Original Article

Dealing with global ageing and declining world interest rates: Fiscal costs and pension reform in small open economies

Received (in revised form): 19th April 2010

Mario Catalán

is an economist at the Western Hemisphere Division of the IMF Institute. He was an assistant professor of international economics and finance at Johns Hopkins University, School of Advanced International Studies (SAIS), and received his PhD from the University of California, Los Angeles.

Jaime Guajardo

serves as an Economist in the World Economic Studies Division of the Research Department at the International Monetary Fund. He received his PhD from the University of California, Los Angeles.

Alexander W. Hoffmaister

serves as a Deputy Division Chief in the European Department of the International Monetary Fund and received his PhD from Boston University.

ABSTRACT How will the worldwide decline in real interest rates associated with global ageing affect small open economies (SOEs) with ageing populations? Lower interest rates will result in higher capital–labor ratios and increased wages. Higher wages will be passed on to pension benefits, exacerbating ageing-related fiscal pressures, increasing taxation and reducing consumption and welfare. The pass-through effect will be stronger if pensions are indexed to nominal wages rather than prices. The article illustrates the interest rates transmission mechanism and its interaction with pension indexation. In addition, the article evaluates the capacity of pension reforms to mitigate the effects of long-run movements in world interest rates. It concludes that pension reforms, particularly those that change the indexation of pensions from wages to prices, protect SOEs against world interest rate changes. These results serve to strengthen policymakers' case for indexation-switching pension reforms.

Pensions (2010) 15, 191–213. doi:10.1057/pm.2010.21

Keywords: pension reform; dynamic general equilibrium model; population ageing

INTRODUCTION

Global population ageing is set to depress world real interest rates in the next three decades. Rapidly ageing large economies will experience

a surge in savings as large numbers of households prepare to retire, while demand for investment will decline as labor forces around the world shrink.^{1,2} The magnitude of the decline in global interest rates, however, is uncertain and hinges on demographic developments and pension reforms in these economies.^{3,4}

How will the decline in world interest rates affect small open economies (SOEs) with ageing

Correspondence: Mario Catalán
International Monetary Fund, 700 19th Street, NW,
Washington, DC 20431, USA
E-mail: mcatalan@imf.org

populations? This article addresses this question and also evaluates the effects of pension reforms, stressing their capacity to mitigate adverse macroeconomic effects of ageing and long-run movements in world interest rates. By examining the interest rate channel, this article helps to understand the international spillover effects triggered by population ageing and pension reforms in large countries.⁵ Although the available literature contains a rich discussion of the impact of temporary world interest rate shocks on business cycles in SOEs,^{6–9} the effects of long-run declines on ageing-related fiscal pressures have not been examined; this study seeks to fill this void.

This article shows that long-run declines in world interest rates will impinge on a SOE's ability to cope with its own demographic ageing process. In a nutshell, lower interest rates will induce higher capital–labor ratios and thereby increased wages. Higher wages, in turn, will boost pension benefits more than contributions, exacerbating ageing-related fiscal pressures, increasing taxation, and reducing consumption and welfare. The pass-through effect of interest rate movements into pension benefits will be stronger if pension benefits, and past wage earnings used to compute these benefits, are indexed to nominal wages rather than prices.

The quantitative analysis is based on an overlapping generations (OLG) model of a SOE with an ageing population that trades intertemporally with the rest of the world while facing exogenously determined world interest rates. The model is calibrated for the European country whose pension expenditures are projected to increase the most, namely Cyprus.^{10,11} The model captures the key institutional features of the Cypriot pension system, including the different regimes for private and public employees and the effect of ageing on health-care spending. The Cypriot case serves to highlight the pass-through effect of lower interest rates into higher pensions and its relation to indexation. This is because public pensions in Cyprus are fully indexed to wages while private pensions are indexed to both wages and prices.¹² Consequently, the pass-through effect is lopsided: a decline in

interest rates boosts the generosity of public pensions relative to that of private pensions.

The simulations discussed below underscore the role of declining world interest rates. Two interest rate scenarios combined with a no-reform baseline and three pension reform scenarios are discussed in this article. First, a constant interest rates scenario with no pension reform confirms the macroeconomic effects of population ageing in Cyprus discussed in Hoffmaister *et al.*¹³ This scenario shows that (consumption) tax rates will need to increase by 7 percentage points to finance an increase in pension expenditure of 7 percentage points of gross national income (GNI) by 2050.

Second, the declining interest rates scenario lays bare the fact that future fiscal pressures and macroeconomic performance are highly sensitive to changes in world interest rates. Specifically, this scenario is characterized by a gradual decline in world interest rates of 100 basis points over three decades and reveals the need to increase the consumption tax rate by 29 percentage points to finance a 13 percentage points increase in pension expenditure as a share of GNI.¹⁴ This result reflects not only the pass-through of interest rates on wages and pensions but also the endogenous response of national income, labor, capital formation, the current account and taxes. Interestingly, the economy runs sustained large current account surpluses as the population ages in the constant interest rates scenario. But these surpluses turn into deficits in the declining world interest rates scenario. Also, lower interest rates reduce national income (GNI) but increase domestic output (GDP) and capital formation.

Turning to pension reforms, the question arises: what reforms are more effective to protect SOEs with ageing populations against long-run declines in world interest rates? In this regard, this article considers three pension reform scenarios. Reforms include increases in the retirement age of all workers in line with projected life expectancy; shifts in the indexation of all pension benefits to prices; and changes in the indexation of wage earnings used to compute pension benefits to prices.

The simulation results make clear that pension reforms, particularly those that change indexation from wages to prices, provide substantial insulation of the economy's performance against long-run interest rate declines. This result is new in the literature discussing pension reforms, which so far has stressed reduced pension expenditures and taxes as the main benefits stemming from indexation-switching reforms.^{15,16} This article shows that this reform can also make the economy more robust to changes in world interest rates.

