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# Aging Population and Public Pensions: Theory and Macroeconometric Evidence

**Summary:** Rapidly aging population in high-income countries has exerted additional pressure on the sustainability of public pension expenditure. We present a theoretical model of public pension expenditure under endogenous human capital, where the latter facilitates a substantial decrease in equilibrium fertility rate alongside the improvement in life expectancy. We demonstrate how higher life expectancy and human capital endowment facilitate a rise of net replacement rate. We then provide and examine an empirical model of old-age expenditure in a panel of 33 countries for the period 1998-2008. Our results indicate that increases in effective retirement age and total fertility rate would reduce age-related expenditure substantially. While higher net replacement rate would alleviate the risk of old-age poverty, further increases would add considerable pressure on the fiscal sustainability of public pensions.

**Key words:** Public pensions, Ageing, Social security, Replacement rate, Life expectancy.

**JEL:** H55, J11, C54.

The 2010 edition of *World Population Prospects* (United Nations 2010) suggests that in the next few decades world regions are set to experience a brisk growth of the share of elderly population in the light of declining fertility rates. Between 2010 and 2050, the share of population aged 65 and older is expected to increase by 6.4 percent in Sweden, 8.1 percent in the United States, 10.5 percent in Germany, and 12.3 percent in Italy. Rapidly aging population is no exception in the developing world either. Until 2050, the share of elderly population in China and India is expected to increase by three-fold.

While the growth of life expectancy in advanced countries led to the downward convergence of fertility rates, it has also exerted a persistent and significant strain on public pension systems. The vast majority of advanced countries adopted pay-as-you-go (PAYG) social security schemes that were left intact ever since its widespread adoption after Bismarckian revolution in 19<sup>th</sup> century Germany.

The actuarial rationale for PAYG schemes rested mainly on the assumption of fertility rates above replacement levels, stationary population growth and low share of elderly population. Early contributions of Paul A. Samuelson (1958) and David Cass and Menahem Yaari (1966) derived the equivalence of population growth rate and market rate of interest as the necessary conditions for the solvency of PAYG schemes. While favourable stationary demographic characteristics constituted a ne-

cessary condition for PAYG schemes, high effective retirement age is a sufficient condition for the relative solvency of PAYG schemes.

From 1970s onwards, European social democracies experienced a sudden decline in effective retirement age, partly because of the widespread adoption of policies favouring early retirement. The decrease in retirement age, well-discussed in the microeconomic literature (*cf.* Tullio Jappelli and Franco Modigliani 1998; Joseph F. Quinn et al. 1998; Emanuele Canegrati 2007; Patricia Peinado and Felipe Serrano 2011, 2014), reflected the increase in life expectancy at age 65, as well as the brisk improvement of medical care embodied in the decline of overall mortality rates or, as Murray Gendell (1998, p. 25) contends: “by the early 1990s, in all four countries (Germany, Japan, Sweden and the U.S.), according to life-tables, no less than 75 percent and as many as 91 percent of the births survived to age 65”.

The increase in life expectancy at various age cohorts, combined with decreasing effective retirement age and persistent increase in the share of elderly population, questioned the fiscal solvency of public pension schemes, since excessive increase in retirement benefits through defined-benefit schemes led to disequilibrium outcomes. The widespread increase in various types of benefits in the 20<sup>th</sup> and 21<sup>st</sup> century developed world created numerous adverse consequences (Nicole Attia and Valérie Berenger 2007). The decrease in effective retirement age resulted in continuous increases in overall and marginal tax rates, while the net replacement rate was already high in high-income OECD countries since, according to Jonathan Gruber and David A. Wise (1998, p. 8): “small deviations from actuarial fairness in the intertemporal pattern of benefits accrual can imply very large tax rates if replacement rates are very high”.

The disequilibrium outcomes purported by large and generous net replacement rates caused some distorting inefficiencies, particularly in the labour market. Given a strong response of the long-run labour supply to changes in tax rates (Edward C. Prescott 2004), higher marginal tax rates and implicit tax rates on work at later ages led to the natural downward adjustment of labour supply by persistent decreases in working hours and labour market participation rates. The incidence of early retirement further extended the unused labour capacity, particularly in the 55-64 age cohort, since high marginal tax rates on work in later ages induced early withdrawal from the labour market. Therefore, the unused labour capacities were resulted partly due to the indirect influence of high tax burden and partly because of the intensity of labour market regulation, particularly concerning working incentives at later ages. The intensity of the labour market regulation, measured by barriers to work and the prevalence of early retirement incentives, therefore encouraged the decision to retire before the statutory age.

The combination of changing demographic landscape and widespread adoption of early retirement mechanisms raised concerns over the fiscal solvency of publicly funded PAYG pension systems. Fiscal implications of aging for the sustainability of public pension systems were further amplified by the fact that the ratio of public pension expenditure to GDP has been rising over time. In 1980, public pension expenditure in OECD amounted to 3.6% of GDP. By 2009, the expenditure share almost doubled, reaching 7% of GDP (Organisation for Economic Co-operation and

Development - OECD 2011b). Although the negative consequences of adverse shocks, such as the aging population, for the fiscal imbalance have been vastly discussed, the literature lacks the appropriate empirical framework to establish an analytical narrative for the assessment of fiscal solvency of public pension systems. On the other hand, the measure of fiscal solvency would be difficult to define without a comprehensive theoretical framework, able to capture the fullest possible influence of the underlying demographic parameters on fiscal sustainability of public pension expenditure in the long-term (recently, European Commission proposed S1 and S2 measures of fiscal solvency, which show durable adjustments of current primary balance required to fulfil finite and infinite intertemporal budget constraints; Aleksander Aristovnik 2008). In fact, the irreversibility of public pension expenditure under high replacement rates might be the missing piece of public economics literature as it sets the major challenge to predict the trends of age-related spending, as well as the resulting impact on macroeconomic stability.

The purpose of this article is thus two-fold; on one hand to provide a sound theoretical framework for studying the effects of changing demographic and economic conditions on the size of public pension expenditure, and on the other to perform a robust empirical analysis of the relationship between public pension expenditure and its key economic determinants with demographic controls for the period 1998-2008 in a panel of 33 countries representing various constitutional and institutional settings.

