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Global Aging and Declining World Interest Rates: Macroeconomic Insurance through Pension Reform in Cyprus

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Global Aging and Declining World Interest Rates: Macroeconomic Insurance Through Pension Reform in Cyprus

Prepared by Mario Catalán, Jaime Guajardo, and Alexander W. Hoffmaister*

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Abstract

How will the world-wide decline in real interest rates associated with global aging affect small open economies (SOEs) with aging populations? Lower interest rates will result in higher capital-labor ratios and increased wages; higher wages, in turn, will be passed on to pension benefits, exacerbating aging-related fiscal pressures. The pass-through effect will be stronger if pensions are indexed to nominal wages rather than prices. Using an overlapping generations model, the paper illustrates the interest rates transmission mechanism and its interaction with pension indexation for the case of Cyprus. In addition, the paper evaluates the capacity of pension reforms to insure the economy against long-run movements in world interest rates. It concludes that pension reforms, particularly those that change the indexation of pensions from wages to prices, provide substantial macro-insurance and shock absorption benefits.

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I. INTRODUCTION

Global population aging is set to depress world real interest rates in the next three decades. Rapidly-aging large economies will experience a surge in savings as large numbers of households prepare to retire, while demand for investment will decline as labor forces around the world shrink (Brooks, 2003 and Domeij and Floden, 2006). The magnitude of the decline in global interest rates, however, is uncertain and hinges on demographic developments and pension reforms in these economies (Börsch and others, 2006).

How will the decline in world interest rates affect small open economies (SOEs) with aging populations? This paper addresses this question and also evaluates the effects of pension reforms, stressing their capacity to insure the economy against long-run movements in world interest rates. By examining the interest rate channel, this paper helps to understand the international spillover effects triggered by population aging and pension reforms in large countries.[1] Although the available literature contains a rich discussion of the impact of temporary world interest rate shocks on business cycles in small open economies,[2] the effects of long-run declines associated with population aging have not been examined; this study seeks to fill this void.

This paper shows that long-run declines in world interest rates will impinge on a SOE's ability to cope with its own demographic shock. In a nutshell, lower interest rates will induce higher capital-labor ratios and thereby increased wages. Higher wages, in turn, will boost pension benefits, exacerbating aging-related fiscal pressures. This pass-through effect will be stronger if pension benefits, and past wage earnings used to compute these benefits, are indexed to nominal wages rather than prices.

The quantitative analysis is based on an overlapping generations (OLG) model of a SOE with an aging population that trades intertemporally with the rest of the world while facing exogenously determined world interest rates. The model is calibrated for the European country whose pension expenditures are projected to increase the most, namely Cyprus.[3] Without reforms and assuming constant international interest rates, the European

[1] This paper abstracts from other channels through which aging in large economies could affect SOEs, such as those related to trade and migration.

[2] Studies in this literature include Gente and others (2006), Uribe and Yue (2006), Neumayer and Perri (2005), Hoffmaister and Roldós (2001), and Mendoza (1991).

[3] The model captures the key institutional features of the Cypriot pension system, including the different regimes for private and public employees. It also captures the effect of aging on health care spending. Specifically, health care expenditures mirror the *j*-shaped profile of health care spending over a household's life: expenditures are typically a bit higher for young children than for young adults and rise sharply later in life. This approach, however, does not account for the impact of medical advances and demand for new capital-intensive treatments (Heller, 2003), beyond those captured by technological advances in the economy.

Commission (2006) projects that pension expenditures in Cyprus' pay-as-you-go system will rise by 12.9 percentage points of GDP by 2050, compared to an average increase of less than 3 percentage points in the European Union.[4] In the same vein but using a dynamic general equilibrium approach, Hoffmaister and others (2007a) find that pension expenditures in Cyprus will rise by 10 percentage points of GDP by 2050. Also, the Cypriot case highlights the pass-through effect of lower interest rates into higher pensions and its relation to indexation. Public pensions are fully indexed to wages while private pensions are indexed to both wages and prices. Consequently, the pass-through effect is lopsided: a decline in interest rates boosts the generosity of public pensions relative to that of private pensions.The simulations discussed below underscore the role of declining world interest rates. Three interest rate scenarios combined with a no-reform baseline and five pension reform scenarios are discussed in this paper. First, a constant interest rates scenario with no pension reform confirms the macroeconomic effects of population aging in Cyprus discussed in Hoffmaister and others (2007a). This scenario shows that (consumption) tax rates will need to increase by 7 percentage points to finance an increase in pension expenditure of 7 percentage points of gross national income (GNI) by 2050.

Second, the two declining interest rates scenarios—characterized by gradual declines in world interest rates of 50 basis points and 100 basis points over three decades—lay bare the fact that future fiscal pressures and macroeconomic performance are highly sensitive to changes in world interest rates. Specifically, the 50-basis-points-decline scenario reveals the need to increase the consumption tax rate by 17 percentage points to finance a 10 percentage points increase in pension expenditure as a share of GNI. The 100-basis-points-decline scenario results in even more dire consequences: the tax rate increases by 29 percentage points while pension expenditure as a share of GNI increases by 13 percentage points. These results reflect not only the pass-through of interest rates on wages and pensions but also the endogenous response of national income, labor, capital formation, the current account, and taxes. Interestingly, the economy runs sustained large current account surpluses as the population ages in the constant interest rates scenario. But these surpluses vanish or turn into deficits in the declining world interest rates scenarios. Also, lower interest rates reduce national income (GNI) but increase domestic output (GDP) and capital formation.

Turning to pension reforms, the question arises: what reforms are more effective to insure Cyprus' macroeconomy against long-run declines in world interest rates? In this regard, this

[4] Although the recent increase in civil servants' retirement age in Cyprus will temper the increase, old-age expenditure is still set to rise by 8 percentage points of GDP (Ministry of Finance, 2006). In addition, health expenditures are also expected to rise by 1.1 percentage points of GDP by 2050; however, this increase is less than in the rest of the EU, where health expenditures are set to increase by about 1.6 percentage points.

paper considers several pension reform scenarios. Reforms include increases in the retirement age of all workers in line with projected life expectancy; cuts in the lump-sum part of pension to public workers; shifts in the indexation of all pension benefits to prices; and changes in the indexation of wage earnings used to compute pension benefits to prices.

The simulation results make clear that pension reforms, particularly those that change indexation from wages to prices, provide substantial shock absorption benefits, insuring the economy's performance against long-run interest rate declines. This result is new in the literature discussing indexation-switching, which so far has stressed the macroeconomic benefits stemming from curtailing pension expenditure and taxes. This paper shows that this reform also provides macro-insurance benefits.

The rest of the paper is organized as follows. Section II discusses the model and its calibration. Sections III presents the baseline simulations with no pension reforms for the three world interest rate scenarios. The simulations of pension reforms are discussed in Section IV. Section V concludes.

II. The Model

A. Model Overview

The framework is a small open economy version of the Auerbach-Kotlikoff model. The economy is populated by overlapping generations of finitely-lived households, atomistic firms, and an infinitely-lived government. Households consume and accumulate assets during their lifetime, work during their youth, and retire when old. Firms produce the single good in the model using labor and capital. The government collects income, consumption and payrolltaxes to finance government expenditures and pension benefits and redeem the initial government debt. Households and the government can borrow funds from (or invest funds in) international capital markets at prevailing interest rates.

Although the general equilibrium structure is standard, the model incorporates specific features of the Cypriot pension system. Specifically, the pension system is segmented: "private" households participate only in the general social insurance scheme (GSIS), whereas "public" households participate in the GSIS and in the government's pension scheme (GEPS). Households are either "private" or "public" their entire lives, and stylized versions of the corresponding pension rules are used to calculate pension contributions and benefits in the GSIS and GEPS.

Labor markets, however, are integrated and characterized by perfect competition and substitutability of private and public households' labor. All households have similar working and retirement periods, and during their work lives, are employed by competitive firms that produce the private good—there is no public good in the model. In this setting, the law of one price (wage rate) holds for given households' labor skills.[5]

In addition, life expectancy is exogenous and increases over time to match demographic projections. Although the retirement age is exogenous, labor supply is endogenous as households choose the amounts of labor and leisure time during their work life. Households' labor skills (productivity) vary exogenously with age to account for the observed hump-shapes in wage rates over years of employment in, respectively, the "private" and "public" sectors. Finally, the model incorporates labor-augmenting productivity growth that causes real wage growth over time, and explicitly accounts for the effects of aging on public health-related expenditures. The model is presented in stationary form and, for the reader's convenience, the notation is summarized in Table 1.

B. Households

Lifetime setting

The lifetime utilities of private and public households born at time t are determined by their lifetime consumption (c) and leisure (l), and are given by equations (1) and (8) in Table 2, where households' lives are characterized by two distinct phases: a work life lasting T_t years ($s = 1,...,T_t$) and a mandatory retirement lasting T_t^R years ($s = T_t + 1,...,T_t + T_t^R$). Across generations, household's life expectancy and retirement age are allowed to vary and are non-decreasing over time. The household is endowed with a fixed number of hours per year, which is normalized so that work (n) and leisure (l) add up to one in equations (2) and (9). Households accumulate assets (A) during their work lives according to the budget constraints (3) and (10), where next year's assets are determined by adding to this year's assets the household's savings, which are obtained by adding net return on assets to net wage income and subtracting consumption. As noted above, household's labor productivity per hour varies with age according to a skill premium—the model allows for differences in the skill profiles of private (e_p^s) and public (e_g^s) households. The premium reflects the productivity of an s-year old household relative to that of a 1-year old (unskilled) private household. Thus, W denotes the wage per unit of labor time of an unskilled private worker. Note that private and public households pay different contribution rates (τ^p, τ^g) and receive different pension benefits in the GSIS. In equations (3)-(6) and (10)-(13), the household takes

[5] This modeling strategy—combining pension system segmentation and labor market integration—allows us to capture some privileges associated with public sector employment while preserving the law of one price in labor markets.

as given the payroll (τ^p, τ^g), income (τ^I), and consumption (τ^c) tax rates; the international (also domestic) interest rates (r); the wage rates (W); and the basic earnings (BE).[6]

During retirement, the *private* household's wage income is replaced by *basic* (bb) and *supplementary* (bs) old-age pension benefits in the budget constraint (4). A points-based system governs the calculation of these pension benefits according to (5) and (6). Over a private household's work life, the number of points accrued is determined by the ratio of wages earned to basic earnings. In each year, the first point accrues to the basic pension and additional points count for the supplementary pension. Note that the stationary-transformed equation (4) reflects differences in indexation of basic and supplementary pension benefits after retirement. On the one hand, basic pension benefits $bb_{t+T_t}^{T_t+1}$ are indexed to the basic earnings index (BE)—which grows over time according to average nominal wage earnings[7]—and this is reflected in the adjustment factor $\frac{BE_{t+s-1}}{BE_{t+T_t}}$. On the other hand, supplementary pension benefits $bs_{t+T_t}^{T_t+1}$ are indexed to prices—and thus do not account forproductivity growth—and this is reflected in the presence of the productivity discount factor $\frac{1}{(1+\xi)^{s-T_t-1}}$.

In contrast, the *public* household's wage income is replaced in the first year of retirement—budget constraint (11)—by lump sum ($bgls$) and annual (bg) pension benefits associated with the GEPS and by basic (bbg) pension benefits associated with the GSIS.[8] The lump sum and annual pension benefits—defined by (12) and (13)—are based on public households' wage earnings in the year before retirement; basic pension benefits paid to public and private households are calculated using the same formula—defined by (5). In subsequent retirement years, the household receives annual pension benefits from the GEPS

[6] The equalization of domestic and international (real) interest rates results from the free capital mobility assumption. Also, note that income taxes are levied on labor income and asset earnings; for simplicity, these tax rates are assumed to be the same.

[7] Specifically, the basic earnings index is calculated as: $BE_t = \theta \cdot W_t \cdot \frac{\sum_{j=1}^{T_t}\left(e_p^j \cdot n_{p,t}^j \cdot P_{p,t}^j + e_g^j \cdot n_{g,t}^j \cdot P_{g,t}^j\right)}{\sum_{j=1}^{T_t}\left(n_{p,t}^j \cdot P_{p,t}^j + n_{g,t}^j \cdot P_{g,t}^j\right)}$.

[8] Note that *public* households *do not* receive *supplementary* pension benefits from the GSIS.

(bg) and basic pension benefits from the GSIS (bbg); both are indexed to the basic earnings index, as reflected in the adjustment factors $\frac{BE_{t+s-1}}{BE_{t+T_t}}$ in equation (11).[9]

The model assumes that there are no intergenerational bequests or inheritances: according to equations (7) and (14), the household is born (enters the labor force) with zero assets at age $s=1$, and dies without assets at age $s = T_t + T_t^R + 1$.

Optimization problem

The *private* household's problem is to choose the paths of consumption, leisure and asset holdings $\left\{c_{p,t+s-1}^s, l_{p,t+s-1}^s, A_{p,t+s-1}^s\right\}_{s=1}^{T_t+T_t^R}$ to maximize its lifetime utility (1) subject to constraints (2)-(7). This problem can be expressed as follows:

$$\underset{\left\{c_{p,t+s-1}^s, l_{p,t+s-1}^s, A_{p,t+s}^{s+1}\right\}_{s=1}^{T_t}}{Max} \sum_{s=1}^{T_t} \beta^{s-1} \cdot \left\{\log(c_{p,t+s-1}^s) + \gamma \cdot \log(l_{p,t+s-1}^s)\right\} + \beta^{T_t} \cdot V(A_{p,t+T_t}^{T_t+1}, bb_{t+T_t}^{T_t+1}, bs_{t+T_t}^{T_t+1})$$

subject to (2)-(7),

where $V(A_{p,t+T_t}^{T_t+1}, bb_{t+T_t}^{T_t+1}, bs_{t+T_t}^{T_t+1})$ is the private household's value function or discounted indirect utility when it retires at time $t+T_t$ having reached the age of T_t+1 years.[10] Upon retirement,

[9] For more extensive descriptions of the Cypriot pension system and its pension benefit rules, see Hoffmaister and others (2007a,b).