It is important to stress that although the *quantitative* results of this article are presented for the case of Cyprus, its *qualitative* results are general. In connection to the literature, Attanasio *et al*⁴ study a two-region world economy in which the ageing North region mimics the group of developed economies while the non-ageing South region mimics the group of developing economies. They assume price indexation in the pension system of the North region and conclude that ageing-related fiscal pressures in the North are similar in open and closed economy versions of their model. This result holds even though interest rates fall more under the open (large) economy assumption.

This article complements the insights presented in Attanasio *et al*⁴ by showing two results. First, wage indexation, which is dominant in OECD countries, exacerbates the fiscal effects of capital flows and interest rate movements. Second, under price indexation, the fiscal effects of interest rate movements are large for SOEs. Many developed countries are unable to affect international prices, and thus, SOE models can better capture the transmission of pension reforms in these countries.

This article also relates to the literature that studies reforms to PAYG pension systems in SOEs. Huang *et al*¹⁷ analyze reforms in the United States under the SOE assumption. They study the distributional impact of fully funding social security but do not focus on the effects of a decline in world interest rates, its fiscal impact, or its relation to pension indexation. Kenc and Sayan¹⁸ study the transmission of population ageing from Europe to the Turkish economy,

and the latter is treated as a SOE. They show that population ageing in large European countries will have sizable effects on Turkey through financial and trade linkages. Unlike this article, however, Kenc and Sayan¹⁸ do not study pension reforms or the partial effects of lower interest rates on fiscal expenditures. Other country-specific studies include Beetsma *et al*¹⁹ (the Netherlands), and Guest²⁰ (Australia).

In sum, all these studies make interesting contributions that do not overlap with the main *qualitative* insights offered in this article: (i) a persistent decline in interest rates will aggravate fiscal pressures by boosting pension benefits more than contributions; (ii) this effect is magnified by wage indexation of pension benefits and wage earnings used to compute pensions; (iii) pension reforms, particularly those that change indexation from wages to prices, can protect the economy against interest rate movements. These insights can be used to strengthen policymakers' case for indexation-switching pension reforms: not only will such reforms improve central long term macroeconomic scenarios in SOEs, but they will also increase economies' robustness to international interest rates shocks.

The rest of the article is organized as follows. Section 'Model overview' presents a brief description of the model and its calibration; further details can be found in Catalán *et al*.²¹ Section 'Baseline simulations' presents the baseline simulations with no pension reforms for the two world interest rate scenarios. The simulations of pension reforms are discussed in Section 'Pension reform simulations'. Section 'Conclusions' concludes.

MODEL OVERVIEW²²

The framework is a small open economy version of the Auerbach-Kotlikoff model. The economy is populated by OLG 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. Households and the government can borrow funds from (or invest funds in) international capital markets at prevailing interest rates.

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

Labor markets, however, are integrated and characterized by perfect competition and substitutability of private and public households’ labor. All households have similar working and retirement periods, and during their work lives, are employed by competitive firms that produce the private good – there is no public good in the model. In this setting, the law of one price (wage rate) holds for given households’ labor skills.²³

In addition, life expectancy is exogenous and increases over time to match demographic projections. Although the retirement age is exogenous, labor supply is endogenous as households choose the amounts of labor and leisure time during their work life. Households’ labor skills (productivity) vary exogenously with age to account for the observed hump-shapes in wage rates over years of employment in, respectively, the ‘private’ and ‘public’ sectors. Finally, the model incorporates labor-augmenting productivity growth that causes real wage growth over time, and explicitly accounts for the effects of ageing on public health-related expenditures.^{24,25} The model is presented in Appendix A, and the notation is summarized in Table 1.

The model is calibrated to match some relevant features of the Cypriot economy. Table 2 summarizes the parameter values used in the calibration and their sources. The calibration

exercise verifies that the endogenous variables in the initial steady state as well as the public variables closely match those in the Cypriot data.

Two features of the calibration deserve special notice. First, the private and public households’ skill profiles are set to capture both the inverted U-shaped profiles of wage incomes observed in the data and wage differences between private and public households. Specifically, wages of public households are higher than those of private households when they enter the labor force. But public households’ wages grow at a lower rate and remain below private households’ wages for most of the working life (Figure 1). To capture health-care-related expenditure pressures arising from population ageing, age-specific health-care expenditures were assigned to each individual according to the age profile presented in Figure 2. Health-care expenditures per capita are low for young adults, but rise sharply for the elderly. We calibrated this profile using the profiles observed in major European economies as Cyprus-specific data are scanty. Finally, the demographic ageing process is a critical exogenous element in the simulations; it is described in Appendix B.^{27,28}

BASELINE SIMULATIONS

The baseline simulations assume that the pension system’s parameters are unchanged over time. These simulations also assume that the government follows a ‘tax-as-you-go’ policy: fiscal pressures arising during the demographic transition are financed by adjusting consumption tax rates so that the government’s budget constraint holds while other taxes and the government non-health expenditure-to-output and debt-to-output ratios remain constant.^{29–31}

Two baseline scenarios are considered. In the first scenario, the exogenous interest rate path is constant; in the second scenario, interest rates decline gradually 100 basis points in 2008–2038. This decline in interest rates is at the bottom end of the range reported by studies based on general equilibrium models of the world economy.¹⁴ In all scenarios, households benefit from perfect foresight and thus fully anticipate the future path of interest rates.

Table 1: Variable definition and notation

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

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.

^aPopulation growth rates are constant only along balanced growth equilibrium paths.

^bAll pension benefits (*bb*, *bs*, *bbg*, *bg*, *bgls*) are subject to the same stationary-transformations.

^cProfits are net of capital depreciation.

^dBasic earnings are subject to the same stationary-transformation.