From the theoretical perspective, we attempt to determine how public pension expenditure is determined by demographic and macroeconomic determinants. Our research questions relate old-age expenditure and aging population under endogenous human capital, where the latter facilitates the rise in net replacement rate alongside a substantial decrease in fertility rate in the context of demographic transition. The model demonstrates the rise in life expectancy at various ages as the cause of higher net replacement rates upon withdrawal from the labour market and, consequently, higher old-age expenditure in the share of GDP (Aristovnik and Ksenja Jaklič 2013).

From the empirical perspective, we examine direction and strength of the relationship between public pension expenditure and a sequence of macroeconomic determinants with demographic controls. In particular, we focus on the effect of effective retirement age, net replacement rate, gross savings, old-age dependency ratio, fertility rate, and life expectancy on public pension expenditure. We shall also attempt to account for the differences in the effect of institutional features of public pension systems on the level of public pension expenditure, considering integrally Continental European, Anglo-Saxon, Nordic, and Mediterranean countries.

The article proceeds as follows. In Section 1, we present a brief overview of the literature, emphasizing the theoretical framework of public pensions and the relevant cross-country evidence on evaluation of the costs and fiscal implications of aging. In Section 2, we provide a theoretical framework by establishing rigorous modelling assumptions and deriving equilibrium conditions for the stated hypotheses. In Section 3, we outline the data sources exploited in this article. In Sections 4 and 5, we present the methodology and then focus on empirical evidence and on interpreta-

tion of results. Section 6 concludes with the main findings and some policy implications.

## 1. Review of the Literature

Under PAYG pension schemes, mandatory contribution rates are determined by net replacement rate, defined as the ratio of old-age pension relative to net earnings prior to the retirement, and the old-age dependency ratio. Early contributions to the theoretical solution to PAYG schemes by Samuelson (1958) and Cass and Yaari (1966) assumed a stationary population in the framework of an overlapping-generations general equilibrium (OLG-GE) model. In this framework, the generational equivalence required to maintain constant consumption streams to retired generations is assumed as the equality of population growth rate and the market interest rate, which broadly reflects the internal rate of return from PAYG schemes or, according to Samuelson (1958, p. 476): “every geometrically growing consumption-loan economy has an equilibrium rate of interest exactly equal to its biological percentage growth rate”.

The equivalence condition required to maintain the sustainability of PAYG pension schemes implies either a stationary growth of the population or low old-age dependency ratio. Samuelson’s generational equivalence condition easily prevailed in a typical Malthusian population, characterized by high fertility rates amid the demographic transition. However, as the demographic dividend came to its end and as the decline of employment-population ratio paced quickly, lower equilibrium rates of population growth were not accompanied by the downward adjustment of the real rate of return from PAYG pension schemes. The inequality of the generational equivalence unfolded the unsustainability of PAYG schemes in the long run, primarily driven by fiscal insolvency of a growing stock of unfunded pension liabilities.

Martin S. Feldstein and Jeffrey Liebman (2001) assessed the theoretical and empirical implications of transition from current PAYG schemes into fully funded pension schemes with investment-based individual savings accounts. While the introduction of PAYG schemes benefitted older age cohorts, it imposed a considerable strain on younger generations facing a small internal rate of return on mandatory contributions into PAYG public schemes. In addition, PAYG schemes impose significant deadweight loss, captured by the elasticity of taxable labour income with respect to marginal tax rates, by distorting labour supply decisions and lowering national savings rate.

The consequences of subsequent ignorance of distributional effects of PAYG schemes were emphasized by Jayasri Dutta, Sandeep Kapur, and Michael J. Orszag (2000), Ary L. Bovenberg and Thijs Knapp (2005) and Nicholas Barr and Peter A. Diamond (2009). The equilibrium implications of the intergenerational redistribution within various birth cohorts suggest the finding, later reinforced by Feldstein and Liebman (2001) that leaving benefit rules within PAYG financing scheme would increase the tax rate required to finance the benefits by 50 percent or more.

Whilst acknowledging the impact of aging population and changing demographic parameters, the vast majority of literature identified early retirement policies as the major cause of budgetary imbalances concerning fiscal implications of aging.

Michael Boskin (1975), utilizing the data from U.S. Panel Study of Income Dynamics, studied the cohort of white married males in their sixties to estimate the model of early retirement behaviour. The findings identify income guarantee and implicit tax rate on work at later ages as the main causes of early retirement, while the results suggest that a decrease in implicit tax rate would substantially reduce the probability of early retirement.

Tryggvi T. Herbertsson and Orszag (2001) provided the theoretical framework to assess the cost of early retirement. Contrary to Gruber and Wise (1998), the study did not incorporate unused labour capacity as the percentage of older workers out of the labour force, but the share of potential GDP lost due to incidence of early retirement in a panel of OECD countries between 1980 and 1998. The study suggests that the loss of potential GDP varies in relation to labour market regulation and the extent to which it affects early retirement behaviour. The loss, estimated at 5-7 percent of annual potential GDP, is characterized as the cost of early retirement at the macro level. It is considerably higher in EU countries of the OECD panel, reflecting more stringent labour market regulation and the significance of early retirement.

In a quest to attain the causes and implications of early retirement, Sveinbjörn Blöndal and Stefano Scarpetta (1999) studied the incidence of early retirement in a cross-section of OECD countries since 1960s. The early withdrawal from the labour market, caused by increased affluence and higher real *per capita* incomes, has resulted in higher demand for leisure, particularly at older ages. The background of the incidence of early retirement in the labour market, such as competitive disadvantage of older workers, has been emphasized as the major cause of early exit from the labour force. In addition to labour market background, the continuous expansion of occupation pension schemes and increased non-employment benefits and old-age pensions, embodied in social security systems, accelerated the incidence of early retirement. The majority of high-income OECD countries have steadily enjoyed high net replacement rates where old-age pension almost matched pre-retirement income. The disincentives for older workers, imparted by the regulation of labour markets, have exerted a strong effect on early retirement decisions, as cross-country differences in effective retirement age are closely related to the extent of the disincentives to work at higher ages. Later, Courtney C. Coile and Gruber (2007) established the significance of future entitlements on retirement decisions, while Coile and Gruber (2004) simulated the effect of several policy changes, such as raising early entitlement age and full-benefit age, and showed that these could affect retirement decisions substantially.