[10] The value function $V(A_{p,t+T_t}^{T_t+1}, bb_{t+T_t}^{T_t+1}, bs_{t+T_t}^{T_t+1})$ is the solution of the following problem:

$V(.) = \underset{\left\{c_{p,t+s-1}^s, A_{p,t+s}^{s+1}\right\}_{s=T_t+1}^{T_t+T_t^R}}{Max} \sum_{s=T_t+1}^{T_t+T_t^R} \beta^{s-1} \cdot \log(c_{p,t+s-1}^s)$ subject to (4), (7), and given $A_{p,t+T_t}^{T_t+1}$, $bb_{t+T_t}^{T_t+1}$ and $bs_{t+T_t}^{T_t+1}$. It is given by

$$V\left(A_{t+T_t}^{T_t+1}, bb_{t+T_t}^{T_t+1}, bs_{t+T_t}^{T_t+1}\right) = \left(\sum_{j=1}^{T_t^R} \beta^{j-1}\right) \cdot \log\left\{\prod_{i=1}^{T_t^R}\left(1+\tilde{r}_{t+T_t+T_t^R-i}\right) \cdot A_{t+T_t}^{T_t+1} + \left\{1 + \sum_{j=1}^{T_t^R-1}\left[\prod_{i=1}^{j}\left(1+\tilde{r}_{t+T_t+T_t^R-i}\right)\right]\right\} \cdot bs_{t+T_t}^{T_t+1}\right.$$
$$\left. + \left\{(1+\xi)^{T_t^R-1} \cdot BE_{t+T_t+T_t^R-1} + \sum_{j=2}^{T_t^R}\left[\prod_{i=1}^{j-1}\left(1+\tilde{r}_{t+T_t+T_t^R-i}\right) \cdot (1+\xi)^{T_t^R-j} \cdot BE_{t+T_t+T_t^R-j}\right]\right\} \cdot \frac{bb_{t+T_t}^{T_t+1}}{BE_{t+T_t}}\right\} - \Omega,$$

where Ω is a constant and $\tilde{r}_t = r_t \cdot (1-\tau_t^I)$. Note that $V(.)$ is also a function of future interest rates, basic earnings and income tax rates. A detailed derivation of this function can be found in Hoffmaister and others (2007b).

he household's optimization problem can be expressed recursively, and a closed-form solution for the value function (V) follows from the log utility assumption.Similarly, the public household's problem is to choose the paths of consumption, leisure and asset holdings $\left\{c_{g,t+s-1}^{s}, l_{g,t+s-1}^{s}, A_{g,t+s-1}^{s}\right\}_{s=1}^{T_t+T_t^R}$ to maximize its lifetime utility (8) subject to constraints (9)-(14).

Two sets of conditions solve the household's problem under standard dynamic optimization techniques; see Tables 3 and 4 for the first order conditions of private and public households' optimization problems. $V_A(.)$, $V_{bb}(.)$, and $V_{bs}(.)$ denote the partial derivatives of $V(.)$ with respect to $A_{p,t+T_t}^{T_t+1}$, $bb_{t+T_t}^{T_t+1}$, and $bs_{t+T_t}^{T_t+1}$.[11]

The first set—equations (15)-(18) and (24)—refers to a household's consumption-leisure choice at specific ages (intra-temporal first order conditions). In each period, the household equates the marginal utility of consumption (scaled by wages) to the marginal utility of leisure. The second set—equations (19)-(23) and (25)-(26)—governs the household's consumption-saving decisions over time (inter-temporal first order conditions or Euler equations).[12] In this case, households equate the marginal utility of current consumption to the discounted marginal utility of future consumption (scaled by the net return on savings).

These sets of equations reflect the peculiarities of the Cypriot pension rules, including whether a household is private or public, working or retired and, when working, whether wage income is higher or lower than basic earnings. Specifically, while the private household is in the labor force and wage income is *lower (higher)* than basic earnings, the consumption-leisure choice reflects the fact that household's labor effort affects its future *basic* (*supplementary*) pension benefits. Also, in the final year of the work life $(s=T_t)$, the consumption-saving decision reflects the retirement of the individual in the following period (V_A). Finally, when the household is retired $(s=T_t+1,...,T_t+T_t^R-1)$, there is no labor supply choice and only the consumption-saving decision remains.[13] Note that for public households, gross wage earnings are always greater than basic earnings in the simulations discussed below;

[11] Note that the first order conditions of the public household's optimization problem (Table 4) do not include derivatives of the value function with respect to pension benefits. Their inclusion would cause an unrealistic jump in work effort by households in the last year before retirement, reflecting the fact that the annual pension benefit formula (bg) in the GEPS is based on wage earnings in that year. To avoid inconsistencies with the data, and possibly reflecting rigidities in public employment, we assumed that public households cannot boost their future pension benefits by exerting more work effort in a single year.

[12] When a household retires, it faces only an inter-temporal condition as it no longer supplies labor.

[13] At time $t=0$ the economy is populated by households of ages $\tilde{s}=2,...,T_0+T_0^R$, which are assumed to have the same work life and retirement periods. Thus, during the first $T_0+T_0^R$ years, the model considers a number of "truncated" optimization problems associated to them.

therefore, the public household's labor effort decision does not affect its (basic) pension benefit in equation (24).

Aggregate consumption (C_t^h), effective labor supply (N_t^h), and assets (A_t^h) are obtained by aggregating individual private and public household's variables at each point in time:

$$N_t^h = N_{p,t}^h + N_{g,t}^h, \qquad N_{j,t}^h = \sum_{s=1}^{T_t} e_j^s \cdot n_{j,t}^s \cdot \frac{P_{j,t}^s}{P_t},$$

$$A_t^h = A_{p,t}^h + A_{g,t}^h, \qquad A_{j,t}^h = \sum_{s=1}^{T_t+T_t^R} A_{j,t}^s \cdot \frac{P_{j,t}^s}{P_t}, \qquad \text{where} \quad j = \{p, g\}.$$

$$C_t^h = C_{p,t}^h + C_{g,t}^h, \qquad C_{j,t}^h = \sum_{s=1}^{T_t+T_t^R} c_{j,t}^s \cdot \frac{P_{j,t}^s}{P_t},$$

C. Firms

Firms maximize profits net of capital depreciation Π_t^f. They do so subject to a constant-returns-to-scale Cobb-Douglas production function with labor-augmenting technological progress,

$$\Pi_t^f = \mathrm{Z} \cdot \left(K_t^f\right)^{\alpha} \cdot \left(N_t^f\right)^{1-\alpha} - (r_t + \delta) \cdot K_t^f - W_t \cdot N_t^f,$$

where δ is the rate of capital depreciation. Both output and factor markets are perfectly competitive and firms face given wages (W_t) and rental rates (r_t). The first order conditions require that W_t and $r_t + \delta$ equal, respectively, the marginal product of labor and capital:

$$W_t = \mathrm{Z} \cdot (1-\alpha) \cdot \left(\frac{K_t^f}{N_t^t}\right)^{\alpha}, \qquad r_t + \delta = \mathrm{Z} \cdot \alpha \cdot \left(\frac{K_t^f}{N_t^t}\right)^{-(1-\alpha)}.$$

D. The Government

The government sets taxes to ensure long-run fiscal sustainability. As noted above, the government collects payroll, income, and consumption taxes from households. Tax revenues are used to finance public consumption (*G*), pension benefits, and redeem government debt (*D*). Public consumption has two components: health-related public consumption whose evolution is driven by changes in the population's age structure; and non health-related public consumption that remains constant as a share of aggregate output. Thus, the government's budget constraint is as follows:[14]

$$D_{t+1}\cdot(1+\xi)\cdot\frac{P_{t+1}}{P_t}=(1+r_t)\cdot D_t+[G_t-\tau_t^I\cdot(r_t\cdot A_t^h+W_t\cdot N_t^h)-\tau_t^c\cdot C_t^h]+\sum_{s=T_t+1}^{T_t+T_t^R}\left[bb_{t+T_t+1-s}^{T_t+1}\cdot\frac{BE_t}{BE_{t+T_t+1-s}}+\frac{bs_{t+T_t+1-s}^{T_t+1}}{(1+\xi)^{s-T_t-1}}\right]\cdot\frac{P_{p,t}^s}{P_t}$$
$$+\sum_{s=T_t+1}^{T_t+T_t^R}\left(bbg_{t+T_t+1-s}^{T_t+1}+bg_{t+T_t+1-s}^{T_t+1}\right)\cdot\frac{BE_t}{BE_{t+T_t+1-s}}\cdot\frac{P_{g,t}^s}{P_t}+bgls_t^{T_t+1}\cdot\frac{P_{g,t}^{T_t+1}}{P_t}-\tau_t^p\cdot W_t\cdot N_{p,t}^h-\tau_t^g\cdot W_t\cdot N_{g,t}^h,$$

where, for clarity, the (non-social security) primary deficit (term in brackets), and the social security deficit (last five terms) are shown separately.

E. Equilibrium

An equilibrium simultaneously places all households and firms on their maximizing paths, establishes the solvency of the government, and clears markets. Consider an initial population of size $P_0=P_{p,0}+P_{g,0}$ with age structure $\left\{P_{p,0}^s,P_{g,0}^s\right\}_{s=1}^{T_0+T_0^R}$, a given sequence of new-born cohorts $\left\{P_{p,t}^1,P_{g,t}^1\right\}_{t=1}^{\infty}$ with work lives $\left\{T_t\right\}_{t=1}^{\infty}$ and life expectancies $\left\{T_t+T_t^R\right\}_{t=1}^{\infty}$, government debt $D_0\geq 0$, capital stock $K_0>0$, and distribution of assets $\left\{A_{p,0}^s,A_{g,0}^s\right\}_{s=1}^{T_0+T_0^R}$, such that $D_0+K_0+A_0^*=A_0^h$ and $A_0^h=A_{p,0}^h+A_{g,0}^h=\sum_{s=1}^{T_0+T_0^R}\left[A_{p,0}^s\cdot\frac{P_{p,0}^s}{P_0}+A_{g,0}^s\cdot\frac{P_{g,0}^s}{P_0}\right]$. Consider also a given path of international—and also domestic, given free capital mobility—interest rates $\left\{r_t\right\}_{t=1}^{\infty}$ and an initial value of the basic earnings index $BE_0>0$. The equilibrium is a collection of lifetime plans for both, private and public households born during the period of analysis ($t\geq 0$), $\left\{c_{p,t+s-1}^s,c_{g,t+s-1}^s,l_{p,t+s-1}^s,l_{g,t+s-1}^s,A_{p,t+s}^{s+1},A_{g,t+s}^{s+1}\right\}_{s=1}^{T_t+T_t^R}$, for $t=0,1,...,\infty$, and for those of ages 2 through $T_0+T_0^R$ at $t=0$ that face "truncated" lifetime plans $\left\{c_{p,s-\tilde{s}}^s,c_{g,s-\tilde{s}}^s,l_{p,s-\tilde{s}}^s,l_{g,s-\tilde{s}}^s,A_{p,1+s-\tilde{s}}^{s+1},A_{g,1+s-\tilde{s}}^{s+1}\right\}_{s=\tilde{s}}^{T_0+T_0^R}$, for $\tilde{s}=2,...,T_0+T_0^R$; a sequence of allocations

[14] The budget constraint, before stationary transformations, is given by

$$\widehat{D}_{t+1}=(1+r_t)\cdot\widehat{D}_t+\left[\widehat{G}_t-\tau_t^I\cdot\left(r_t\cdot\widehat{A}_t^h+\widehat{W}_t\cdot\widehat{N}_t^h\right)-\tau_t^c\cdot\widehat{C}_t^h\right]+\sum_{s=T_t+1}^{T_t+T_t^R}\left[\left(\widehat{bb}_t^s+\widehat{bs}_t^s\right)\cdot P_{p,t}^s+\left(\widehat{bbg}_t^s+\widehat{bg}_t^s\right)\cdot P_{g,t}^s\right]+\widehat{bgls}_t^{T_t+1}\cdot P_{g,t}^{T_t+1}-\tau_t^p\cdot\widehat{W}_t\cdot\widehat{N}_{p,t}^h-\tau_t^g\cdot\widehat{W}_t\cdot\widehat{N}_{g,t}^h$$

where $\widehat{bb}_t^s=\widehat{bb}_{t+T_t+1-s}^{T_t+1}\cdot\frac{\widehat{BE}_t}{\widehat{BE}_{t+T_t+1-s}}$, $\widehat{bbg}_t^s=\widehat{bbg}_{t+T_t+1-s}^{T_t+1}\cdot\frac{\widehat{BE}_t}{\widehat{BE}_{t+T_t+1-s}}$ and $\widehat{bg}_t^s=\widehat{bg}_{t+T_t+1-s}^{T_t+1}\cdot\frac{\widehat{BE}_t}{\widehat{BE}_{t+T_t+1-s}}$.

for the firms $\left\{K_t^f, N_t^f\right\}_{t=0}^{\infty}$; a sequence of relative prices of labor $\left\{W_t\right\}_{t=0}^{\infty}$; a sequence of government variables including payroll, income, and consumption tax rates, and government consumption and debt, $\left\{\tau_t^p, \tau_t^g, \tau_t^I, \tau_t^c, G_t, D_t\right\}_{t=0}^{\infty}$; and a sequence of the basic earnings index $\left\{BE_t\right\}_{t=0}^{\infty}$, such that for $t \geq 0$: firms and households solve their optimization problems; the government budget constraint is satisfied; the labor market clears,
$N_t = N_t^f = N_{p,t}^h + N_{g,t}^h = \sum_{s=1}^{T_t}\left(e_p^s \cdot n_p^s \cdot \frac{P_{p,t}^s}{P_t} + e_g^s \cdot n_g^s \cdot \frac{P_{g,t}^s}{P_t}\right)$; the asset market clears,
$K_t^f + D_t + A_t^* = A_t^h = A_{p,t}^h + A_{g,t}^h = \sum_{s=1}^{T_t+T_t^R}\left(A_{p,t}^s \cdot \frac{P_{p,t}^s}{P_t} + A_{g,t}^s \cdot \frac{P_{g,t}^s}{P_t}\right)$; and the economy's aggregate flow constraint is satisfied: $A_{t+1}^* \cdot (1+\xi) \cdot \frac{P_{t+1}}{P_t} = (1+r_t) \cdot A_t^* + Y_t - C_t - G_t - \left[K_{t+1} \cdot (1+\xi) \cdot \frac{P_{t+1}}{P_t} - (1-\delta) \cdot K_t\right]$, where $Y_t = Y_t^f$ and $C_t = C_t^h$ are the equilibrium aggregate output and consumption levels.[15]

F. Balanced Growth Equilibrium and Calibration

The model is calibrated to match some relevant features of the Cypriot economy. To do so, a balanced growth equilibrium is defined assuming constant population growth rate (p), labor augmenting technological progress (γ), work life ($T_t = T$), retirement period ($T_t^R = T^R$), and a fiscal policy that is characterized by constant tax rates and unchanged ratios of public expenditure and debt-to-output ratios. This equilibrium is used to express the steady state in terms of *detrended* variables in the stationary-transformed model.[16] Along the balanced growth equilibrium path, all endogenous variables grow at constant rates. Table 5 summarizes the parameter values used in the calibration and their sources. The calibration exercise verifies that the endogenous variables in the initial steady state and public expenditure and tax ratios closely match those in the Cypriot data.

[15] The economy's aggregate flow constraint is obtained from the aggregate constraint of the household sector, the first-order conditions of firms, the market equilibrium conditions, and the government budget constraint. The aggregate constraint of the household sector at time t is given by

$$A_{t+1}^h \cdot (1+\xi) \cdot \frac{P_{t+1}}{P_t} = [1 + r_t \cdot (1-\tau_t^I)] \cdot A_t^h + (1-\tau_t^I-\tau_t^p) \cdot W_t \cdot N_{p,t}^h + (1-\tau_t^I-\tau_t^g) \cdot W_t \cdot N_{g,t}^h + \sum_{s=T_t+1}^{T_t+T_t^R}\left[bb_{t+T_t+1-s}^{T_t+1} \cdot \frac{BE_t}{BE_{t+T_t+1-s}} + \frac{bs_{t+T_t+1-s}^{T_t+1}}{(1+\xi)^{s-T_t-1}}\right] \cdot \frac{P_{p,t}^s}{P_t}$$
$$+ \sum_{s=T_t+1}^{T_t+T_t^R}\left(bbg_{t+T_t+1-s}^{T_t+1} + bg_{t+T_t+1-s}^{T_t+1}\right) \cdot \frac{BE_t}{BE_{t+T_t+1-s}} \cdot \frac{P_{g,t}^s}{P_t} + bgls_t^{T_t+1} \cdot \frac{P_{g,t}^{T_t+1}}{P_t} - (1+\tau_t^c) \cdot C_t^h.$$

[16] The age structure of the population remains invariant over time, and thus, both components of public consumption (health-related and non health-related) are constant as a share of output.