Scenario 1: Constant world interest rates

Since the world interest rate is constant, so is the capital–labor ratio. This and the gradual fall in the labor supply associated with population

ageing imply that capital and output per capita decline over time. National income per capita also falls, but less so than domestic output per capita because the economy runs persistent current account surpluses (Figure 3).³²

Table 2: Calibration of the model (initial steady state)

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

Source: Staff estimates.

^aThe adjustment factor applied is 0.051.

^bThe adjustment factor applied is 0.047.

^cThe adjustment factor applied is 0.067.

Figure 1: Labor skills profile by age.

Source: Author's estimates based on information provided by country authorities during IMF article IV consultations.

Figure 2: Health-care expenditure by age group (per cent of GDP per capita).
Source: OECD.²⁶

Figure 3: Macroeconomic results – Baseline scenarios under constant and declining interest rates^{a,b} (unless otherwise indicated, variables are expressed as deviations from trend).

^aScenario 1 corresponds to a constant world interest rate, while scenario 2 corresponds to a declining world interest rate by 100 basis points between 2008 and 2038.

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

Figure 3: Continued.

These external surpluses reflect higher savings driven by the increased life expectancy and rising share in the population of old working households – whose asset holdings peak at retirement – and by lower domestic investment. The sustained accumulation of external assets reverses the country's net foreign asset position: starting as a net international debtor, it becomes a net creditor by 2020.

Also, the excess of national income over domestic output allows households to sustain consumption over time. Thus, relatively small increases in consumption tax rates (7 percentage points between 2008 and 2048) suffice to finance large ageing-related expenditure pressures. Note that a flatter consumption path and lower taxes

are benefits of an open capital account: in a closed economy, the capital–labor ratio would increase and investment returns would decline, hampering consumption; also, higher wages would increase pensions and taxes, reducing welfare.

Note also that as the wage rate remains constant over time, fiscal expenditure pressures result only from changes in the age structure of the population (dependency ratio). Individual pension benefits remain roughly constant because of the unchanged wage rate – small fluctuations in private households' pensions arise from changes in the age and labor skill structure of the work force during the demographic transition.³³ Still, the generosity of pensions – defined as the

Figure 3: Continued.

present value of lifetime pension benefits calculated at retirement – increases over time owing to longer life expectancies of future generations. This increase in generosity, however, benefits private and public households and thus the measure of relative generosity remains unchanged. In sum, with constant world interest rates pension expenditure pressures are fully accounted for by variations in the dependency ratio.

The sources of expenditure pressures can be uncovered by a numerical decomposition of changes in the pension expenditure-to-GNI ratio (Table 3). Pension expenditure as a share of GNI increases by 7.5 percentage points in 2007–2048. The endogenous decline in income (GNI)

per capita – from the fall in labor and capital per capita, and the disincentives associated with higher consumption tax rates – accounts for 1.8 percentage points, while the increase in pension expenditure per capita contributes 5.6 percentage points. The latter, in turn, is decomposed respectively into 3.5 and 2.1 per cent contributions of private and public pension expenditures per capita.

Scenario 2: Declining world interest rates

The decline in world interest rates implies a gradual increase in the capital–labor ratio (Figure 3). Work hours and the capital stock per capita, and thus domestic output, decline less than in the

Table 3: Pension expenditure reductions from reforms^a (changes from 2007 to 2048, percentage points of GNI)

	Baseline	Reform 1	Reform 2	Reform 3
		Retirement age and lump sum	Partial reform	Full reform
<i>Scenario 1: Constant interest rate</i>				
Level in 2007	9.3	9.3	9.3	9.3
Level in 2048	16.7	13.2	11.1	7.4
Change from 2007 to 2048	7.5	3.9	1.8	-1.9
Expenditures	5.6	3.0	1.2	-2.0
Private	3.5	2.2	1.3	-1.3
Basic	2.2	1.4	0.5	-0.9
Supplementary	1.3	0.8	0.8	-0.4
Public	2.1	0.8	-0.1	-0.7
Pension	2.1	1.2	0.3	-0.3
Lump sum	0.0	-0.4	-0.4	-0.4
GNI (decline)	1.8	0.9	0.6	0.1
Consumption tax rate (percentage point)	7.1	2.7	-1.6	-8.8
<i>Scenario 2: Interest rate falling by 100 basis points</i>				
Level in 2007	9.7	9.7	9.7	9.7
Level in 2048	22.0	17.4	14.6	9.9
Change from 2007 to 2048	12.2	7.7	4.9	0.2
Expenditures	7.5	4.6	2.6	-1.0
Private	4.2	2.9	1.9	-1.0
Basic	2.5	1.6	0.6	-0.9
Supplementary	1.7	1.3	1.3	-0.1
Public	3.3	1.7	0.7	0.0
Pension	3.0	1.9	0.9	0.3
Lump sum	0.3	-0.3	-0.3	-0.3
GNI (decline)	4.8	3.1	2.3	1.2
Consumption tax rate (percentage point)	28.1	22.7	16.0	5.4
<i>Differences between interest rate scenarios</i>				
Interest rate falling by 100 basis points minus constant interest rate	4.8	3.8	3.1	2.1

^aThe decomposition is obtained by re-expressing the pension expenditure-to-output ratio as $Ratio = x/y = \text{Pension expenditure per capita} / \text{Output per capita}$. Then, we decompose the (exact) growth rate of the ratio for the period 2007–2048 as

$\widehat{Ratio} = \widehat{x} - ((\widehat{y} + \widehat{x} \cdot \widehat{y}) / (1 + \widehat{y}))$. The first term, $\widehat{x}$, is the growth contribution of pension expenditure per capita; the term $-(\widehat{y} + \widehat{x} \cdot \widehat{y}) / (1 + \widehat{y})$ is the growth contribution of output per capita.

constant interest rates scenario. Still, national income falls more than in the constant interest rates scenario as the lower interest rates discourage savings and the current account surpluses turn into deficits and result in negative net foreign asset positions.