The incidence of early retirement in transition countries had been documented by Jan Svejnar (1996), Miroslav Verbič (2007) and Sašo Polanec, Aleš Ahčan, and Verbič (2013). In early 1990s, transition countries experienced the crisis of PAYG pension systems. Demographic stratification of transition countries departed from the homogeneity of the demographic structure, as high-income transition countries (Slovenia, Czech Republic) resembled the OECD average more than lower-income countries in Eastern Europe. The period of transition in Central and Eastern Europe was characterized by deteriorating labour market conditions (David Blanchflower and Richard Freeman 1994), which further resulted in high net replacement rates and low

effective retirement age. The existence of PAYG pension schemes in transition countries in early 1990s imposed high tax burden on earnings. The sudden incidence of early retirement set the stage for intergenerational distribution, lowering net replacement rates for prospective generations amid growing old-age dependency ratios, although the introduction of stringent eligibility criteria in the Czech Republic and notional defined contributions in Poland and Hungary leaned towards mitigating adverse shocks of an ageing population on public pension expenditure.

Accordingly, Jože Mencinger (2008) attempted to establish the determinants of the share of pensions in GDP using a simple, theoretically unfounded econometric model for the EU27. He determined that despite a considerable increase of the old-age dependency ratio, the shares of pensions in GDP in EU countries stabilised due to the developments in retirement age, replacement rate, old-age ratio and development level. He also concluded that solutions for the ageing of the EU population could be found within the existing PAYG systems, provided there were jobs available.

The accuracy of estimating public pension expenditure in the future, however, depends crucially on demographic and macroeconomic assumptions. Recent forecasts of pension spending as a share of GDP (European Commission 2006) suggest that until 2050 European countries would experience higher share of spending on public pensions in GDP under constant fertility rates, increased longevity and gradually increasing old-age dependency ratio. As Thai-Thanh Dang, Pablo Antolin, and Howard Oxley (2001, p. 18) contend: “pension spending is projected to fall as a share of the GDP in Poland, where shifts are taking place towards private pension arrangements, as well as for the United Kingdom, and to remain broadly stable for Italy, partly reflecting recent reforms. In contrast, increases of more than 4 percentage points of GDP are projected for ten countries, and for seven among these it will be 5 percentage points or more”. In addition, estimates by Richard Disney (1999) suggest that, by 2030, European countries would have to raise tax-to-GDP ratio significantly to keep net debt constant under unchanged PAYG financing scheme.

Finally, of the most adverse consequences of PAYG pension schemes under prospective demographic parameters is the implicit pension debt, broadly defined as the present value of prospective entitlement under current fiscal policy regime (Laurence J. Kotlikoff and Willi Leibfritz 1999). Paul Van den Noord and Richard Herd (1993) established that in the early 1990s, net pension liabilities in OECD countries were considerably lower in the U.S. (43 percent of GDP), compared to Japan (200 percent of GDP), Italy (233 percent of GDP) and France (286 percent of GDP). Unfunded fiscal obligations for European countries were studied by Jagadeesh Gokhale (2009), suggesting that fiscal imbalance of social security in terms of present value is excessively higher compared to the size of GDP. Implicit debt of PAYG pension schemes was also the subject of intensive debate in Latin America, following the introduction of individual savings accounts in Chile in 1981. Jorge Bravo and Andras Uthoff (1999) suggested significant transitional fiscal costs in shifting from unfunded PAYG schemes to individual savings accounts.

## 2. Expenditure on Public Pensions: Theory and Hypotheses

The aim of this section is to provide a theoretical framework to study the effects of changing macroeconomic and demographic parameters on the size of public pension expenditure. Earlier attempts to provide a coherent theoretical framework include Samuelson (1958), Diamond (1965), Cass and Yaari (1966), Olivier J. Blanchard (1985) and Mark Gertler (1999). In order to analyze the long-run impact of fiscal policy and social security, we propose that the missing gap of the literature is to incorporate demographic effects, notably fertility rate and old-age dependency ratio, in the relationship explaining the long-run pressure of ageing and replacement rates on public pensions, defined as the ratio of pension expenditure to GDP.

First, we state some crucial motivating assumptions of our model. Consider a set of economies  $i$ ,  $i = 1, \dots, I$ , with a horizon in discrete time  $t$ ,  $t = 1, \dots, T$ . As the representative agents in countries  $1, \dots, I$  discount the future by discount factor  $\beta_i$ , the net lifetime benefit of the representative agent,  $NB_{it}$ , can be written as (cf. Daron Acemoglu 2005):

$$NB_{it} = \sum_{t=1}^T \beta_i (y_{it} - e_{it}), \quad (1)$$

where  $y_{it}$  represents representative agent's lifetime earnings and  $e_{it}$  represents agent's lifetime expenditure. Each representative agent has access to the following Cobb-Douglas technology to produce the final good  $q_{it}$  in the economy:

$$q_{it} = \frac{1}{1 - \alpha_i} A_{it}^{\alpha_i} Z_{it}^{1 - \alpha_i}, \quad (2)$$

where  $Z_{it}$  denotes investment in country  $i$  at time  $t$ , while  $A_t$  represents the level of public goods in country  $i$  at time  $t$ , and  $\alpha_i$  is the appropriate (partial) elasticity.