Two features of the calibration exercise deserve special notice. First, the private and public households' skill profiles are set to capture both the inverted U-shaped profiles of wage incomes observed in the data and wage differences between private and public households. Specifically, wages of public households are higher than those of private households when such households enter the labor force. But public households' wages also grow at a lower rate and remain below private households' wages for most of the working life (Figure 1). Second, to capture health-care-related expenditure pressures arising from population aging, age-specific health care expenditures were assigned to each individual according to the profile presented in Figure 2. Health care expenditures per capita are higher for children than for young adults and rise sharply for the elderly. We calibrated this profile using the average profile observed in major European economies as Cyprus-specific data are not available.

G. Demographic Transition

The demographic shock and the path of the world interest rate are critical exogenous elements in the simulations. The time line in the model corresponds to a 360-year period, with the middle 160 years (1957−2117) covering the demographic transition from a high to a low fertility rate and continuing gains in life expectancy. In the first century, life expectancy is constant at 80 years, and the growth rate of new entrants to the labor force is set at 0.85 percent, which is the average population growth. During the demographic transition, however, life expectancy increases a year per decade until it reaches 90 in 2114 and the labor force growth rate varies to replicate the dependency ratio—defined as the ratio of the population over 63 years to the population between 23 and 63 years—in Eurostat's baseline population projections for 2004−51 (Figure 3). In other words, the dependency ratio in the model peaks at over twice its current rate in about 2050. The final century sees a constant life expectancy (90 years) and labor force entrants growing at a fixed rate of 0.5 percent per annum; the dependency ratio falls back but remains higher than it is currently.[17]

III. Baseline Simulations

The baseline simulations assume that the pension system's parameters are unchanged over time. These simulations also assume that the government follows a "tax-as-you-go" policy: fiscal pressures arising during the demographic transition are financed by adjusting consumption tax rates so that the government's budget constraint holds while other taxes and the government nonhealth expenditure-to-output and debt-to-output ratios remain constant. Three baseline scenarios are considered. In the first scenario, the exogenous interest rate path is constant; in the second and third scenarios, interest rates decline gradually by 50 basis points and 100 basis points in 2008-2038. In all scenarios, households benefit from perfect foresight and thus fully anticipate the future path of interest rates. Also, the SOE and perfect

[17] For a more detailed description of demographic projections for Cyprus, see Hoffmaister and others (2007a,b).

capital mobility assumptions mean that capital moves across borders to equalize the marginal productivity of domestic capital (net of depreciation) to world interest rates.

A. Scenario 1: Constant World Interest Rates

Since the world interest rate is constant, so is the capital-labor ratio. This and the gradual fall in the labor supply associated with population aging imply that capital and output per capita decline over time. National income per capita also falls, but less so than domestic output per capita because the economy runs persistent current account surpluses (Figure 4).[18]
These external surpluses reflect higher savings driven by the increased life expectancy and rising share in the population of old working households—whose asset holdings peak at retirement—and by lower domestic investment. The sustained accumulation of external assets reverses the country's net foreign asset position: starting as a net international debtor, it becomes a net creditor by 2020.

Also, the excess of national income over domestic output allows households to sustain consumption over time. Thus, relatively small increases in consumption tax rates suffice to finance large aging-related expenditure pressures. Note that a flatter consumption path and lower taxes are benefits of an open capital account: in a closed economy, the capital-labor ratio would increase and investment returns would decline, hampering consumption; also, higher wages would increase pensions and taxes, reducing welfare.

Individual pension benefits remain roughly constant due to the unchanged wage rate—small fluctuations in private households' pensions arise from changes in the age and labor skill structure of the work force during the demographic transition.[19] Still, the generosity of pensions—defined as the present value of lifetime pension benefits calculated at retirement—increases over time due to longer life expectancies of future generations. This increase in generosity, however, benefits private and public households and thus the measure of relative generosity remains unchanged. In sum, with constant world interest rates pension expenditure pressures are (almost) fully accounted for by variations in the dependency ratio. The sources of expenditure pressures can be uncovered by a numerical decomposition of changes in the pension expenditure-to-GNI ratio (Table 6). Pension expenditure as a share of GNI increases by 7.5 percentage points in 2007-2048. The endogenous decline in income (GNI) per capita—from the fall in labor and capital per capita, and the disincentives associated with higher consumption tax rates—accounts for 1.8 percentage points, while the increase in pension expenditure per capita contributes 5.6 percentage points. The latter, in

[18] Note that in Figure 4, variables are stationary-transformed as indicated in Table 1—adjusted by technological progress and population growth. Accordingly, changes in these variables must be interpreted as deviations from their long term trend.

[19] These changes affect the labor force (weighted) average skills in the basic earnings formula (footnote 7).

turn, is decomposed respectively into 3.5 and 2.1 percent contributions of private and public pension expenditures per capita.

B. Scenarios 2 and 3: Declining World Interest Rates

The decline in world interest rates implies a gradual increase in the capital-labor ratio (Figure 4). Both domestic output and the capital stock per capita decline less than in the constant interest rates scenario. Still, the welfare of all generations is unambiguously lower as households consume less and work more.

Households' welfare and the economy are adversely affected through two channels. First, a pass-through effect of lower interest rates to higher wages and pension benefits exacerbates the fiscal challenge, requiring higher taxes. Second, lower interest rates discourage savings and the current account surpluses vanish or turn into deficits and result in negative net foreign asset positions. Hence, the wedge between national income and domestic output narrows, reducing affordable consumption relative to the constant-rates scenario.

Although lower world interest rates boost pension benefits, the pass-through effect is lopsided reflecting differences in indexation: by 2050 the generosity of private pensions rises 13 percent in the third scenario compared to the first scenario; the generosity of public pensions rises 30 percent. In relative terms, the generosity of public versus private pension benefits rises from about 1.75 in the first scenario—that is, public household's benefits are 75 percent higher than private household's—to about 2.1 in the third scenario.

The numerical decomposition of pension expenditure-to-GNI ratios highlights the differences with the constant-rates scenario. When interest rates decline by 50 and 100 basis points, the expenditure ratios increase respectively by 9.7 percent of GNI and 12.2 percent of GNI by 2050—2.3 percentage points and 4.8 percentage points higher than in the constant-rates scenario. These larger increases result from changes in both pension expenditures per capita (numerator) and income per capita (denominator). The pass-through effect of lower interest rates exacerbates the increase in pension expenditure per capita—adding 0.9 percentage points and 1.9 percentage points to the 50 and 100 basis points decline scenarios. Thus, taxes need to rise more—17 and 29 percentage points, respectively—and result in larger reductions in income per capita, which further contribute 1.4 and 3 percentage points to the increase in the pension expenditure-to-GNI ratio.[20]

[20] Note the non-linear relation between increases in pension expenditure-to-GNI ratios and tax rates across interest rate scenarios. Declines in interest rates cause adverse wealth effects—Cyprus becomes a net international creditor in the constant-rates scenario—that result in smaller tax bases (consumption per capita). Thus, consumption tax rates need to rise to offset this decline in tax bases *and* to finance the additional expenditure pressures.

Also, the decomposition of the increase in pension expenditure per capita reflects the lopsided nature of the pass-through effect: public pensions account for 38 percent of this increase in the constant-rates scenario; but account for respectively 41 and 44 percent of the increase in the 50 and 100 basis points decline scenarios.

IV. PENSION REFORM SIMULATIONS

A. Description of Pension Reforms

Five pension reform scenarios are considered. Reforms are cumulative and thus each subsequent scenario involves farther-reaching reforms:

- ***Reform 1 (retirement age)***: the *retirement age* increases in line with projected life expectancy developments; that is, by one year in 2013 and 2018, and starting in 2028, by one year per decade up to a maximum increase of 10 years.

- ***Reform 2 (plus lump sum)***: in addition, reforms gradually cut *lump-sum retirement transfers* to public workers from 28 to 20 monthly salaries in 2013 and from 20 to 12 monthly salaries in 2018.

- ***Reform 3 (plus benefit indexation, "partial")***: further reforms to the system result from shifting the *indexation of all pension benefits* to prices in 2013. Specifically, the shift in indexation affects the basic pension benefits associated with the GSIS—received both by private (bb) and public (bbg) households—and the annual pension benefits associated with the GEPS—paid out only to public households (bg). Supplementary pension benefits received by private households (bs) are already indexed to inflation and are unaffected by the reform.

- ***Reform 4 (plus wage earnings indexation, "full")***: in addition, reforms shift the *indexation of past wage earnings* used to compute pensions to inflation instead of wages in 2013, and partially offset the effect on pensions by increasing the replacement coefficients. These coefficients are increased so that pension benefits are unchanged in the initial steady state—once the indexation of past wage earning is changed. Specifically, the replacement coefficient of basic pensions (α_B) is increased 56 percent, while the replacement coefficient of the supplementary pension (α_S) is increased 48 percent.

- ***Reform 5 (plus wage earnings indexation, "uncompensated full")*** : similar to Reform 4, but the replacement coefficients do not increase.

B. Simulation Results for Constant Interest Rates

For a given world interest rates path, pension reforms reduce the aging-related pressures relative to the no-reform baseline. The farther reaching the reforms the smaller the increases in pension expenditure-to-GNI ratios and tax rates, which result in higher output, labor, capital accumulation and consumption (Figure 5 and Table 6).

These macroeconomic benefits improve the welfare of all households, except for some public households born before the year 2000 in reform scenarios that lower lump-sum retirement transfers (Reforms 2-5). As expected, even as these reforms reduce the relative generosity of public pensions, these remain more generous than private pensions in all reform scenarios. The relative generosity of public pensions increases, however, in the uncompensated full reform scenario.

Note that private households shoulder most of the burden in the uncompensated full reform scenario because their basic and supplementary pension benefits are calculated based on their lifetime wage earnings. For public households, however, only basic pension benefits are calculated in this way. The other pension benefits are computed based on wage earnings in the last year before retirement, and are thus unaffected by the reform.

C. Pension Reforms as Macroeconomic Insurance

The simulation results discussed above point to the role of pension reforms as "providers" of macroeconomic insurance against long-run declines in world interest rates (Figure 6). Specifically, when interest rates are constant, increasing the retirement age reduces the increase in the pension expenditure-to-GNI ratio by 3.1 percentage points (7.5 percent in the baseline versus 4.4 percent in the first reform scenario) by 2048. But when interest rates decline 100 basis points, increasing the retirement age cuts the increase in the ratio by a larger amount: 3.7 percentage points (12.2 percent in the baseline compared to 8.5 percent in the first reform scenario). This reform thus offsets expenditure pressures more when these are exacerbated by declining interest rates.

This macro-insurance effect is particularly powerful in pension reforms shifting the indexation of pensions or wage incomes used to compute pensions.

In regard to shifts in the indexation of pension benefits, note that the increase in the pension expenditure-to-GNI ratio that results from a 100 basis points decline in interest rates—relative to the constant-rates scenario—is smaller in the "partial reform" scenario (3.1 percent of GNI) than in the "retirement age plus lump-sum" (3.8 percent of GNI) and baseline (4.8 percent of GNI) scenarios (Table 6).

The decomposition of increases in pension expenditure per capita highlights the distributional effects of changing the indexation of pension benefits. In the "partial reform" (Reform 3) the burden of expenditure declines falls disproportionately on public pensions—because, in addition to the fall in lump sum transfers, the reform shifts the indexation of basic and annual public pensions from wages to prices. For private households, however, only the indexation of basic pensions is changed—supplementary benefits are already indexed to prices.

In regard to shifts in the indexation of wage incomes used to compute pensions, the full reforms (Reforms 4-5) reduce further the size of the pass-through effect. The pass-through effect is even smaller in the "uncompensated full reform"—when the indexation shift is not offset by increasing replacement ratios. The increase in the pension expenditure-to-GNI ratio that results from a 100 basis points decline in interest rates—compared to the constant-rates scenario—is smaller in the "full reform" scenario (3.0 percent of GNI) than in the "partial reform" (3.1 percent of GNI) and "baseline" (4.8 percent of GNI) scenarios; it is even smaller in the "uncompensated full reform scenario" (2.1 percent of GNI). In this last scenario the pension expenditure-to-GNI ratio is lower in 2048 than in 2007 when interest rates are constant or decline by 50 basis points. It remains roughly constant between 2007 and 2048 when interest rates fall by 100 basis points, but at the cost of large reductions in the basic and supplementary pensions associated to the GSIS. In this case, the private households shoulder most of the burden of the reform, and the relative generosity of public pensions increases.

V. Conclusions

How will the decline in world real interest rates associated with global population aging affect SOEs which are also aging? The short answer is that aging-related fiscal pressures in SOEs will be exacerbated. This is because lower interest rates and capital inflows will result in higher capital-labor ratios and wages, which in turn will be passed on to pension benefits. Higher pension benefits, along with increased dependency rates, will boost aging-related fiscal pressures, particularly when pension benefits and wage earnings used to compute pensions are indexed to wages.

This paper also shows that pension reforms, particularly those that change indexation from wages to prices, provide macroeconomic insurance against long-run declines in world interest rates. In the Cypriot case, an aging population poses substantial macroeconomic challenges. Without pension reforms and assuming unchanged world interest rates, age-related spending is slated to increase by 7.5 percent of GNI by 2050. This increase is exacerbated when world interest rates decline as the resulting increase in the capital-labor ratio boosts wages and pension benefits which are indexed to wages. Moreover, asymmetries in benefit indexation translate into an increased generosity of public pension benefits relative to private pension benefits. In an unreformed system, a decrease of 100 basis points in world interest rates increases pension expenditures by 4.8 percentage points of GNI compared to the baseline scenario with constant interest rates. In contrast, when the pension system is "fully" reformed, this increase is limited to 2.1 percentage points of GNI. While these results underscore the need for pension reforms, changing the indexation of benefits from wages to prices provides an added bonus: macroeconomic insurance against long-run declines in world interest rates.

Beyond country-specific results, this paper points to broader lessons for SOEs that are or will be dealing with an aging population in the context of global aging. By depressing global interest rates, global aging has the potential to magnify the adverse macroeconomic impact of aging in SOEs, particularly in economies where pension benefits are indexed to wages. Pension reforms that shift the indexation of pension benefits from wages to prices provide macroeconomic insurance against long-run declines in interest rates. While not a panacea, as other reforms are typically needed to address aging in SOEs, this result should provide reasons to revisit the current reform trend relinking pension benefits to wages.

