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CYPRUS

Selected Issues

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Approved by the European Department

January 12, 2007

As background to the 2006 Article IV Consultation, this Selected Issues paper explores the economic consequences of aging and its impact on long-run fiscal sustainability.

The study analyzes the potential macroeconomic impact of different approaches to deal with the fiscal costs of aging. The study goes beyond a simple quantification of the fiscal impact by explicitly examining the trade-offs of alternative policies within the context of a general equilibrium overlapping generation framework. This approach captures an individual's responses to changing incentives that follow pension reform.

It concludes that addressing the fiscal consequences of aging will require increasing the retirement age to 65 years, followed by further increases to keep up with demographic trends. Moreover, the simulations verify the harmful macroeconomic effects of relying on increases in labor taxes instead of consumption taxes. The consequent reduction in welfare reflects the fact that the burden of labor taxes falls on the shoulders of a dwindling working force. Also, switching the indexation of pension benefits to prices can help moderate age-related spending and, by setting the stage for lower taxes than otherwise possible, protect net-of-tax pension benefits. Rebalancing the generous public pension benefits with those of the private sector further improves the macroeconomic results.

[1]The authors are thankful to Zenon Kontolemis for invaluable help in understanding the Cypriot pension system, and the participants of the informal seminar held in Nicosia on October 30, 2006.

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PENSION REFORM: ADDRESSING THE CONSEQUENCES OF AGING

A. Introduction

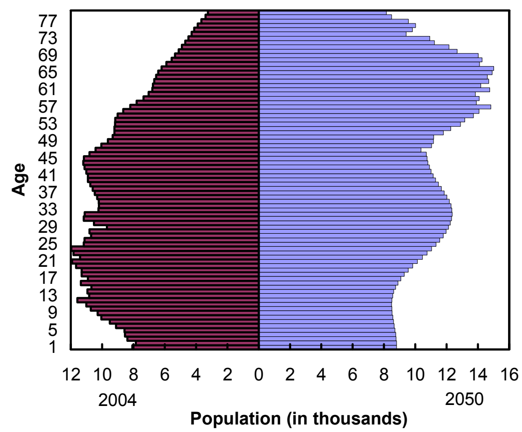
1. **In the coming 50 years, the population of Cyprus is expected to age substantially**. While people over 65 years of age currently make up 12 percent of the population, that ratio is set to double to over 25 percent by 2050. Aging will be even more pronounced for the very elderly. The absolute number of people over the age of 80 is set to quadruple between 2004 and 2050, more than tripling their share in the total population, from about 2½ percent to over 8 percent. Mirroring this, the share of the working-age population (age 15−64) is set to decrease from about 68 percent to 61 percent over the same period (text figure, and Figure 1).[2] These aging trends are in line with, though slightly less severe than, those in the EU (text table).

Table 2. Cyprus and EU: Population by Age, 2004–50

	2004	2030	2050
	(Percent of total population)		
Working age (15-64)			
Cyprus	68.1	63.8	60.5
EU-25	67.2	61.3	56.7
Elderly (65+)			
Cyprus	11.9	21.0	26.1
EU-25	16.5	24.7	29.9
Very elderly (80+)			
Cyprus	2.6	5.4	8.2
EU-25	4.0	7.2	11.4

Source: European Commission, Aging Working Group.

Age Pyramid for Cyprus, 2004 and 2050



Source: European Commission, Aging Working Group.

2. **Just as in many other countries, declining fertility rates and increasing life expectancy are underlying these aging trends** (Table 1). In particular, while as late as 1980 the Cypriot fertility rate was 2.5 births per woman, by 2005 it had dropped to 1.5, and is projected to remain at that level in the medium term. Also, life expectancy at birth increased from 70 years for men and 73 years for women in 1970 to, respectively, 77 years and 81 years in 2005. Moreover, further gains in life expectancy of about five years are expected by 2050.

3. **It is noteworthy that these population projections assume a substantial amount of immigration**. Cumulative net arrivals are projected to exceed a quarter of a million people in the course of the first half of this century (text table). With no immigration, the population would decrease by 3 percent between now and 2050, exacerbating the aging problem

[2] The population forecasts used in this study correspond to those of Eurostat's baseline projections.

correspondingly. Instead, in the baseline projection, the population of Cyprus grows by 33.5 percent by 2050.

Cyprus: Population Projections and Immigration

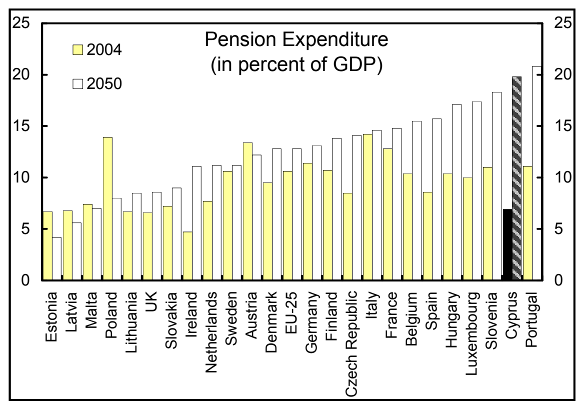
(In thousands, unless otherwise indicated)

	2005	2010	2020	2030	2040	2050
Total Population	739	784	866	921	952	975
Immigrant population 1/	103	134	188	234	281	329
Share of immigrants (In percent)	13.9	17.1	21.8	25.3	29.5	33.7

Sources: Eurostat and Staff Projections.

1/ Reflects projected immigration flows starting in 2005 and is estimated as the difference between the baseline population projection and the zero net migration scenario.

4. **These demographic trends challenge the long-run sustainability of the pension system in Cyprus**. Recent estimates by the EC's Aging Working Group (AWG) for the pay-as-you-go system (PAYG) suggest that, without reforms, pension expenditures in Cyprus will rise by 12.9 percentage points of GDP by 2050, compared with an average increase of less than 3 percentage points in the EU (text table). Although these estimates account for all of the elements of the system—including the general and the civil servant regimes—the projected increase may be overstated as it does not reflect the recent increase in the retirement age of civil servants. Still, even after accounting for this reform—as in the baseline simulation discussed below—old-age expenditure will increase substantially. In large part, expenditure will rise because the system has been essentially unchanged since it was introduced in 1980, when the life expectancy was 75 years—5 years less than it is currently—and the fertility rate was twice as high. Thus, by 2050, expenditure is poised to leap to among the highest in the EU from its current low position (text figure).



Source: European Commission, Aging Working Group.

Cyprus: The Demographic Shock

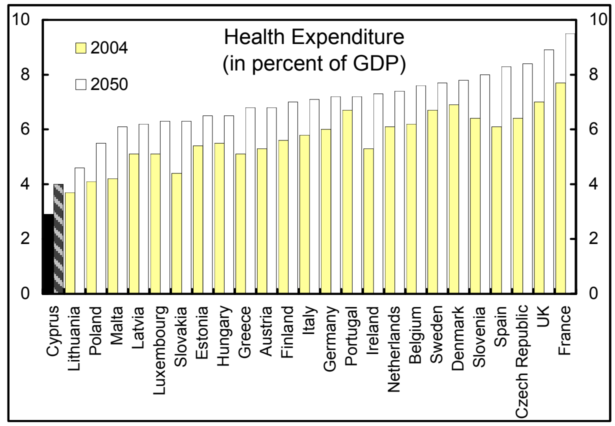
(In percent of GDP, unless otherwise noted)

	Old-Age Dependency Ratio 1/		Public Pension Expenditures		Peak Pension Expenditures	
	Change to 2050	2050	Change to 2050	2050	Peak Year	Value
Cyprus	14	27	12.9	19.8	2050	19.8
EU-25	13	30	2.2	12.8	2044	12.8
EU-15	13	30	2.3	12.9	2043	13.0
EU-10	16	29	0.3	11.1	2050	11.1

Source: Eurostat, and European Commission, Aging Working Group.

1/ Ratio of dependents to total population (in percent), where dependents are those above 64 years of age.

5. **Health expenditures are also set to increase**. The problem in Cyprus is less severe than in the rest of the EU. Cyprus's current public health expenditure is 2.9 percent of GDP, less than half the EU-25 average (text figure), although health expenditures have roughly doubled as a share of GDP in the past 20 years. Expenditures are expected to increase by 1.1 percentage points of GDP by 2050, against the EU average increase of 1.6 percentage points.



Source: European Commission, Aging Working Group.

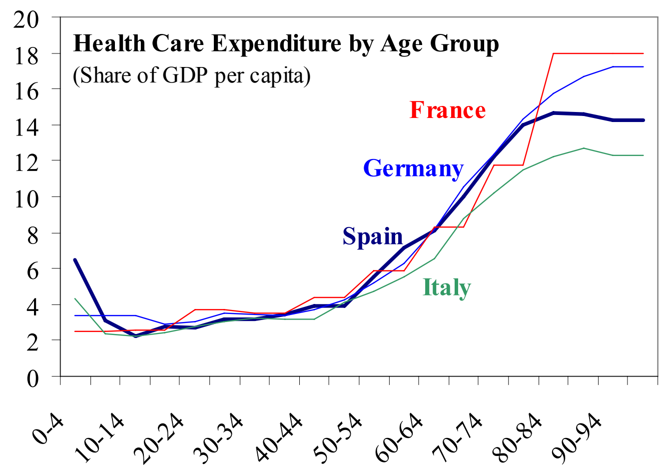
6. **Against this background, in 2005 the government announced increasing the retirement age of civil servants from 60 to 63 by 2008**. Although this reform places civil servants' retirement age in line with the average retirement age in Cyprus, it still met with stiff opposition from trade unions. The authorities are considering extending such increases to educational services and semi government organizations. In addition, the Convergence Program 2006–10 considers two waves of parametric reforms for the Cypriot pension system. These reform would include tightening the criteria for pension eligibility and early retirement—thereby increasing the effective retirement age to 65 years—and increasing social security contributions. The time line for these reforms has not been spelled out.

7. **This study analyzes the potential macroeconomic impact of pension reform for Cyprus using an overlapping-generations general equilibrium model**. Although others have measured the fiscal implications of aging in Europe and in Cyprus (notably the EC's AWG and the authorities' Actuarial Notes) these exercises have largely involved extrapolating past macroeconomic trends in light of demographic profiles. Those results are useful in illustrating the implausible adjustments in contributions or benefits that, in the absence of broader reforms, would be required to ensure the sustainability of the pension system. But they provide a partial view of the implications of reforms, as an individual's behavior is taken as independent of the implicit incentives change.

8. **The model used in this study—in the tradition of Auerbach-Kotlikoff—endogenizes an individual's lifetime labor-leisure and consumption-savings decisions**. In each period, and throughout a person's work life, an individual maximizes his or her utility by deciding how much time to devote to work and how much to save. An individual's productivity, moreover, changes as he or she gains work experience. Also, the model used in this study explicitly captures key institutional features of the Cypriot pension system, including the different regimes for private and public employees. The model assumes that Cyprus is a small, open economy and thus faces an exogenously determined world interest rate. As discussed below, each scenario is simulated under two alternative world interest rate paths. The first is the unlikely case of unchanged interest rates. The second mimics the path of world interest rates, reflecting worldwide aging patterns on capital flows (Börsch-Supan,

Ludwig, and Winter, 2005); a conservative path is considered in this case to illustrate the sensitivity of the simulation results to world interest rate developments. Also, the model includes population growth—capturing the transitional effects of the demographic shock—and micro- and macro-economic feedback effects. This study is thus better able to explore the macroeconomic effects of pension reform in Cyprus.[3]

9. **The model also accounts for the effect of aging on health care spending**. Specifically, health care expenditures in the model reflect the *j*-shaped profile of health care spending over a household's life (text figure). In other words, health care expenditure is typically a bit higher for young children than for young adults but rises sharply later in life. For Cyprus, the simulations use the health care profile observed for large European countries, scaled to match health care expenditure given Cyprus's demographic profile.[4] This approach, however, is incomplete. It does not account for the impact of medical advances—underlying the development of new medical treatments—and demand for new capital-intensive treatments (Heller, 2003), nor does it reflect the potential beneficial impact on an individual's productivity stemming from advances in health.[5]



Source: OECD working paper, Spending on health and long-term care: projections to 2050 revisited.

10. **The model is used to analyze the macroeconomic implications of three policy scenarios**:

- **Baseline scenario**. This provides a benchmark to contrast the macroeconomic effects of the pension reform. Individuals enter the workforce at age 23 and, having worked

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[3] In the model, the labor force entry (inclusive of immigration flows) was calibrated so that, together with gains in life expectancy, the model matched the dependency ratio path in Eurostat's population projections.

[4] Specifically, the profile used is that of Spain, which is roughly an average of the profiles of France, Germany, and Italy. Over time, health care costs for individuals increase with productivity gains, and thus the health care expenditure profile (as a share of GDP) remains constant.

[5] Also, the analysis does not account for the introduction of the National Health Insurance Scheme in 2008, which will phase in much-needed competition in the provision of health care. Public hospitals will remain sheltered from competition for the first three years.

for 40 years, retire at age 63. After retirement, private and public sector employees receive their corresponding pension benefits through the remainder of their lifetime. At the outset of the simulations, the retirement period is 18 years, corresponding to a life expectancy of 80 years. In the simulations, the retirement period increases with life expectancy projections (one year per decade) until it reaches 28 years in 100 years, that is, in 2108. The economy benefits from (labor augmenting) technological progress—2½ percent per year—in line with historical trends. The scenario assumes that consumption taxes are adjusted as needed to keep public debt unchanged in percent of GDP; also government consumption remains constant as a share of GDP.[6]

- **The Convergence Program** (CP). This scenario is designed to capture the key features of the parametric reforms envisaged in the CP. Specifically, it considers the effects of increasing the effective retirement age from 63 years to 65 years by 2018 and adjusting social security contributions by 5 percentage points. These reforms are taken to be announced in 2008, and, effective immediately thereafter, social security contribution rates would be increased. Starting in 2013 (2018) individuals would work one (two) more year(s) before retiring. Although the model does not account for additional once-and-for-all improvement associated with a tightening of eligibility requirements,[7] savings in old-age pensions are substantial. In large part, this is because the implementation of these reforms assumes limited grandfathering.

- **Additional parametric reforms**. As improvements in life expectancy are envisaged for the next several decades, this scenario proposes to further increase the retirement age gradually to ensure that the pension system keeps up with demographic trends. Specifically, after the retirement age reaches 65 years, for the next 100 years it would increase one year per decade until it reaches 73 in 2098. To further limit age-related expenditure increases, and, in contrast with the CP, this scenario also includes switching the indexation so that all pension benefits are indexed to prices. In addition, the scenario addresses the mismatch in generosity between public and private pension benefits by gradually reducing the lump-sum payment awarded to public sector employees at retirement from 28 months to 12 months of pay.

11. **The simulations suggest that the severity of the macroeconomic consequences of aging can be mitigated by implementing parametric pension reforms**. Not reforming the social security system would substantially reduce output growth and economic welfare for

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[6] Public debt can be lowered by prefunding the demographic shock, that is by increasing tax rates ahead of time, and/or by reducing public consumption.

[7] The CP proposes tightening the eligibility requirements for old-age pensions. Currently, individuals who have worked at least 10 years and contributed to social security for 3 years are eligible for old-age pension benefits at age 65. Eligibility for a basic pension requires the average annual income and contribution period to be at least 25 percent of the basic earnings and 3 years, respectively. Introducing this effect in the model requires heterogeneity in individuals, the complexity of which lies beyond the scope of this analysis.

decades. Although the reforms envisaged in the CP lower age-related expenditure, they would not suffice, as future gains in life expectancy will offset these savings. Moreover, the perverse incentives to work associated with social security rate increases, tend to lower household's welfare. As discussed below, additional reforms are needed to keep up with demographic trends, limit welfare losses and align the generosity of public and private pension schemes.

B. The Cypriot Pension System

12. **The pension system comprises the General Social Insurance Scheme** (GSIS)**, the Government Employees' Pension Scheme** (GEPS) **and a few smaller schemes**. In 2005, total pension expenditure in Cyprus was about 8.5 percent of GDP (Table 2). Expenditures in the GSIS will grow from 6.3 percent of GDP in 2005 to 12.6 percent in 2050 (Republic of Cyprus, 2005). Although the PAYG GSIS has an element of prefunding—as it currently runs a surplus and accumulates reserves—the authorities estimate that social contribution rates (payroll taxes) will have to increase by about 5 percentage points to 22.9 percent by 2050. Expenditures in the GEPS are set to grow from 2.2 percent of GDP in 2005 to 4.1 percent of GDP in 2050 (Republic of Cyprus, 2005). The GEPS is financed by (reduced) contributions of public sector employees and tax revenues. The current pension system was established in September 1980,[8] and its components are briefly discussed in turn.

The General Social Insurance Scheme (GSIS)

13. **The GSIS is a universal, compulsory pension scheme and by far the largest component of national pension expenditures**. It accounts for about three-fourths of total old-age pension expenditure (Table 2). It is funded by tripartite contributions totaling 16.6 percent of earned income (text table). Contributions, however, are capped, as income in excess of ₤C 2,077 per month is not subject to compulsory contributions. Past favorable demographic trends have generated large surpluses; reserves have reached the equivalent to 37 percent of GDP, or about eight times the annual pension outlays. Almost the entire reserve is invested in central bank bonds.

Contribution Rates to Social Security
(In percent of earnings)

General social insurance scheme 1/	16.6
Employee	6.3
Employer	6.3
Government	4.0
Government employee pension scheme 2/	3.2
Employee	3.2

Source: The Ministry of Labor and Social Insurance.

1/ Income in excess of CYP 2,077 monthly is not subject to compulsory contribution.
2/ The government does not contribute a fixed share of earnings. Benefit payments exceeding employees' contributions are financed through the budget.

[8] The previous system—based on flat-rate contributions and benefits—had been in place since the late 1950s. It established retirement at 65 years of age (lowered to 63 years in 1991) and provided a subsistence-level benefit, which, in essence, was preserved in the form of the basic pension in the current system.

14. **The old-age pension benefit under the GSIS comprises an earnings-related basic and supplementary pension benefits as follows**:

$$Pension^{GSIS}_{T+i} = Basic_{T+i} + Supplementary_{T+i},$$

where T and i denote the retirement year and the number of years since retirement. These components reflect an individual's work life and annual income earnings,

$$Basic_{T+i} = \alpha_B \times \left(\frac{Pts_{LowerBand}}{InsurableLife}\right) \times BasicEarnings_{T+i}, \text{ and}$$

$$Supplementary_{T+i} = \alpha_S \times Pts_{UpperBand} \times BasicEarnings_T \times \left(\frac{CPI_{T+i}}{CPI_T}\right),$$

where

- α denotes the replacement rate and the subscript denotes the benefit component (0.6 for the basic component and 0.015 for the supplementary component);[9]

- *BasicEarnings* corresponds to the statutory earnings set each year and expressed as an annual amount (in 2005, it was set at £C 79.9 weekly, or £C 4,155 annually);

- *Pts*, represents cumulative points earned toward each pension component: $Pts = \sum_{t=1}^{T} pts_t$. Points per year are calculated as $pts_t = wages_t / BasicEarnings_t$, with the first point accruing to the lower band (basic pension) and remaining points accruing to the upper band (supplementary pension);

- *InsurableLife* is the number of years in the workforce since an individual's 16th birthday (or since October 5, 1964, whichever is less);[10] and

- *CPI* is the consumer price index.

The basic pension benefit is computed each year based on the corresponding basic earnings. Thus, it is indexed to wages because basic earnings are. In contrast, the supplementary pension is computed once, given the basic earnings at the time of retirement, and subsequently adjusted by inflation.

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[9] α_B increases by 0.1 for each dependent child and by 0.2 if an individual is married.

[10] If an individual's wages exceed *BasicEarnings* every year, the basic component of the pension would be $Basic_{T+i} = \alpha_B \times 1 \times BasicEarnings_{T+i}$.

15. **Currently, the basic pension is about 27 percent of the average insurable earnings** (up to £C 24,924 per year). This is about 20 percent of the average income earnings. The supplementary benefit virtually doubles this amount, and thus the after-tax replacement rate is close to 60 percent. Individuals who have worked at least 10 years and contributed to social security for 3 years are eligible for old-age pension benefits at age 65. Still, individuals who have contributed to social security for 28½ years can retire at 63, and many do so: the average retirement age is close to 63. To be eligible for the basic pension, $Basic_{T+i}$, average annual income during an individual's work life must be at least 25 percent of the basic earnings, and the insurable life must be at least three years.[11] Also, note that there is an upper limit on this annual pensionable income (£C 24,924 in 2005). Beyond that level, the social pension contributions stop, and insurable points are not earned.

