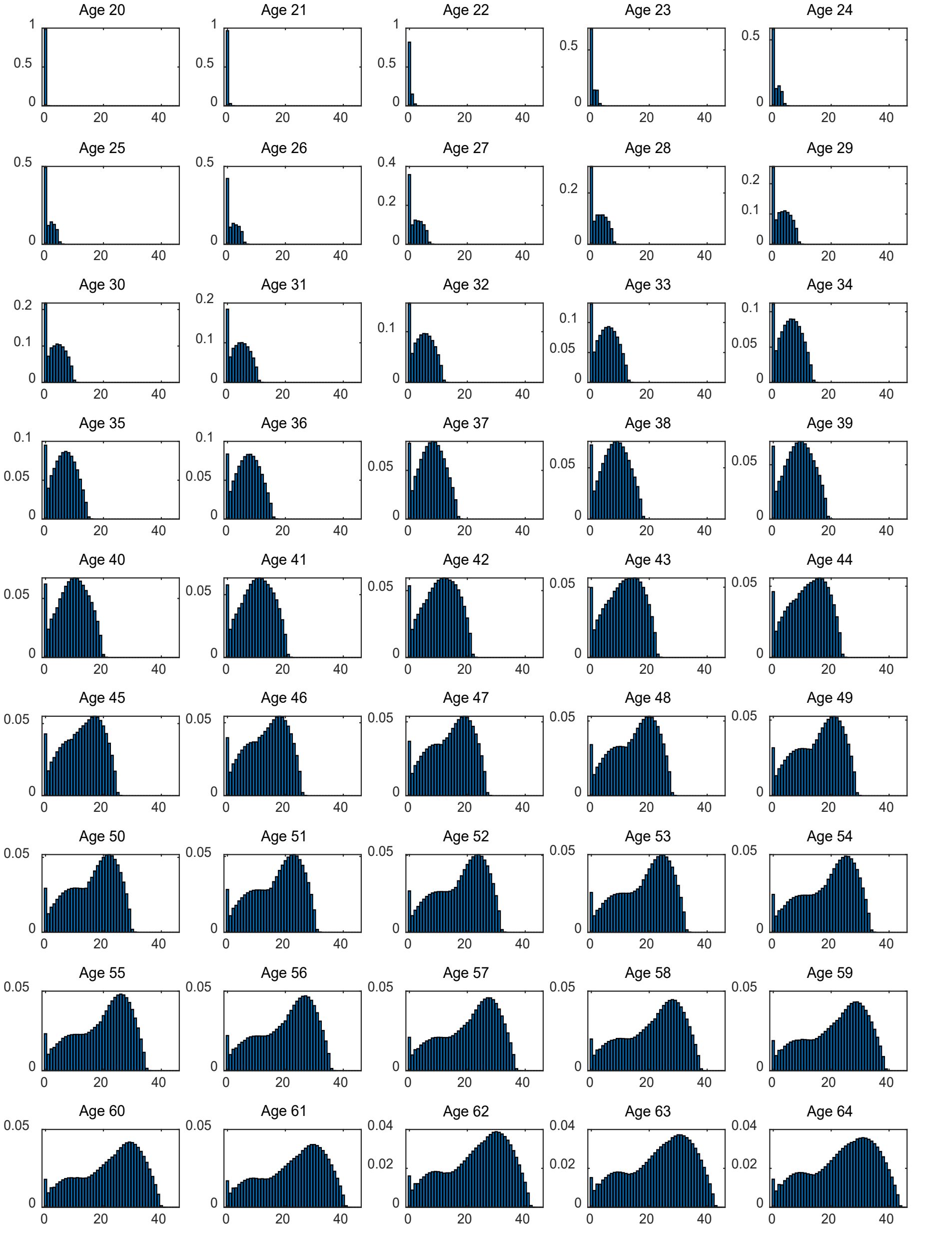

FIGURE A1. CONTRIBUTION PERIOD DENSITY OF THE MODEL

Note: The x-axis in all panels represents the contribution period.