Table 1. Variable Definition and Notation

Variable	Notation	Stationary Transformation	Variable	Notation	Stationary Transformation
Parameters					
Discount factor (utility)	β		Rate of labor augmenting technological progress	ξ	
Leisure preference (utility)	γ		Replacement ratios (pension benefit formulas)	α_S, α_B α_G, λ	
Capital share (production)	α		Constant rate of population growth 1/	p	
Capital depreciation rate	δ		Total factor productivity	Z	
Labor skill (*)	e^s		Basic earnings coefficient	θ	
Population					
s -year old population (*)	P_t^s		Total population (*)	P_t	
Households					
Labor effort (*)	n_t^s		Aggregate effective labor supply (*)	$\hat{N}_t^h$	$N_t^h = \dfrac{\hat{N}_t^h}{P_t}$
Leisure (*)	l_t^s		Aggregate labor effort (*)	$\hat{n}_t^h$	$n_t^h = \dfrac{\hat{n}_t^h}{P_t}$
Consumption (*)	$\hat{c}_t^s$	$c_t^s = \dfrac{\hat{c}_t^s}{(1+\xi)^t}$	Aggregate consumption (*)	$\hat{C}_t^h$	$C_t^h = \dfrac{\hat{C}_t^h}{(1+\xi)^t \cdot P_t}$
Asset holdings (*)	$\hat{A}_t^s$	$A_t^s = \dfrac{\hat{A}_t^s}{(1+\xi)^t}$	Aggregate asset holdings (*)	$\hat{A}_t^h$	$A_t^h = \dfrac{\hat{A}_t^h}{(1+\xi)^t \cdot P_t}$
Annual pension (*) 2/	$\widehat{bb}_{t+T_t}^{T_t+1}$	$bb_{t+T_t}^{T_t+1} = \dfrac{\widehat{bb}_{t+T_t}^{T_t+1}}{(1+\xi)^{t+T_t}}$	Aggregate foreign assets (*)	$\hat{A}_t^*$	$A_t^* = \dfrac{\hat{A}_t^*}{(1+\xi)^t \cdot P_t}$
Firms					
Aggregate capital demand	$\hat{K}_t^f$	$K_t^f = \dfrac{\hat{K}_t^f}{(1+\xi)^t \cdot P_t}$	Aggregate labor demand	$\hat{N}_t^f$	$N_t^f = \dfrac{\hat{N}_t^f}{P_t}$
Aggregate output	$\hat{Y}_t^f$	$Y_t^f = \dfrac{\hat{Y}_t^f}{(1+\xi)^t \cdot P_t}$	Profits (net) 3/	$\hat{\Pi}_t^f$	$\Pi_t^f = \dfrac{\hat{\Pi}_t^f}{(1+\xi)^t \cdot P_t}$
Factor Prices					
Gross rate of return on assets	r_t		Wage rate 4/ (unskilled labor)	$\hat{W}_t$	$W_t = \dfrac{\hat{W}_t}{(1+\xi)^t}$
Tax Rates					
Social security contribution (*)	τ_t		Consumption tax	τ_t^c	
Income tax	τ_t^I				
Government					
Debt	$\hat{D}_t$	$D_t = \dfrac{\hat{D}_t}{(1+\xi)^t \cdot P_t}$	Expenditure	$\hat{G}_t$	$G_t = \dfrac{\hat{G}_t}{(1+\xi)^t \cdot P_t}$

Note: Superscripts (subscripts) indicate the age of the household (time period); stock variables are dated at the beginning of the corresponding year. (*) indicates that separate but similar definitions are used to differentiate private and public households in the main text—using scripts p and g. 1/ Population growth rates are constant only along balanced growth equilibrium paths. 2/ All pension benefits ($bb, bs, bbg, bg, bgls$) are defined in Table 2 and are subject to the same stationary-transformations. 3/ Profits are net of capital depreciation. 4/ Basic earnings are subject to the same stationary-transformation.

Table 2. Household's Optimization Problems

	"Private" Households		"Public" Households 1/	
Utility	$U_{p,t} = \sum_{s=1}^{T_t+T_t^R} \beta^{s-1} \cdot \left\{ \log(c_{p,t+s-1}^s) + \gamma \cdot \log(l_{p,t+s-1}^s) \right\}$	(1)	$U_{g,t} = \sum_{s=1}^{T_t+T_t^R} \beta^{s-1} \cdot \left\{ \log(c_{g,t+s-1}^s) + \gamma \cdot \log(l_{g,t+s-1}^s) \right\}$	(8)
Time constraint	$l_{p,t+s-1}^s = \begin{cases} 1-n_{p,t+s-1}^s & s=1,\dots,T_t \\ 1 & s=T_t+1,\dots T_t+T_t^R \end{cases}$	(2)	$l_{g,t+s-1}^s = \begin{cases} 1-n_{g,t+s-1}^s & s=1,\dots,T_t \\ 1 & s=T_t+1,\dots T_t+T_t^R \end{cases}$	(9)
Budget constraint in work-life $(s=1,\dots,T_t-1)$	$(1+\xi)\cdot A_{p,t+s}^{s+1} = [1+r_{t+s-1}\cdot(1-\tau_{t+s-1}^I)]\cdot A_{p,t+s-1}^s + (1-\tau_{t+s-1}^p - \tau_{t+s-1}^I)\cdot$ $\cdot W_{t+s-1}\cdot e_p^s \cdot n_{p,t+s-1}^s - (1+\tau_{t+s-1}^c)\cdot c_{p,t+s-1}^s,$	(3)	$(1+\xi)\cdot A_{g,t+s}^{s+1} = [1+r_{t+s-1}\cdot(1-\tau_{t+s-1}^I)]\cdot A_{g,t+s-1}^s + (1-\tau_{t+s-1}^g - \tau_{t+s-1}^I)\cdot$ $\cdot W_{t+s-1}\cdot e_g^s \cdot n_{g,t+s-1}^s - (1+\tau_{t+s-1}^c)\cdot c_{g,t+s-1}^s$	(10)
Budget constraint in retirement $(s=T_t+1,\dots,T_t+T_t^R-1)$	$(1+\xi)\cdot A_{p,t+s}^{s+1} = [1+r_{t+s-1}\cdot(1-\tau_{t+s-1}^I)]\cdot A_{p,t+s-1}^s + bb_{t+T_t}^{T_t+1}\cdot \frac{BE_{t+s-1}}{BE_{t+T_t}}$ $+\frac{bs_{t+T_t}^{T_t+1}}{(1+\xi)^{s-T_t-1}} - (1+\tau_{t+s-1}^c)\cdot c_{p,t+s-1}^s .$	(4)	$(1+\xi)\cdot A_{g,t+T_t+1}^{T_t+2} = [1+r_{t+T_t}\cdot(1-\tau_{t+T_t}^I)]\cdot A_{g,t+T_t}^{T_t+1} + bg_{t+T_t}^{T_t+1} + bgls_{t+T_t}^{T_t+1}$ $+bbg_{t+T_t}^{T_t+1} - (1+\tau_{t+T_t}^c)\cdot c_{g,t+T_t}^{T_t+1};\ s=T_t+1$ $(1+\xi)\cdot A_{g,t+s}^{s+1} = [1+r_{t+s-1}\cdot(1-\tau_{t+s-1}^I)]\cdot A_{g,t+s-1}^s + bg_{t+T_t}^{T_t+1}\cdot\frac{BE_{t+s-1}}{BE_{t+T_t}}$ $+bbg_{t+T_t}^{T_t+1}\cdot\frac{BE_{t+s-1}}{BE_{t+T_t}} - (1+\tau_{t+s-1}^c)\cdot c_{g,t+s-1}^s;\ s=T_t+2,\dots,T_t+T_t^R-1$	(11)
Pension benefits at retirement	Basic: $bb_{t+T_t}^{T_t+1} = \frac{\alpha_B}{T_t}\cdot\left[\sum_{j=1}^{T_t} Min\left\{1, \frac{W_{t+j-1}\cdot e_p^j \cdot n_{p,t+j-1}^j}{BE_{t+j-1}}\right\}\right]\cdot BE_{t+T_t}$	(5)	Annual: $bg_{t+T_t}^{T_t+1} = \alpha_G \cdot \frac{W_{t+T_t-1}\cdot e_g^{T_t}\cdot n_{g,t+T_t-1}^{T_t}}{(1+\xi)}$	(12)
	Supplementary: $bs_{t+T_t}^{T_t+1} = \alpha_S \cdot \left[\sum_{j=1}^{T_t} Max\left\{0, \frac{W_{t+j-1}\cdot e_p^j \cdot n_{p,t+j-1}^j}{BE_{t+j-1}} - 1\right\}\right]\cdot BE_{t+T_t}$	(6)	Lump sum: $bgls_{t+T_t}^{T_t+1} = \lambda \cdot \frac{W_{t+T_t-1}\cdot e_g^{T_t}\cdot n_{g,t+T_t-1}^{T_t}}{(1+\xi)}$	(13)
No bequest, inheritance constraint	$A_{p,t}^1 = A_{p,t}^{T_t+T_t^R+1} = 0$	(7)	$A_{g,t}^1 = A_{g,t}^{T_t+T_t^R+1} = 0$	(14)

1/ Basic pension benefits paid by the general scheme GSIS to public households (bg) are calculated using the formula (5)—the same formula used to calculate private household's basic benefits.

Table 3. First Order Conditions—Private Household's Optimization Problem

	Consumption-Leisure Decision (Intra-temporal condition)	Consumption-Saving Decision (Inter-temporal condition)
Working Age $(s=1,...,T_t-1)$		
1) if $\frac{W_{t+s-1}\cdot e_p^s\cdot n_{p,t+s-1}^s}{BE_{t+s-1}}\leq 1$	$\frac{\gamma}{l_{p,t+s-1}^s}=\frac{W_{t+s-1}\cdot e_p^s\cdot(1-\tau_{t+s-1}-\tau_{t+s-1}^I)}{c_{p,t+s-1}^s\cdot(1+\tau_{t+s-1}^c)}+W_{t+s-1}\cdot e_p^s\cdot\frac{\alpha_B}{T_t}\cdot\beta^{T_t+1-s}\cdot V_{bb}(A_{p,t+T_t}^{T_t+1},bb_{t+T_t}^{T_t+1},bs_{t+T_t}^{T_t+1})$ (15)	$\frac{(1+\xi)}{c_{p,t+s-1}^s\cdot(1+\tau_{t+s-1}^c)}=\beta\cdot\frac{[1+r_{t+s}\cdot(1-\tau_{t+s}^I)]}{c_{p,t+s}^{s+1}\cdot(1+\tau_{t+s}^c)}$ (19)
2) if $\frac{W_{t+s-1}\cdot e_p^s\cdot n_{p,t+s-1}^s}{BE_{t+s-1}}>1$	$\frac{\gamma}{l_{p,t+s-1}^s}=\frac{W_{t+s-1}\cdot e_p^s\cdot(1-\tau_{t+s-1}-\tau_{t+s-1}^I)}{c_{p,t+s-1}^s\cdot(1+\tau_{t+s-1}^c)}+W_{t+s-1}\cdot e_p^s\cdot\alpha_S\cdot\beta^{T_t+1-s}\cdot V_{bs}(A_{p,t+T_t}^{T_t+1},bb_{t+T_t}^{T_t+1},bs_{t+T_t}^{T_t+1})$ (16)	$\frac{(1+\xi)}{c_{p,t+s-1}^s\cdot(1+\tau_{t+s-1}^c)}=\beta\cdot\frac{[1+r_{t+s}\cdot(1-\tau_{t+s}^I)]}{c_{p,t+s}^{s+1}\cdot(1+\tau_{t+s}^c)}$ (20)
$(s=T_t)$		
1) if $\frac{W_{t+s-1}\cdot e_p^{T_t}\cdot n_{p,t+T_t-1}^{T_t}}{BE_{t+T_t-1}}\leq 1$	$\frac{\gamma}{l_{p,t+T_t-1}^{T_t}}=\frac{W_{t+T_t-1}\cdot e_p^{T_t}\cdot(1-\tau_{t+T_t-1}-\tau_{t+T_t-1}^I)}{c_{p,t+T_t-1}^{T_t}\cdot(1+\tau_{t+T_t-1}^c)}+W_{t+T_t-1}\cdot e_p^{T_t}\cdot\frac{\alpha_B}{T_t}\cdot\beta\cdot V_{bb}(A_{p,t+T_t}^{T_t+1},bb_{t+T_t}^{T_t+1},bs_{t+T_t}^{T_t+1})$ (17)	$\frac{(1+\xi)}{c_{p,t+T_t-1}^{T_t}\cdot(1+\tau_{t+T_t-1}^c)}=\beta\cdot V_A(A_{p,t+T_t}^{T_t+1},bb_{t+T_t}^{T_t+1},bs_{t+T_t}^{T_t+1})$ (21)
2) if $\frac{W_{t+s-1}\cdot e_p^{T_t}\cdot n_{p,t+T_t-1}^{T_t}}{BE_{t+T_t-1}}>1$	$\frac{\gamma}{l_{p,t+T_t-1}^s}=\frac{W_{t+T_t-1}\cdot e_p^{T_t}\cdot(1-\tau_{t+T_t-1}-\tau_{t+T_t-1}^I)}{c_{p,t+T_t-1}^s\cdot(1+\tau_{t+T_t-1}^c)}+W_{t+T_t-1}\cdot e_p^{T_t}\cdot\alpha_S\cdot\beta\cdot V_{bs}(A_{p,t+T_t}^{T_t+1},bb_{t+T_t}^{T_t+1},bs_{t+T_t}^{T_t+1})$ (18)	$\frac{(1+\xi)}{c_{p,t+T_t-1}^{T_t}\cdot(1+\tau_{t+T_t-1}^c)}=\beta\cdot V_A(A_{p,t+T_t}^{T_t+1},bb_{t+T_t}^{T_t+1},bs_{t+T_t}^{T_t+1})$ (22)
Retirement $(s=T_t+1,...,T_t+T_t^R-1)$		$\frac{(1+\xi)}{c_{p,t+s-1}^s\cdot(1+\tau_{t+s-1}^c)}=\frac{\beta\cdot[1+r_{t+s}\cdot(1-\tau_{t+s}^I)]}{c_{p,t+s}^{s+1}\cdot(1+\tau_{t+s}^c)}$ (23)

Table 4. First Order Conditions—Public Household's Optimization Problem

	Consumption-Leisure Decision (Intra-temporal condition)		Consumption-Saving Decision (Inter-temporal condition)	
Working Age $(s=1,\ldots,T_t)$	$\frac{\gamma}{l^s_{g,t+s-1}} = \frac{W_{t+s-1}\cdot e^s_g \cdot (1-\tau^l_{t+s-1})}{c^s_{g,t+s-1}\cdot(1+\tau^c_{t+s-1})}$	(24)	$\frac{(1+\xi)}{c^s_{g,t+s-1}\cdot(1+\tau^c_{t+s-1})} = \beta\cdot\frac{[1+r_{t+s}\cdot(1-\tau^l_{t+s})]}{c^{s+1}_{g,t+s}\cdot(1+\tau^c_{t+s})}$	(25)
Retirement $(s=T_t+1,\ldots,T_t+T^R_t-1)$			$\frac{(1+\xi)}{c^s_{g,t+s-1}\cdot(1+\tau^c_{t+s-1})} = \frac{\beta\cdot[1+r_{t+s}\cdot(1-\tau^l_{t+s})]}{c^{s+1}_{g,t+s}\cdot(1+\tau^c_{t+s})}$	(26)