The Government Employees' Pension Scheme (GEPS)

16. **The GEPS is a compulsory pension scheme for public sector employees and the second-largest social insurance expenditure**. In 2005, it accounted for about 25 percent of the total social insurance expenditure and covered about 30,000 people. It is funded by employee contributions—0.75 percent of earning up to the maximum insurable earnings and 1.75 percent above that level—and shortfalls in contributions are financed by the public purse. The government employee scheme has a retirement age of 60, which is set to increase to 63 by 2008. For certain careers, such as police, the retirement age is 55. Furthermore, civil servants are allowed to retire five years early without an early retirement penalty. The average age of retirement of government workers is 57.

17. **The retirement pension benefit under the GEPS comprises the basic pension, a monthly pension and a onetime lump-sum payment at retirement**. Besides the basic pension, which is computed in the same manner as for private households, public sector employees receive an additional monthly pension benefit that is a fraction α of the final salary, $Salary_T$,:

$$Pension_{T+i}^{GPES} = Basic_{T+i} + Public_{T+i},$$

$$Basic_{T+i} = \alpha_B \times \left(\frac{Pts_{LowerBand}}{InsurableLife}\right) \times BasicEarnings_{T+i},$$

$$Public_{T+i} = \alpha \times Salary_T \times \left(\frac{Wages_{T+i}}{Wages_T}\right).$$

The replacement rate α is equal to the number of months of service, up to a maximum of 400 months, divided by 800. Thus, the pension is at most 50 percent of a government employee's

[11] Provided that the average salary is at least equal to the basic earning.

final salary. Subsequently, the GEPS benefit is indexed to wages. Besides the basic and monthly pension benefit, at retirement government employees receive a lump-sum payment

$$Lump\ Sum_T = \lambda \times Salary_T,$$

equal to 28 (λ) times their final monthly salary if they have served at least 400 months; a prorated amount is paid to those with shorter service.

18. **Employees of the semigovernment institutions have their own pension schemes**. The semigovernment employees' pension schemes, which cover employees of public utilities, local governments, and similar entities, are funded by the respective employers. In other words, shortfalls in these pension schemes will also be reflected in the government's budget. However, these represent a much smaller portion of old-age spending.

Other components

19. **These components comprise the Special Allowance to Pensioners, the Social Pension Scheme and Voluntary Provident Funds**. These are considerably smaller as a share of total pension expenditure, and are as follows:

- The *Special Allowance* (between £C 456-620 per year) granted to anyone whose pension income is below £C6,500 (ranging about two to three times the basic pension). This allowance is financed by tax revenues and accounts for 6 percent of total pension expenditures by the government.

- The *Social Pension* scheme designed to provide a minimum standard of living to those who for whatever reason, did not take part in the GSIS; it provides a minimum-subsistence standard of living. The amount of pension is set at 81 percent of the basic social insurance pension, which itself is about 25 (20) percent of the median (mean) labor income. The pension is also financed by tax revenues and amounts to 3 percent of total pension expenditures by the government.

- *Voluntary Provident Funds* are employer- or profession-based defined-contribution savings schemes that provide a lump-sum payment upon retirement. These are not widely available: for the majority of participants in the GSIS, the universal pension was their only pension income. Less than 43 percent of pensioners benefit from additional pension income.

C. The Cypriot System in Context and Reforms in Selected Countries

20. **Several elements of the Cypriot pension system are similar to those in advanced countries**. Like Cyprus, most OECD countries have a defined-benefit scheme. The statutory retirement age in the private sector in Cyprus is roughly in line with the OECD averages. In most of the advanced countries, pension amounts are calculated based on average lifetime earnings, a method that is similar to the Cypriot point system (discussed above). In about half

of the OECD countries, pensions are indexed to wages, while in the other half they are indexed to prices. As a result, the replacement rates in Cyprus are similar to OECD averages. Because many of the advanced countries also face demographic pressures, many pension systems have undergone reforms. This section briefly reviews the pension reform experiences of three countries.[12] Greece illustrates a highly complex system with a number of different pension schemes. Italy presents the case of a system with wage indexation and differential treatment of public and private sector employees and reforms that switched indexation to prices and unified the public and private sector pension systems. Sweden offers an alternative system with innovative elements.

Greece

21. **The Greek pension system comprises of a large number of self-governed social insurance funds, which arose in part from prior occupational schemes**. As a result, rules for contributions, investing, and payouts vary substantially. Efforts have been under way for some time to reduce these differences and consolidate the funds, including by merging them with the largest (IKA). Still, in 2005, 173 social insurance funds remained, of which 24 were primary funds which provide the main pension, and the rest were supplementary funds. All are backed by the government, and, therefore. all are included in the general government fiscal position.

22. **The Greek pension system as a whole already has a significant deficit, and outlays are projected to rise sharply in the years ahead**. According to Gagales and Roehler (2006), under the baseline scenario the current pension system is in a dire state, with the public debt set to reach some 400 percent of GDP by 2050 in the absence of policy adjustment.

23. **The government began a series of reform attempts in the late 1980s**. However, it was not until 1990-92 that a deep crisis in Greece's public finances, combined with the initiation of EMU negotiations prompted a first wave of reforms:

- The "Sioufas Law" of 1990 introduced some spending cuts and introduced gradual increases in contributions but fell well short of correcting the structural deficiencies of the system.

- The "Manos Law" of 1992 was a substantially watered-down version of an initial comprehensive reform draft that had proved politically infeasible. The reform was largely parametric: retirement age and contributions were increased, but the fragmentation of the system and the inequities of provision remained. Still, its sustainability was ensured through 2010.

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[12] For more detailed treatment and further country cases, see OECD (2005).

- The Spraos Report of 1996, the Yannistis Report of 2001, and other reform initiatives were thwarted by fierce political opposition.

- The Reppas package of 2002, taking such opposition into account, provided for differential treatment of older and younger workers, and was included along with a large (€1.3 billion) up-front injection of government funds, into the largest social security fund. The sum total of measures was designed to ensure pension fund sustainability to 2030, but at the cost of annual transfers equivalent to 1 percent of GDP from the state budget to the pension funds.

Italy

24. **The Italian pension system is based on notional accounts**. This amounts to a modified pay-as-you-go public pension system. Individual contributions earn a (notional) rate of return that is related to real GDP growth. The resulting pension benefits are a function of accumulated notional capital and an actuarial factor; the latter reflects average life expectancy at retirement. This system applies to labor market entrants from 1996 onward**.**

25. **Pension expenditures increased rapidly in Italy during the 1970s and 1980s, as the system was becoming more inclusive**. By 1992, pension expenditure was 14.9 percent of GDP, considerably higher than the EU average. While Italy has the highest pension expenditure as a share of GDP in the EU, this share, according to the latest EU estimates, is projected to increase minimally between now and 2050. These projections, however, may be based on overly optimistic assumptions about growth and productivity, as well as full implementation of the above reforms. Alternative projections by IMF staff—as well as those by some academics—suggest much higher increases if labor productivity fails to substantially exceed the rate achieved in Italy over the last decade.

26. **Three successive rounds of reforms sought to contain rising spending and ensure long-run sustainability**:

- The 1992 Amato reform raised the retirement age by 5 years; lengthened the reference period for calculating pensions from 5 to 10 years, and to the entire working life for younger workers; raised the minimum number of years of contributions to be eligible for a pension from 15 to 20 years; changed the indexation of pensions from wages to prices; and harmonized pension rules across public and private sector workers. The reform was widely seen as a success, reducing the net present value of pension liabilities by more than 100 percent of GDP. Furthermore, it set the tone for an ambitious pension reform agenda.

- The 1995 Dini reform had as its primary objective reducing the distortions in the labor market and improving fairness. In effect, it marked a structural change in the Italian pension system, beginning the process of a gradual transition from a defined-benefit to a defined contribution scheme, which will be completed by 2030.[13] The reform instituted notional individual social security accounts while making labor market decisions more flexible. For instance, while the reform directed pension amounts to be calculated based on the contribution over the entire working life, it also reduced the retirement age and the minimum number of years in the scheme needed to be eligible to draw a pension. While the reform fundamentally transformed the structure of the pension system in Italy, it had little immediate impact on pension spending, as the replacement rates changed only marginally for older workers. However, these rates will drop significantly for those retiring after 2012.

- The Maroni-Tremonti reform adopted in 2004 further raised the retirement age for certain types of pensions, in a sequence of steps envisioned to begin in 2008. In addition, it provided for the creation of a supplementary private sector pillar, also due to come into effect in 2008. Other things equal, the increase in the retirement age would contribute significantly to fiscal sustainability by lowering pension spending by up to ¾ of 1 percentage point of GDP in 2012−30—at the time of the expected "hump" of age-related spending in Italy. However, proposals have recently been made to modify some aspects of this reform before it comes into effect that could weaken its fiscal impact.

Sweden

27. **The prereform Swedish pension system was a defined-benefit one**. However, with the impact of future demographic trends, a slowdown in growth during the 1980s, and the recession in the early 1990s, the system was recognized as being unsustainable in the long run. Legislation for a new pension system was enacted in 1994.

28. **The key objectives in designing the new pension system were to ensure its long-run sustainability and to maintain social justice, even in the face of demographic shocks**. As a result, a so-called notional defined-contribution scheme was introduced. It has four main features. First, the pension is calculated based on contributions over the entire lifetime. Second, pensions are indexed to wages. Third, annuity payments are adjusted to changes in life expectancy, so that an increase in life expectancy implies either a decrease in pension amounts or a later retirement age. As a result of these changes, the system is also more flexible on retirement age, lowering it from 65 to 61, and allowing retired persons to accumulate pensionable income if they continue working past retirement. And fourth, the reform introduced a supplemental pension to top up the earnings-based pension for low income individuals.

29. **According to the latest EU projections, pension spending in Sweden will not rise much as a fraction of GDP by 2050**. However, it is important to note that sustainability in

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[13] Currently, however, the pension system continues to be mostly defined benefits.

this case is ensured by automatic adjustments to pension benefits, and thus a risk remains that these benefits may decrease beyond to what is politically acceptable.

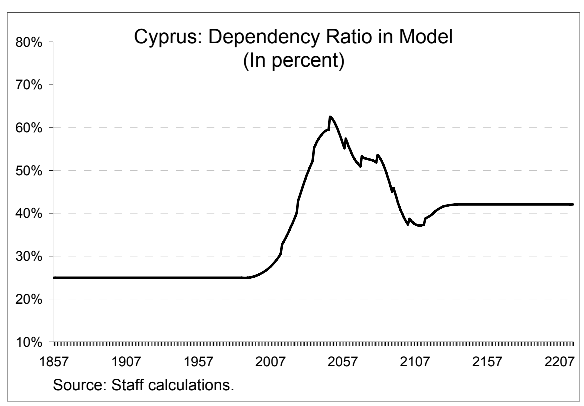
D. The Model and Simulations

The model is designed to capture the main features of the Cypriot system and examine the macroeconomic effects of pension reform. As discussed below, the model takes as given world interest rate and demographic developments.

Model overview and demographic transition

30. **The macroeconomic effects of the demographic shock in Cyprus are examined using an overlapping-generations model in the Auerbach-Kotlikoff tradition**.[14] In this type of model, the economy is populated by overlapping generations of households, atomistic firms, and the government. Households consume and accumulate assets during their lifetime, work during their youth and middle age, and retire when old. Firms produce a single good using labor and capital, and the government collects income, consumption, and payroll taxes to finance government expenditures and pension benefits, and redeem the initial government debt. Although the general equilibrium structure is standard, the model incorporates specific features of the Cypriot pension system. Specifically, as discussed above, it includes separate old-age pension regimes for private and public sector employees. The former reflects the points based system and indexation mechanisms of the basic and supplementary pension benefits; the latter accounts for the pension benefit based on the last salary and the onetime lump-sum payment at retirement. The model also includes labor-augmenting productivity growth. Details of the formal model and its calibration can be found in Appendix I.

31. **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 300-year period, with the middle century (1957−2057) covering the demographic transition from a high to a low fertility rate. In the first century, the growth rate of new entrants to the labor force was set at 0.85 percent, which is the average population growth during 1960−2005. During the demographic transition, however, the labor force growth rate varies to replicate the dependency ratio—defined as the ratio of the population aged 23−63 to

[14]See Auerbach and Kotlikoff (1987). For a more recent survey of this literature, see Kotlikoff (2000); numerical methods to solve these models are described in Heer and Maußner (2004) and Judd (1999).

the population over 63—in Eurostat's baseline population projections for the period 2004−51 (text figure). In other words, the dependency ratio in the model peaks at over twice its current rate toward the end of the middle century (2050). The final century sees labor force entrants growing at a rate of 0.5 percent per annum, and the dependency ratio falling back but remaining higher than it is currently. As noted above, two interest rate paths are considered in the simulations discussed below. The first keeps the real interest rate unchanged. In the context of global aging, however, this scenario is unlikely. As the world ages—at different rates and starting from differing starting points—global savings are envisaged to increase.[15] Increased savings will depress real interest rates for the next few decades. Börsch-Supan, Ludwig and Winter (2005) estimate that—under alternative regional pension reform scenarios—real interest rates will decline by about 100 basis points by 2050. In this study, a more conservative 50-basis-point reduction in real interest rates is considered.

32. **For the discussion of the results below, it is important to understand household's behavior in this framework**:

- **Two sets of conditions solve the household's objective—maximizing lifetime utility—under standard dynamic optimization techniques**. The first set refers to household's consumption-leisure decision in a specific year (intratemporal first-order conditions). In each period, the household equates the marginal utility of consumption (scaled by wages)—made possible by increasing time devoted to work—to the marginal utility of leisure. The second set governs the household's consumption-savings decisions over time (intertemporal first-order conditions, or Euler equation).[16] In this case, households equate the marginal utility of current consumption to the marginal utility of future consumption (scaled by the rate of return on savings).

- ***Each set of equations reflects whether a household is in the labor force or not, and the peculiarities of the pension rule***. The pension rule introduces two subperiods in a household's life: working years and retirement. Private sector households, in the first subperiod, comply with the intratemporal (consumption-savings decision) and intertemporal (labor-leisure decision) conditions. The intratemporal condition reflects the fact that wage earnings provide additional utility during retirement because of their effect on the pension benefit. When the household retires, there is no labor supply choice, by definition, and only the consumption-savings decision remains. For public sector households, however, there is one difference: in the first subperiod, the intratemporal (consumption-savings) condition does not reflect the fact that wage

[15] The increase in savings follows even though, at different stages of aging, a country or geographical region will initially export capital and accumulate foreign assets as it saves for retirement; subsequently it will draw down these assets in retirement.

[16] When households retire, they face only an intertemporal condition, as they no longer supply labor.

earnings accrued in this subperiod provide additional utility during retirement.[17] This is because the pension benefit is based on the salary in the year before retirement.

Simulations

33. **As noted above, three scenarios** (Table 3) **are used to assess the medium- and long-run consequences of aging on the economy**. Note that the deterioration in public finances caused by demographic transition stems from two sources: an increase in pension expenditure as the dependency ratio increases, and the impact of aging on health care expenditures.[18] The simulation results are as follows.

The baseline

34. **The macroeconomic consequences of an unreformed system are severe** (Figure 2). The simulations suggest that pension expenditures will increase by between 8 and 10 percent of GDP by 2050, regardless of the real interest rate scenario. The economy suffers as this increase in expenditures would require sharp increases in consumption taxes so that public debt remains sustainable, that is, a constant debt (as a percent of GDP) and compliance with the intertemporal budget constraint. Moreover, when interest rates decline the adverse macroeconomic outcome is worsened by a negative wealth effect—associated with the lower return on savings.

35. **Consider first the simulation results assuming a constant real interest rate**:

- **At its peak (about 2050), the consumption tax rate would increase by about 10 percentage points to finance old-age expenditures**. Until 2050, output growth and GDP per capita would suffer, even though consumption per capita would remain robust. As the share of the population in the work force declines, aggregate hours of work per capita decline sharply by 2050. Since the capital-labor ratio is pinned down by the (constant) interest rate, the capital stock will fall. As forward-looking households live longer, they will save more to finance a longer retirement. This improves the current account balance (CAB) during the demographic transition;[19] large surpluses will turn Cyprus into a net creditor country.

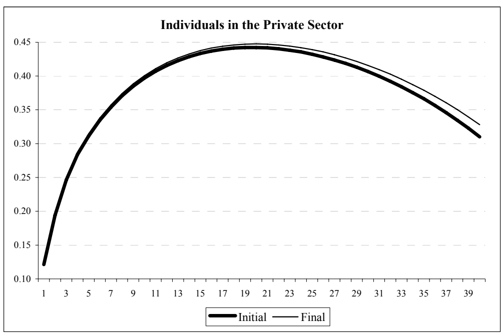
[17] Formally, the fact that the pension benefit for public employees is based on the final wage implies that labor effort should jump sharply the year before retirement. However, the model restricts labor effort to be independent of its impact on pension benefits, as public employees are not compensated by increasing their work hours.

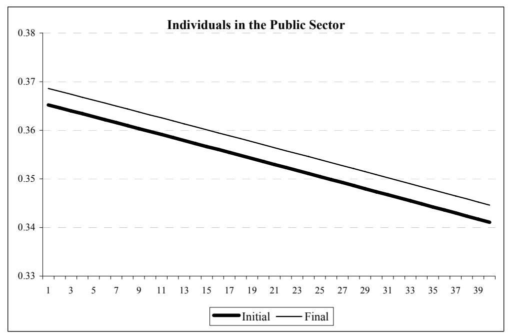
[18] Note that a third source of stress emerges in the variable interest rate scenarios: changes in factor prices.

[19] This mirrors the accumulation of assets in countries with aging populations (Börsch-Supan, Ludwig, and Winter, 2005).

- **Private sector employees see their pension benefit increase because the decline in the basic pension benefit is more than offset by the increase in the supplementary pension**. The former declines as households exert less work effort during the initial years in the workforce and thus acquire fewer basic points. Still, they work harder later in their work life as their work skills improve and receive greater rewards for their efforts (wages); thus they acquire more supplementary points. Public sector households' work effort increases throughout their work life to save more for a longer retirement, but these households are constrained not to increase their work efforts at the end of their work life (text figures).[20] The present value of public-versus-private pension benefits (relative generosity) remains roughly unchanged, favoring the former by about 80 percent.

Individual Labor Allocations in Initial and Final Steady States





Source: Staff estimates.

36. **Consider the results assuming a variable interest rate**:

- **Although macroeconomic developments are qualitatively similar to those discussed above, their effects are more severe in this case**. Forward-looking households will need to save more than before to finance longer retirements because the return on savings falls with the world interest rate. This negative wealth effect would lower aggregate consumption and savings. The CAB worsens, and Cyprus would remain a net debtor country.

- **As the tax base declines and old-age pension and health expenditure remain roughly unchanged, higher tax rates will be needed to finance these expenditures**.[21]

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[20] As noted above, an unconstrained public sector household would maximize utility by reducing work effort in the first 39 years on the job and sharply increasing its work effort in the final year, when wage earnings have the extra benefit of increasing pension benefits for the remainder of its life.

[21] This does not depend on the assumption that consumption taxes will be adjusted to finance old-age expenditure. Alternative assumptions of adjusting income or payroll taxes would also imply higher rates, as their corresponding tax bases—income and work hours—also decline. Moreover, using either of these taxes creates more perverse macroeconomic effects. This is because the burden of these taxes falls disproportionately on working-age generations.

- **The relative generosity of public-versus-private pension tilts more toward the public sector as the additional work effort of public sector employees boosts the monthly benefit and the lump sum payment**.

The Convergence Program

37. **The Convergence Program** (CP) **envisages, over the period 2005–10, a gradual increase in the normal pension age to 65 years of age from 63 years**. It also envisages increasing social contributions (payroll taxes) to finance increased age-related spending. Compared with the baseline, the reform package generates a reduction of about 3 percentage points in old-age spending at the peak of the demographic shock. In other words, the simulations suggests that pension expenditures will increase between 5 and 7 percent of GDP by 2050; as above, the real interest rate scenario does not affect old-age expenditures. Note that the higher labor taxes in this reform package translate into lower consumption tax rates through 2030.

38. **Consider the CP simulation results with a constant real interest rate assumption** (Figure 3).