The baseline level of public pension expenditure is derived from public investment in the Cobb-Douglas technology setup, and is financed by a continuum of taxes. The tax rate  $\tau_{it}$  is assumed to be determined exogenously,  $\tau_{it} \in \{0, 1\}$ . Hence, tax revenues  $T$  at time  $t$  in country  $i$  are given by:

$$T_{it} = \tau_{it} y_{it}. \quad (3)$$

At tax rate  $\tau_{it}$ , the agent's lifetime consumption can be written as:

$$c_{it} \leq (1 - \tau_{it})(1 - s_{it})q_{it}, \quad (4)$$

where  $s_{it}$  represents the representative agent's savings rate. The ruling political elite at time  $t$  decides on how much to spend on public goods at time  $t + 1$ :

$$A_{it+1} = \left[ \frac{(1 - \alpha_i) \delta_i}{\alpha_i} G_{it} \right]^{\frac{1}{\delta_i - \theta_i}}, \quad (5)$$

where  $\bar{G}_i$  denotes the share of government spending on public goods in country  $i$ . Parameter  $\delta_i$  captures the returns to scale, where decreasing returns to scale are assumed, i.e.  $\delta_i > 1$ . In addition,  $\theta_i$  represents the distribution parameter of power to pressure the political elite to increase the share of government spending; an increasing  $\theta_i$  implies greater pressure on the government to raise its spending on particular public good at time  $t + 1$ ,  $A_{it+1}$ .

The first-best allocation mechanism (Acemoglu 2005) can be described by the choice of lifetime earnings and expenditure, as to maximize the total surplus of the economy,  $NY_i$ :

$$NY_i = \sum_{t=0}^T \beta_i \left[ (1 - \tau_{it}) y_{it} \left( \frac{1}{1 - \alpha} A_{it}^\alpha Z_{it}^{1 - \alpha_i} - Z_{it} \right) - \frac{\alpha_i}{(1 - \alpha_i)(\delta_i - \theta_i)} A_{it+1}^{\delta_i - \theta_i} \right]. \tag{6}$$

Assume that the continuum of agents consists of old and young citizens. The elderly retire effectively at age  $a_i$ , while the young have no prior information about the anticipated effective retirement age.

The elderly will pressure the governing political elite through  $\theta_i$  to increase the share of  $G_i$  from time  $t$  to time  $t + j$ . Hence, they will maximize the utility of lifetime consumption as discounted net present value of  $A_{it}$ ,  $W(A_{it})$ . The characterization of the lifetime consumption of the elderly can be written by a Richard E. Bellman’s (1957) equation:

$$W(A_{it+j}) = \max_{A_{it+j}} \left\{ \Gamma_{it+j} - \frac{\alpha_i}{(1 - \alpha_i)(\delta_i - \theta_i)} A_{it+j}^{\delta_i + \theta_i} + \beta_i W(A_{it+j}) \right\}. \tag{7}$$

Since  $\delta_i > 1$ , the initial payoff to the political elite is bounded, continuously differentiable and concave, and the value of  $W$  is continuously differentiable as well. The first-order condition for choosing  $A_{it+j}$  is thus:

$$\frac{\alpha_i}{1 - \alpha_i} A_{it+j}^{\delta_i - \theta_i} = \beta_i W'(A_{it+1}). \tag{8}$$

Next, we shall incorporate into our model fertility rate, human capital, life expectancy, and old-age dependence. At last, we shall combine the studied economic and demographic effects as determinants and controls of public pension expenditure.

### 2.1 Fertility and Human Capital

We derive old-age dependency ratio from the state of demographic variables, such as life expectancy and fertility. Since fertility rates differ across countries and income levels, the dynamic of population growth follows an inverted U-shape of the fertility-income relationship or, as Robert E. Lucas (2002, p. 161) contends: “as income increases from its Malthusian steady state level, population first increases, then de-



creases, (where) the role played by demography in this model is entirely passive". Hence, fertility rates across different levels of *per capita* income crucially depend on the level of endogenous human capital.

Under typical Cobb-Douglas constant-return technology, a purely exogenous treatment of human capital would thereby facilitate technological improvement by increasing the fertility rate alongside the equilibrium path of balanced growth. In the simplest possible form (*cf.* Lucas 2002), we consider the following utility preference function:

$$W(c_i, n_i, w_i) = c_i^{1-\beta} n_i^\phi w_i^\beta, \quad (9)$$

where  $c_i$ ,  $n_i$  and  $w_i$  represent household consumption, number of children and fraction of time devoted to goods production in country  $i$ , respectively. In addition,  $\phi_i$  represents the fertility allocation parameter, which is assumed to be normally distributed in a cross-country distribution.

Letting  $h_{it}$  denote human capital, production per household can be arranged into  $h_{it}w_{it}$ . The remaining time is considered to be devoted to child raising. As simultaneous human capital decisions set the course for technological change, the growth of human capital is further endogenized:

$$h_{it+1} = h_{it}\lambda(v_{it}), \quad (10)$$

where  $v_{it}$  denotes the fraction of time endowment devoted to raising one child in the household, whereas  $\lambda_i$  represents the growth rate of human capital. The fraction of time devoted to child-raising,  $v_{it}$ , is assumed to increase alongside the increase in stock of human capital, which further implies an immediate reduction in the equilibrium number of children. In addition,  $v_{it}$  enters the Equation (10) exogenously. The resource constraint of the representative household is as follows:

$$c_i \leq h_i(1 - v_i n_i). \quad (11)$$

The household's Bellman equation would then take the form:

$$f(h_i) = \max_{c_i, n_i, v_i} W(c_i, n_i, g(h_i \lambda(v_i))), \quad (12)$$

subject to Equation (11). Following the Gary S. Becker, Kevin Murphy, and Robert Tamura (1990) setting, we assume that dynamic human capital growth takes the exponential form:

$$\lambda(v_i) = \bar{\varsigma}_i v_i^{\mathcal{G}_i}, \quad (13)$$

where  $\bar{\varsigma}_i$  represents baseline fertility rate, whereas  $\mathcal{G}_i$  embodies the human capital growth parameter. We further identify  $\bar{\varsigma}_i = n_i / F_i$  as the total fertility rate, defined as the average number of children born to a woman over her lifetime, the number of women being denoted by  $F_i$ .

As fertility rates and human capital decision are derived simultaneously in the exponential example, any particular changes in the baseline parameter  $\bar{\zeta}_i$  leave behavioural response to the stock of human capital unaltered. An increase in  $\mathcal{G}_i$  leads to greater amount of time  $\nu_i$  endowed with human capital investment, and to a corresponding reduction in equilibrium fertility rate.