Table 5. Calibration of the Model (Initial Steady State)

Symbol	Definition	Value	Source
β	Discount factor on preferences	0.95	From the real business cycles literature
γ	Leisure parameter on preferences	1.87	Value set so that the fraction of working time for average household is 0.274
α	Share of capital in production function	0.33	From the real business cycles literature
δ	Depreciation rate	0.08	From the real business cycles literature
Z	Total factor productivity	2.40	Value set to obtain a capital-to-output ratio of 1.81
ξ	Rate of technological progress	0.025	Average GDP per capita growth 1993 - 2006
p	Rate of population growth	0.0085	Average population growth 1960-2006
r	World interest rate	0.102	Set to obtain a current account deficit of 1.0 percent of output
α_B	Replacement rate basic pension (GSIS)	0.307	From pension rule (0.60), adjusted to get a ratio of private pension expenditure-to-output of 0.051[1]
α_S	Replacement rate supplementary pension (GSIS)	0.0077	From pension rule (0.015), adjusted to get a ratio of private pension expenditure-to-output of 0.051[1]
α_G	Replacement rate public pension (GEPS)	0.233	From pension rule (0.50), adjusted to get a ratio of pension expenditure-to-output of 0.0347[2]
λ	Lump sum payment factor (GEPS)	1.555	From pension rule (2.33), adjusted to get a ratio of pension expenditure-to-output of 0.0347[3]
T	Work life (years)	40	Set to match individuals' entry to the labor force at age 23 and retirement at age 63
T^R	Retirement life (years)	18	Set to match individuals' life expectancy of 80
τ^p	Private social security payroll tax rate	0.149	Social security contribution-to-output (7.2%)
τ^g	Public social security payroll tax rate	0.030	Social security contribution-to-output (7.2%)
τ^I	Capital and labor income tax rate	0.110	Ratio of direct tax revenues-to-output (9.1%)
τ^c	Consumption tax rate	0.29	Ratio of revenues from VAT-to-output (15.9%)
G/Y	Government consumption to output	0.235	Average 1999 - 2006
D/Y	Government debt to output	0.70	General government debt in 2005

Source: Staff estimates.
[1] The adjustment factor applied is 0.051.
[2] The adjustment factor applied is 0.047.
[3] The adjustment factor applied is 0.067.

Table 6. Pension Expenditure Reductions from Reforms[1/]
(Changes from 2007 to 2048, Percentage points of GNI)

	Baseline	Reform 1 Retirement Age	Reform 2 Ret. Age and Lump Sum	Reform 3 Partial Reform	Reform 4 Full Reform	Reform 5 Uncompensated Full Reform
Scenario 1: Constant Interest Rate						
Level in 2007	9.3	9.3	9.3	9.3	9.3	9.3
Level in 2048	16.7	13.7	13.2	11.1	10.5	7.4
Change from 2007 to 2048	7.5	4.4	3.9	1.8	1.2	-1.9
Expenditures	5.6	3.4	3.0	1.2	0.8	-2.0
Private	3.5	2.2	2.2	1.3	0.9	-1.3
Basic	2.2	1.4	1.4	0.5	0.3	-0.9
Suplementary	1.3	0.8	0.8	0.8	0.6	-0.4
Public	2.1	1.2	0.8	-0.1	-0.1	-0.7
Pension	2.1	1.1	1.2	0.3	0.2	-0.3
Lump Sum	0.0	0.0	-0.4	-0.4	-0.4	-0.4
Output (decline)	1.8	1.0	0.9	0.6	0.5	0.1
Consumption Tax Rate (percentage points)	7.1	3.6	2.7	-1.6	-2.5	-8.8
Scenario 2: Interest Rate Falling by 50 Basis Points						
Level in 2007	9.5	9.5	9.5	9.5	9.5	9.5
Level in 2048	19.2	15.8	15.2	12.8	12.1	8.6
Change from 2007 to 2048	9.7	6.4	5.7	3.3	2.7	-0.9
Expenditures	6.5	4.2	3.8	1.9	1.4	-1.5
Private	3.8	2.5	2.5	1.6	1.2	-1.2
Basic	2.3	1.5	1.5	0.5	0.4	-0.9
Suplementary	1.5	1.0	1.0	1.1	0.8	-0.2
Public	2.7	1.7	1.2	0.3	0.2	-0.3
Pension	2.6	1.5	1.5	0.6	0.5	0.0
Lump Sum	0.1	0.2	-0.3	-0.3	-0.3	-0.3
Output (decline)	3.2	2.1	2.0	1.4	1.2	0.6
Consumption Tax Rate (percentage points)	16.8	13.4	12.0	6.6	5.5	-2.2
Scenario 3: Interest Rate Falling by 100 Basis Points						
Level in 2007	9.7	9.7	9.7	9.7	9.7	9.7
Level in 2048	22.0	18.2	17.4	14.6	13.9	9.9
Change from 2007 to 2048	12.2	8.5	7.7	4.9	4.2	0.2
Expenditures	7.5	5.1	4.6	2.6	2.1	-1.0
Private	4.2	2.9	2.9	1.9	1.5	-1.0
Basic	2.5	1.6	1.6	0.6	0.4	-0.9
Suplementary	1.7	1.3	1.3	1.3	1.1	-0.1
Public	3.3	2.2	1.7	0.7	0.6	0.0
Pension	3.0	1.9	1.9	0.9	0.8	0.3
Lump Sum	0.3	0.3	-0.3	-0.3	-0.3	-0.3
Output (decline)	4.8	3.4	3.1	2.3	2.1	1.2
Consumption Tax Rate (percentage points)	28.1	24.7	22.7	16.0	14.7	5.4
Differences Between Interest Rate Scenarios						
Interest Rate Falling by 50 Basis Points Minus Constant Interest Rate	2.3	2.0	1.8	1.5	1.4	1.0
Interest Rate Falling by 100 Basis Points Minus Constant Interest Rate	4.8	4.1	3.8	3.1	3.0	2.1

1/ The decomposition is obtained by re-expressing the pension expenditure-to-output ratio as $Ratio = \frac{x}{y} = \frac{\text{Pension expenditure per capita}}{\text{Output per capita}}$.

Then, we decompose the (exact) growth rate of the ratio for the period 2007-2048 as: $\widehat{\text{Ratio}} = \hat{x} - \left(\frac{\hat{y} + \hat{x}\cdot\hat{y}}{1+\hat{y}}\right)$. The first term, $\hat{x}$, is the growth contribution of pension expenditure per capita; the term $-\left(\frac{\hat{y} + \hat{x}\cdot\hat{y}}{1+\hat{y}}\right)$ is the growth contribution of output per capita.

Figure 1. Labor Skills Profile by Age

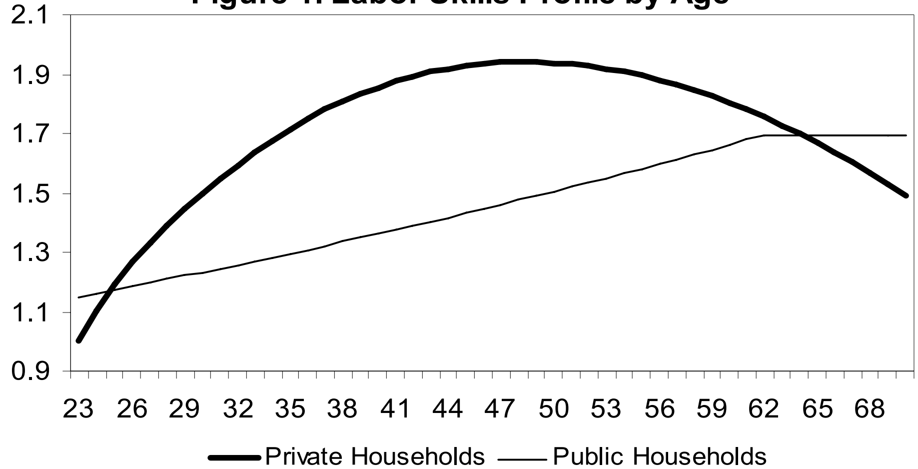
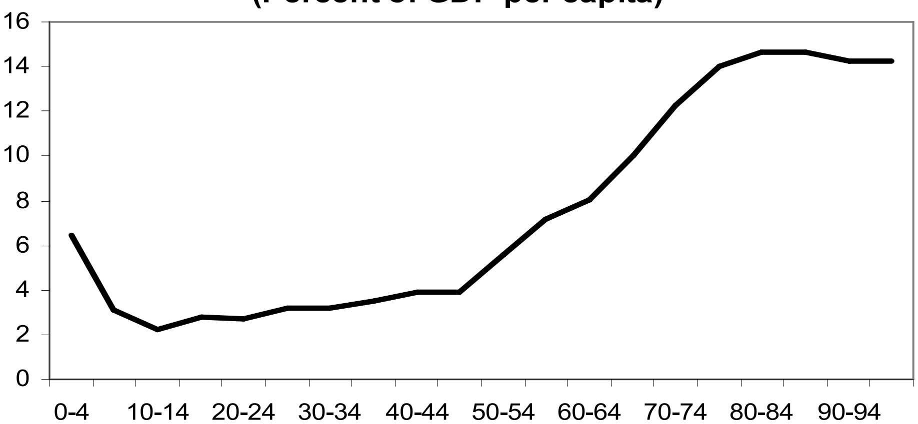
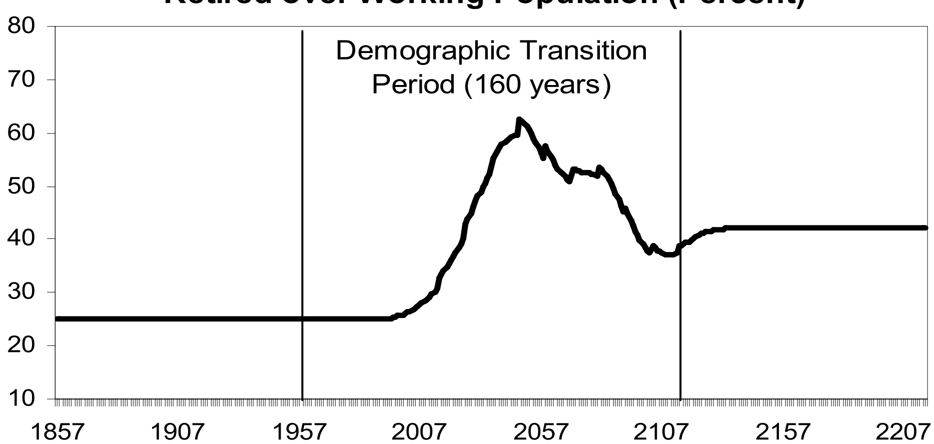


Figure 2. Health Care Expenditure by Age Group (Percent of GDP per capita)



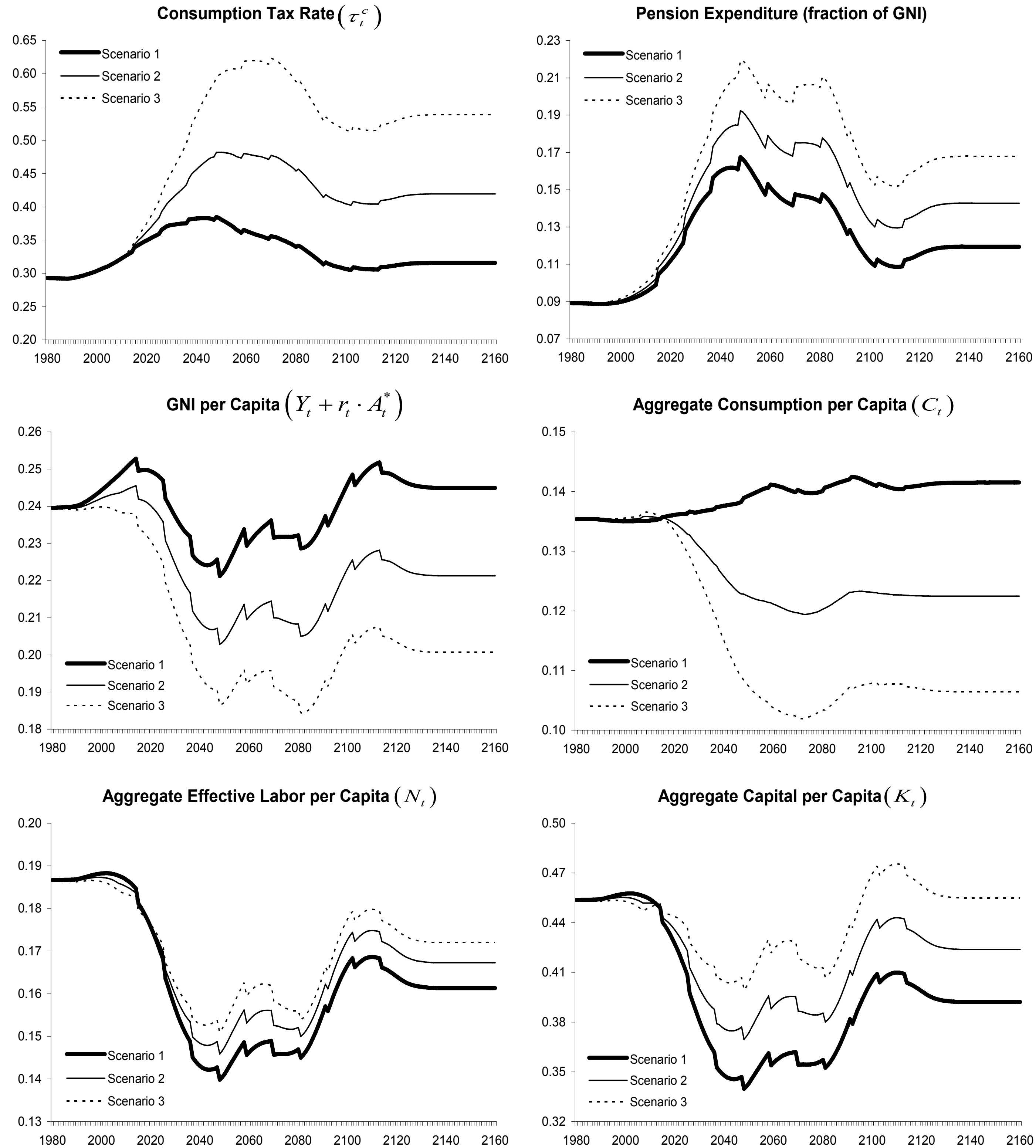
Source: OECD (2003)

Figure 3. Dependency Ratio in the Model: Retired over Working Population (Percent)