- **Although the macroeconomic results under the CP are better than those under the baseline scenario, quantitatively the differences are not substantial**. By 2050, GDP, hours worked, and capital stock (all in per capita terms) are about 5 percent higher. Between now and 2030, GDP growth and GDP per capita would suffer, but less so than before: consumption per capita would increase due to an easing of the tax burden. Afterwards, consumption per capita declines due to lower net wages. The CAB and external debt would remain broadly as in the baseline scenario; Cyprus becomes a net creditor country. It is interesting to note the path of the consumption tax rates. On impact, these decline because the tax collection from payroll taxes increases. Also, because of the increases in payroll tax rate, consumption tax rates would only increase, at their peak (about 2050), by roughly 2 percentage points (about 8 percentage points less than in the baseline). In the long run, consumption tax rates would increase by about 2 percentage points while payroll taxes would remain 5 percentage points higher.

- **The reform package has a different impact on private and public sector labor supply**. Private sector households face two opposing effects. The increase in the retirement age means that they need to save less to finance a shorter retirement period, and thus households lower their work effort. Nonetheless, the increase in the work life adds two more years of wages to be considered under the points system, implying that the average points under the basic pension rises. Moreover, the increase in labor taxes adversely affects the incentive to supply labor. Thus, when the reform is implemented, the basic pension benefit increases but the supplementary pension benefit decreases. In contrast, public sector workers do not see any increase in their basic pension, and thus their labor effort declines, resulting in lower savings, pension benefits and lump-sum payments.

- **Similarly, these reforms have a differential impact on the present value of pension benefits for private and public sector employees**. The present value of the pension income (at the time of retirement) for private households declines as the retirement period shrinks. However, the present value of pension income of private sector households increases after 2050 because, in contrast with public sector households, they adjust their labor effort and thus receive a higher basic pension. Thus, the relative generosity of public-versus-private pension benefits declines by roughly 15 percentage points.

- **The reform reduces welfare for both private and public sector employees**. This is because of the higher labor taxes needed to finance pension benefits and the reduction in pension benefits. All future generations will be hurt unambiguously, but the welfare of some younger generations will remain unchanged.

39. **Consider the CP results assuming a variable interest rate** (Figure 4):

- **The macroeconomic developments under this assumption are qualitatively similar to those discussed above, but the effects, while slightly worse than above, are still less severe than in the baseline scenario**. The lower interest rate would reduce households' wealth, and, hence, consumption and savings decline. As a consequence, the tax base narrows and higher consuption tax rates are needed to finance the old-age pension and health expenditures. Moreover, tax rates remain higher in the long run. The CAB worsens, and Cyprus remains a net debtor country.

- **Other results broadly reproduce those of the constant interest rate case, albeit with more severe effects**.

Additional parametric reforms

40. **Further reforms are needed to categorically address the demographic shock and offset the increasing relative generosity of public-versus-private pensions**. In particular, this scenario envisages: (i) following the increase in the retirement age in the CP, further increases in the retirement age: one year per decade beginning in 2028 until the retirement age reaches 73 in 2098; (ii) switching the indexation so that all pension benefits to prices; and (iii) reducing the lump-sum payment by 4 months every five years until it declines to 12 months in 2028. The increases in the retirement age are designed to offset the increase in the share of the retirement period in life expectancy that emerges in the CP reform scenario, and to gradually lower the retirement period (as a share of life expectancy) to that prevailing in 2005 (text table). The other two reforms are to reverse the trend increase in the relative generosity of public-versus-private pensions. Note that payroll taxes are held constant.

Cyprus: Life Expectancy and Retirement Period

(In years, unless otherwise indicated)

	1980	1990	2000	2005
Life expectancy	75	76	78	80
Retirement age 1/	65	63	63	63
Retirement Period 2/	11	14	16	18
Memo item (In percent):				
Retirement as a share of life	13	17	19	21

Source: World Bank, *World Development Indicators*; and Ministry of Finance.

1/ The retirement age was lowered to 63 years in 1991.

2/ Computed as the difference between the life expectancy and the retirement age plus one.

41. **The additional parametric reforms safeguard the system from declining world interest rates and enhance the fairness of the pension benefits**. Although the increase in overall pension spending by 2050 is about 2 percentage points of GDP, pension spending will decline below current levels in the long run (Figures 5 and 6). The use of less distortionary consumption tax increases and the more limited need to increase these rates, underlies the substantially better macroeconomic results: per capita hours worked, and output, consumption, and capital stock are about 10 percent higher. In the long run, the resulting increase in the tax base leads to a consumption tax rate that is about 3 percentage points lower than in the CP, and thus about 5 percentage points lower than it is currently. Reflecting the higher levels of consumption, the CAB is slightly higher than in the CP.

42. **In contrast to the CP, these additional parametric reforms increase labor supply for private and public households**. The further increases in the retirement age imply that private households need to save less to finance a shorter retirement period, and thus they lower their work effort. However, labor supply increases in the aggregate as the number of cohorts in the labor market rises. As in the CP, the increase in the work life adds wages that are considered in the points system, implying that the average points for the basic pension rise. For public sector employees, the additional reforms reduce the labor effort in each period and thus lower their pension income: both the monthly benefit and the lump-sum payment fall.

43. **Although with additional parametric reforms pensions become less generous for both private and public sectors, the mismatch between the two systems narrows**. The mismatch between private and public pension generosity declines as the retirement age increases, but the decline in public pension generosity is greater because of the switch to price indexation and the fall in the lump-sum payment. The ratio of public to private generosity falls to about 1.1 (1.3) in the constant (variable) interest rate scenario. In any event, welfare for both households will improve because the tax rate needed to keep public debt constant will decline. Private households experience higher welfare in the long run and the losses to younger generations are far smaller than in the CP. Public households would also experience higher welfare in the long run, but younger generations would experience some losses as they shoulder a large share of the reform burden.

E. Summary of Results and Conclusions

44. **Aging severely challenges Cyprus's economy and fiscal accounts**. The outlook of an unreformed social security system is bleak. Consumption tax rates will need to increase by 10 percentage points to finance old-age pension and health expenditure. As a result, average output growth will fall to about 1½ percent in the decade ending in 2030 from roughly 3½ percent in the last 10 years. Pension benefits in the public sector would continue to be much more generous—about 80 percent—than those in the private sector. Moreover, if world interest rates decline—as envisaged in models accounting for differing global aging patterns—the outlook is far worse because the associated negative wealth effects will hinder households efforts to accumulate assets and finance longer retirement periods.

45. **The reforms envisaged in the Convergence Program would lessen the adverse macroeconomic effects but fall short, particularly if world interest rates decline**. In the unlikely best case scenario—constant real interest rates—the Convergence Program lessens the adverse macroeconomic effects by safeguarding consumption. As a result of the increases in payroll taxes and retirement age, the needed increase in consumption tax rates are smaller, as are the macroeconomic consequences; however, while declining, the relative generosity of public sector pensions remains high. Moreover, even a conservative reduction in world interest rates—half of what current estimates suggest—would render the consumption tax rate permanently higher, with adverse macroeconomic consequences; this would also increase the relative generosity of public sector versus price sector pensions. Regardless of world interest rate developments, welfare declines for future generations due to the reliance on payroll taxes—whose burden falls on workers—to partially finance age-related expenditure increases.

46. **Additional parametric reforms are therefore needed**. As gains in life expectancy continue, the burden of financing a longer retirement period and the potentially lower returns on savings render the reforms considered in the Convergence Program insufficient to address the macroeconomic consequences of aging. Keeping up with demographic trends will require further increases in the retirement age to stabilize the retirement period as a share of life expectancy. By further limiting increases in age related expenditure, switching the indexation of all pension benefits to prices can safeguard the net-of-tax pension benefit. Also, realigning the relative generosity of public-versus-private pensions can be achieved by lowering the lump-sum payment awarded at retirement; public pensions would still be more generous in the constant interest case. In contrast with the CP, welfare improves for future generations due to the reliance on consumption taxes—whose burden is spread more evenly across all age groups, and thus reduces deadweight loses—to finance age-related expenditure increases.

47. **The reform package discussed in this study—the "additional parametric reforms" scenario—illustrates what is needed to counteract the macroeconomic impact of aging under specific population and world interest rate projections**. Although the simulation results depend critically on inherently imprecise population and world interest rate projections, these point to the vulnerability of the Cypriot social security system. In this

connection, the redesigned pension system should be mindful of the intrinsic uncertainty involved, as deep reforms will be needed. One way of addressing the uncertainty is typified by the Swedish case. Sweden has established a rule that automatically links benefits to the evolution of social security trends: it requires benefit cuts when trends are unfavorable. In Cyprus, a degree of flexibility in the system to keep up with demographic trends could be achieved by increasing the (effective) retirement age to 65 within the next decade and automatically increasing the retirement age thereafter (say, on a ten-year basis) in line with gains in life expectancy. In addition, changing the indexation of pension benefits to prices can help moderate age-related expenditure and, by setting the stage for lower taxes than otherwise possible, safeguard the net-of-tax pension benefits. In lieu of a full harmonization of public and private pension systems—as in Italy's 1992 Amato reform—a gradual reduction of the lump-sum payment can help align the public pension benefit more closely with that of the private sector.

48. **Setting in place the needed pension reforms is thus urgent**. Deep parametric reforms will be needed for the old-age pension system to catch up, and keep up, with demographic trends. These reforms will involve substantial adjustments to the social security system and changes in household's incentives to work, consume and save. These changes point to the desirability of phasing in reforms gradually and grandfathering workers' rights. This is feasible, however, if the decisions to reform the system are set in place promptly.

Table 1. Cyprus: Key Demographic Trends Affecting the Pension System, 2005–50

	2005	2050	Change 2005 to 2050
Dependency ratios			
Potential economic: not in labor force 15+/ labor force 15+	99	105	5.6
Effective economic: not employed 15+/ employed 15+	104	105	1.6
Total: all not employed 0-90+/ employed 15-64	107	114	6.2
Old age: population 65+/ population 15-64	18	43	25.5
Population projections (in thousands)			
Total population	739.2	975.1	235.9
Age structure			
0-14	143.7	129.7	-13.9
15-64	505.9	590.4	84.5
65+	89.6	255.0	165.3
Of which: 80+	19.6	80.2	60.6
Key factors determining population evolution			
Life expectancy at birth, male	76.5	81.9	5.4
Life expectancy at birth, female	80.9	85.1	4.2
Fertility rate	1.5	1.5	0.1
Migration per annum (thousand)	6.2	4.9	-1.3
Labor market assumptions			
Employed 15-64 (percent of age group)			
Males	78	74	-4.2
Females	63	72	9.3
Labor participation rates			
Males 15-54	82	87	4.3
Males 55-64	77	84	7.7
Males 65+	24	25	1.0
Females 15-54	70	81	10.8
Females 55-64	38	56	18.7
Females 65+	9	12	3.3
Unemployment ratio (in percent)	4	4	0.1
Basic macroeconomic assumptions1/			
Labor productivity	2.4	1.9	-0.5
Potential GDP growth	4.3	1.9	-2.4

Source: EuroStat; and 2005 Economic Policy Commission.

1/ Annual averages; 2005 refers to initial 5 year period, 2050 refers to total projection period

Table 2. Cyprus: Pension Expenditures

	1998	1999	2000	2001	2002	2003	2004	2005
				(In millions of £C)				
Total pension expenditure								
General social insurance scheme	263.0	284.5	316.4	331.6	367.9	402.3	443.2	488.1
Government employees pension scheme	84.5	94.6	112.1	108.9	122.5	155.8	166.0	166.8
Contributions to the general social insurance scheme:								
By employers	108.3	111.5	120.0	138.3	151.5	155.1	184.7	191.3
By employees	91.9	96.2	104.5	118.7	128.5	134.1	153.3	158.9
By self employed	19.7	19.2	19.4	21.1	23.5	23.1	24.6	25.5
By government	118.1	123.1	132.7	145.7	151.2	158.8	169.4	206.1
General contribution	71.8	74.4	80.2	90.2	92.0	90.3	100.8	133.3
As an employer	46.3	48.7	52.5	55.5	59.2	68.6	68.7	72.8

Source: Ministry of Finance.

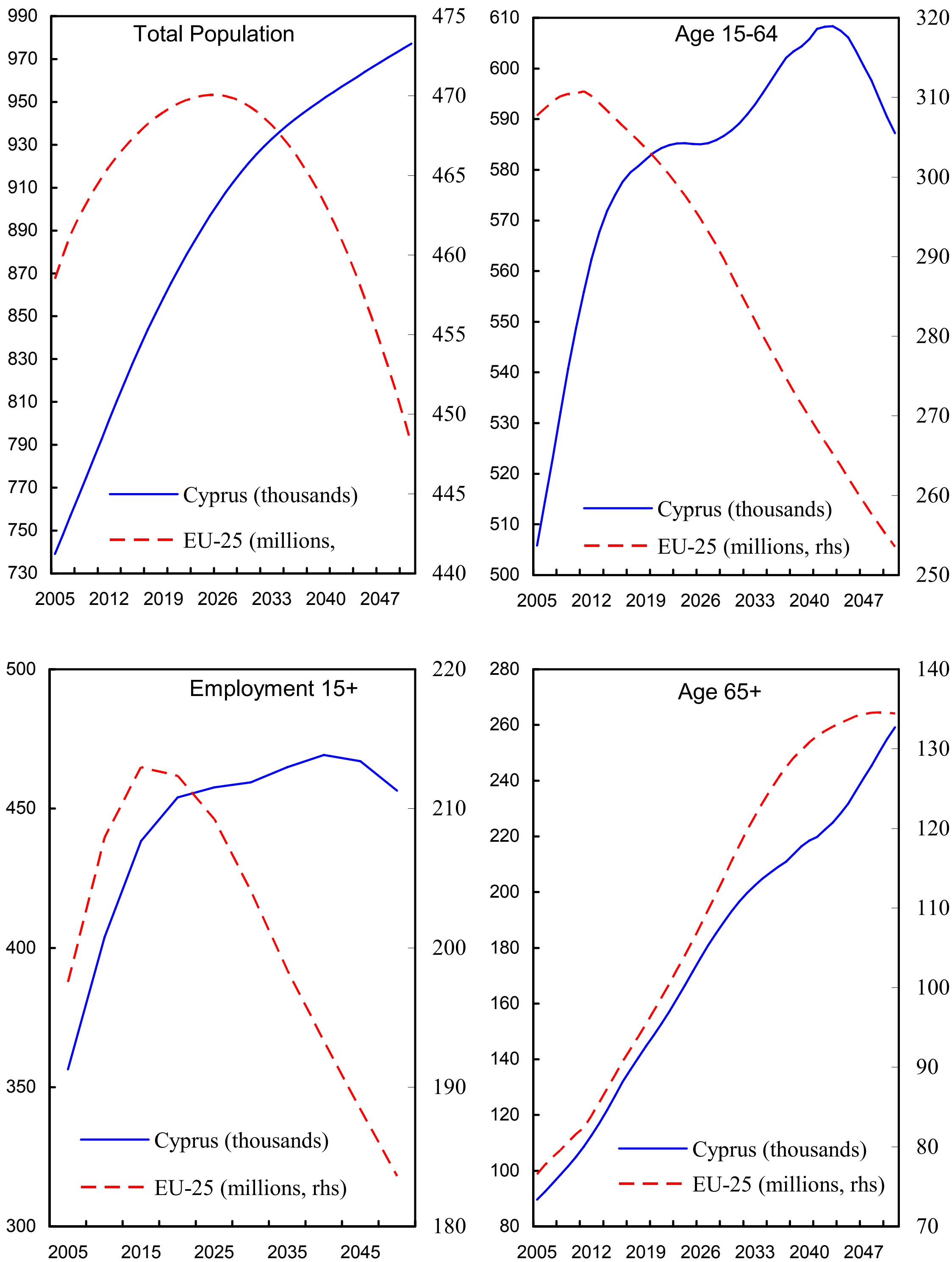
Table 3. Cyprus: Pension Reform Scenarios

	2005	2008	2013	2018	2028	2038	2048	2058
Baseline								
Social security contributions (in percent)	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6
Retirement age	63	63	63	63	63	63	63	63
Retirement period 2/	18	19	19	20	21	22	23	24
(Retirement period, share of life expectancy)	21	22	22	23	24	25	26	27
Benefit indexation								
Basic pension	Wages	Wages	Wages	Wages	Wages	Wages	Wages	Wages
Supplemental pension	CPI	CPI	CPI	CPI	CPI	CPI	CPI	CPI
GEPS	Wages	Wages	Wages	Wages	Wages	Wages	Wages	Wages
GEPS lump sum payment (maximum, in months)	28	28	28	28	28	28	28	28
Convergence Plan								
Social security contributions (in percent) 1/	16.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6
Retirement age	63	63	64	65	65	65	65	65
Retirement period 2/	18	19	18	18	19	20	21	22
(Retirement period, share of life expectancy)	21	22	21	21	22	23	24	25
Benefit indexation								
Basic pension	Wages	Wages	Wages	Wages	Wages	Wages	Wages	Wages
Supplemental pension	CPI	CPI	CPI	CPI	CPI	CPI	CPI	CPI
GEPS	Wages	Wages	Wages	Wages	Wages	Wages	Wages	Wages
GEPS lump sum payment (maximum, in months)	28	28	28	28	28	28	28	28
Additional Reforms								
Social security contributions (in percent)	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6
Retirement age 3/	63	63	64	65	66	67	68	69
Retirement period 2/	18	19	18	18	18	18	18	18
(Retirement period, share of life expectancy)	21	22	21	21	20	20	20	20
Benefit indexation								
Basic pension	Wages	CPI	CPI	CPI	CPI	CPI	CPI	CPI
Supplemental pension	CPI	CPI	CPI	CPI	CPI	CPI	CPI	CPI
GEPS	Wages	CPI	CPI	CPI	CPI	CPI	CPI	CPI
GEPS max lump sum payment	28	28	24	20	12	12	12	12
Memo item:								
Life expectancy in years (at 50 years)	80	81	81	82	83	84	85	86

Source: European Commisssion, Aging Working Group, Convergence Program of the Republic of Cyprus, and staff projections.

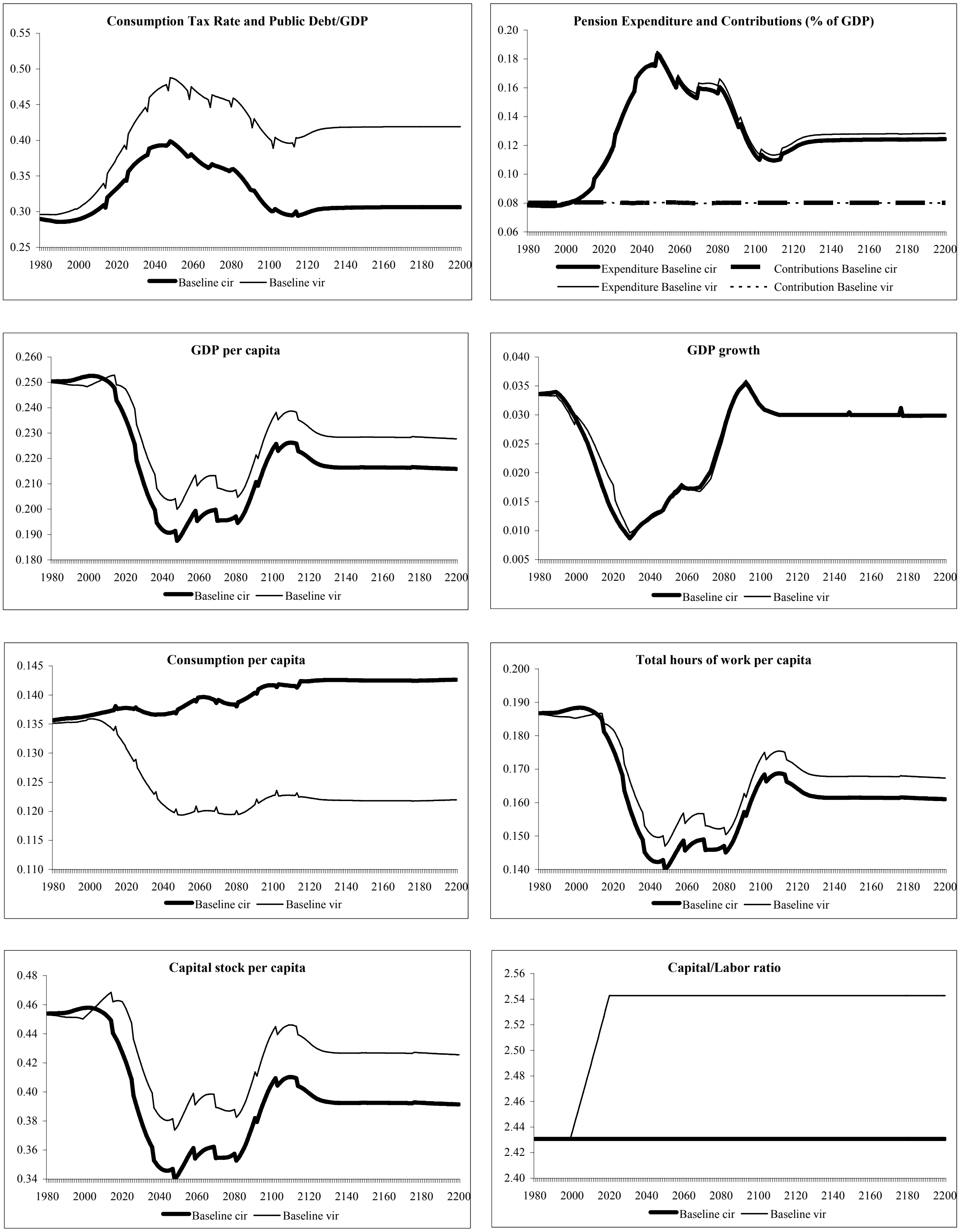
1/ Social security contributions for public sector employees also increase 5 percentage points to 8.2 percent in 2008.
2/ Computed as the difference between the life expectancy and retirement age plus one.
3/ The retirement age continues increasing to 70 (71) years of age in 2068 (2078) and so that the retirement period remains unchanged at 17 years.