The economy is adversely affected through another channel. The pass-through effect of lower interest rates to higher wages and pension benefits exacerbates the fiscal challenge, requiring higher taxes. As a result of the lower national income and higher consumption taxes, households' consumption falls and their labor effort increases relative to the constant interest rates scenario,

unambiguously reducing the welfare of all generations.

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

Although lower world interest rates boost pension benefits, the pass-through effect is

lopsided reflecting differences in indexation: by 2050 the generosity of private pensions rises 13 per cent in the second scenario compared to the first scenario; the generosity of public pensions rises 30 per cent. In relative terms, the generosity of public versus private pension benefits rises from about 1.75 in the first scenario – that is, public household's benefits are 75 per cent higher than private household's – to about 2.1 in the second scenario.

The numerical decomposition of pension expenditure-to-GNI ratios highlights the differences with the constant-rates scenario. When interest rates decline, the expenditure ratios increase by 12.2 per cent of GNI by 2050 – 4.8 percentage points higher than in the constant-rates scenario. These larger increases result from changes in both pension expenditures per capita (numerator) and income per capita (denominator). The pass-through effect of lower interest rates exacerbates the increase in pension expenditure per capita – adding 1.9 percentage points of GNI to the 100 basis points decline scenario. Thus, taxes need to rise more – 29 percentage points – and result in larger reductions in income per capita, which further contribute 3 percentage points to the increase in the pension expenditure-to-GNI ratio. Also, the decomposition of the increase in pension expenditure per capita reflects the lopsided nature of the pass-through effect: public pensions account for 38 per cent of this increase in the constant-rates scenario; but account for 44 per cent of the increase in the 100 basis points decline scenarios.

PENSION REFORM SIMULATIONS

Description of pension reforms

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

- *Reform 1 (retirement age and lump sum)*: The *retirement age* increases in line with projected life expectancy developments; that is, by 1 year in 2013 and 2018, and starting in 2028, by 1 year per decade up to a maximum increase of 10 years.
- *Reform 2 (plus benefit indexation, 'partial')*: Further reforms to the system result from shifting the *indexation of all pension benefits* to prices in 2013. Specifically, the shift in indexation affects the basic pension benefits associated with the GSIS – received both by private (*bb*) and public (*bbg*) households – and the annual pension benefits associated with the GEPS – paid out only to public households (*bg*). Supplementary pension benefits received by private households (*bs*) are already indexed to inflation and are unaffected by the reform.
- *Reform 3 (plus wage earnings indexation, 'full')*: In addition, reforms shift the *indexation of past wage earnings* used to compute pensions to prices instead of wages in 2013.

Almost all the quantitative implications of Reform 1 stem from the effects of increasing the retirement age. This was confirmed by simulating a reform scenario that increases the retirement age in line with life expectancy but leaves unchanged the lump sum benefits. The results of these simulations were similar to those of Reform 1 and are not shown in the article.

A variant of Reform 3 was also studied but is not reported. It shifts the *indexation of past wage earnings* used to compute pensions to prices instead of wages in 2013 and partially offsets the effect on pensions by increasing the replacement coefficients. These coefficients are increased so that pension benefits are unchanged in the initial steady state – once the indexation of past wage earnings is changed.³⁴ The simulation results fall in between those reported for Reforms 2 and 3 below.

Simulation results for constant interest rates

For a given world interest rates path, pension reforms reduce the ageing-related pressures relative to the no-reform baseline. The farther reaching the reforms the smaller the increases in pension expenditure-to-GNI ratios and tax rates, which result in higher output, labor,

capital accumulation and consumption (Figure 4 and Table 3). In all reform scenarios, the welfare of all households improves, except for some public households born before the year 2000.³⁵

Reform 1 (retirement age and lump sum)

Increasing the retirement age boosts effective labor per capita and lowers the dependency ratio by increasing the number of cohorts working in each period. The international interest rate and the capital–labor ratio remain constant; hence, aggregate capital, output and income per capita rise relative to the baseline scenario. Also, payroll tax collection rises as more workers contribute to

social security, and pension expenditures decline as fewer cohorts are retired. This results in reduced consumption tax rates and higher households' disposable income which, in turn, boosts consumption per capita relative to the baseline scenario. Aggregate saving, however, declines as households have to finance a shorter retirement period. This decline in saving, along with the increase in investment, results in smaller current account surpluses.

Regarding households' pensions, these decline slightly once grandfathering safeguards expire, reflecting a small reduction in households' labor effort per year. Thus, households exert more labor effort in the extensive margin (years) and

Figure 4: Macroeconomic results – Reform scenarios under constant and declining interest rates (unless otherwise indicated, variables are expressed as deviations from trend)^a

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

Figure 4: Continued.

partially offset it by reducing effort in the intensive margin (hours).

Reform 2 (plus benefit indexation, 'partial')

This reform lowers the present value of pension benefits received by households: in the first retirement year pension benefits remain unchanged, but in subsequent years pension benefits grow at a slower rate than in the Reform 1 scenario owing to the indexation shift. Note that the reform has no effect on households' labor supply; and thus, labor, capital and output per capita remain unchanged. National income per capita, however, rises relative to the Reform 1 scenario because

households respond to reduced pension benefits by increasing saving during their work lives. This, in turn, implies that the economy runs larger current account surpluses.

The reform reduces government pension expenditures and taxes, increasing households' disposable income and aggregate consumption and saving per capita. Note that a virtuous loop of second round effects arises: the endogenous expansion of the tax base (consumption) allows further reductions in tax rates that, in turn, increase disposable income and consumption.

As noted above, in the baseline and Reform 1 scenarios public pensions are fully indexed to

Figure 4: Continued.

wages while private pensions are only partially indexed to wages. From this starting point, the post-retirement shift of pensions' indexation from wages to prices has a larger (negative) impact on public pensions, and hence, the relative generosity of public pensions declines.