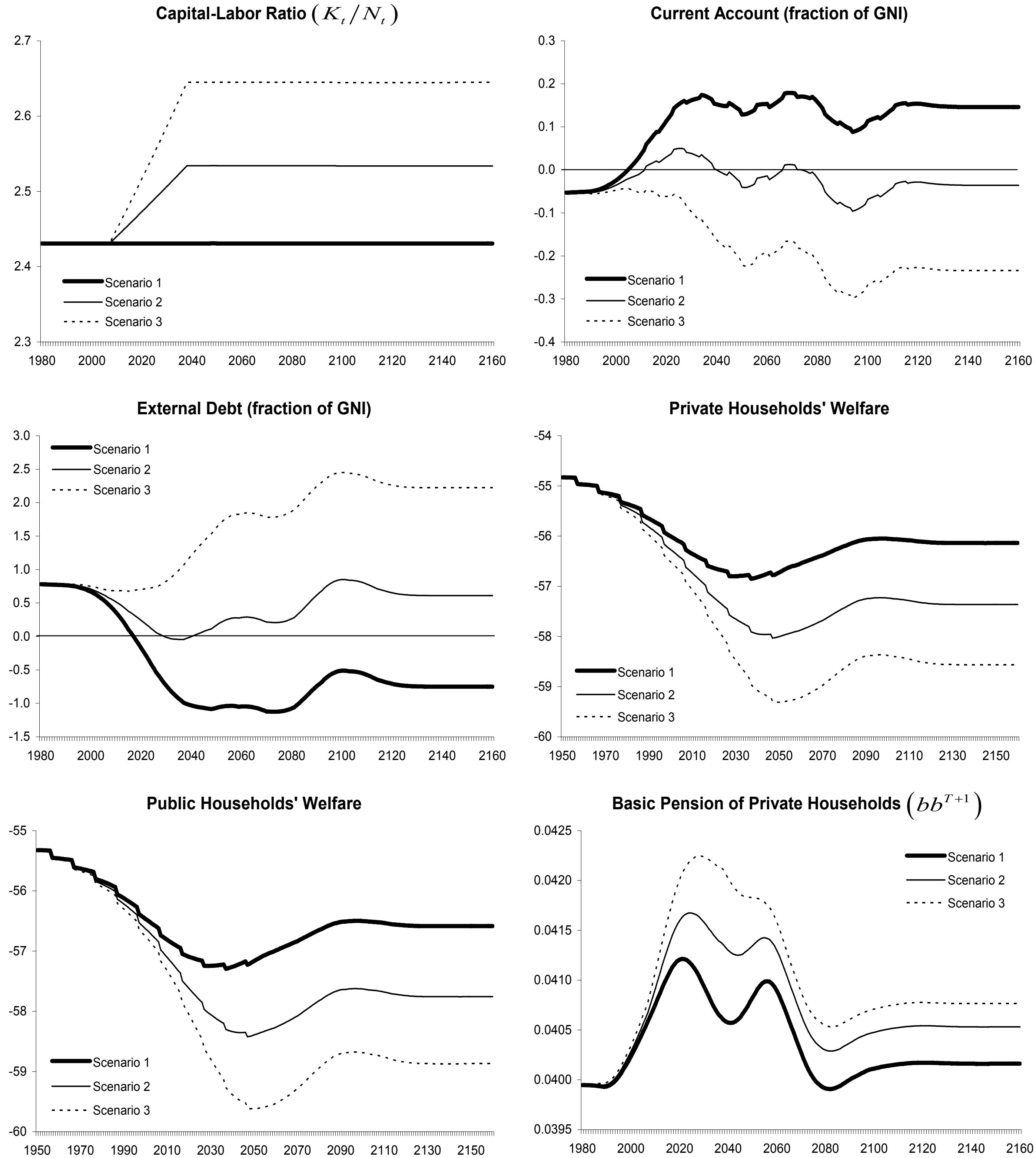
Source: Staff calculations.

Figure 4. Macroeconomic Results—Baseline Scenarios under Constant and Declining Interest Rates /1
(Unless otherwise indicated, variables are expressed as deviations from trend)



1/ Scenario 1 corresponds to a constant world interest rate, while scenarios 2 and 3 correspond to declining world interest rates by 50 and 100 basis points between 2008 and 2038, respectively.

Figure 4. Macroeconomic Results—Baseline Scenarios under Constant and Declining Interest Rates (cont.) 1/
(Unless otherwise indicated, variables are expressed as deviations from trend)



1/ Scenario 1 corresponds to a constant world interest rate, while scenarios 2 and 3 correspond to declining world interest rates by 50 and 100 basis points between 2008 and 2038, respectively.

Figure 4. Macroeconomic Results—Baseline Scenarios under Constant and Declining Interest Rates (cont.) /1
(Unless otherwise indicated, variables are expressed as deviations from trend)

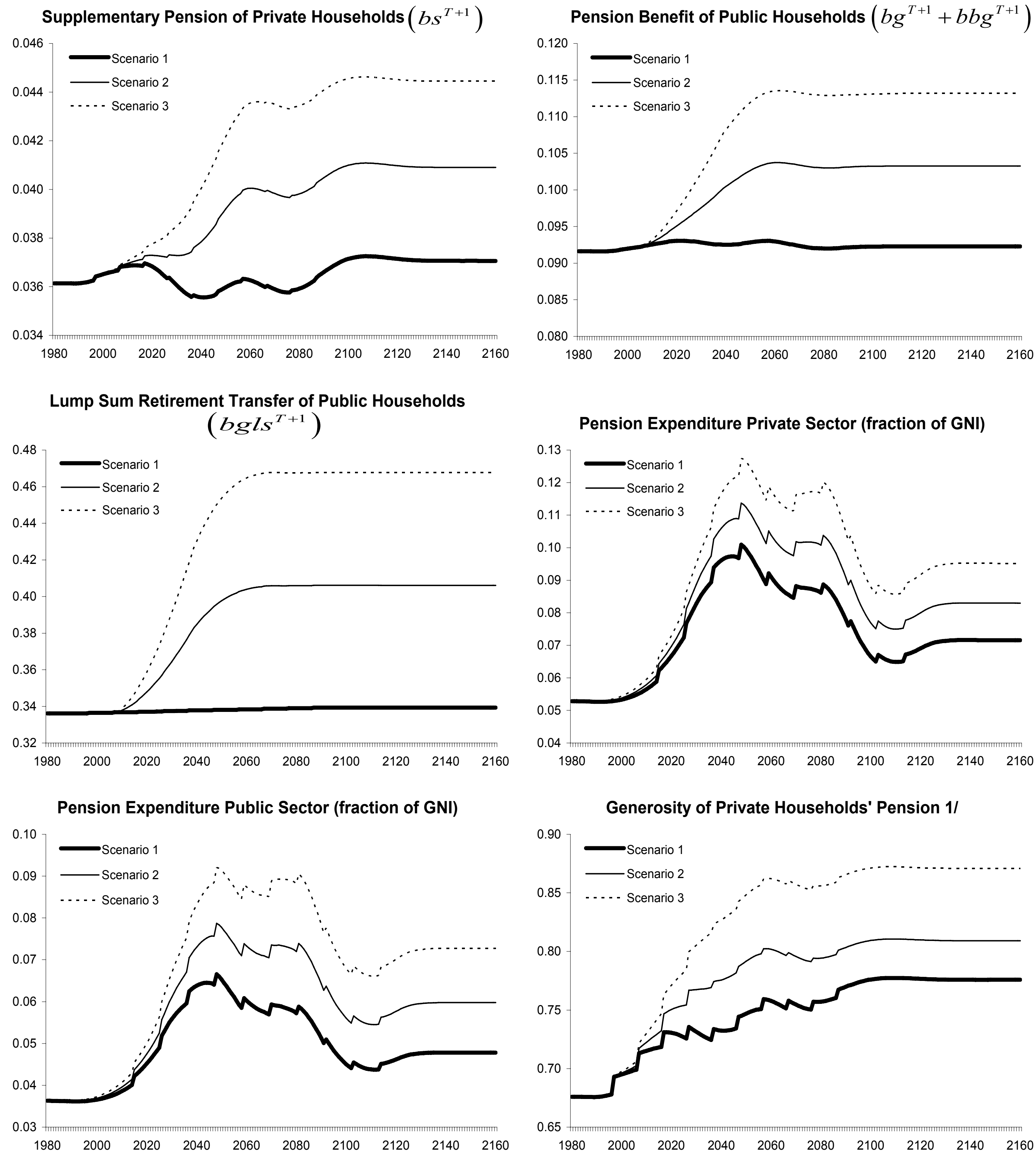


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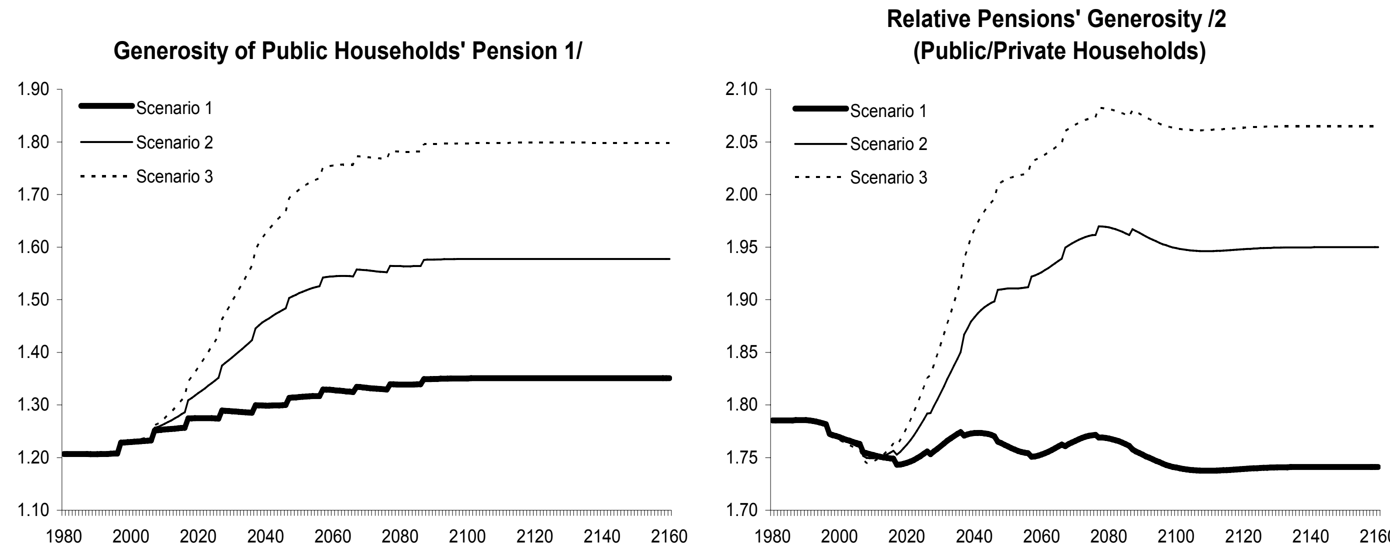
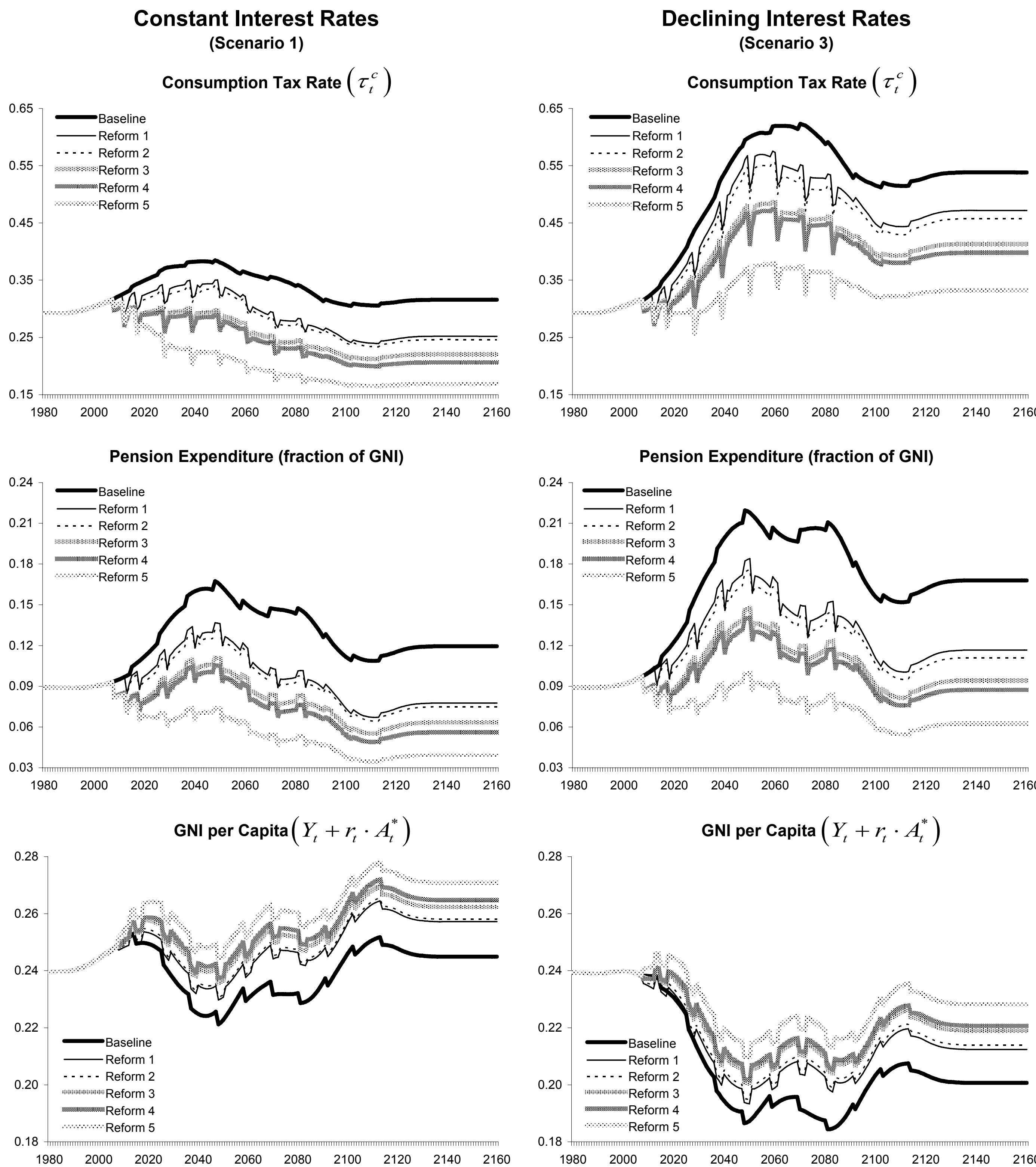
Figure 4. Macroeconomic Results—Baseline Scenarios under Constant and Declining Interest Rates /1
(Unless otherwise indicated, variables are expressed as deviations from trend)



1/ Scenario 1 corresponds to a constant world interest rate, while scenarios 2 and 3 correspond to declining world interest rates by 50 and 100 basis points between 2008 and 2038, respectively.

2/ The Pensions' Generosity Index is defined as the present value of pension benefits and lump sum transfers received by households during retirement, which is calculated at the time of retirement using the market interest rate.

Figure 5. Macroeconomic Results—Reform Scenarios under Constant and Declining Interest Rates
(Unless otherwise indicated, variables are expressed as deviations from trend)



1/ Scenario 1 corresponds to a constant world interest rate, while scenarios 2 and 3 correspond to declining world interest rates by 50 and 100 basis points between 2008 and 2038, respectively.