Figure 1. Cyprus: Population and Employment, 2005–50



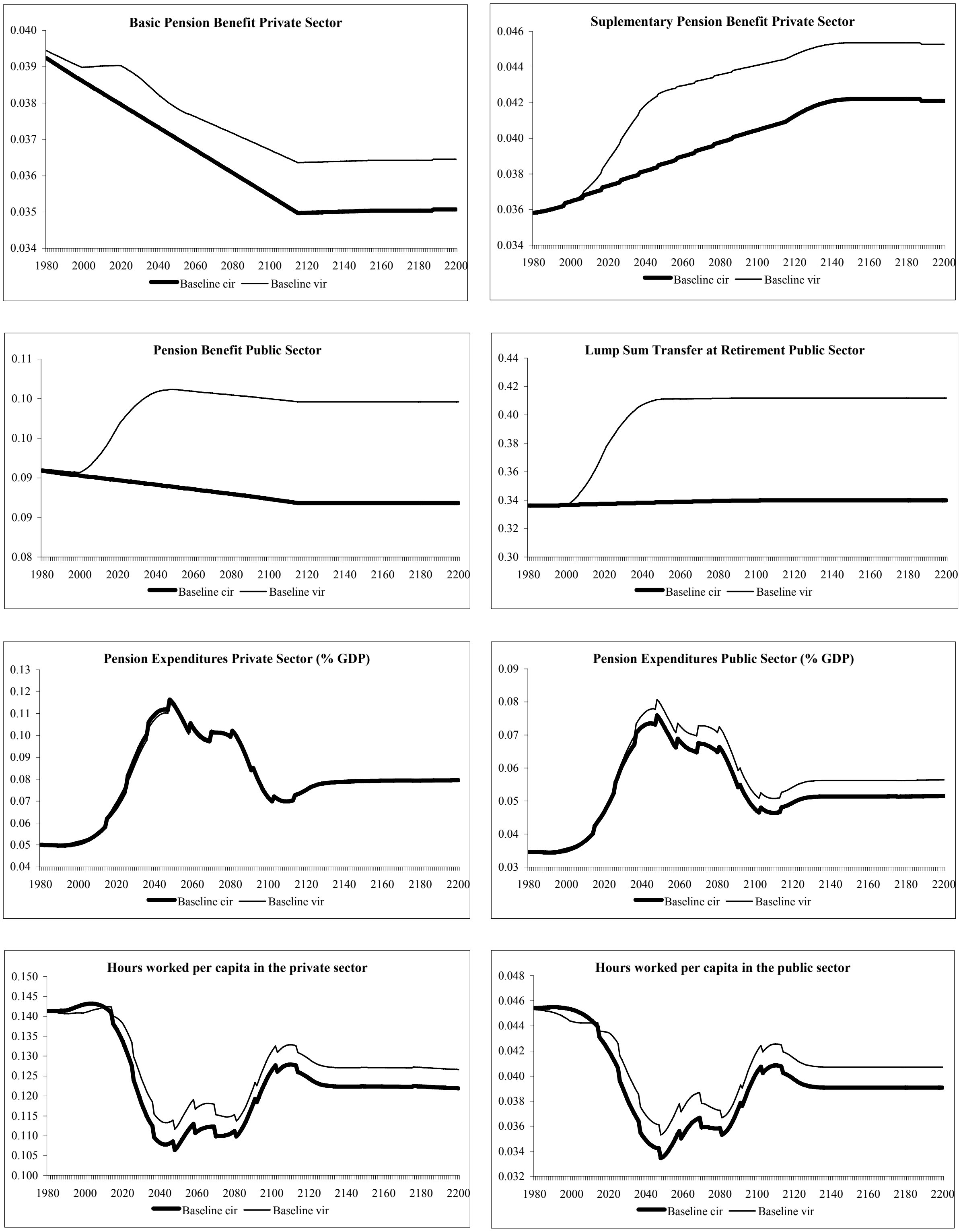
Source: EuroStat; and 2005 Economic Policy Commission.

Figure 2: Baseline Scenario with Constant (cir) and Variable (vir) Interest Rates (Cont.)



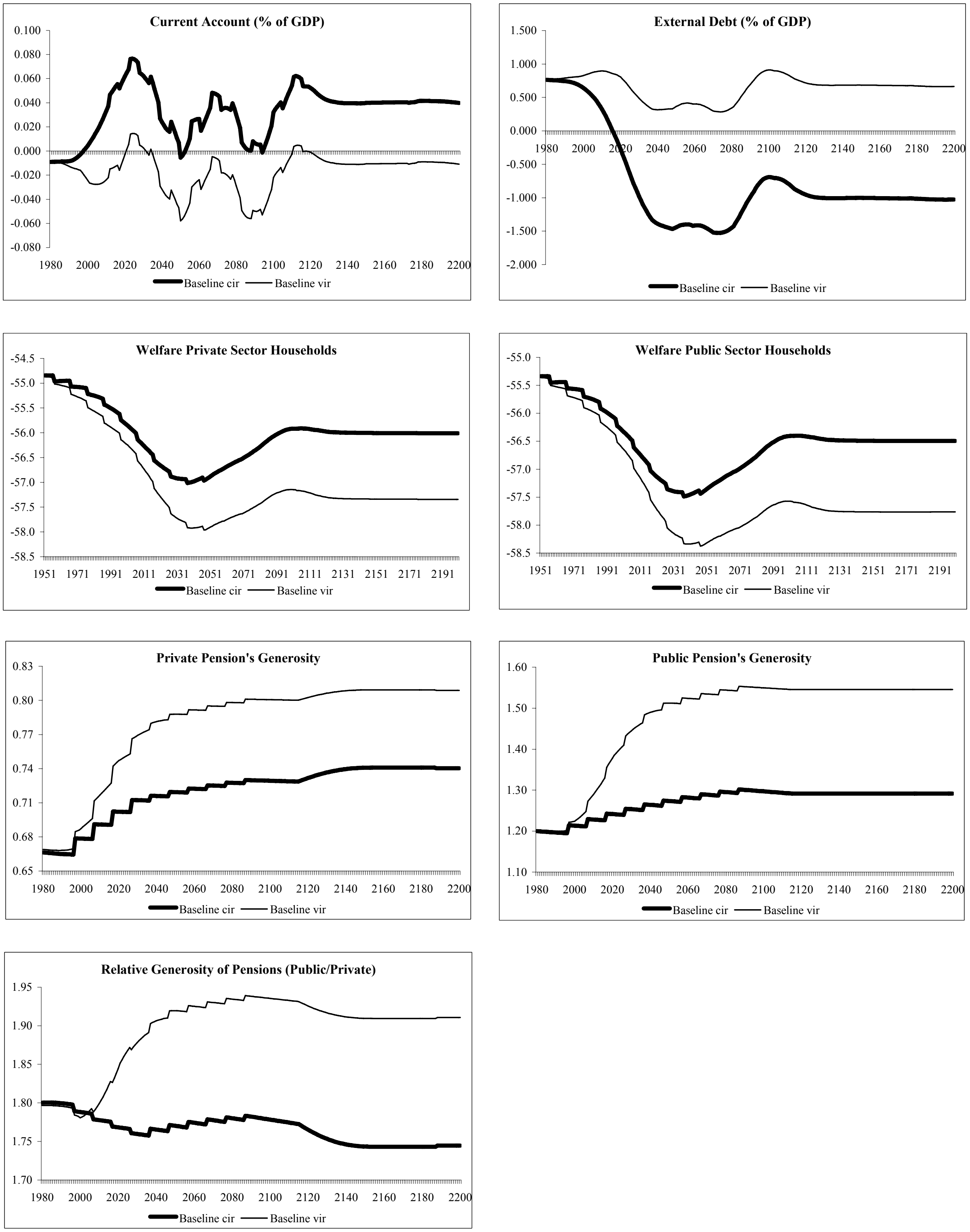
Source: Staff calculations.

Figure 2: Baseline Scenario with Constant (cir) and Variable (vir) Interest Rates (Cont.)



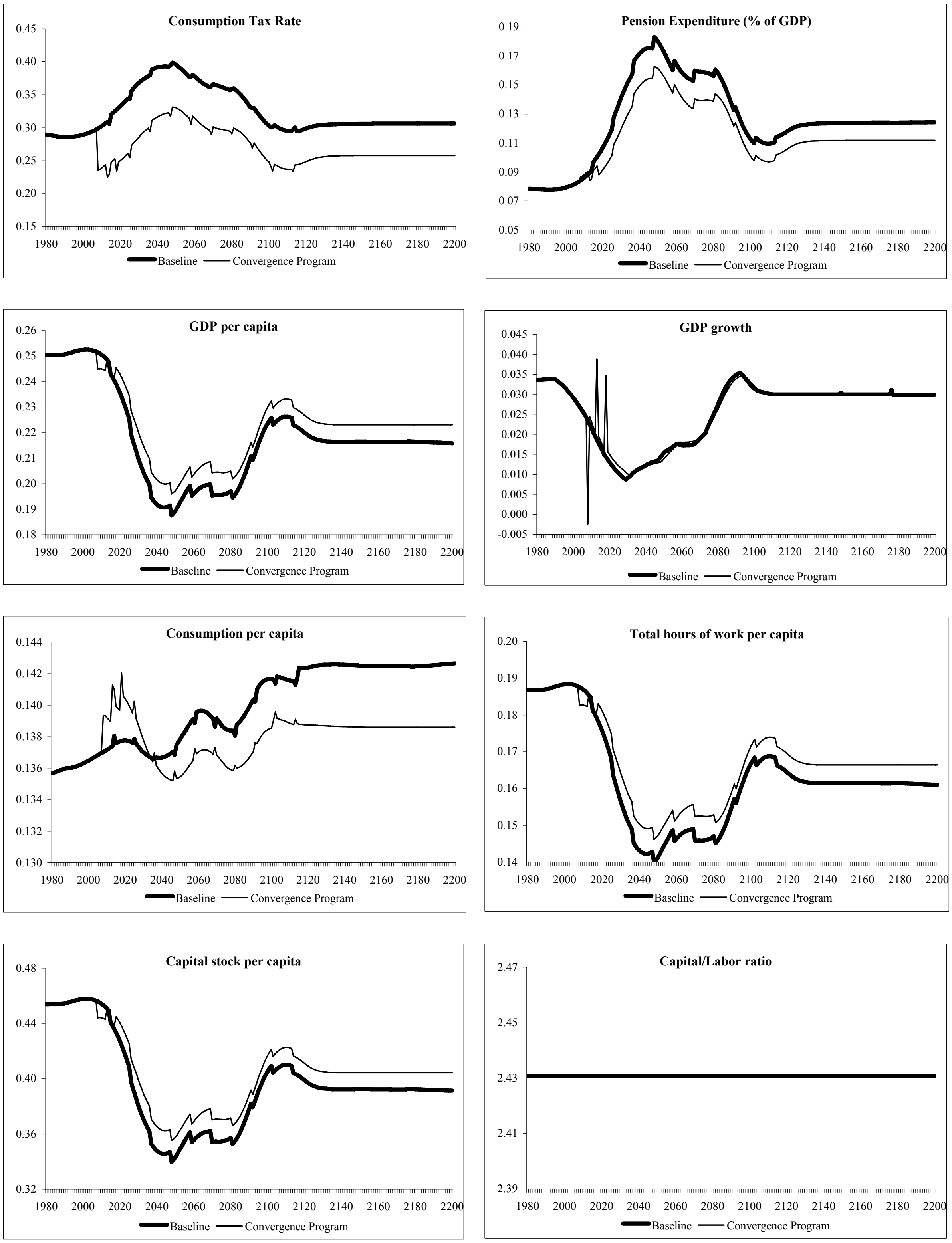
Source: Staff calculations.

Figure 2: Baseline Scenario with Constant (cir) and Variable (vir) Interest Rates (Concl.)



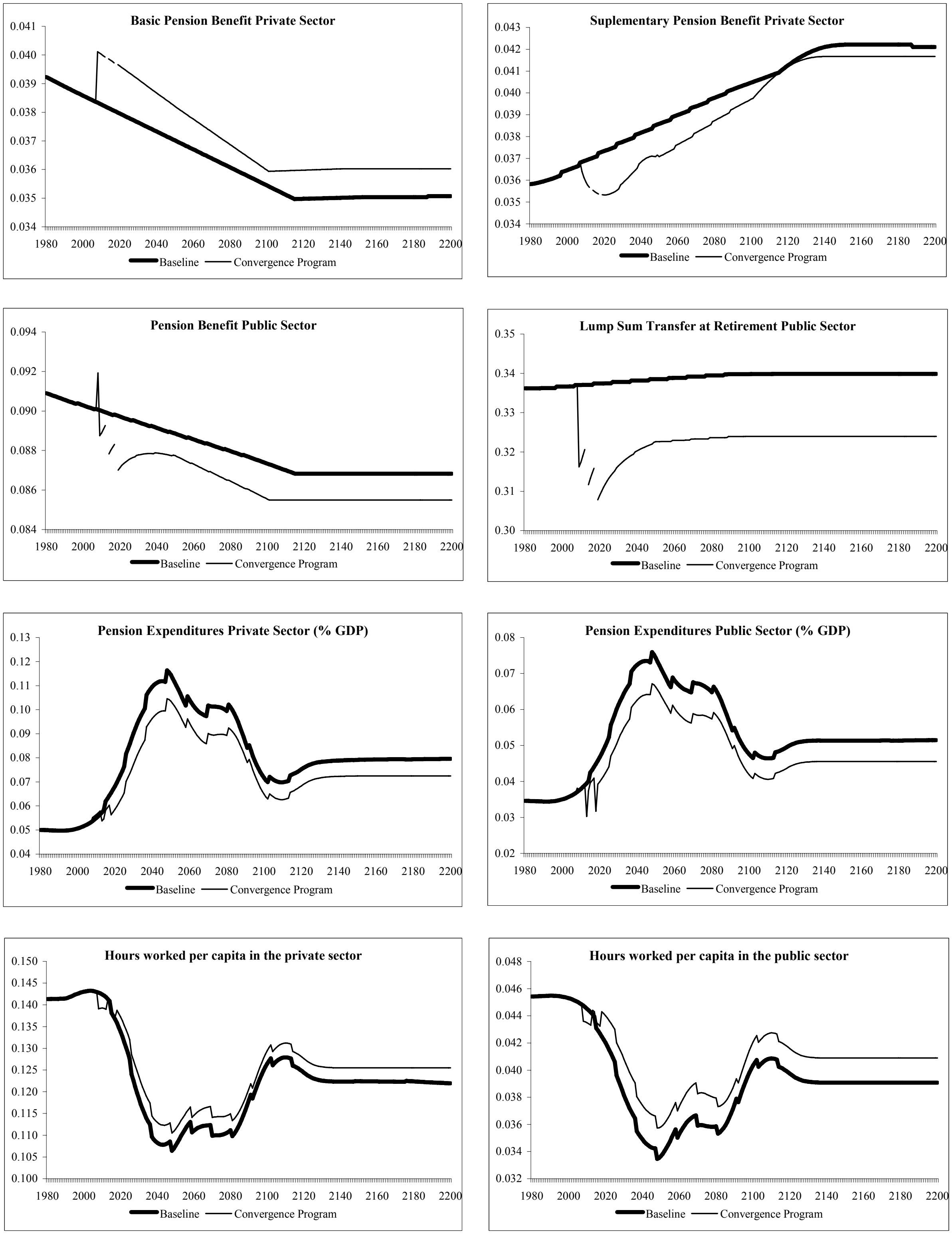
Source: Staff calculations.

Figure 3: Increasing the Retirement Age and Payroll Taxes (Cont.)
(Constant Interest Rates)



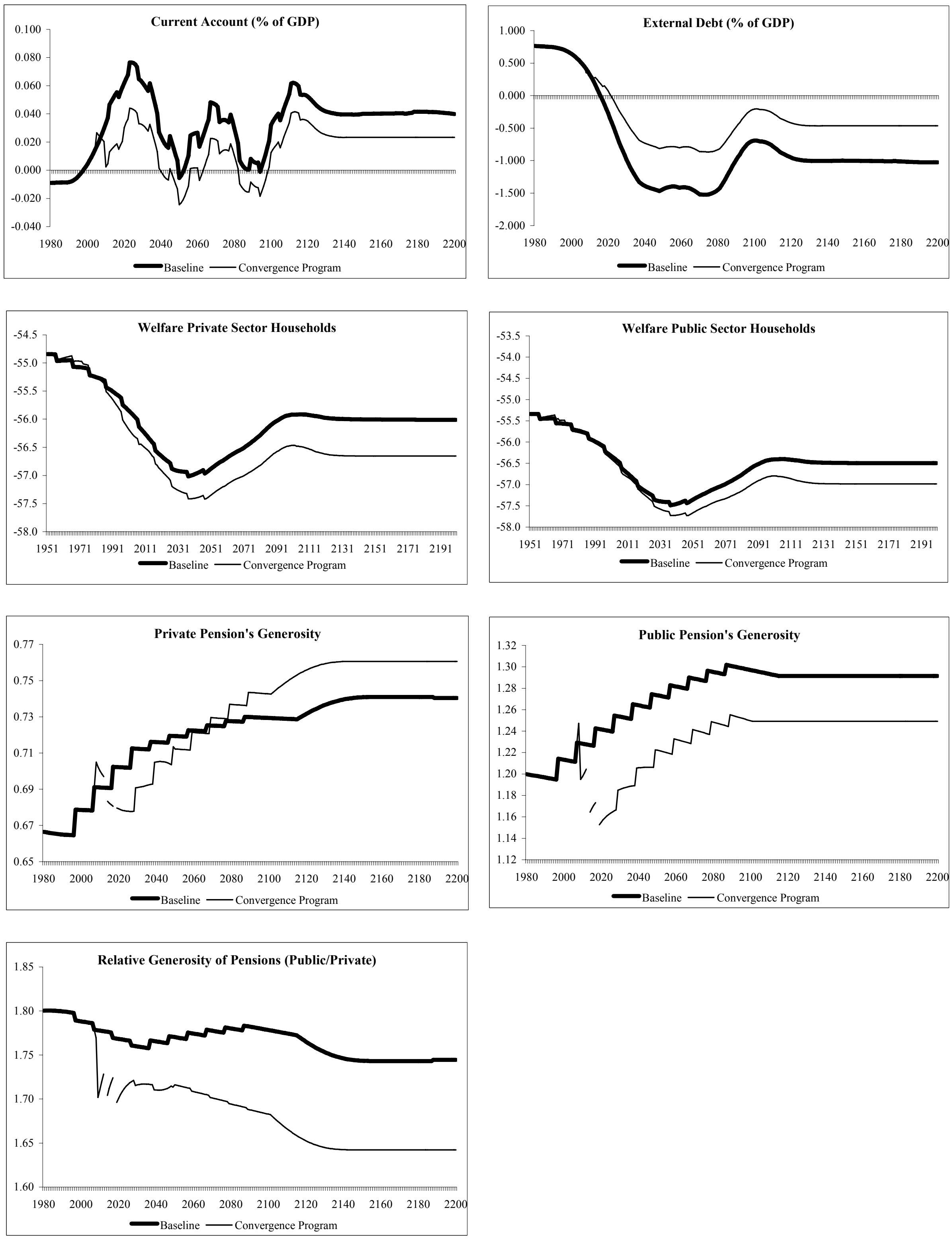
Source: Staff calculations.