(Unit: population)

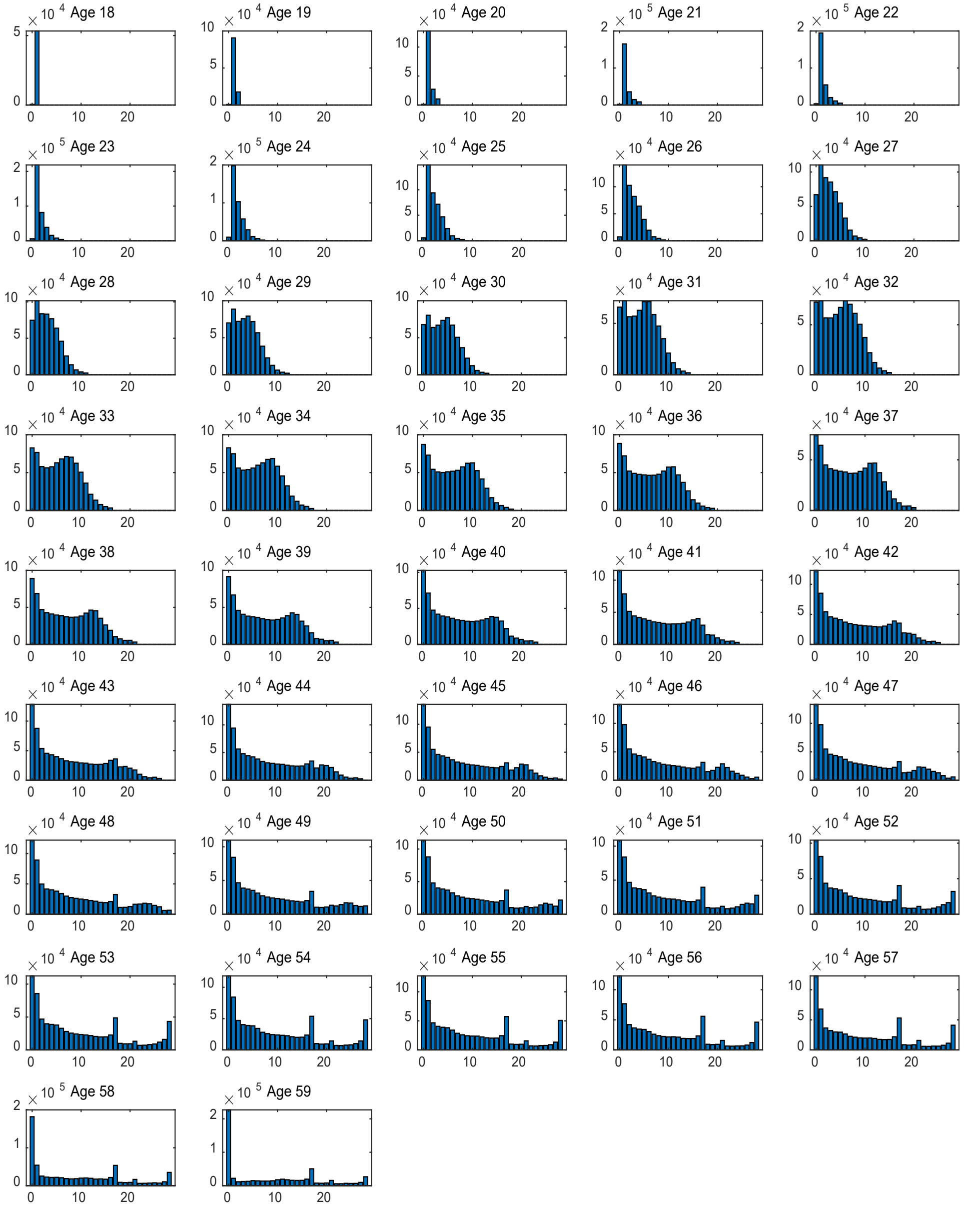

FIGURE A2. POPULATION BY AGE×ENROLLMENT PERIOD IN 2022

Note: The x-axis in all panels represents the contribution period in years.

Source: Author's calculations using 2022 data provided by the Ministry of Health and Welfare.

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