Figure 5. Macroeconomic Results—Reform Scenarios under Constant and Declining Interest Rates (cont.)
(Unless otherwise indicated, variables are expressed as deviations from trend)

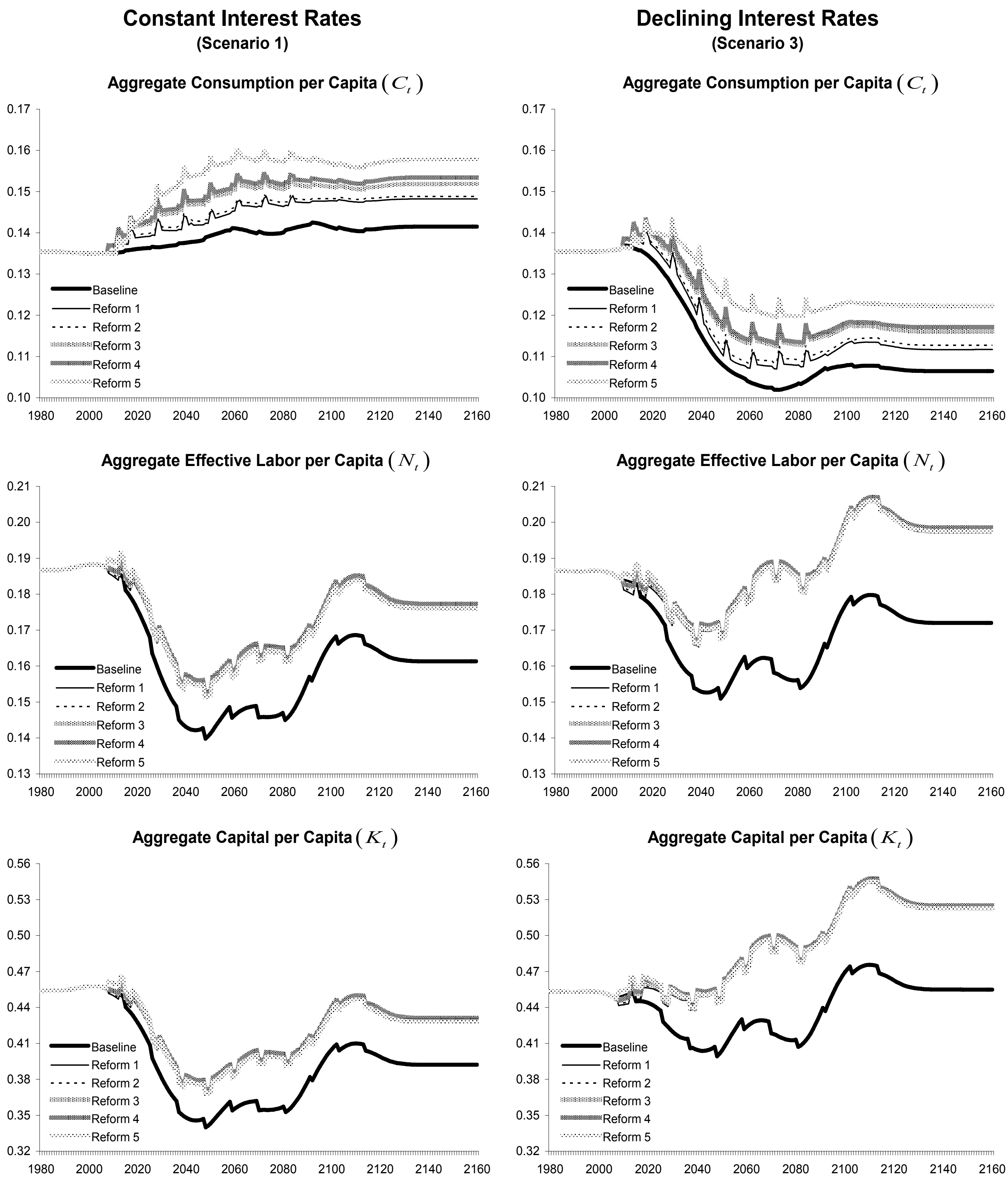


Figure 5. Macroeconomic Results—Reform Scenarios under Constant and Declining Interest Rates (cont.)
(Unless otherwise indicated, variables are expressed as deviations from trend)

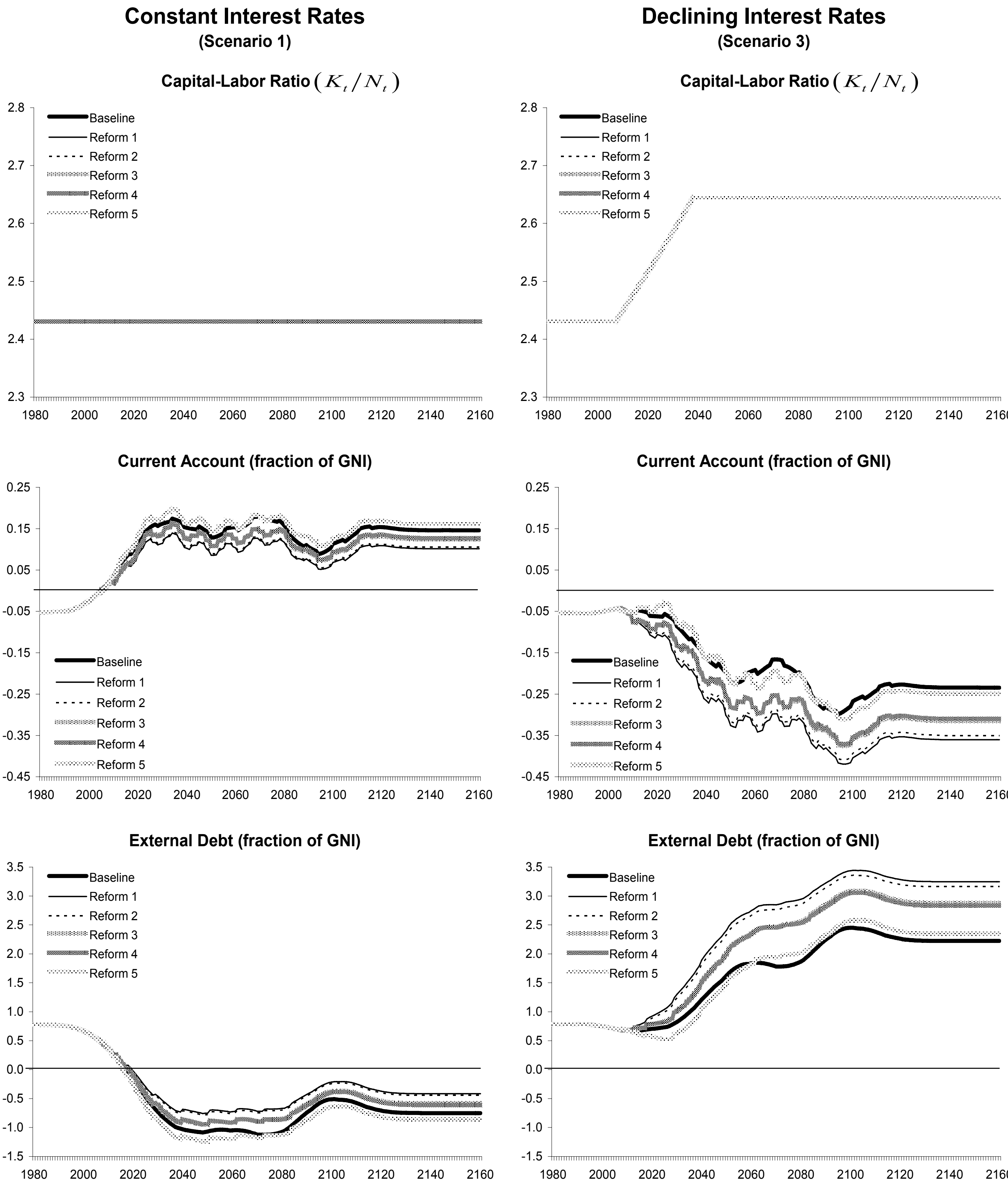


Figure 5. Macroeconomic Results—Reform Scenarios under Constant and Declining Interest Rates (cont.)
(Unless otherwise indicated, variables are expressed as deviations from trend)

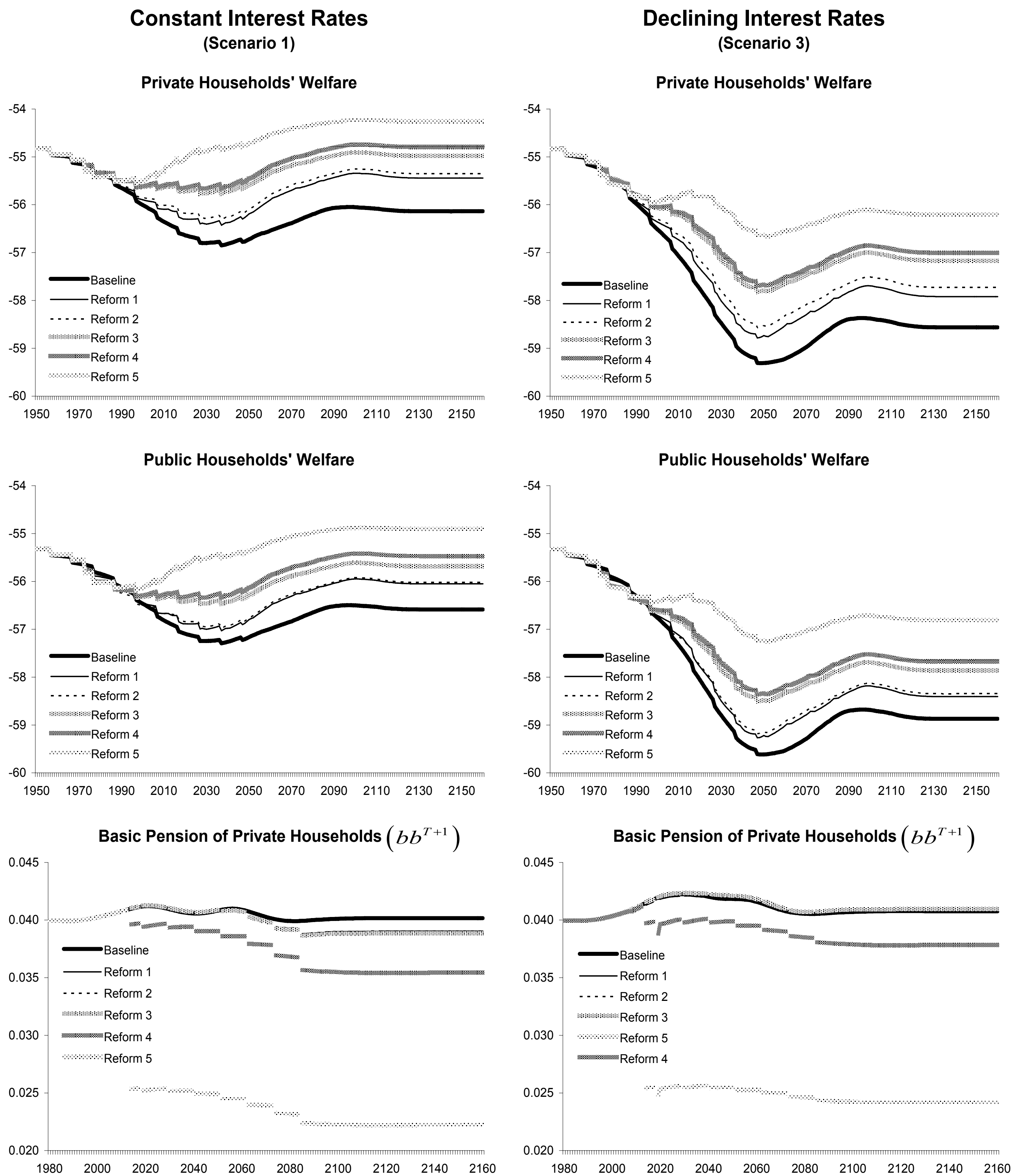
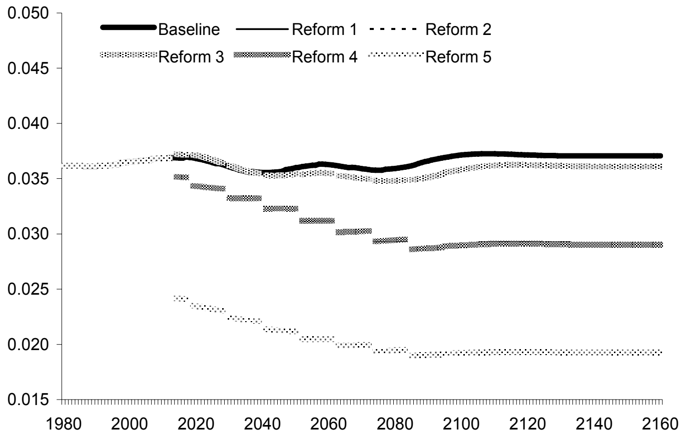


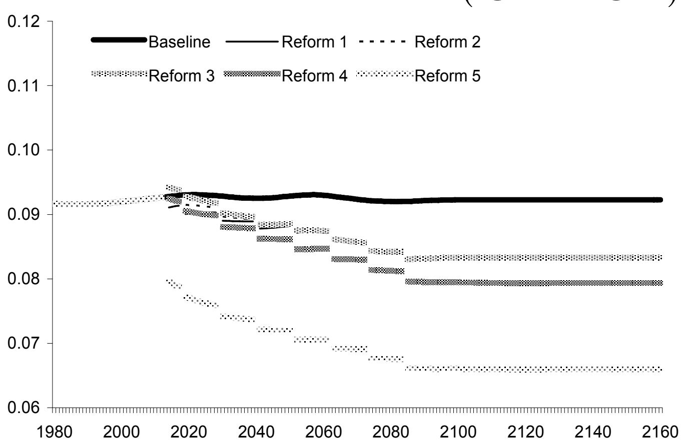
Figure 5. Macroeconomic Results—Reform Scenarios under Constant and Declining Interest Rates (cont.)
(Unless otherwise indicated, variables are expressed as deviations from trend)

Constant Interest Rates
(Scenario 1)

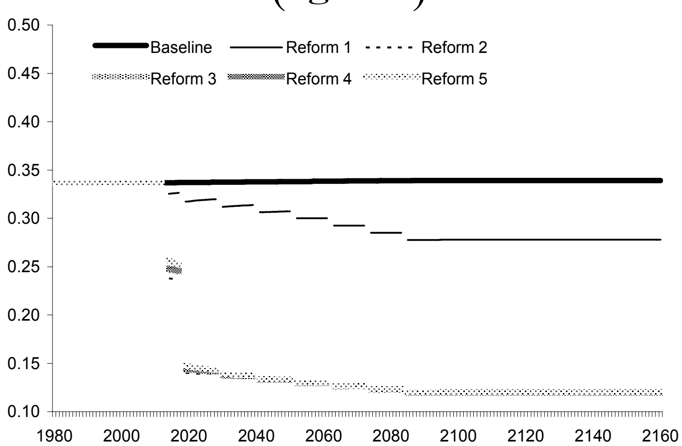
Supplementary Pension of Private Households $\left(bs^{T+1}\right)$