Reform 3 (plus wage earnings indexation, 'full')

This reform reduces further the present value of households' pension benefits and delivers macroeconomic effects that are qualitatively similar but larger than in Reform 2 – to the extent that pension expenditure as a fraction of GNI declines in the midst of the demographic transition.³⁶

Note that this reform has (negative) effects on pension benefits that are calculated based on households' lifetime wage earnings. Indeed, private households shoulder most of the burden because their basic and supplementary pension benefits are calculated in this way. In contrast, for public households only basic pension benefits are calculated based on lifetime wage earnings. The other pension benefits are computed based on wage earnings in the last year before retirement, and are thus unaffected by the reform. The asymmetric distributional impact of the reform is reflected in the increase in the relative generosity of public pensions.

Figure 4: Continued.

The reform scenarios 2 and 3 discussed above stress the role of indexation switching in reducing ageing-related fiscal pressures when interest rates are constant. The next sub-section shows that these reforms can also make the economy more robust to changes in world interest rates.

Pension reforms and declining interest rates

Comparing the effects of pension reforms in the constant and declining interest rates scenarios reveals the role of pension reforms as 'providers' of macroeconomic protection against long-run movements in world interest rates (Figures 4 and 5).

Specifically, when interest rates are constant, increasing the retirement age reduces the increase in the pension expenditure-to-GNI ratio by 3.6 percentage points (7.5 per cent in the baseline versus 3.9 per cent in the first reform scenario) by 2048. But when interest rates decline 100 basis points, increasing the retirement age cuts the increase in the ratio by a larger amount: 4.5 percentage points (12.2 per cent in the baseline compared to 7.7 per cent in the first reform scenario). This reform thus offsets expenditure pressures more when these are exacerbated by declining interest rates.

This macro-protection effect is particularly powerful in pension reforms shifting the

Figure 4: Continued.

indexation of pensions or wage incomes used to compute pensions.

In regard to shifts in the indexation of pension benefits (Reform 2), the increase in the pension expenditure-to-GNI ratio that results from a decline in interest rates – relative to the constant-rates scenario – is smaller in the ‘partial reform’ scenario (3.1 per cent of GNI) than in the ‘retirement age and lump-sum’ (3.8 per cent of GNI) and baseline (4.8 per cent of GNI) scenarios (bottom line in Table 3). Also, the decomposition of increases in pension expenditure per capita highlights the distributional

effects of changing the indexation of pension benefits. Specifically, in the ‘partial reform’ scenario (Reform 2) the burden of expenditure declines falls disproportionately on public pensions.

In regard to shifts in the indexation of wage incomes used to compute pensions (Reform 3), the ‘full reform’ reduces further the size of the pass-through effect. Specifically, the increase in the pension expenditure-to-GNI ratio that results from a decline in interest rates – compared to the constant-rates scenario – is smaller in the ‘full reform’

Figure 4: Continued.

scenario (2.1 per cent of GNI) than in the 'partial reform' (3.1 per cent of GNI) and 'baseline' (4.8 per cent of GNI) scenarios. As noted above, the pension expenditure-to-GNI ratio is lower in 2048 than in 2007 when interest rates are constant; however, it remains roughly constant between 2007 and 2048 when interest rates fall. In this case, the decomposition of increases in pension expenditure per capita shows that private households shoulder most of the burden of the reform.

In sum, the numerical simulations point to the following conclusion: the reforms, particularly

those that change the indexation of pensions from wages to prices, weaken the pass-through effect of interest rate declines into pension benefits and thus mitigate their adverse macroeconomic consequences.

CONCLUSIONS

How will the decline in world real interest rates associated with global population ageing affect SOEs which are also ageing? This article shows that ageing-related fiscal pressures in SOEs will be exacerbated, increasing taxation and reducing consumption and welfare. This is because lower

Figure 5: Decomposition of pension expenditure-to-GNI ratios – Pension reform and interest rate scenarios.

interest rates and capital inflows will result in higher capital-labor ratios and wages, which in turn will be passed on to pension benefits. Higher pension benefits, along with increased dependency rates, will boost ageing-related fiscal pressures, particularly when pension benefits and wage earnings used to compute pensions are indexed to wages. Moreover, asymmetries in pension benefit indexation will result in increased generosity of some pension benefits relative to others.

This article also draws broad lessons for SOEs that are or will be dealing with an ageing population in the context of global ageing. It shows that pension reforms, particularly those that change indexation from wages to prices, provide macroeconomic protection against long-run declines in world interest rates.

ACKNOWLEDGEMENTS

We are grateful for useful comments received from Christoph Klingen, Vladimir Borgy and conference participants at the 6th International Workshop on Pension and Saving, University Paris-Dauphine (2008).

REFERENCES AND NOTES

- 1 Brooks, R. (2003) Population ageing and global capital flows in a parallel universe. *IMF Staff Papers* 50(2): 200–221.
- 2 Domeij, D. and Floden, M. (2006) Population ageing and international capital flows. *International Economic Review* 47(3): 1013–1032.
- 3 Borsch-Supan, A., Ludwig, A. and Winter, J. (2006) Ageing, pension reform, and capital flows: A multicountry simulation model. *Economica* 73: 625–658.
- 4 Attanasio, O., Kitao, S. and Violante, G. (2007) Global demographic trends and social security reform. *Journal of Monetary Economics* 54: 144–198.
- 5 This article abstracts from other channels through which ageing in large economies could affect SOEs, such as those related to trade and migration.