### 2.2 Life Expectancy and Old-Age Dependence

The fraction of the elderly in country  $i$  at time  $t$ ,  $N_{O_i} / N_i$ , is a function of life expectancy at birth,  $\Gamma(l_{it})$ :

$$\left( \frac{N_{O_i}}{N_i} \right) = \Gamma(l_{it}), \tag{14}$$

where  $N_i$  and  $N_{O_i}$  represent the total population and the elderly population, respectively. We assume  $\Gamma'(l_{it}) > 0$ , i.e. the elasticity of old-age population with respect to changes in life expectancy to be greater than zero, so that life expectancy improvements facilitate increases in old-age population. We assume that the individuals in country  $i$  at time  $t$  live until life expectancy at age 65. The latter is determined for a representative agent by external effects to the agent's length of life (cf. Lucas 2002).

The net replacement rate is defined as the ratio between real pension earnings and pre-retirement earnings in time  $t \in \{1, \dots, T_i\}$ :

$$\frac{r_i}{y_i} = \omega_i \left[ \sum_{t=1}^{T_i'} y_{it} (1 - \tau_{it}) \right], \tag{15}$$

where  $y_i$  represents agent's earnings, which are then adjusted for effective tax rate  $\tau_i$ , while  $r_i$  represents real retirement income. In addition,  $T_i'$  represents the age of withdrawal from the labour market, as pre-retirement income is earned until effective retirement age  $a_i$ . The distribution parameter  $\omega_i$  captures the share of agent's earnings in fixed pension income from  $T_i'$  onwards. By definition,  $\omega_i \leq 1$  and the share of retirement income is thus not assumed to be unique across the stratum of the elderly.

Suppose that the elderly population is characterized by high and low endowment of human capital. The difference in human capital return between the two representative individuals in country  $i$ , i.e. the one with high and the one with low endowment of human capital, is denoted by  $\psi_i$ . Hence, adjusting net replacement rate for differences in human capital return yields the aggregate net replacement rate:

$$\frac{r_i}{y_i} = \omega_i \left[ \sum_{t=1}^{T_i'} y_{it} (1 - \tau_{it}) \right]^{\frac{1}{1-\psi_i}}, \tag{16}$$

where  $\psi_i \leq 1$ , so that there exist increasing returns to education. Considering the pension expenditure, we assume a non-stationary pay-as-you-go pension scheme.

The budget constraint of the net replacement rate  $r_i / y_i$  is, as an instantaneous relationship, determined by the old-age dependency ratio. We derive the constraint as:

$$\frac{r_i}{y_i} = \sum_{t=1}^T \mu_t \frac{N_{Ai}}{N_{Oi}}, \quad (17)$$

where  $\mu_t$  denotes the baseline discount rate defined in time  $t$  over  $T$  number of periods, whereas  $N_{Ai}$  represents the working-age population.

### 2.3 Public Pension Expenditure

Based on the above findings, the level of public pension expenditure in country  $i$  at time  $t$ ,  $G_{it}$ , is jointly determined by a sequence of macroeconomic determinants and demographic controls.

In the set of macroeconomic determinants, the response of the expenditure level to increases in net replacement rate  $r_{it} / y_{it}$ , is positive, while the response to increases in the savings-to-GDP ratio  $s_{it}$  is negative as higher aggregate savings decrease the pressure on the baseline budget constraint. Nevertheless, a reduction is expected in the level of public pension expenditure in response to increases in effective retirement age  $a_{it}$ .

Among the demographic controls, the level of expenditure responds negatively to the increase in total fertility rate  $\zeta_{it}$ , as the old-age dependency ratio would decline proportionately to the positive shocks in fertility rate. On the other hand, the response of the expenditure level to the fraction of the elderly ( $N_{Oit} / N_{it}$ ), and to increases in life expectancy at various ages (at birth,  $l_{0it}$ , and at age 65,  $l_{65it}$ ), is positive.

Hence, by extending the existing theoretical framework by the set of demographic and macroeconomic determinants we obtain the following equation:

$$\begin{aligned} G_{it} = & \gamma_1 + \gamma_2 a_{it} + \gamma_3 \left( \frac{r}{y} \right)_{it} - \gamma_4 s_{it} + \gamma_5 \left( \frac{N_0}{N} \right)_{it-p} - \\ & - \gamma_6 \zeta_{it-p} + \gamma_7 l_{0it-p} + \gamma_8 l_{65it-p} + v_{it}, \end{aligned} \quad (18)$$

where  $\gamma_j, j=1, \dots, 8$  are the parameters of the model to be estimated by an appropriate econometric technique, and  $v_{it}$  is the disturbance term. The sign of any given coefficient in Equation (18) represents the expected direction of effect of that determinant on public pension expenditure (to be examined hereinafter).

### 3. Data Sources

To analyze the relationship between public pension spending and macroeconomic and demographic indicators, we utilize the data available from national statistics and various other data sources, as described below. Although we are aware of potential measurement errors and biases, we aimed at building a comprehensive panel that would allow an evaluation of within- and between-country variation effects of ageing, fertility, effective retirement age and savings-to-GDP ratio.

Once the variation in demographic and macroeconomic variables is exploited, the estimated coefficients would allow a cross-country comparison of the direct effect of ageing and fertility on the future size of public pension spending, which should be given considerable attention given the lack of literature on these issues.

Our panel consists of 33 countries: Australia, Austria, Belgium, Canada, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Malta, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom, and United States. We thus have in our sample 30 high-income OECD economies, Mexico that - according to World Bank's Country Group Classification - is classified as an upper-middle income country, and two non-OECD countries (Cyprus and Malta). Time period 1998-2008 is used for the analysis, which gives us 363 observations in total (a strongly balanced panel).