Pension Benefit of Public Households $\left(bg^{T+1}+bbg^{T+1}\right)$

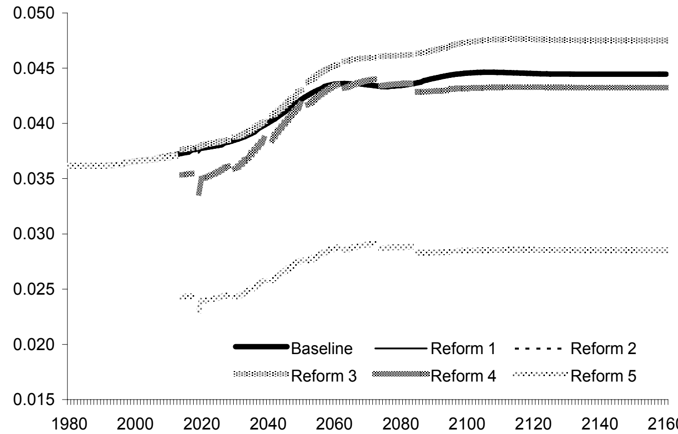


Lump Sum Retirement Transfer of Public Households $\left(bgls^{T+1}\right)$

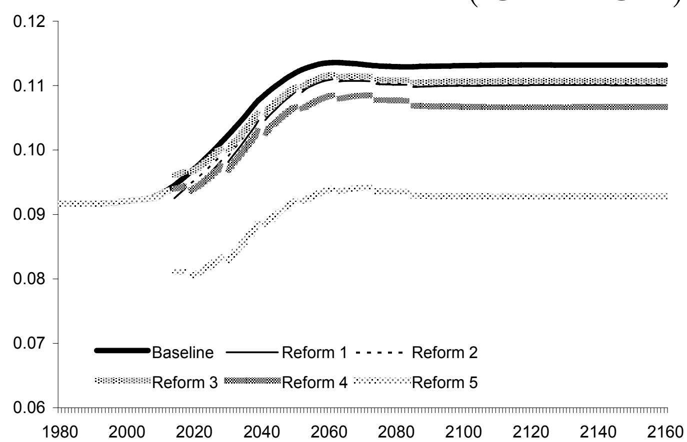


Declining Interest Rates
(Scenario 3)

Supplementary Pension of Private Households $\left(bs^{T+1}\right)$



Pension Benefit of Public Households $\left(bg^{T+1}+bbg^{T+1}\right)$



Lump Sum Retirement Transfer of Public Households $\left(bgls^{T+1}\right)$

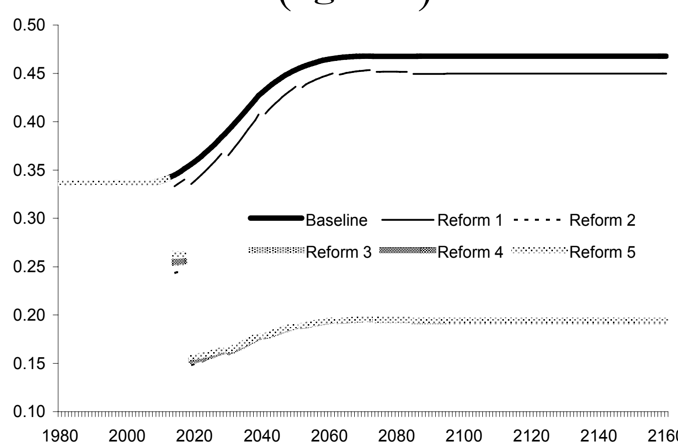


Figure 5. Macroeconomic Results—Reform Scenarios under Constant and Declining Interest Rates (cont.)
(Unless otherwise indicated, variables are expressed as deviations from trend)

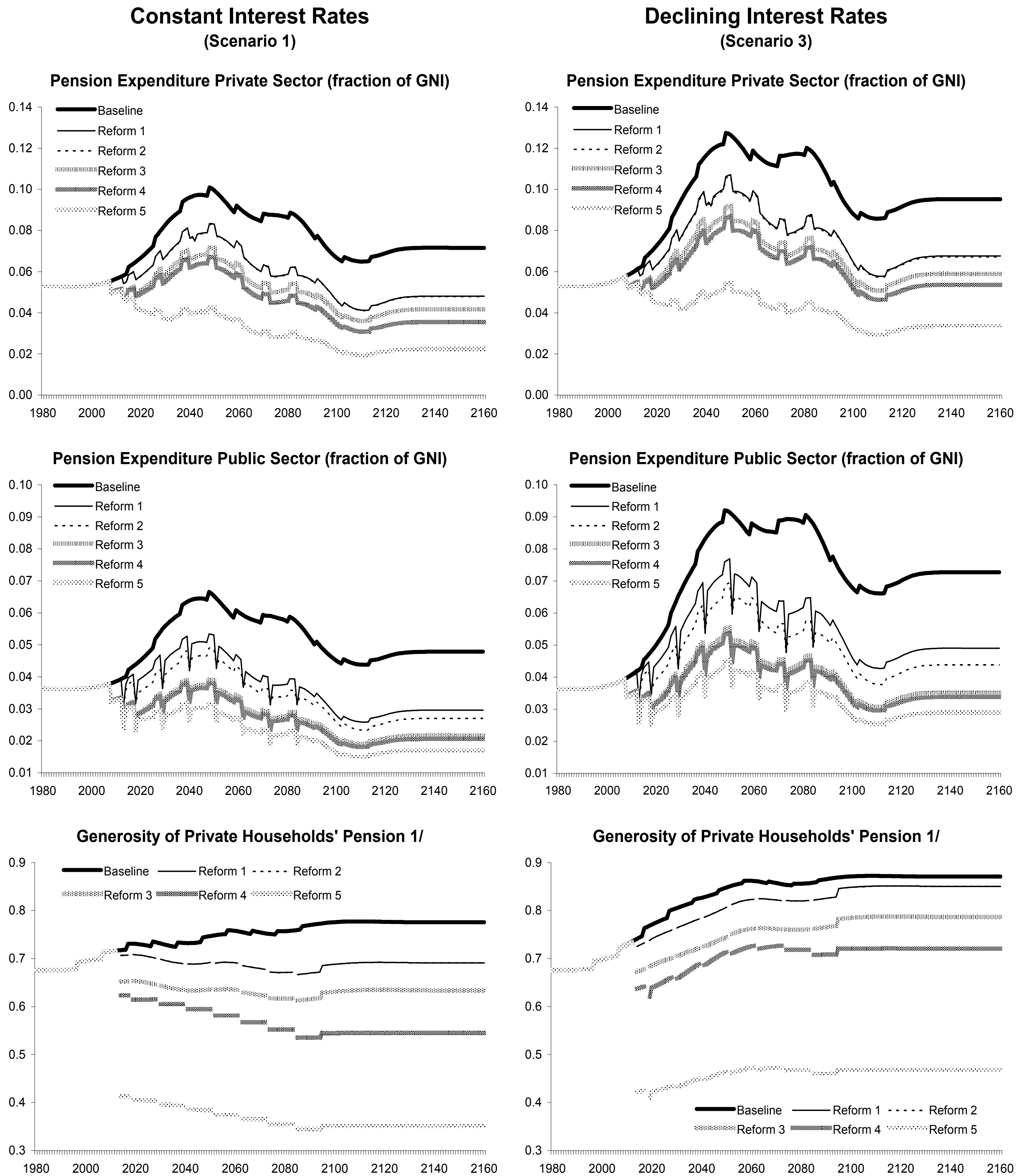
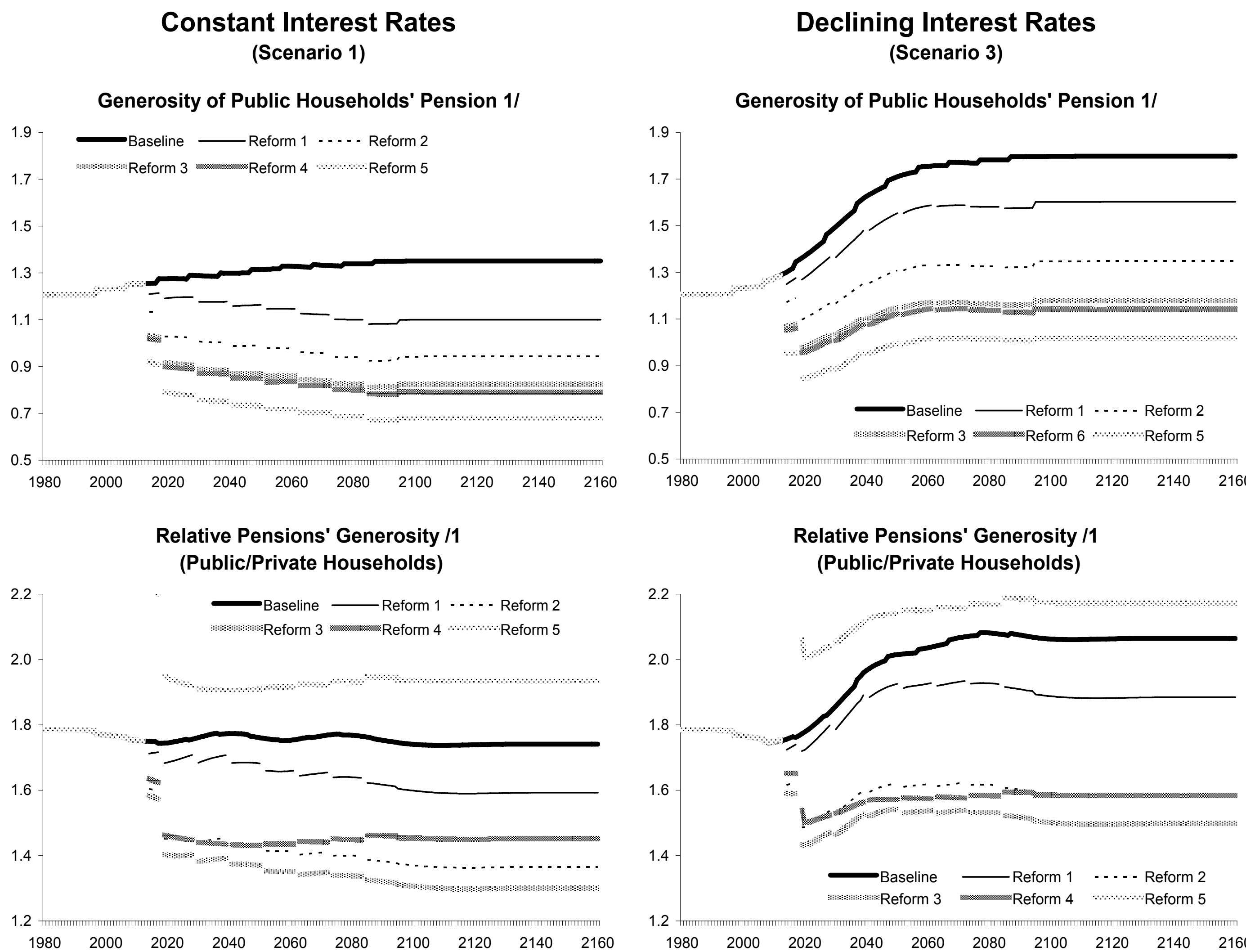
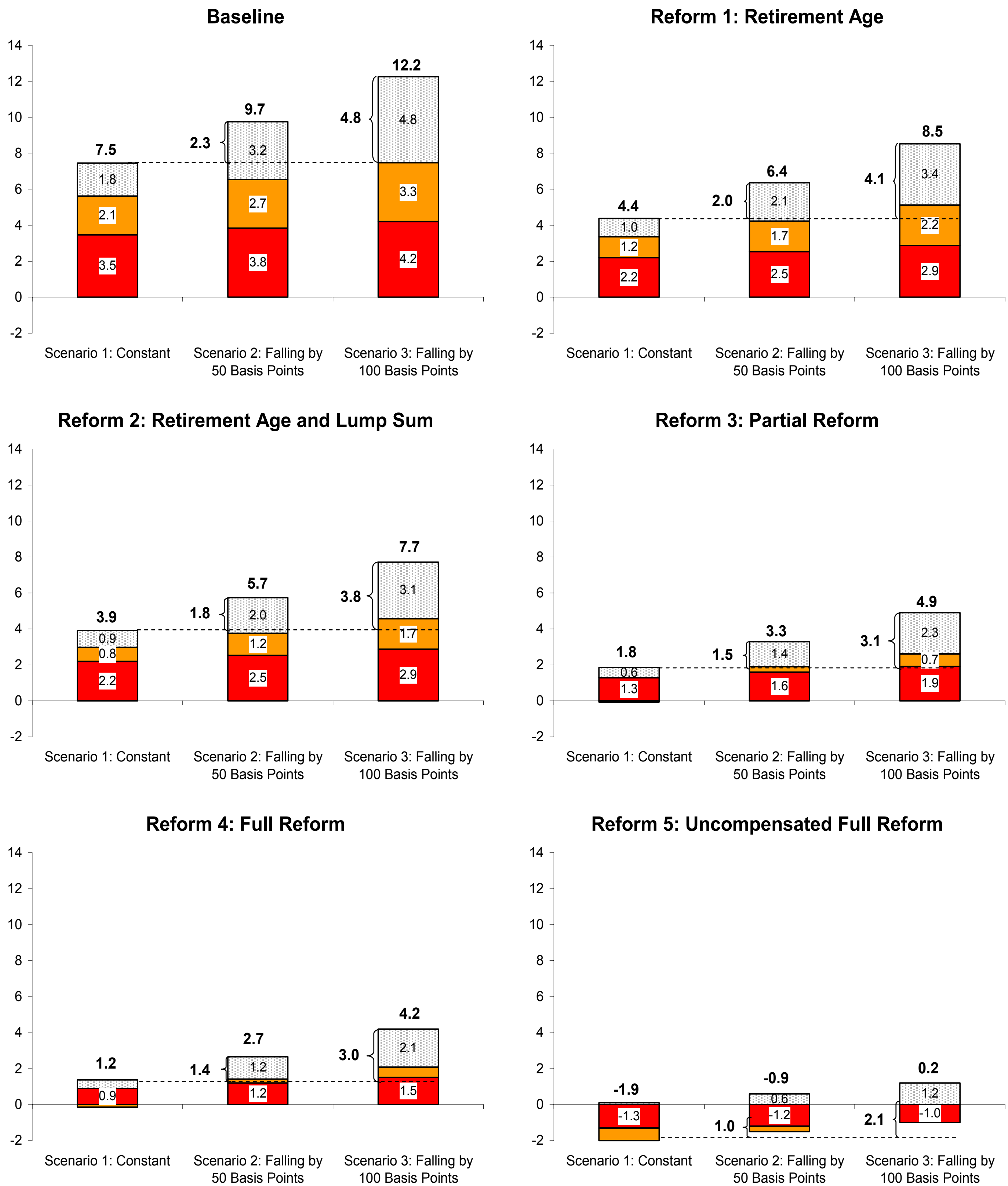


Figure 5. Macroeconomic Results—Reform Scenarios under Constant and Declining Interest Rates
(Unless otherwise indicated, variables are expressed as deviations from trend)



1/ The Pensions' Generosity Index is defined as the present value of pension benefits and lump sum transfers received by households during retirement, which is calculated at the time of retirement using the market interest rate.

Figure 6. Decomposition of Pension Expenditure-to-GNI Ratios—Pension Reform and Interest Rate Scenarios



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