Figure 3: Increasing the Retirement Age and Payroll Taxes (Cont.)
(Constant Interest Rates)



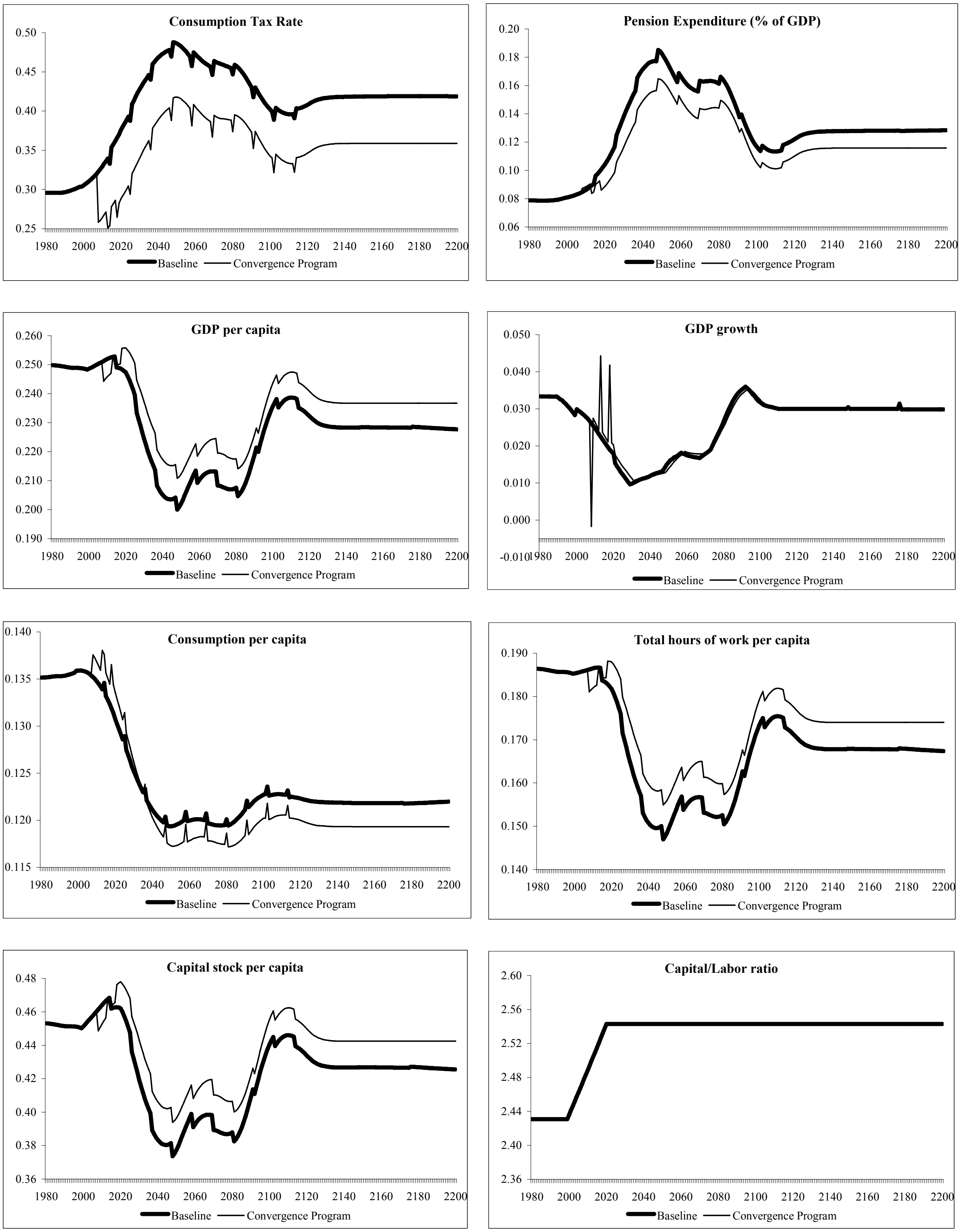
Source: Staff calculations.

Figure 3: Increasing the Retirement Age and Payroll Taxes (Concl.)
(Constant interest rates)



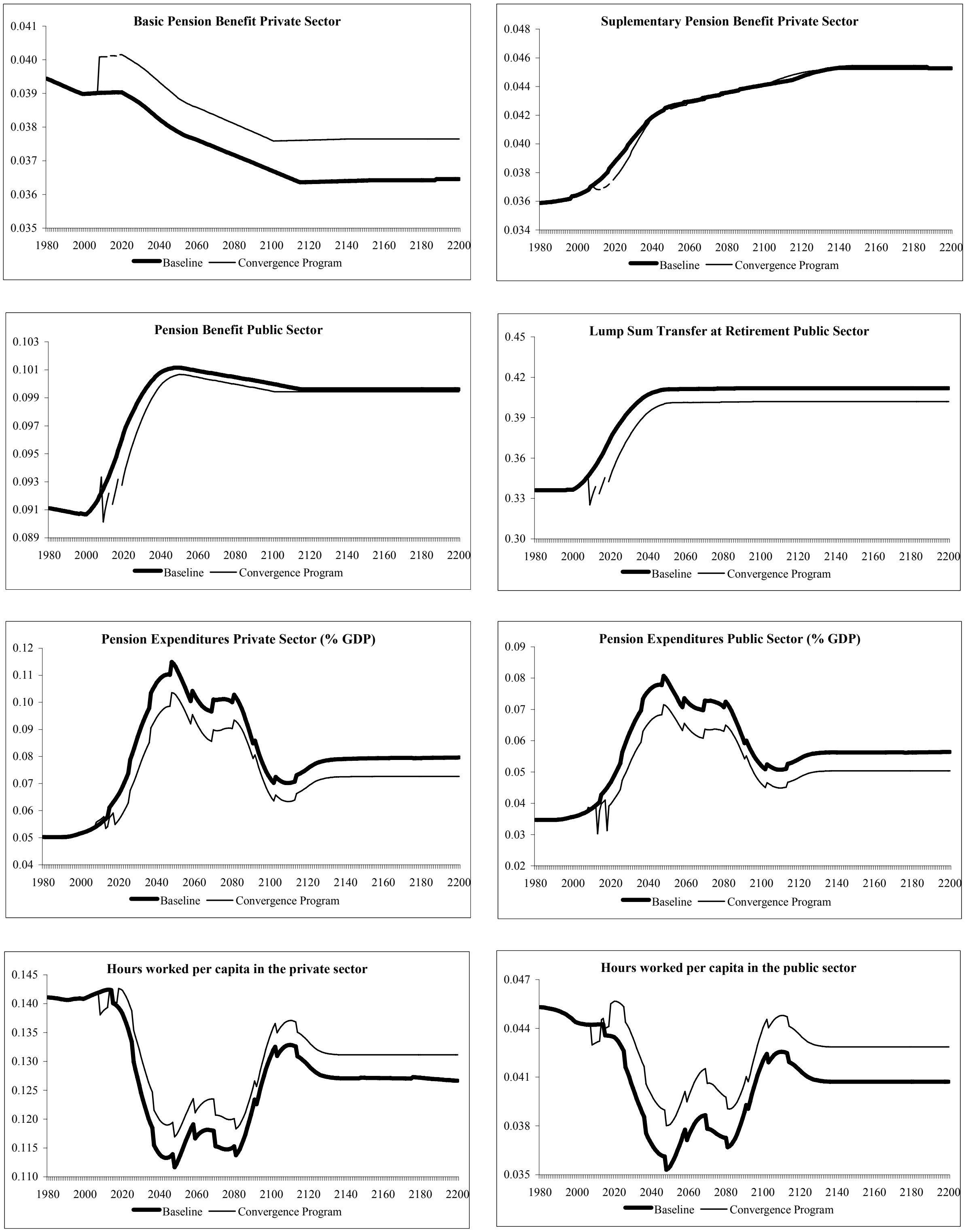
Source: Staff calculations.

Figure 4: Increasing the Retirement Age and Payroll Taxes (Cont.)
(Variable interest rates)



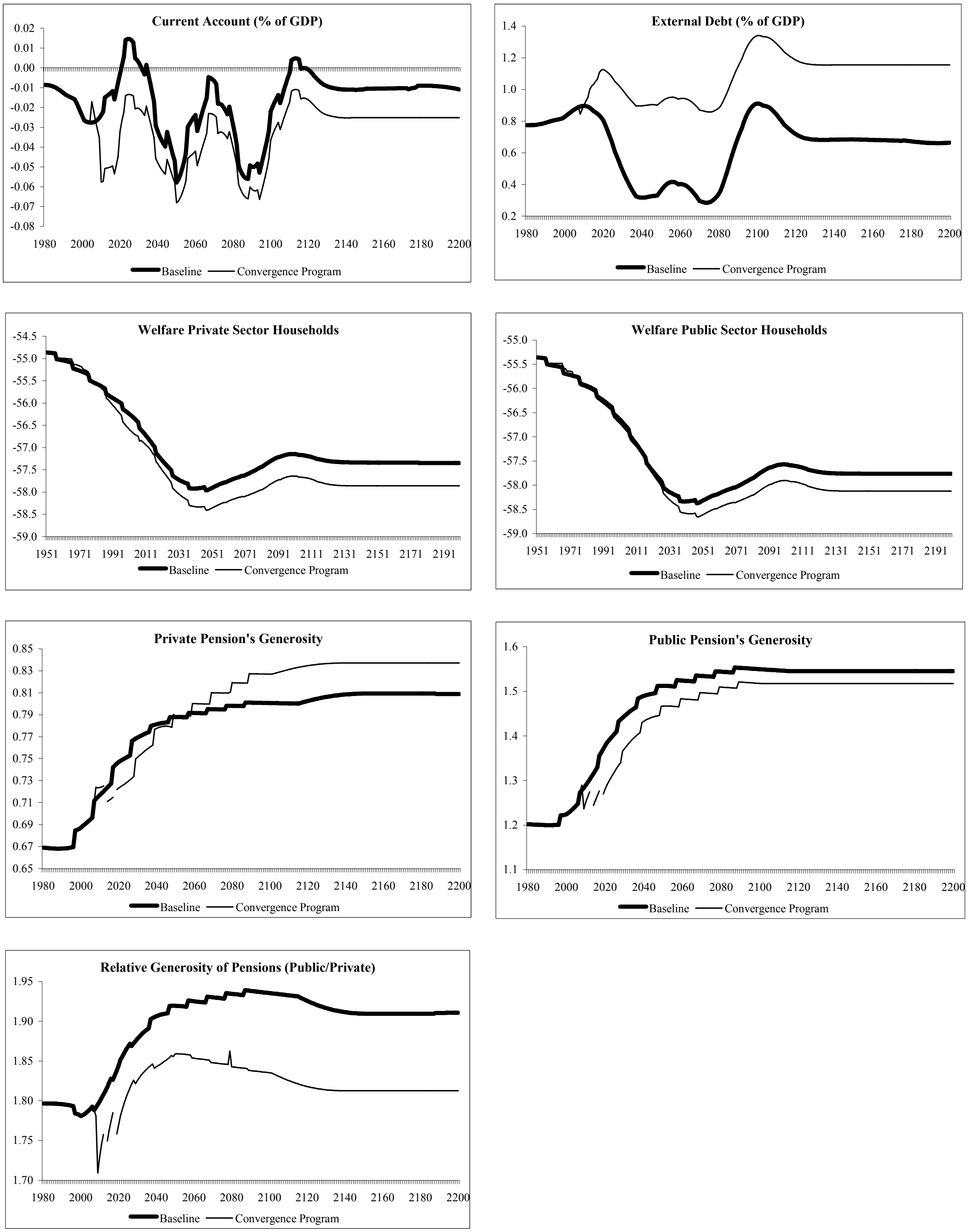
Source: Staff calculations.

Figure 4: Increasing the Retirement Age and Payroll Taxes (Cont.)
(Variable interest rates)



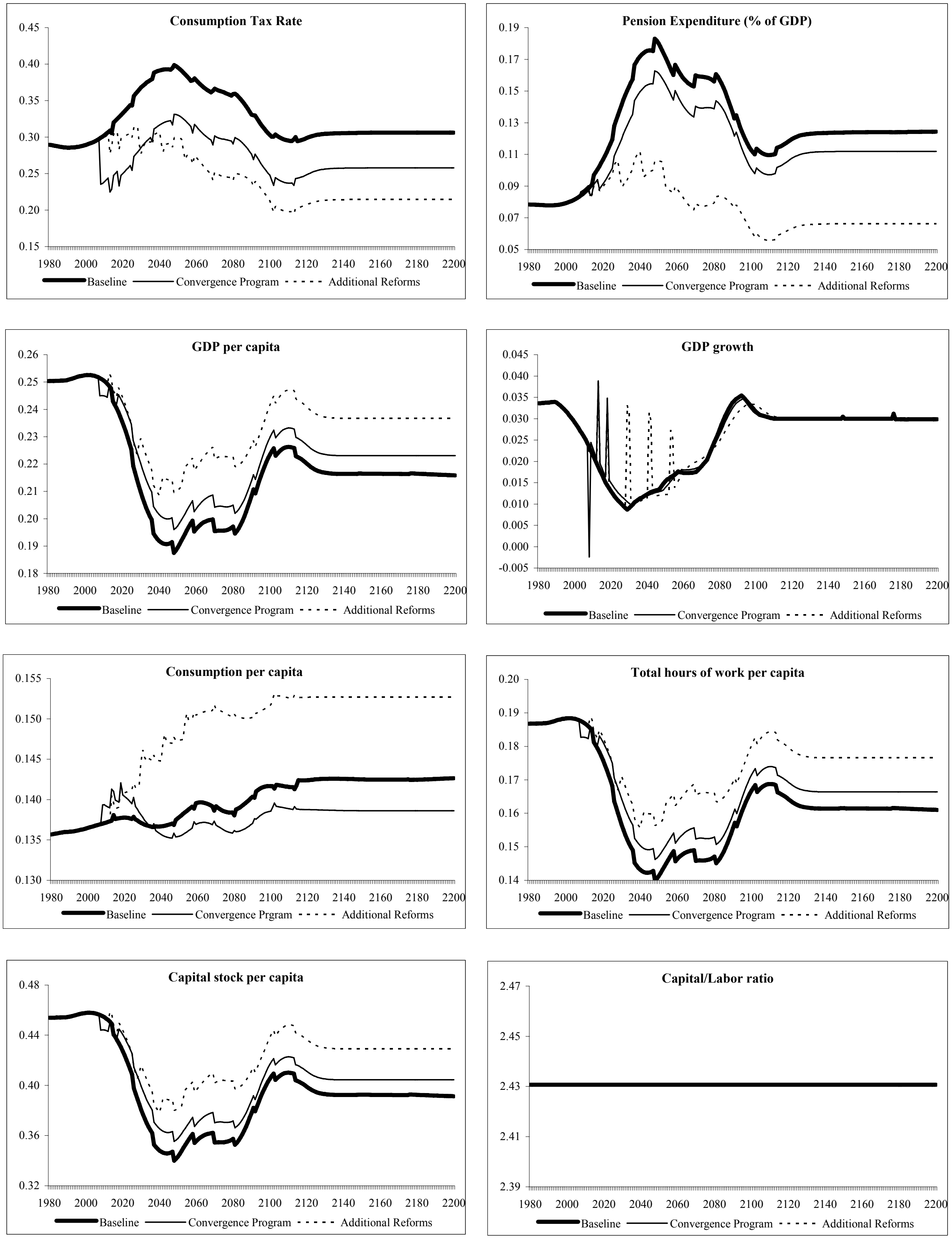
Source: Staff calculations.

Figure 4: Increasing the Retirement Age and Payroll Taxes (Concl.)
(Variable interest rates)



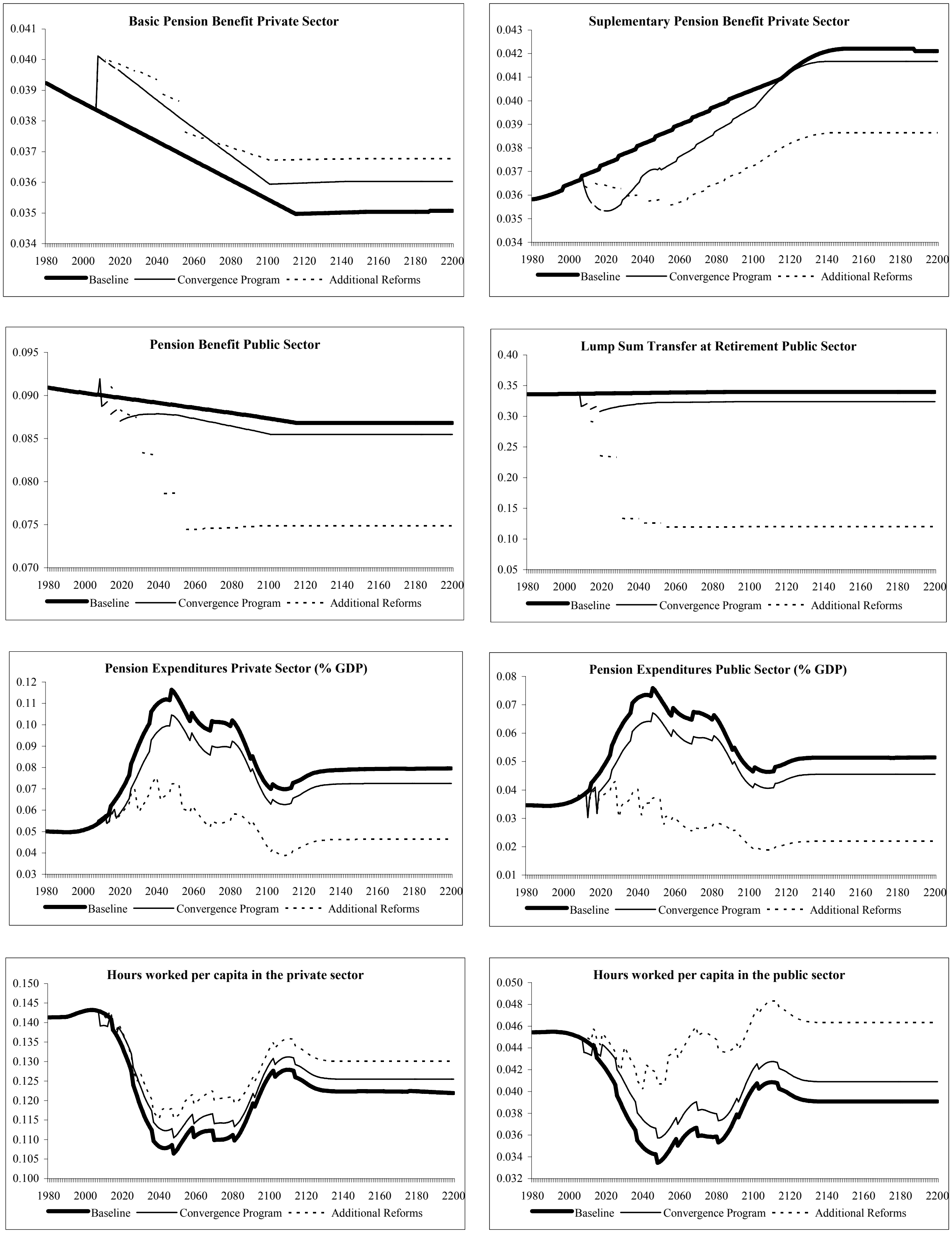
Source: Staff calculations.