- 6 Studies in this literature include Uribe and Yue,⁷ Neumeyer and Perri,⁸ and Hoffmaister and Roldós.⁹
- 7 Uribe, M. and Yue, V. (2006) Country spreads and emerging countries: Who drives whom? *Journal of International Economics* 69: 6–36.
- 8 Neumeyer, P. and Perri, F. (2005) Business cycles in emerging economies: The role of interest rates. *Journal of Monetary Economics* 52: 345–380.
- 9 Hoffmaister, A. and Roldós, J. (2001) The sources of macroeconomic fluctuations in developing countries: Brazil and Korea. *Journal of Macroeconomics* 23(Spring): 213–239.
- 10 Without reforms and assuming constant international interest rates, the European Commission¹¹ projects that pension expenditures in Cyprus' pay-as-you-go (PAYG) system will rise by 12.9 percentage points of GDP by 2050, compared to an average increase of less than 3 percentage points in the European Union.
- 11 European Commission. (2006) The Impact of Ageing on Public Expenditure: Projections for the EU25 Member States on Pensions, Health Care, Long-term Care, Education and Unemployment Transfers. Brussels: European Commission. Special Report no. 1/2006.
- 12 Specifically, private pensions have two components: A basic benefit indexed to wages, and a supplementary benefit indexed to prices.
- 13 Hoffmaister, A.W., Catalán, M. and Guajardo, J. (2007a) Addressing the macroeconomic consequences of ageing in Cyprus: The case for pension reform. *Cyprus Economic Policy Review* 1(1): 3–25.
- 14 In Domeij and Floden,² and Börsch *et al.*,³ interest rates decline by about 100–150 basis points in the period 2010–2050. Attanasio *et al.*⁴ show much larger interest rate declines. Specifically, in the open economy version of their model the interest rate falls about 300 basis points between 2010 and 2050; the decline is even larger (450 basis points) when developed countries privatize social security.
- 15 For a brief but comprehensive review of indexation-switching reforms in OECD countries, see Whiteford and Whitehouse.¹⁶
- 16 Whiteford, P. and Whitehouse, E. (2006) Pension challenges and pension reforms in OECD countries. *Oxford Review of Economic Policy* 22(1): 78–94.
- 17 Huang, H., Imrohorglu, S. and Sargent, T.J. (1997) Two computations to fund social security. *Macroeconomic Dynamics* 1: 7–44.
- 18 Sayan, S. and Kenc, T. (2001) Demographic shock transmission from large to small countries: An overlapping generations CGE analysis. *Journal of Policy Modeling* 23: 677–702.
- 19 Beetsma, R., Bettendorf, L. and Broer, P. (2003) The budgeting and economic consequences of ageing in the Netherlands. *Economic Modelling* 20: 987–1013.
- 20 Guest, R. (2006) Population ageing, capital mobility and optimal saving. *Journal of Policy Modeling* 28: 89–102.
- 21 Catalán, M., Hoffmaister, A.W. and Guajardo, J. (2010) Dealing with global ageing and declining world interest rates: Fiscal costs and pension reform in small open economies. mimeo, <http://sites.google.com/site/mariocatalaneconomics/research>.
- 22 For a detailed presentation of the model and its solution, see Catalán *et al.*²¹
- 23 This strategy – combining pension system segmentation and labor market integration – allows us to capture some privileges associated with public sector employment while preserving the law of one price in labor markets.
- 24 Specifically, health-care expenditures mirror the j-shaped profile of health-care spending over a household's life: expenditures are low for young adults and rise sharply later in life. This approach, however, does not account for the impact of medical advances and demand for new capital-intensive treatments (Heller²⁵), beyond those captured by technological advances in the economy.
- 25 Heller, P. (2003) *Who Will Pay? Coping with Ageing Societies, Climate Change and Other Long-term Fiscal Challenges*. Washington: International Monetary Fund.
- 26 Organization for Economic Co-operation and Development (OECD). (2003) Spending on Health and Long-term Care. *Macroeconomic and Structural Policy Analysis*, Working Party No. 1, March.
- 27 For a more extensive description of the Cypriot pension system and the demographic projections, see Hoffmaister *et al.*^{13,28}
- 28 Hoffmaister, A.W., Catalán, M., Guajardo, J. and Levchenko, A. (2007b) *Cyprus: Selected Issues 'Pension Reform: Addressing the Consequences of Ageing'*, Washington: IMF. IMF Country Report no. 07/71.
- 29 Previous quantitative studies of social security systems in economies experiencing demographic transitions show that financing ageing-related fiscal costs with consumption taxes is less distortionary than financing them with payroll or income taxes. For the United States, see Auerbach and Kolikoff³⁰ and De Nardi *et al.*³¹
- 30 Auerbach, A. and Kotlikoff, L. (1987) *Dynamic Fiscal Policy*. Cambridge: Cambridge University Press.
- 31 De Nardi, M., Selahattin, I. and Sargent, T. (1999) Projected US demographics and social security. *Review of Economic Dynamics* 2: 575–615.
- 32 Note that in Figure 3, variables are stationary-transformed as indicated in Table 1 – Adjusted by technological progress and population growth. Accordingly, changes in these variables must be interpreted as deviations from their long-term trend.
- 33 These changes affect the labor force (weighted) average skills in the basic earnings formula.
- 34 Specifically, the replacement coefficient of basic pensions (α_B) is increased 56 per cent to 0.479, whereas the replacement coefficient of the supplementary pension (α_S) is increased 48 per cent from to 0.0114.
- 35 The welfare losses for these households stem from lower lump-sum retirement transfers.
- 36 This reform provides enough fiscal space to consider also less extreme reform scenarios that increase the replacement coefficients in the pension benefit formulas to partially offset the decline in pensions. As noted above, we also studied one such reform but do not report the simulation results.

APPENDIX A

The model

The model is presented in stationary form.