We avoided the aggregation bias of country size by defining public pension expenditure as a share of GDP. The data on public pension expenditure in the share of GDP for Australia, Canada, Iceland, Japan, Korea, Mexico, New Zealand, Norway, Switzerland, and the U.S. were reported in *Social Expenditure Database* (OECD 2011c)<sup>1</sup>, while the relevant data for EU countries were reported by Eurostat's *Pension Expenditure Database* (Eurostat 2011)<sup>2</sup>.

We attempted to capture the effect of old-age dependency ratio on the size of public pension expenditure, as dependency ratio incorporates the effect on old-age pension more efficiently than the share of population aged 65 years and above (65+), given a significant between-country variation in effective retirement age. The data on old-age dependency ratio for OECD member states were reported in *Pensions at a Glance* (OECD 2011b), while the data for Cyprus, Estonia, Malta and Slovenia for the period 1998-2008 were obtained from Eurostat (2011).

Although the increase in retirement age to prevent early retirement has been an essential measure to ensure the sustainability of age-related public expenditure, there is little evidence on the link between retirement age and age-related expenditure (cf. Coile and Gruber 2004; Gary Burtless and Quinn 2002; Randall Filer and Marjorie Honig 2005). To fill in the missing gap, we collected cross-country data on

<sup>1</sup> OECD. 2011c. "Social Expenditure Database." [http://stats.oecd.org/Index.aspx?DataSetCode=SOCX\\_AGG](http://stats.oecd.org/Index.aspx?DataSetCode=SOCX_AGG).

<sup>2</sup> Eurostat. 2011. "Statistical Office of the European Commission." [http://epp.eurostat.ec.europa.eu/portal/page/portal/employment\\_social\\_policy\\_equality/social\\_protection\\_social\\_inclusion/indicators/pension](http://epp.eurostat.ec.europa.eu/portal/page/portal/employment_social_policy_equality/social_protection_social_inclusion/indicators/pension).

average effective retirement age for the period 1998-2008, obtained from *Pensions at a Glance* (OECD 2011b) and Rafal Chomik and Edward R. Whitehouse (2010).

Additionally, we attempt to explain the variation in age-related expenditure by the shifts in life expectancy. In fact, the increasing life expectancy that high-income countries are set to experience in the next decades has been rising faster than effective retirement age, reflecting the improvements in medical care. The increase in life expectancy, prolonging longevity and reducing mortality risks, accounts for a significant share of the anticipated increase in age-related expenditure (David E. Bloom et al. 2009). We collected data on life expectancy at birth and at age 65, to account for the difference in the response of age-related expenditure on increases in life expectancy at various ages. The data were reported by *World Development Indicators* (World Bank 2011)<sup>3</sup> and *OECD Health Data* (OECD 2011a), while for Cyprus and Malta the data were provided by Eurostat (2011).

As discussed earlier, the impact of fertility on public pension expenditure is unambiguous (Robert J. Barro and Becker 1989; Berthold U. Wigger 1999; Michele Boldrin, Mariacristina De Nardi, and Larry E. Jones 2005; Volker Meier and Matthias Wrede 2010). The empirical evidence suggests a negative relationship between age-related government spending and equilibrium fertility rates, the former causing a decline in the latter. We provide an empirical framework in which cross-country variation in fertility rates accounts for the differences in response of age-related expenditure to changes in fertility rates. The data on fertility rates for the period 1998-2008 were provided by *U.S. Census International Data Base* (United States Census Bureau 2011)<sup>4</sup>.

The data on savings-to-GDP ratio were reported by *World Development Indicators* (World Bank 2011). While the empirical evidence suggests a strong link between savings-to-GDP ratio and public pension expenditure (*cf.* Feldstein and Elena Rangelova 2001; Julia L. Coronado 2002; Diamond 2005), we provide estimates of the effect of savings-to-GDP ratio on age-related expenditure as a share of GDP, therefore controlling for the income effect.

Finally, we analyzed the impact of net replacement rates on the variation of age-related spending. Given the difficulty of calculating net replacement rates from the income distribution, there is no single international statistical source that would report the rates and enable a straightforward international comparison. We therefore collected data on average net wages and average net old-age pensions to calculate replacement rates. Table 1 reports statistical sources from which we calculated net replacement rates for each country studied in the sample.

<sup>3</sup> **World Bank.** 2011. "World Development Indicators." <http://data.worldbank.org/datacatalog/world-development-indicators>.

<sup>4</sup> **United States Census Bureau.** 2011. "International Data Base." <http://www.census.gov/population/international/data/idb/informationGateway.php>.

**Table 1** Statistical Sources for Net Replacement Rates

Country	Statistical source
Australia	Australian Prudential Regulation Authority (2007)
Austria	Statistics Austria (2011)
Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, UK	OECD (2011b)
Canada	Statistics Canada (2004)
Czech Republic	Czech Statistical Office (2011)
Greece	Hellenic Statistical Authority (2009)
Iceland	Statistics Iceland (2010), Eurostat (2011)
Japan	Japan Statistics Bureau (2011)
Korea	National Pension Service (2009)
Malta	Anita Schwarz, Alberto Musalem, and Tatyana Bogomolova (2004), Human Development Group (2010)
Mexico	Instituto Nacional de Estadística y Geografía (2010)
New Zealand	New Zealand Superannuation Fund (2010), Statistics New Zealand (2010)
United States	Social Security Administration (2010)

Source: Authors.

## 4. Methodology

For our panel of 33 countries (time period 1998-2008), we estimated fixed-effects and random-effects empirical specifications of the model based on Equation (18), using as regressors effective retirement age, savings-to-GDP ratio, and a vector of demographic controls. To check for the orthogonality of the common effects and regressors we performed Jerry Hausman's (1978) specification test for fixed *versus* random effects. It turned out that the test statistic was sufficiently high to reject random effects in all tested specifications. We thus concluded that the random effects estimator is inconsistent and focused on fixed effects estimates.