Figure 5: Additional Reforms Scenario (Cont.)
(Constant interest rates)



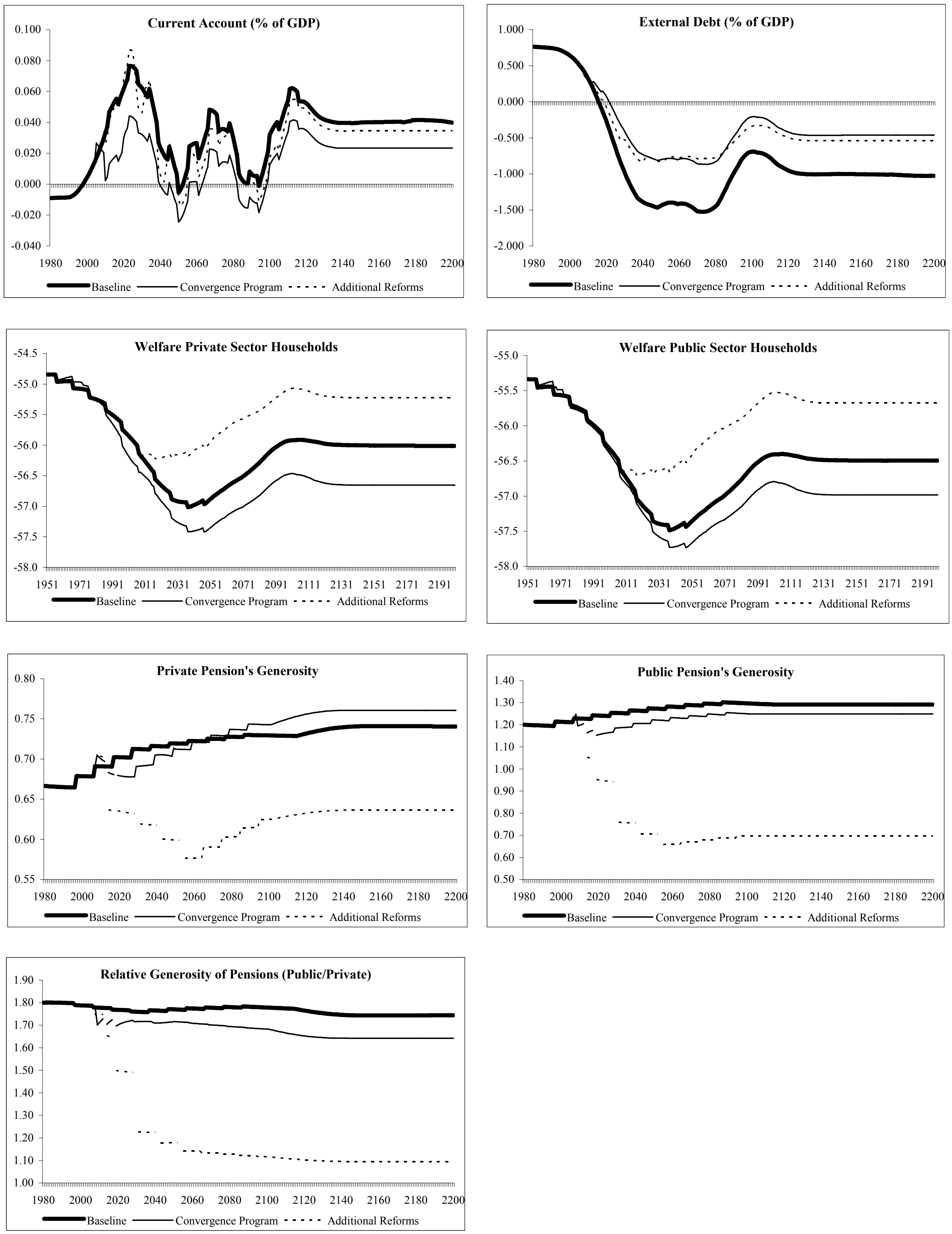
Source: Staff calculations.

Figure 5: Additional Reforms Scenario (Cont.)
(Constant interest rates)



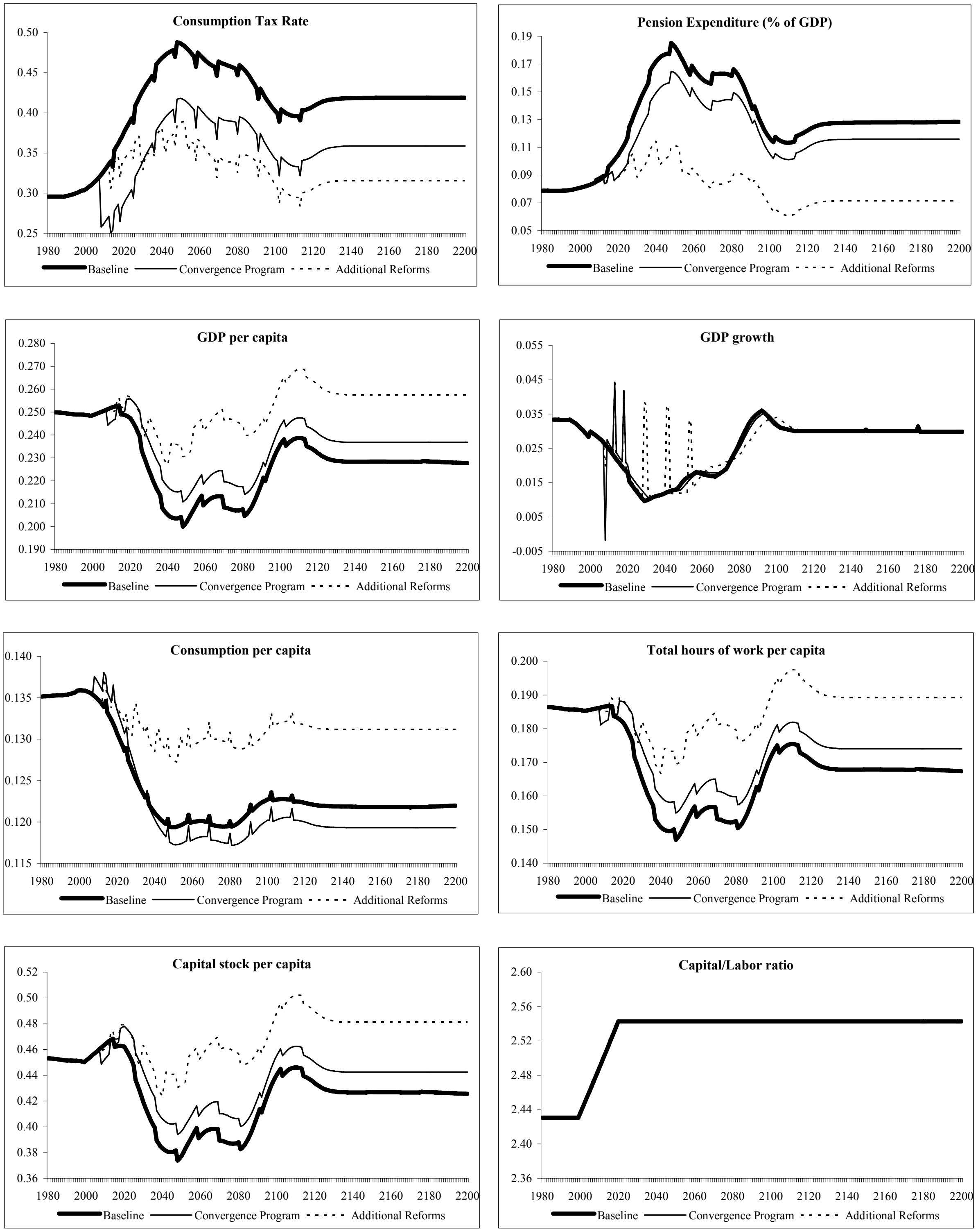
Source: Staff calculations.

Figure 5: Additional Reforms Scenario (Concl.)
(Constant interest rates)



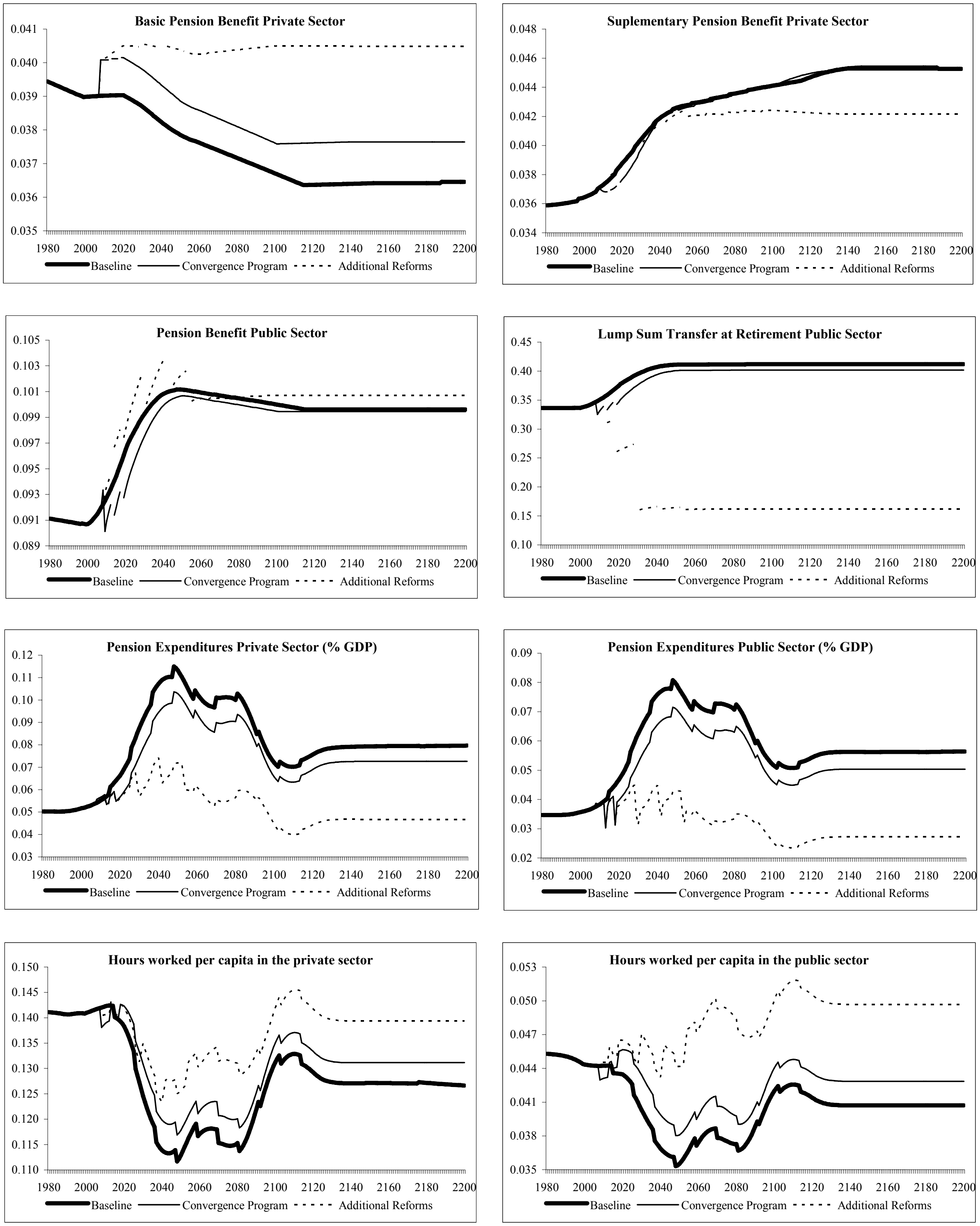
Source: Staff calculations.

Figure 6: Additional Reforms Scenario (Cont.)
(Variable interest rates)



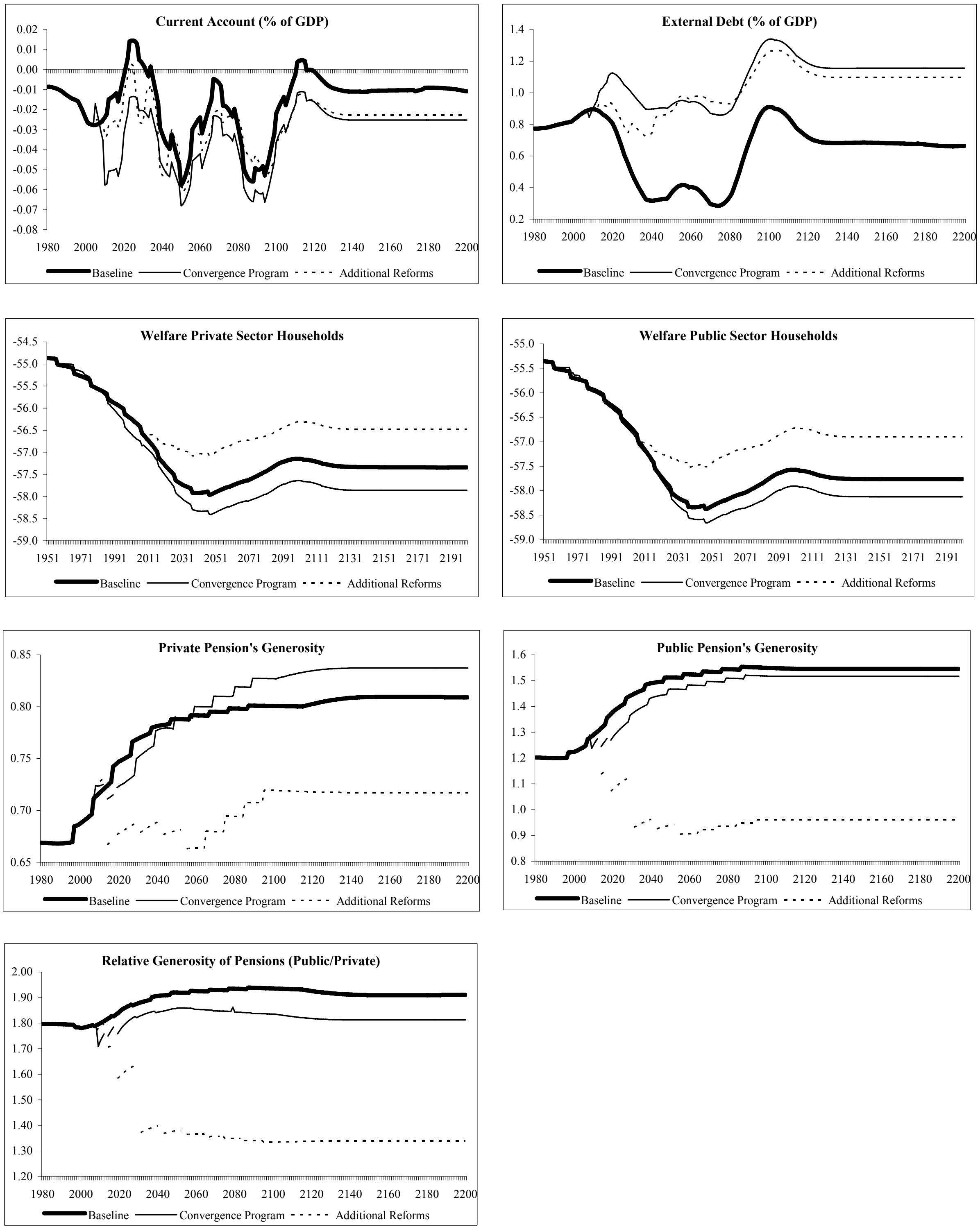
Source: Staff calculations

Figure 6: Additional Reforms Scenario (Cont.)
(Variable interest rates)



Source: Staff calculations

Figure 6: Additional Reforms Scenario (Concl.)
(Variable interest rates)



Source: Staff calculations

APPENDIX I. THE MODEL

Model Overview

The framework is a small open economy version of the Auerbach-Kotlikoff model.[22] 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 payroll taxes to finance government expenditures and pension benefits, and redeem the initial government debt.

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). The system is segmented because households stay either "private" or "public" their whole lives.[23] Stylized versions of the corresponding pension rules are used to calculate pension contributions and benefits in the GSIS and GEPS.

Labor markets, however, are characterized by competition and free mobility. 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 environment, the law of one price (wage rate) holds for given households' labor skills.

In addition, to capture the effects on household behavior of aging and pension reform, the model includes the following elements. Life expectancy is exogenous but increases over time to match current demographic projections. Households retire at an exogenously given age, but 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. Labor-augmenting productivity growth causes real wage growth over time. Finally, the model explicitly accounts for the effects of aging on public health-related expenditures. These features allow the model to meaningfully quantify the effects of pension reforms on labor market incentives and macroeconomic outcomes, including complementarities with alternative tax policies to finance old-age related spending. For the reader's convenience, the model's notation is summarized in Table A1.

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[22] A survey of the literature—extending back to Auerbach and Kotlikoff (1987)—can be found in Kotlikoff (2000). The numerical solution methods involved are described in Heer and Maußner (2004) and Judd (1999).

[23] This modeling strategy allows us to capture some privileges associated with public sector employment and the GEPS while the law of one price still holds in labor markets.

Households

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 A2, where households' lives are characterized by two distinct phases: a work life lasting T_t periods or years ($s = 1,...,T_t$) and a mandatory retirement lasting T_t^R years ($s = T_t + 1,...,T_t + T_t^R$). Note that the model allows the household's life expectancy and retirement age to vary across generations, and henceforth, these are assumed to be 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 relative productivity of an s -year old household to that of a 1-year old (unskilled) household. Thus, W denotes the wage per unit of labor time of an unskilled 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 as given the payroll (τ), income (τ^I), and consumption (τ^c) tax rates, and the interest (r) and wage rates (W).[24]

During retirement, the *private* household's wage income is replaced by *basic* (bb) and *supplementary* (bs) old-age pensions—defined by (5) and (6)—in the budget constraint (4).

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 by nominal wage growth, and this is reflected in the adjustment factor $\frac{W_{t+s-1}}{W_{t+T_t}}$. On the other hand, supplementary pension benefits $bs_{t+T_t}^{T_t+1}$ are indexed by inflation—but not by productivity growth—and this is reflected in the presence of the productivity discount factor $\frac{1}{(1+\xi)^{s-T_t-1}}$. In the pension benefit formulas (5) and (6), the household takes as given the index of basic earnings (BE)—which evolves over time according to nominal wage growth.

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

[24] Income taxes are levied on labor income and asset earnings; for simplicity, these tax rates are assumed to be the same.

GEPS and by basic (bbg) pension benefits associated with the GSIS[25]. After the first retirement year, the household receives annual pension benefits from the GEPS (bg) and basic pension benefits from the GSIS (bbg); both are indexed by nominal wage growth, as reflected in the adjustment factors $\frac{W_{t+s-1}}{W_{t+T_t}}$ in equation (11).

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 $s=T_t+T_t^R+1$.

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 a sequence of two dynamic optimization problems, 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. Upon retirement, the household's optimization problem can be expressed recursively, and a closed-form solution for the value function (V) follows from the log utility assumption.[26]

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). It can be expressed as a sequence of two dynamic optimization problems, as follows:

$$\underset{\left\{c_{g,t+s-1}^s, l_{g,t+s-1}^s, A_{g,t+s}^{s+1}\right\}_{s=1}^{T_t}}{Max} \sum_{s=1}^{T_t} \beta^{s-1} \cdot \left\{\log(c_{g,t+s-1}^s) + \gamma \cdot \log(l_{g,t+s-1}^s)\right\} + \beta^{T_t} \cdot V(A_{g,t+T_t}^{T_t+1}, bgls_{t+T_t}^{T_t+1}, bg_{t+T_t}^{T_t+1}, bbg_{t+T_t}^{T_t+1}, bsg_{t+T_t}^{T_t+1})$$

subject to (9)-(14).

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

[26] Notice that the household's value function $V(.)$ depends not only on its stock of assets at retirement ($A_{p,t+T_t}^{T_t+1}$) and its future annual pension benefits ($bb_{t+T_t}^{T_t+1}, bs_{t+T_t}^{T_t+1}$) but also on future interest rates, wage rates, and income tax rates. A detailed derivation of the value function (V) can be found in Appendix II.

where $V(A_{g,t+T_t}^{T_t+1}, bgls_{t+T_t}^{T_t+1}, bg_{t+T_t}^{T_t+1}, bbg_{t+T_t}^{T_t+1}, bsg_{t+T_t}^{T_t+1})$ is the public household's value function or discounted indirect utility at retirement.

Two sets of conditions solve the household's problem under standard dynamic optimization techniques; see Tables A3 and A4 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 $A_{p,t+T_t}^{T_t+1}$ (or $A_{g,t+T_t}^{T_t+1}$), $bb_{t+T_t}^{T_t+1}$, and $bs_{t+T_t}^{T_t+1}$.[27]

The first set—equations (15)-(18) and (24)-(25)—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 (26)-(28)—governs the household's consumption-saving decisions over time (inter-temporal first order conditions or Euler equations).[28] 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 working or retired and, when working, whether wage income is higher or lower than basic earnings. Specifically, while the household is in the labor force and wage income is lower (higher) than basic earnings, the consumption-leisure choice, or its intra-temporal first-order conditions, 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.[29]

The stationary-transformed aggregate household 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

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[27] Note that the first order conditions of the public household's optimization problem (Table A4) 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 observed facts, 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.

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

[29] The analysis starts with a full set of generations, $T_0+T_0^R$, at time $t=0$. Thus, during the first $T_0+T_0^R$ years a number of "truncated" optimization problems are associated with those households of ages $\tilde{s}=2,...,T_0+T_0^R$ that were born before $t=0$. Notice that we are assuming that all "truncated" generations have the same work life and retirement periods.

variables at each point in time, as follows:[30]

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

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

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

Firms

Firms maximize a (stationary-transformed) profit function 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 therefore, individual firms face given wages (W_t) and rental rates (r_t). The first order conditions require that W_t ($r_t + \delta$) equal the marginal product of labor (capital):

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

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:[31]

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[30] Note the difference between the *aggregate effective labor supply* (N_t^h) and the *aggregate labor effort* (n_t^h). The *aggregate effective labor supply* is the sum of the time devoted to work by all the generations in the labor force in a given year, where each generation's working time is weighted by its skills and population size. In contrast, the *aggregate labor effort* (n_t^h) is the weighted (by population size) sum of the time devoted to work by all generations in the labor force, without accounting for skill differences: $n_t^h = \sum_{s=1}^{T_t} n_t^s \cdot \frac{P_t^s}{P_t}$.