Households: The lifetime utilities of private (p) and public (g) households born at time t are determined by their lifetime consumption (c) and leisure (l), and are given by

$$U_{H,t} = \sum_{s=1}^{T_t+T_t^R} \beta^{s-1} \times \{\log(c_{H,t+s-1}^s) + \gamma \cdot \log(l_{H,t+s-1}^s)\} \quad (\text{A.1})$$

where the subindex $H=p,g$ denotes the type of household. Households' lives are characterized by two phases: a work life lasting T_t years ($s=1, \dots, T_t$) and a mandatory retirement lasting T_t^R years ($s=T_t+1, \dots, T_t+T_t^R$). Across generations, household's life expectancy and retirement age are allowed to vary. A 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

$$l_{H,t+s-1}^s = 1 - n_{H,t+s-1}^s \text{ for } s=1, \dots, T; \\ \text{and } l_{H,t+s-1}^s = 1 \text{ for } s=T_t+1, \dots, T_t+T_t^R. \quad (\text{A.2})$$

Households accumulate assets (A) during their work lives according to the budget constraint:

$$(1+\xi) \cdot A_{H,t+s}^{s+1} = [1+r_{t+s-1} \cdot (1-\tau_{t+s-1}^I)] \\ \times A_{H,t+s-1}^s + (1-\tau_{t+s-1}^H - \tau_{t+s-1}^I) \\ \times W_{t+s-1} \cdot e_H^s \cdot n_{H,t+s-1}^s - (1+\tau_{t+s-1}^c) \cdot c_{H,t+s-1}^s. \quad (\text{A.3})$$

Note that income taxes are levied on labor income and asset earnings; for simplicity, these tax rates are assumed to be equal. As noted above, household's labor productivity per hour varies with age according to a skill premium – the model allows for differences in the skill profiles of private (e_p^s) and public (e_g^s) households. The premium reflects the productivity of an s -year old household relative

to that of a 1-year old (unskilled) private household. Thus, W denotes the wage per unit of labor time of an unskilled private worker. Note that private and public households pay different payroll contribution rates (τ^p, τ^g).

During retirement, the household's wage income is replaced by an old-age pension (b) in the budget constraint, as follows:

$$(1+\xi) \cdot A_{H,t+s}^{s+1} = [1+r_{t+s-1} \cdot (1-\tau_{t+s-1}^I)] \\ \times A_{H,t+s-1}^s + b_{H,t+s-1} \\ - (1+\tau_{t+s-1}^c) \cdot c_{H,t+s-1}^s. \quad (\text{A.4})$$

The private household's pension has *basic* (bb) and *supplementary* (bs) components and a points-based system governs the calculation of these pension benefits, as follows:

$$b_{p,t+s-1} = bb_{t+T_t}^{T_t+1} \cdot \frac{BE_{t+s-1}}{BE_{t+T_t}} + \frac{bs_{t+T_t}^{T_t+1}}{(1+\xi)^{s-T_t-1}}, \quad (\text{A.5})$$

$$bb_{t+T_t}^{T_t+1} = \frac{\alpha_B}{T_t} \cdot \left[\sum_{j=1}^{T_t} \text{Min} \left\{ 1, \frac{W_{t+j-1} \cdot e_p^j \cdot n_{p,t+j-1}^j}{BE_{t+j-1}} \right\} \right] \\ \times BE_{t+T_t}, \quad (\text{A.6})$$

$$bs_{t+T_t}^{T_t+1} = \alpha_S \cdot \left[\sum_{j=1}^{T_t} \text{Max} \left\{ 0, \frac{W_{t+j-1} \cdot e_p^j \cdot n_{p,t+j-1}^j}{BE_{t+j-1}} - 1 \right\} \right] \\ \times BE_{t+T_t} \cdot a \quad (\text{A.7})$$

Over a private household's work life, the number of points accrued is determined by the ratio of wages earned to basic earnings (BE). Note in (A.6) and (A.7) that each year, the first point accrues to the basic pension and additional points count for the supplementary pension. Note also that the *stationary-transformed* equation (A.5) reflects the different indexation of basic and supplementary pension benefits after retirement. The basic pension benefits $bb_{t+T_t}^{T_t+1}$ are indexed to the BE index – which grows over time according

to average nominal wage earnings – and this is reflected in the adjustment factor $(BE_{t+s-1})/BE_{t+T_i}$. The supplementary pension benefits $bs_{t+T_i}^{T_i+1}$ are indexed to prices – and thus do not account for productivity growth – and this is reflected in the presence of the productivity discount factor $1/(1+\xi)^{s-T_i-1}$.

The *public* household's pension has three components: lump sum (*bgl*s) and annual (*bg*) benefits associated with the GEPS, and basic (*bbg*) benefits associated with the GSIS – note that *public* households *do not* receive *supplementary* pension benefits from the GSIS.

$$b_{g,t+s-1} = \begin{cases} bgl_{t+T_i}^{T_i+1} + bg_{t+T_i}^{T_i+1} + bbg_{t+T_i}^{T_i+1} & \text{for } s = T_i + 1 \\ bgl_{t+T_i}^{T_i+1} \cdot \frac{BE_{t+s-1}}{BE_{t+T_i}} + bbg_{t+T_i}^{T_i+1} \cdot \frac{BE_{t+s-1}}{BE_{t+T_i}} & \text{for } s = T_i + 2, \dots, T_i + T_i^R - 1 \end{cases} \quad (\text{A.8})$$

$$bgl_{t+T_i}^{T_i+1} = \lambda \cdot \frac{W_{t+T_i-1} \cdot e_g^{T_i} \cdot n_{g,t+T_i-1}^{T_i}}{(1+\xi)}, \quad (\text{A.9})$$

$$bg_{t+T_i}^{T_i+1} = \alpha_G \cdot \frac{W_{t+T_i-1} \cdot e_g^{T_i} \cdot n_{g,t+T_i-1}^{T_i}}{(1+\xi)}. \quad (\text{A.10})$$

$$bbg_{t+T_i}^{T_i+1} = \frac{\alpha_B}{T_i} \times \left[\sum_{j=1}^{T_i} \text{Min} \left\{ 1, \frac{W_{t+j-1} \cdot e_g^j \cdot n_{g,t+j-1}^j}{BE_{t+j-1}} \right\} \right] \times BE_{t+T_i}, \quad (\text{A.11})$$

The lump sum and annual pension benefits are based on public households' last wage earning before retirement. In contrast, the basic pension is calculated based on lifetime wage earnings. Note that the basic pension paid to private and public households are calculated using the same formula – defined by (A.6) and (A.11). After the first retirement year, public households receive the annual pension from the GEPS (*bg*) and the basic pension from the GSIS (*bbg*); both are indexed to the *BE*, as reflected in the adjustment factors BE_{t+s-1}/BE_{t+T_i} in equation (A.8).