The fixed-effects empirical model specification, based on Equation (18) and explored further in this section, takes the form:

$$G_{it} = \alpha_i + \mathbf{X}\boldsymbol{\gamma}_1 + \mathbf{Z}\boldsymbol{\gamma}_2 + \varepsilon_{it}, \quad (19)$$

where, as given at the end of Section 3,  $\mathbf{X} \in \mathbb{R}^{NT \times k_1}$  is a matrix of data for  $k_1$  economic explanatory variables,  $\mathbf{Z} \in \mathbb{R}^{NT \times k_2}$  is a matrix of data for  $k_2$  demographic controls, and  $\boldsymbol{\gamma}_1 \in \mathbb{R}^{k_1 \times 1}$  and  $\boldsymbol{\gamma}_2 \in \mathbb{R}^{k_2 \times 1}$  are the corresponding vectors of parameters. Matrix  $\mathbf{Z}$  includes, as column vectors, country-specific interaction dummy variables measuring the groupwise impact of net replacement rate on the size of old-age expenditure. Additionally, given the fixed-effect specification of the model, the disturbances from

Equation (18) can now be decomposed as  $v_{it} = \alpha_i + \varepsilon_{it}$ , where  $\alpha_i$  captures time-invariant country-specific effects and  $\varepsilon_{it} \sim IID(0, \Sigma)$ .

A major drawback of this model is the neglect for the endogeneity of key macroeconomic variables used to explain cross-country variation in the ratio of public pension expenditure to GDP. Ratio of gross savings-to-GDP, used as a proxy for savings rate, could e.g. be endogenously determined by the government's fiscal insolvency regarding old-age expenditure, which might affect the aggregate savings behaviour. Therefore, the major limitation of the above model specification is the presence of an omitted-variable bias that could potentially lead to inconsistent results and misleading interpretations regarding the effects of macroeconomic and demographic factors on old-age expenditure.

We address endogeneity by constructing an instrumental variable - two-stage least squares (IV-2SLS) framework to account for inconsistencies arising from omitted variable bias, particularly related to the effects of savings and net replacement rate on ratio of public pensions-to-GDP. In addressing endogeneity, we exploit the cross-country differences in public fiscal solvency as: (i) an instrument for the extent of net replacement rate and (ii) an exogenous source of variation to identify the effect of replacement rate on the share of public pensions in the GDP. Greater pressure on government's financial liabilities could indicate a possible downward adjustment of net replacement rate to improve the fiscal solvency of public pension system. The data on gross financial government liabilities from OECD (2011b) is used to construct the share of gross liabilities in the GDP as an instrument for net replacement rate.

In addition, savings rate can simultaneously respond to the weaker fiscal solvency of public pension system to meet the liability requirements for old-age expenditure, which leads to an additional endogeneity channel that renders possible inconsistencies arising from baseline fixed-effects model specification, such as the inability to identify the effect of savings-to-GDP ratio on public pensions.

To a large extent, higher savings rate could reflect the perceived negative pressure on the solvency of public pension system arising either from parametric changes, such as low retirement age, or demographic changes, such as continuously improving life expectancy. In this respect, we calculate based on OECD (2011b) data 20-year changes in life expectancy and effective retirement age as instruments for the ratio of gross savings-to-GDP, in order to capture exogenous institutional and demographic adjustments to the pension system and identify the subsequent effect of savings rate on the ratio of public pensions-to-GDP. Hence, we also consider a full set of time-fixed effects as an additional instrument for savings-to-GDP ratio, which allows us to exploit the variation in unobserved time shocks as an independent and exogenous source of cross-country differences in public pensions. The inclusion of time-fixed effects also facilitates the control for cross-country policy changes and subsequent effects on public pensions, which is not directly observed in our model, given a considerable institutional heterogeneity across public pension systems in OECD countries.

We thus extend our Equation (19) by endogenizing baseline fixed-effects model specification with respect to savings rate and net replacement rate, by positing the reduced-form relationships:

$$\begin{pmatrix} r \\ y \end{pmatrix}_{it} = \varphi_1 + \varphi_2 GFL_{it} + \mathbf{X}\varphi_3 + z_{1it}, \quad (20)$$

$$s_{it} = \kappa_1 + \kappa_2 \Delta l_{0it} + \kappa_3 \Delta a_{it} + \mathbf{T}\kappa_4 + \mathbf{X}\kappa_5 + z_{2it}, \quad (21)$$

where  $GFL$  denotes the share of government's gross financial liabilities in GDP, and  $z_1$  captures the reduced-form cross-country disturbances. In reduced-form specification for savings rate,  $\Delta l_0$  and  $\Delta a$  denote 20-year changes in life expectancy at birth and effective retirement age, respectively,  $\mathbf{T}$  captures unobserved time-fixed effects on savings rate, and  $z_2$  denotes the respective disturbance term.

The validity of instruments is gauged by the exogeneity and relevance conditions to consistently estimate the above relationships. Invoking the posited first-stage relationship in Equations (20) and (21), gross financial liabilities in the share of GDP are assumed exogenous with respect to the dependant variable. Empirically, the exogeneity criterion is met in a sense that the impact of liabilities on the ratio of public pensions-to-GDP is not absorbed by the stochastic disturbance in the structural relationship in Equation (19). Conceptually, the exogeneity condition is assumed in the sense that gross financial liabilities are determined outside the structural system, in which we examine the effects of aging and macroeconomic variables on public pensions. Higher share of liabilities in the GDP possibly causes lower expected replacement rates, endangering fiscal sustainability of public pensions when the replacement rates rise in a world of rapidly aging population with constantly improving life expectancy. Therefore, gross liabilities as an instrument for the replacement rate impact the ratio of public pensions-to-GDP indirectly, though the level and composition of net replacement rates.

Similarly, long-term changes in life expectancy are assumed an exogenous instrument for the savings rate with respect to the resulting impact on public pension-to-GDP ratio, unabsorbed by the stochastic component in the structural relationship between public pensions-to-GDP ratio, demographic covariates and macroeconomic determinants. Over time, improving longevity leads to rising old-age consumption in a PAYG public pension scheme, causing a downward adjustment of savings rate. Rising old-age consumption has been further encouraged by continuously declining effective retirement age. Both, decreasing retirement age and improving longevity are assumed to take place outside the structural system, where the ratio of public pensions-to-GDP is determined. In this respect, 20-year changes in effective retirement age and life expectancy at birth are exploited as the exogenous source of variation in the ratio of public pensions-to-GDP.