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

(continued…)

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

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

Equilibrium

An equilibrium is defined as a state of affairs that 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 thus a collection of lifetime plans for both, households born during the period of analysis ($t\geq 0$),

$$\left\{c_{p,t+s-1}^s,c_{g,t+s-1}^s,l_{p,t+s-1}^s,l_{g,t+s-1}^s,A_{p,t+s}^{s+1},A_{g,t+s}^{s+1}\right\}_{s=1}^{T_t+T_t^R}\text{, for } t=0,1,\ldots,\infty,$$

and those born before then ($t<0$)—households of ages 2 through $T_0+T_0^R$ at $t=0$—that face "truncated" lifetime plans

$$\left\{c_{p,s-\tilde{s}}^s,c_{g,s-\tilde{s}}^s,l_{p,s-\tilde{s}}^s,l_{g,s-\tilde{s}}^s,A_{p,1+s-\tilde{s}}^{s+1},A_{g,1+s-\tilde{s}}^{s+1}\right\}_{s=\tilde{s}}^{T_0+T_0^R}\text{, for } \tilde{s}=2,\ldots,T_0+T_0^R;$$

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

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

a sequence of allocations for the firms $\left\{K_t^f, N_t^f\right\}_{t=0}^{\infty}$; a sequence of relative prices of labor (wage rates) $\left\{W_t\right\}_{t=0}^{\infty}$; a sequence of government policy 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 growth rule for the basic earnings index $BE_t = BE_0 \cdot \frac{W_t}{W_0}$, such that:

- the sequence of allocations $\left\{K_t^f, N_t^f\right\}_{t=0}^{\infty}$ solves the firm's optimization problem;
- the lifetime plans for households born during the period of analysis $\left\{c_{p,t+s-1}^s, c_{g,t+s-1}^s, l_{p,t+s-1}^s, l_{g,t+s-1}^s, A_{p,t+s}^{s+1}, A_{g,t+s}^{s+1}\right\}_{s=1}^{T_t+T_t^R}$; $t = 0,1,...,\infty$ solve their optimization problems, and the lifetime plans for households of ages $\tilde{s} = 2,...,T_0 + T_0^R$ at time $t = 0$ $\left\{c_{p,s-\tilde{s}}^s, c_{g,s-\tilde{s}}^s, l_{p,s-\tilde{s}}^s, l_{g,s-\tilde{s}}^s, A_{p,1+s-\tilde{s}}^{s+1}, A_{g,1+s-\tilde{s}}^{s+1}\right\}_{s=\tilde{s}}^{T_0+T_0^R}$ solve their truncated optimization problems;
- the government budget constraint is satisfied for $t \geq 0$;
- the labor market clears, $N_t = N_t^f = N_{p,t} + N_{g,t} = \sum_{s=1}^{T_t}\left(e_p^s \cdot n_p^s \cdot \frac{P_{p,t}^s}{P_t} + e_g^s \cdot n_g^s \cdot \frac{P_{g,t}^s}{P_t}\right)$, for $t \geq 0$; the asset market clears, $K_t^f + D_t + A_t^* = A_t^h = A_{p,t}^h + A_{g,t}^h = \sum_{s=1}^{T_t+T_t^R}\left(A_{p,t}^s \cdot \frac{P_{p,t}^s}{P_t} + A_{g,t}^s \cdot \frac{P_{g,t}^s}{P_t}\right)$, for $t \geq 0$; and the economy's aggregate flow constraint is satisfied for all $t \geq 0$, $A_{t+1}^* \cdot (1+\xi) \cdot \frac{P_{t+1}}{P_t} = (1+r_t) \cdot A_t^* + Y_t - C_t - G_t - \left[K_{t+1} \cdot (1+\xi) \cdot \frac{P_{t+1}}{P_t} - (1-\delta) \cdot K_t\right]$, where $Y_t = Y_t^f$ and $C_t = C_t^h$ are the equilibrium aggregate output and consumption levels.[32]

[32] 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

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

$$+ \sum_{s=T_t+1}^{T_t+T_t^R}\left(bbg_{t+T_t+1-s}^{T_t+1} \cdot \frac{W_t}{W_{t+T_t+1-s}} + \frac{bsg_{t+T_t+1-s}^{T_t+1}}{(1+\xi)^{s-T_t-1}} + bg_{t+T_t+1-s}^{T_t+1} \cdot \frac{W_t}{W_{t+T_t+1-s}}\right) \cdot \frac{P_{g,t}^s}{P_t} + bgls_t^{T_t+1} \cdot \frac{P_{g,t}^{T_t+1}}{P_t} - (1+\tau_t^c) \cdot C_t^h.$$

Balanced Growth Equilibrium and Calibration

To calibrate the model and start off the quantitative analysis, a balanced growth equilibrium is defined. The economy is said to exhibit a balanced-growth equilibrium—assuming constant population growth rate (p), work life ($T_t = T$), and retirement period ($T_t^R = T^R$)—when the government implements a fiscal policy characterized by a constant government expenditure-to-output ratio, constant tax rates, and a constant debt-to-output ratio.[33] Along the balanced growth equilibrium path, all endogenous variables grow at constant rates. The balanced-growth equilibrium can be expressed as a *steady state in "detrended" variables* by transforming aggregate variables to eliminate the effects of technological progress and population growth.

The model is calibrated to match the stylized facts and relevant features of the Cypriot economy, as follows.

- Standard parameter values in the real business cycle literature are used for the household's discount factor (β) and the depreciation rate (δ). The share of capital in production (α) is obtained from the literature. The total factor productivity parameter (Z) is set so that the capital-output ratio in the initial steady state is consistent with Cyprus's data. The rate of labor-augmenting technological progress is set to be consistent with long-term output per capita growth. The value of (p) matches the average population growth rate for 1960-2005. The leisure parameter is calibrated so that the fraction of time worked by a representative household in the population is 0.274.[34]

- Tax rates are calibrated to match effective rates observed in 2005. Specifically, the payroll tax rates (τ^P and τ^G) match the observed ratio of social security contributions to wage income, and the consumption (τ^c) and income tax rates (τ^I) match, respectively, the ratios of indirect tax revenues to private consumption and direct tax revenues to GDP.

- The pension replacement ratios (basic, supplementary, and public) are set to be consistent with the Cypriot numerical pension rules. The values of the work life and retirement periods are set so that households enter the labor force when they are on average 23 years old, retire at age 63 and live 80 years with certainty, which is the implicit "life expectancy" at birth.

[33] 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.

[34] Assuming that a household or individual sleeps 8 hours per day, the leisure-work decision is made for the remaining 16 hours. This translates into a total of 112 (=7x16) hours per week. Assuming 40 working hours per week, the individual works 35.7 (=40/112) percent of the time that he/she is awake. Adjusting the fraction of time worked by labor force participation—about 77 percent for those between the ages of 16-64—yields 0.274.

- The private household's labor skills profile by age (e_p^s) was calibrated to match the profiles of average hourly wages by age of workers in the US economy—as reported by Hansen (1993). Accordingly, skills are low at the beginning of the household's work life, peak at about 50 years of age, and decline to intermediate levels by the end of the work life. The public household's labor skills profile by age (e_g^s) is flatter than that of the private household, but starts from a higher level. These differences reflect stylized features of the Cypriot labor markets.

Labor skills profiles
(by age in the model)

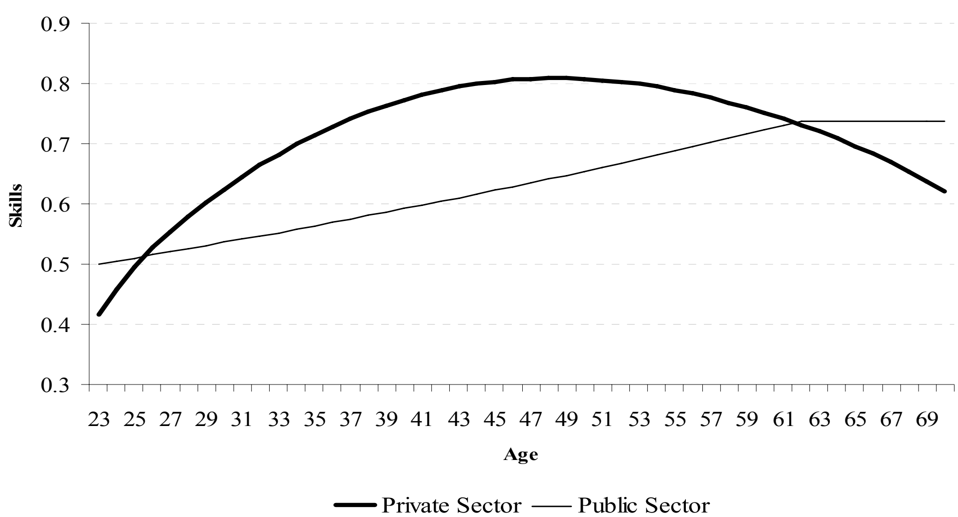

Table A5 shows the parameter values. Given these parameter values, the calibration exercise verifies that the resulting values of the endogenous variables in the initial steady state and the fiscal ratios closely resemble those observed in the Cypriot data.

APPENDIX II: VALUE FUNCTION AT RETIREMENT

The "private" household's 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:

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

subject to (4), (7), and given $A_{p,t+T_t}^{T_t+1}$, $bb_{t+T_t}^{T_t+1}$ and $bs_{t+T_t}^{T_t+1}$. Notice that the household's asset holdings at retirement ($A_{p,t+T_t}^{T_t+1}$), and the annual pension benefits ($bb_{t+T_t}^{T_t+1}, bs_{t+T_t}^{T_t+1}$) are given by household's past decisions.

Let $\tilde{r}_t$ denote the year t rate of return on assets holdings net of the income tax, $\tilde{r}_t = r_t \cdot (1-\tau_t^I)$. We use the budget constraint (4) to solve for $c_{p,t+s-1}^{s}$ and to express the value function recursively, in a Bellman's equation form (for $s = T_t+1, \ldots, T_t+T_t^R$), as follows:

$$V\left(A_{p,t+s-1}^{s}, bb_{t+T_t}^{T_t+1}, bs_{t+T_t}^{T_t+1}\right) = \underset{A_{p,t+s}^{s+1}}{Max} \; \log\left\{(1+\tilde{r}_{t+s-1}) \cdot A_{p,t+s-1}^{s} + bb_{t+T_t}^{T_t+1} \cdot \frac{W_{t+s-1}}{W_{t+T_t}} + \frac{bs_{t+T_t}^{T_t+1}}{(1+\xi)^{s-T_t-1}} - (1+\xi) \cdot A_{p,t+s}^{s+1}\right\}$$
$$+ \beta \cdot V\left(A_{p,t+s}^{s+1}, bb_{t+T_t}^{T_t+1}, bs_{t+T_t}^{T_t+1}\right).$$

We obtain the value function by backward induction, that is, we start with the household's problem in its last year of life, and proceed backwards. This is done in four steps as follows:

1. The household's problem at date $t+T_t+T_t^R-1$ (household's age is $s = T_t+T_t^R$) is given by

$$V\left(A_{p,t+T_t+T_t^R-1}^{T_t+T_t^R}, bb_{t+T_t}^{T_t+1}, bs_{t+T_t}^{T_t+1}\right) = \underset{A_{p,t+T_t+T_t^R}^{T_t+T_t^R+1}}{Max} \; \log\left\{\left(1+\tilde{r}_{t+T_t+T_t^R-1}\right) \cdot A_{p,t+T_t+T_t^R-1}^{T_t+T_t^R} + bb_{t+T_t}^{T_t+1} \cdot \frac{W_{t+T_t+T_t^R-1}}{W_{t+T_t}}\right.$$
$$\left. + \frac{bs_{t+T_t}^{T_t+1}}{(1+\xi)^{T_t^R-1}} - (1+\xi) \cdot A_{p,t+T_t+T_t^R}^{T_t+T_t^R+1}\right\}.$$

The household consumes all its remaining assets in its last period of life, as it leaves no bequests and the no-Ponzi condition ($A_{p,t+T_t+T_t^R}^{T_t+T_t^R+1} = 0$) is satisfied. Thus, the solution is given by

$$V\left(A_{p,t+T_t+T_t^R-1}^{T_t+T_t^R}, bb_{t+T_t}^{T_t+1}, bs_{t+T_t}^{T_t+1}\right) = \log\left\{\left(1+\tilde{r}_{t+T_t+T_t^R-1}\right) \cdot A_{p,t+T_t+T_t^R-1}^{T_t+T_t^R} + bb_{t+T_t}^{T_t+1} \cdot \frac{W_{t+T_t+T_t^R-1}}{W_{t+T_t}} + \frac{bs_{t+T_t}^{T_t+1}}{(1+\xi)^{T_t^R-1}}\right\}.$$

2. The household's problem at date $t+T_t+T_t^R-2$ (household's age is $T_t+T_t^R-1$) is given by

$$V\left(A_{p,t+T_t+T_t^R-2}^{T_t+T_t^R-1}, bb_{t+T_t}^{T_t+1}, bs_{t+T_t}^{T_t+1}\right) = \underset{A_{p,t+T_t+T_t^R-1}^{T_t+T_t^R}}{Max} \log\left\{\left(1+\tilde{r}_{t+T_t+T_t^R-2}\right)\cdot A_{p,t+T_t+T_t^R-2}^{T_t+T_t^R-1} + bb_{t+T_t}^{T_t+1}\cdot\frac{W_{t+T_t+T_t^R-2}}{W_{t+T_t}} + \frac{bs_{t+T_t}^{T_t+1}}{(1+\xi)^{T_t^R-2}}\right.$$
$$\left. -(1+\xi)\cdot A_{p,t+T_t+T_t^R-1}^{T_t+T_t^R}\right\} + \beta\cdot V\left(A_{p,t+T_t+T_t^R-1}^{T_t+T_t^R}, bb_{t+T_t}^{T_t+1}, bs_{t+T_t}^{T_t+1}\right).$$

Plug the solution of $V\left(A_{p,t+T_t+T_t^R-1}^{T_t+T_t^R}, bb_{t+T_t}^{T_t+1}, bs_{t+T_t}^{T_t+1}\right)$ found in 1 to obtain the following expression:

$$V\left(A_{p,t+T_t+T_t^R-2}^{T_t+T_t^R-1}, bb_{t+T_t}^{T_t+1}, bs_{t+T_t}^{T_t+1}\right) = \underset{A_{p,t+T_t+T_t^R-1}^{T_t+T_t^R}}{Max} \log\left\{\left(1+\tilde{r}_{t+T_t+T_t^R-2}\right)\cdot A_{p,t+T_t+T_t^R-2}^{T_t+T_t^R-1} + bb_{t+T_t}^{T_t+1}\cdot\frac{W_{t+T_t+T_t^R-2}}{W_{t+T_t}} + \frac{bs_{t+T_t}^{T_t+1}}{(1+\xi)^{T_t^R-2}}\right.$$
$$\left. -(1+\xi)\cdot A_{p,t+T_t+T_t^R-1}^{T_t+T_t^R}\right\} + \beta\cdot\log\left\{\left(1+\tilde{r}_{t+T_t+T_t^R-1}\right)\cdot A_{p,t+T_t+T_t^R-1}^{T_t+T_t^R} + bb_{t+T_t}^{T_t+1}\cdot\frac{W_{t+T_t+T_t^R-1}}{W_{t+T_t}} + \frac{bs_{t+T_t}^{T_t+1}}{(1+\xi)^{T_t^R-1}}\right\}.$$

Find the first order condition of this optimization problem and solve for $A_{p,t+T_t+T_t^R-1}^{T_t+T_t^R}$,

$$A_{p,t+T_t+T_t^R-1}^{T_t+T_t^R} = \frac{\beta\cdot\prod_{i=1}^{2}\left(1+\tilde{r}_{t+T_t+T_t^R-i}\right)\cdot A_{p,t+T_t+T_t^R-2}^{T_t+T_t^R-1}}{(1+\xi)\cdot(1+\beta)\cdot\left(1+\tilde{r}_{t+T_t+T_t^R-1}\right)} - \frac{\left[1-\beta\cdot\left(1+\tilde{r}_{t+T_t+T_t^R-1}\right)\right]\cdot\frac{bs_{t+T_t}^{T_t+1}}{(1+\xi)^{T_t^R-2}}}{(1+\xi)\cdot(1+\beta)\cdot\left(1+\tilde{r}_{t+T_t+T_t^R-1}\right)}$$
$$-\frac{\left[(1+\xi)\cdot W_{t+T_t+T_t^R-1} - \beta\cdot\left(1+\tilde{r}_{t+T_t+T_t^R-1}\right)\cdot W_{t+T_t+T_t^R-2}\right]\cdot\frac{bb_{t+T_t}^{T_t+1}}{W_{t+T_t}}}{(1+\xi)\cdot(1+\beta)\cdot\left(1+\tilde{r}_{t+T_t+T_t^R-1}\right)};$$

plug this expression into the value function $V\left(A_{p,t+T_t+T_t^R-2}^{T_t+T_t^R-1}, bb_{t+T_t}^{T_t+1}, bs_{t+T_t}^{T_t+1}\right)$ and solve, as follows:

$$V\left(A_{t+T_t+T_t^R-2}^{T_t+T_t^R-1}, bb_{t+T_t}^{T_t+1}, bs_{t+T_t}^{T_t+1}\right) = (1+\beta)\cdot\log\left\{\prod_{i=1}^{2}\left(1+\tilde{r}_{t+T_t+T_t^R-i}\right)\cdot A_{t+T_t+T_t^R-2}^{T_t+T_t^R-1} + \left(2+\tilde{r}_{t+T_t+T_t^R-1}\right)\cdot\frac{bs_{t+T_t}^{T_t+1}}{(1+\xi)^{T_t^R-2}}\right.$$
$$\left. +\left[(1+\xi)\cdot W_{t+T_t+T_t^R-1} + \left(1+\tilde{r}_{t+T_t+T_t^R-1}\right)\cdot W_{t+T_t+T_t^R-2}\right]\cdot\frac{bb_{t+T_t}^{T_t+1}}{W_{t+T_t}}\right\} - \Omega_1,$$

where Ω_1 is a constant: $\Omega_1 = \log\left(1+\tilde{r}_{t+T_t+T_t^R-1}\right) + (1+\beta)\cdot\log(1+\beta) + \beta\cdot\log(1+\xi) - \beta\cdot\log(\beta)$.