There are no intergenerational bequests or inheritances: the household is born (enters the

labor force) with zero assets at age $s=1$, and dies without assets at age $s = T_i + T_i^R + 1$:

$$A_{H,t}^1 = A_{H,t}^{T_i+T_i^R+1} = 0. \quad (\text{A.12})$$

The *private* household's problem is to choose the paths of consumption, leisure and asset holdings $\{c_{p,t+s-1}^s, l_{p,t+s-1}^s, A_{p,t+s-1}^s\}_{s=1}^{T_i+T_i^R}$ to maximize its lifetime utility (A.1) subject to constraints (A.2)–(A.7) and (A.12). Similarly, the *public* household chooses the paths of consumption, leisure and asset holdings $\{c_{g,t+s-1}^s, l_{g,t+s-1}^s, A_{g,t+s-1}^s\}_{s=1}^{T_i+T_i^R}$ to maximize its

lifetime utility (A.1) subject to constraints (A.2)–(A.4), (A.8)–(A.11) and (A.12). At time $t=0$ the economy is populated by households of ages $\tilde{s} = 2, \dots, T_0 + T_0^R$ which are assumed to have the same work life and retirement periods. Thus, during the first $T_0 + T_0^R$ years, the model considers a number of 'truncated' optimization problems associated to them. Households take as given the payroll ($\tau^p \tau^s$), income (τ^l) and consumption (τ^c) tax rates; the international (also domestic) interest rates (r); the wage rates (W); and the *BE*. Aggregate consumption (C_t^h), effective labor supply (N_t^h) and assets (A_t^h) are obtained by aggregating individual private and public household's variables at each point in time:

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

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

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

where $j = \{p, g\}$.

Firms: Firms maximize profits Π_t^f net of capital depreciation δ . They do so subject to a constant-returns-to-scale Cobb-Douglas production function with labor-augmenting technological progress $\Pi_t^f = Z \cdot (K_t^f)^\alpha \cdot (N_t^f)^{1-\alpha} - (r_t + \delta) \cdot K_t^f - W_t \cdot N_t^f$. Both output and factor markets are perfectly competitive and firms face given wages (W_t) and rental rates (r_t).

The Government: The government sets and collects payroll, income and consumption taxes from households to ensure long-run fiscal sustainability. Tax revenues 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:

$$\begin{aligned} D_{t+1} \cdot (1 + \xi) \cdot \frac{P_{t+1}}{P_t} &= (1 + r_t) \cdot D_t \\ &+ [G_t - \tau_t^l \cdot (r_t \cdot A_t^h + W_t \cdot N_t^h) \\ &- \tau_t^c \cdot C_t^h] + \sum_{s=T_t+1}^{T_t+T_t^R} \left[b b_{t+T_t+1-s}^{T_t+1} \right. \\ &\times \left. \frac{BE_t}{BE_{t+T_t+1-s}} + \frac{b s_{t+T_t+1-s}^{T_t+1}}{(1 + \xi)^{s-T_t-1}} \right] \cdot \frac{P_{p,t}^s}{P_t} \\ &+ \sum_{s=T_t+1}^{T_t+T_t^R} (b b_{t+T_t+1-s}^{T_t+1} + b g_{t+T_t+1-s}^{T_t+1}) \\ &\times \frac{BE_t}{BE_{t+T_t+1-s}} \cdot \frac{P_{g,t}^s}{P_t} + b g_{t+T_t+1-s}^{T_t+1} \\ &\times \frac{P_{g,t}^{T_t+1}}{P_t} - \tau_t^p \cdot W_t \cdot N_{p,t}^h \\ &- \tau_t^g \cdot W_t \cdot N_{g,t}^h, \end{aligned}$$

where, for clarity, the (non-social security) primary deficit (term in brackets), and the social

security deficit (last five terms) are shown separately.

Equilibrium: Given initial conditions and an exogenous path of international interest rates, an equilibrium is a set of allocations, prices and government variables that simultaneously places all households and firms on their maximizing paths, establishes the solvency of the government, and clears markets.

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

For a detailed description of the model and its solution, see Catalán *et al.*²¹

APPENDIX B

Demographic transition

The time line in the model corresponds to a 360-year period, with the middle 160 years (1957–2117) covering the demographic transition from a high to a low fertility rate and continuing gains in life expectancy. In the first century, life expectancy is constant at 80 years, and the growth rate of new entrants to the labor force is set at 0.85 per cent, which is the average population growth. During the demographic transition, however, life

Figure B1: Dependency ratio in the model: retired over working population (per cent).
Source: Staff calculations.

expectancy increases a year per decade until it reaches 90 in 2114 and the labor force growth rate varies to replicate the dependency ratio – defined as the ratio of the population over 63 years to the population between 23 and 63 years – in Eurostat’s baseline population projections for 2004–2051 (Figure B1). In other

words, the dependency ratio in the model peaks at over twice its current rate in 2050. The final century sees a constant life expectancy (90 years) and labor force entrants growing at a fixed rate of 0.5 per cent per annum; the dependency ratio falls back but remains higher than it is currently.