3. The household's problem at date $t+T_t+T_t^R-3$ (household's age is $s=T_t+T_t^R-2$):

$$V\left(A^{T_t+T_t^R-2}_{t+T_t+T_t^R-3}, bb^{T_t+1}_{t+T_t}, bs^{T_t+1}_{t+T_t}\right) = \underset{A^{T_t+T_t^R-1}_{t+T_t+T_t^R-2}}{Max} \log\left\{\left(1+\tilde{r}_{t+T_t+T_t^R-3}\right)\cdot A^{T_t+T_t^R-2}_{t+T_t+T_t^R-3} + bb^{T_t+1}_{t+T_t}\cdot\frac{W_{t+T_t+T_t^R-3}}{W_{t+T_t}} + \frac{bs^{T_t+1}_{t+T_t}}{\left(1+\xi\right)^{T_t^R-3}}\right.$$
$$\left. -\left(1+\xi\right)A^{T_t+T_t^R-1}_{t+T_t+T_t^R-2}\right\} + \beta\cdot V\left(A^{T_t+T_t^R-1}_{t+T_t+T_t^R-2}, bb^{T_t+1}_{t+T_t}, bs^{T_t+1}_{t+T_t}\right).$$

Replacing $V\left(A^{T_t+T_t^R-1}_{t+T_t+T_t^R-2}, bb^{T_t+1}_{t+T_t}, bs^{T_t+1}_{t+T_t}\right)$ from 2, we can write the previous expression as follows:

$$V\left(A^{T_t+T_t^R-2}_{t+T_t+T_t^R-3}, bb^{T_t+1}_{t+T_t}, bs^{T_t+1}_{t+T_t}\right) = \underset{A^{T_t+T_t^R-1}_{t+T_t+T_t^R-2}}{Max} \log\left\{\left(1+\tilde{r}_{t+T_t+T_t^R-3}\right)\cdot A^{T_t+T_t^R-2}_{t+T_t+T_t^R-3} + bb^{T_t+1}_{t+T_t}\cdot\frac{W_{t+T_t+T_t^R-3}}{W_{t+T_t}} + \frac{bs^{T_t+1}_{t+T_t}}{\left(1+\xi\right)^{T_t^R-3}}\right.$$
$$\left. -\left(1+\xi\right)A^{T_t+T_t^R-1}_{t+T_t+T_t^R-2}\right\} + \beta\cdot\left(1+\beta\right)\cdot\log\left\{\prod_{i=1}^{2}\left(1+\tilde{r}_{t+T_t+T_t^R-i}\right)\cdot A^{T_t+T_t^R-1}_{t+T_t+T_t^R-2} + \left(2+\tilde{r}_{t+T_t+T_t^R-1}\right)\cdot\frac{bs^{T_t+1}_{t+T_t}}{\left(1+\xi\right)^{T_t^R-2}}\right.$$
$$\left. +\left[\left(1+\xi\right)\cdot W_{t+T_t+T_t^R-1} + \left(1+\tilde{r}_{t+T_t+T_t^R-1}\right)\cdot W_{t+T_t+T_t^R-2}\right]\cdot\frac{bb^{T_t+1}_{t+T_t}}{W_{t+T_t}}\right\} - \beta\cdot\Omega_1.$$

Find the first order condition and solve for $A^{T_t+T_t^R-1}_{t+T_t+T_t^R-2}$,

$$A^{T_t+T_t^R-1}_{t+T_t+T_t^R-2} = \frac{\beta\cdot(1+\beta)\cdot\prod_{i=1}^{3}\left(1+\tilde{r}_{t+T_t+T_t^R-i}\right)\cdot A^{T_t+T_t^R-2}_{t+T_t+T_t^R-3}}{\left(1+\xi\right)\cdot\left(1+\beta+\beta^2\right)\cdot\prod_{i=1}^{2}\left(1+\tilde{r}_{t+T_t+T_t^R-i}\right)} + \frac{\left[\beta\cdot(1+\beta)\cdot\prod_{i=1}^{2}\left(1+\tilde{r}_{t+T_t+T_t^R-i}\right) - \left(2+\tilde{r}_{t+T_t+T_t^R-1}\right)\right]\cdot\frac{bs^{T_t+1}_{t+T_t}}{\left(1+\xi\right)^{T_t^R-3}}}{\left(1+\xi\right)\cdot\left(1+\beta+\beta^2\right)\cdot\prod_{i=1}^{2}\left(1+\tilde{r}_{t+T_t+T_t^R-i}\right)}$$
$$-\frac{\left[\left(1+\xi\right)^2\cdot W_{t+T_t+T_t^R-1} + \left(1+\xi\right)\cdot\left(1+\tilde{r}_{t+T_t+T_t^R-1}\right)\cdot W_{t+T_t+T_t^R-2} - \beta\cdot(1+\beta)\cdot\prod_{i=1}^{2}\left(1+\tilde{r}_{t+T_t+T_t^R-i}\right)\cdot W_{t+T_t+T_t^R-3}\right]\cdot\frac{bb^{T_t+1}_{t+T_t}}{W_{t+T_t}}}{\left(1+\xi\right)\cdot\left(1+\beta+\beta^2\right)\cdot\prod_{i=1}^{2}\left(1+\tilde{r}_{t+T_t+T_t^R-i}\right)}.$$

Plug this previous expression into the value function $V\left(A^{T_t+T_t^R-2}_{t+T_t+T_t^R-3}, b^{T_t+1}_{t+T_t}\right)$ and solve,

$$V\left(A^{T_t+T_t^R-2}_{t+T_t+T_t^R-3}, bb^{T_t+1}_{t+T_t}, bs^{T_t+1}_{t+T_t}\right) = \left(1+\beta+\beta^2\right)\cdot\log\left\{\prod_{i=1}^{3}\left(1+\tilde{r}_{t+T_t+T_t^R-i}\right)\cdot A^{T_t+T_t^R-2}_{t+T_t+T_t^R-3} + \left[1+\left(1+\tilde{r}_{t+T_t+T_t^R-1}\right)+\prod_{i=1}^{2}\left(1+\tilde{r}_{t+T_t+T_t^R-i}\right)\right]\cdot\frac{bs^{T_t+1}_{t+T_t}}{\left(1+\xi\right)^{T_t^R-3}}\right.$$
$$\left. +\left[\left(1+\xi\right)^2\cdot W_{t+T_t+T_t^R-1} + (1+\xi)\cdot\left(1+\tilde{r}_{t+T_t+T_t^R-1}\right)\cdot W_{t+T_t+T_t^R-2} + \left(1+\tilde{r}_{t+T_t+T_t^R-1}\right)\cdot\left(1+\tilde{r}_{t+T_t+T_t^R-2}\right)\cdot W_{t+T_t+T_t^R-3}\right]\cdot\frac{bb^{T_t+1}_{t+T_t}}{W_{t+T_t}}\right\} - \Omega_2,$$

where Ω_2 is a constant: $\Omega_2 = \log\left(1+\tilde{r}_{t+T_t+T_t^R-1}\right) + \log\left(1+\tilde{r}_{t+T_t+T_t^R-2}\right) + \left(1+\beta+\beta^2\right)\cdot\log\left(1+\beta+\beta^2\right)$

$$+\beta\cdot\left(1+\beta\right)\cdot\log\left(1+\xi\right) - \beta\cdot\left(1+\beta\right)\cdot\log\left[\beta\cdot\left(1+\beta\right)\right].$$

4. Repeating the procedure backwards, the value function at date $t+T_t$ (household's age is T_t+1) is given by

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

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

where Ω is a constant. The derivatives of the value function with respect to changes in asset holdings $\left(V_A\right)$, basic $\left(V_{bb}\right)$ and supplementary pension benefits $\left(V_{bs}\right)$ are given by

$$V_A(.)=\frac{\left(\sum_{j=1}^{T_t^R}\beta^{j-1}\right)\cdot\prod_{i=1}^{T_t^R}\left(1+\tilde{r}_{t+T_t+T_t^R-i}\right)}{\Delta},$$

$$V_{bs}(.)=\frac{\left(\sum_{j=1}^{T_t^R}\beta^{j-1}\right)\cdot\left\{1+\sum_{j=1}^{T_t^R-1}\left[\prod_{i=1}^{j}\left(1+\tilde{r}_{t+T_t+T_t^R-i}\right)\right]\right\}}{\Delta},$$

$$V_{bb}(.)=\frac{\left(\sum_{j=1}^{T_t^R}\beta^{j-1}\right)\cdot\left\{(1+\xi)^{T_t^R-1}\cdot W_{t+T_t+T_t^R-1}+\sum_{j=2}^{T_t^R}\left[\prod_{i=1}^{j-1}\left(1+\tilde{r}_{t+T_t+T_t^R-i}\right)\cdot(1+\xi)^{T_t^R-j}\cdot W_{t+T_t+T_t^R-j}\right]\right\}\cdot\frac{1}{W_{t+T_t}}}{\Delta},$$

where

$$\Delta=\prod_{i=1}^{T_t^R}\left(1+\tilde{r}_{t+T_t+T_t^R-i}\right)\cdot A_{t+T_t}^{T_t+1}+\left\{1+\sum_{j=1}^{T_t^R-1}\left[\prod_{i=1}^{j}\left(1+\tilde{r}_{t+T_t+T_t^R-i}\right)\right]\right\}\cdot bs_{t+T_t}^{T_t+1}+\left\{(1+\xi)^{T_t^R-1}\cdot W_{t+T_t+T_t^R-1}\right.$$

$$\left.+\sum_{j=2}^{T_t^R}\left[\prod_{i=1}^{j-1}\left(1+\tilde{r}_{t+T_t+T_t^R-i}\right)\cdot(1+\xi)^{T_t^R-j}\cdot W_{t+T_t+T_t^R-j}\right]\right\}\cdot\frac{bb_{t+T_t}^{T_t+1}}{W_{t+T_t}}.$$

Table A1. 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 ratio (pension rule)	ψ	
Capital share (production)	α		Constant rate of population growth 1/	p	
Capital depreciation rate	δ		Total factor productivity	Z	
Labor skill (*)	e^s				
Population					
s -year old population (*)	P_t^s		Total population	P_t	
Households					
Labor effort (*)	n_t^s		Aggregate effective labor supply	$\hat{N}_t^h$	$N_t^h = \frac{\hat{N}_t^h}{P_t}$
Leisure (*)	l_t^s		Aggregate labor effort	$\hat{n}_t^h$	$n_t^h = \frac{\hat{n}_t^h}{P_t}$
Consumption (*)	$\hat{c}_t^s$	$c_t^s = \frac{\hat{c}_t^s}{(1+\xi)^t}$	Aggregate consumption	$\hat{C}_t^h$	$C_t^h = \frac{\hat{C}_t^h}{(1+\xi)^t \cdot P_t}$
Asset holdings (*)	$\hat{A}_t^s$	$A_t^s = \frac{\hat{A}_t^s}{(1+\xi)^t}$	Aggregate asset holdings	$\hat{A}_t^h$	$A_t^h = \frac{\hat{A}_t^h}{(1+\xi)^t \cdot P_t}$
Annual pension (*) 2/	$\hat{bb}_{t+T_t}^{T_t+1}$	$bb_{t+T_t}^{T_t+1} = \frac{\hat{bb}_{t+T_t}^{T_t+1}}{(1+\xi)^{t+T_t}}$	Aggregate foreign assets	$\hat{A}_t^*$	$A_t^* = \frac{\hat{A}_t^*}{(1+\xi)^t \cdot P_t}$
Firms					
Aggregate capital demand	$\hat{K}_t^f$	$K_t^f = \frac{\hat{K}_t^f}{(1+\xi)^t \cdot P_t}$	Aggregate labor demand	$\hat{N}_t^f$	$N_t^f = \frac{\hat{N}_t^f}{P_t}$
Aggregate output	$\hat{Y}_t^f$	$Y_t^f = \frac{\hat{Y}_t^f}{(1+\xi)^t \cdot P_t}$	Profits (net) 3/	$\hat{\Pi}_t^f$	$\Pi_t^f = \frac{\hat{\Pi}_t^f}{(1+\xi)^t \cdot P_t}$
Factor Prices					
Gross rate of return on assets	r_t		Wage rate (unskilled labor)	$\hat{W}_t$	$W_t = \frac{\hat{W}_t}{(1+\xi)^t}$
Tax Rates					
Social security contribution (*)	τ_t		Consumption tax	τ_t^c	
Income tax	τ_t^I				
Government					
Debt	$\hat{D}_t$	$D_t = \frac{\hat{D}_t}{(1+\xi)^t \cdot P_t}$	Expenditure	$\hat{G}_t$	$G_t = \frac{\hat{G}_t}{(1+\xi)^t \cdot P_t}$

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 A2 and are subject to the same stationary-transformations. 3/ Profits are net of capital depreciation.

Table A2. Household's Optimization Problems

	"Private" Households		"Public" Households 1/	
Utility	$U_{p,t} = \sum_{s=1}^{T_t+T_t^R} \beta^{s-1} \cdot \left\{ \log(c^s_{p,t+s-1}) + \gamma \cdot \log(l^s_{p,t+s-1}) \right\}$	(1)	$U_{g,t} = \sum_{s=1}^{T_t+T_t^R} \beta^{s-1} \cdot \left\{ \log(c^s_{g,t+s-1}) + \gamma \cdot \log(l^s_{g,t+s-1}) \right\}$	(8)
Time constraint	$l^s_{p,t+s-1} = \begin{cases} 1-n^s_{p,t+s-1} & s=1,\dots,T_t \\ 1 & s=T_t+1,\dots T_t+T_t^R \end{cases}$	(2)	$l^s_{g,t+s-1} = \begin{cases} 1-n^s_{g,t+s-1} & s=1,\dots,T_t \\ 1 & s=T_t+1,\dots T_t+T_t^R \end{cases}$	(9)
Budget constraint in work-life $(s=1,\dots,T_t-1)$	$(1+\xi)\cdot A^{s+1}_{p,t+s} = [1+r_{t+s-1}\cdot(1-\tau^I_{t+s-1})]\cdot A^s_{p,t+s-1} + (1-\tau^p_{t+s-1}-\tau^I_{t+s-1})\cdot$ $\cdot W_{t+s-1}\cdot e^s_p \cdot n^s_{p,t+s-1} - (1+\tau^c_{t+s-1})\cdot c^s_{p,t+s-1},$	(3)	$(1+\xi)\cdot A^{s+1}_{g,t+s} = [1+r_{t+s-1}\cdot(1-\tau^I_{t+s-1})]\cdot A^s_{g,t+s-1} + (1-\tau^g_{t+s-1}-\tau^I_{t+s-1})\cdot$ $\cdot W_{t+s-1}\cdot e^s_g \cdot n^s_{g,t+s-1} - (1+\tau^c_{t+s-1})\cdot c^s_{g,t+s-1}$	(10)
Budget constraint in retirement $(s=T_t+1,\dots,T_t+T_t^R-1)$	$(1+\xi)\cdot A^{s+1}_{p,t+s} = [1+r_{t+s-1}\cdot(1-\tau^I_{t+s-1})]\cdot A^s_{p,t+s-1} + bb^{T_t+1}_{t+T_t}\cdot \frac{W_{t+s-1}}{W_{t+T_t}}$ $+ \frac{bs^{T_t+1}_{t+T_t}}{(1+\xi)^{s-T_t-1}} - (1+\tau^c_{t+s-1})\cdot c^s_{p,t+s-1}\ .$	(4)	$(1+\xi)\cdot A^{T_t+2}_{g,t+T_t+1} = [1+r_{t+T_t}\cdot(1-\tau^I_{t+T_t})]\cdot A^{T_t+1}_{g,t+T_t} + bg^{T_t+1}_{t+T_t} + bgls^{T_t+1}_{t+T_t}$ $+ bbg^{T_t+1}_{t+T_t} - (1+\tau^c_{t+T_t})\cdot c^{T_t+1}_{g,t+T_t};\ \ s=T_t+1$ $(1+\xi)\cdot A^{s+1}_{g,t+s} = [1+r_{t+s-1}\cdot(1-\tau^I_{t+s-1})]\cdot A^s_{g,t+s-1} + bg^{T_t+1}_{t+T_t}\cdot\frac{W_{t+s-1}}{W_{t+T_t}}$ $+ bbg^{T_t+1}_{t+T_t}\cdot\frac{W_{t+s-1}}{W_{t+T_t}} - (1+\tau^c_{t+s-1})\cdot c^s_{g,t+s-1};\ \ s=T_t+2,\dots,T_t+T_t^R-1$	(11)
Pension benefits at retirement	Basic: $bb^{T_t+1}_{t+T_t} = \frac{\alpha_B}{T_t}\cdot\left[\sum_{j=1}^{T_t} Min\left\{1, \frac{W_{t+j-1}\cdot e^j_p \cdot n^j_{p,t+j-1}}{BE_{t+j-1}}\right\}\right]\cdot BE_{t+T_t}$	(5)	Annual: $bg^{T_t+1}_{t+T_t} = \alpha \cdot \frac{W_{t+T_t-1}\cdot e^{T_t}_g \cdot n^{T_t}_{g,t+T_t-1}}{(1+\xi)}$	(12)
	Supplementary: $bs^{T_t+1}_{t+T_t} = \alpha_S \cdot\left[\sum_{j=1}^{T_t} Max\left\{0, \frac{W_{t+j-1}\cdot e^j_p \cdot n^j_{p,t+j-1}}{BE_{t+j-1}} - 1\right\}\right]\cdot BE_{t+T_t}$	(6)	Lump sum: $bgls^{T_t+1}_{t+T_t} = \lambda \cdot \frac{W_{t+T_t-1}\cdot e^{T_t}_g \cdot n^{T_t}_{g,t+T_t-1}}{(1+\xi)}$	(13)
No bequest, inheritance constraint	$A^1_{p,t} = A^{T_t+T_t^R+1}_{p,t} = 0$	(7)	$A^1_{g,t} = A^{T_t+T_t^R+1}_{g,t} = 0$	(14)

1/ Basic pension benefits paid by the general scheme GSIS to public households are calculated using the formulas (5) and (6)—the same formulas used to calculate private household's basic benefits.

Table A3. First Order Conditions—Private Household's Optimization Problem

	Consumption-Leisure Decision (Intra-temporal condition)	Consumption-Saving Decision (Inter-temporal condition)
Working Age $(s=1,\dots,T_t-1)$		
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 $(s=T_t+1,\dots,T_t+T_t^R-1)$		$\frac{(1+\xi)}{c_{p,t+s-1}^s\cdot(1+\tau_{t+s-1}^c)}=\frac{\beta\cdot[1+r_{t+s}\cdot(1-\tau_{t+s}^I)]}{c_{p,t+s}^{s+1}\cdot(1+\tau_{t+s}^c)}$ (23)

Table A4. First Order Conditions—Public Household's Optimization Problem

	Consumption-Leisure Decision (Intra-temporal condition)		Consumption-Saving Decision (Inter-temporal condition)	
Working Age				
$(s=1,\ldots,T_t-1)$	$\frac{\gamma}{l^{s}_{g,t+s-1}}=\frac{W_{t+s-1}\cdot e^{s}_{g}\cdot(1-\tau^{l}_{t+s-1})}{c^{s}_{g,t+s-1}\cdot(1+\tau^{c}_{t+s-1})}$	(24)	$\frac{(1+\xi)}{c^{s}_{g,t+s-1}\cdot(1+\tau^{c}_{t+s-1})}=\beta\cdot\frac{[1+r_{t+s}\cdot(1-\tau^{l}_{t+s})]}{c^{s+1}_{g,t+s}\cdot(1+\tau^{c}_{t+s})}$	(26)
$(s=T_t)$	$\frac{\gamma}{l^{T_t}_{g,t+T_t-1}}=\frac{W_{t+T_t-1}\cdot e^{T_t}_{g}\cdot(1-\tau^{l}_{t+T_t-1})}{c^{T_t}_{g,t+T_t-1}\cdot(1+\tau^{c}_{t+T_t-1})}$	(25)	$\frac{(1+\xi)}{c^{T_t}_{g,t+T_t-1}\cdot(1+\tau^{c}_{t+T_t-1})}=\beta\cdot V_A(A^{T_t+1}_{g,t+T_t},bg^{T_t+1}_{t+T_t},bgls^{T_t+1}_{t+T_t},bbg^{T_t+1}_{t+T_t})$	(27)
Retirement				
$(s=T_t+1,\ldots,T_t+T^{R}_t-1)$			$\frac{(1+\xi)}{c^{s}_{g,t+s-1}\cdot(1+\tau^{c}_{t+s-1})}=\frac{\beta\cdot[1+r_{t+s}\cdot(1-\tau^{l}_{t+s})]}{c^{s+1}_{g,t+s}\cdot(1+\tau^{c}_{t+s})}$	(28)

Table A5. Calibration of the Model (Initial Steady State)

Symbol	Definition	Value	Source
α	Share of capital	0.3300	From the real business cycle literature.
γ	Leisure preference	1.5700	Value set so that the fraction of working time for the representative household is 0.274.
β	Discount factor	0.9500	From the real business cycle literature.
δ	Depreciation rate	0.0800	From the real business cycle literature.
Z	Total factor productivity	0.6100	Value set so that the capital- output ratio is 1.81.
τ^P	Social security payroll tax rate private household.	0.1650	Social security contributions over wage income.
τ^G	Social security payroll tax rate public household.	0.0320	Social security contributions over wage income.
τ	Consumption tax rate	0.2300	Ratio of revenues from VAT to GDP (16%).
τ^I	Capital-income tax rate	0.1100	Ratio of direct tax revenues to GDP (9.2%).
p	Rate of population growth	0.0085	Average 1900-1970.
G/Y	Government consumption (fraction of total output)	0.2350	Average 1994-2004.
D/Y	Government debt (fraction of total output)	0.7000	General government 2004.
α_B	Replacement rate basic penison	0.6000	From pension rule.
α_S	Replacement rate supplementary penison	0.0150	From pension rule.
α	Replacement rate public penison	0.5000	From pension rule.
λ	Lumpsum payment factor	28.0000	From pension rule.
x	Rate of labor-augmenting technological progress	0.0150	Set to result in a 1.5 percent annual rate of output per capita growth (average).
T	Work life (years).	40.0000	Set to match individual's entry to the labor force at age 23 and retirment at 63.
T^R	Retirement life.	18.0000	Set to match life expectancy of 80 years.

Source: Staff estimates.

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