Moreover, the validity of instruments is further reinforced by the empirical correlation between the endogenous macroeconomic variables and instruments. The partial panel correlation coefficient between gross financial liabilities in the share of GDP and net replacement rate is 0.28 and statistically significant at 1%, whereas the partial correlation between gross savings in the share of GDP and 20-year change in life expectancy is 0.13 and is statistically significant at 5%. In addition, the established correlation coefficient between gross savings in the share of GDP and 20-year changes in effective retirement age is 0.12 and is also significant at 5%, after partialling out the effects of other covariates.



As already indicated, four dummy variables were generated denoting country-specific characteristics based on the general institutional settings of pension systems. In general, countries in our panel differ in terms of institutional structure of the pension system and welfare state based on: (a) the extent of PAYG pension system, and the relationship between defined-benefit and defined-contribution schemes; (b) early retirement incentives and (c) retirement age. We identified four different general institutional settings and thus placed each country into Anglo-Saxon, Continental European, Nordic, or Mediterranean group. This is based on crucial institutional cross-country differences in public pension schemes; Continental European countries share an ambiguous Bismarckian public pension system, public pension systems in Anglo-Saxon countries have been emulated on Beveridgian principle, while public pension schemes in Nordic countries share both institutional maxima. Despite a lack of thorough discussion in the literature, John Gal (2010) also established the peculiar institutional originality of Mediterranean welfare states.

In our panel, the institutional differences in the pension system can be observed through: (1) public pension expenditure relative to GDP; (2) effective retirement age and (3) net replacement rates. Institutional heterogeneity of public pension systems is inherent in significant cross-country differences in the ratio of public pensions-to-GDP, which ranges from 5.5% in Anglo-Saxon group, to 9% in Nordic countries, and 10% in both Continental and Mediterranean countries. Moreover, effective retirement age ranges from the highest level, observed in Anglo-Saxon countries (63.5), to the lowest retirement age in the Mediterranean group. Institutional differences are further amplified by significant differences in net replacement rate, ranging from 36% of pre-retirement earnings level in Anglo-Saxon group, 58% among Nordic countries, 67% in the Mediterranean group, and 73% in the Continental European countries.

As running separate regressions for each group may disallow the implicit comparison of country heterogeneity, we decided to form interaction dummies by inserting each country dummy in specified empirical relationship. The robustness of sample coefficients could provide rigorous estimates of differences in the impact of net replacement rates on public pension expenditure. Table 2 provides a detailed overview of the variables used in empirical model specifications, together with the statistical sources of data.

In Table 3, we provide descriptive statistics for our panel of data. The share of public pension expenditure in GDP exerts a strong correlation with GDP *per capita*, although the tendency is not uniform in cross-country variation. Given a relatively favourable fertility distribution, countries with stronger fully funded pension systems, such as Iceland or Switzerland, have experienced stable or falling ratio of public pensions-to-GDP over time, with mild upward tendency when extrapolating the estimates into the future. Although the correlation between public pension expenditure and effective retirement age is moderate (-0.476), it is statistically significant at the 1% level, suggesting a systematic negative relationship between the two. On average, countries with lower effective retirement age suffer either from higher public pension expenditure or from “benign” prospects of future expenditure, whereas the phenomena of very low retirement age is confined to transition economies, ranging from 56 years in Slovenia (1998) to 62.6 years in Estonia (2006) while, in general, effective retirement age increased during 1998-2008 in 26 out of 33 countries in our panel.

**Table 2** Variables of the Estimated Model Specifications

Variable	Source or description
Public pension expenditure (% of GDP)	Eurostat (2011), OECD (2011c)
Average effective retirement age	Chomik and Whitehouse (2010), Eurostat (2011), OECD (2011b)
Net replacement rate (% of median earnings)	Eurostat (2011), OECD (2011b)
Gross savings (% of GDP)	World Bank (2011)
Old-age dependency ratio	Eurostat (2011), OECD (2011b)
Fertility rate	United States Census Bureau (2011)
Life expectancy at birth	World Bank (2011)
Life expectancy at age 65	World Bank (2011)
Continental European	1 if country belongs to Continental Europe, 0 otherwise
Nordic	1 if country belongs to Nordic countries, 0 otherwise
Anglo-Saxon	1 if country belongs to Anglo-Saxon countries, 0 otherwise
Mediterranean	1 if country belongs to Mediterranean countries, 0 otherwise

Source: Authors.

Moreover, many countries from our sample implemented extensive pension reforms during the estimation horizon, such as: (i) increasing pension age for women (Australia, Austria, Portugal, Switzerland); (ii) general increases in effective retirement age (Czech Republic, Sweden, UK) and (iii) adjustment of retirement incentives through lower replacement rates (Denmark, Finland, Germany, Italy, Spain). Such reforms invariably affect our results, most notably the negative effect of retirement age on age-related fiscal expenditure in GDP. However, this negative effect is partially offset by the implementation of extensive pension reform measures aimed at increasing work incentives, promoting labour supply at older age, and discouraging early retirement.

**Table 3** Descriptive Statistics

Variable	Mean	Std. dev.	Min	Max
Public pension expenditure (% of GDP)	8.91	3.60	0.60	14.97
Effective retirement age	62.26	3.56	56.00	74.98
Net replacement rate (average net pension as % of full-time earnings)	60.80	23.90	13.90	120.90
Gross savings (% of GDP)	21.77	5.90	5.20	39.44
Old-age dependency ratio	23.46	4.91	9.03	37.00
Total fertility rate	1.60	0.31	1.08	2.75
Life expectancy at birth	78.03	2.54	69.79	82.59
Life expectancy at age 65	17.89	1.44	14.05	21.10
Gross financial liabilities (% of GDP)	58.49	31.52	7.31	169.54

Source: Authors' calculations.

Although declining fertility rates have led to negative real return on PAYG pension schemes, there is a wide variation in cross-country fertility rates over time. Not taking into account Mexico as a middle-income country, fertility rates differ substantially in Anglo-Saxon countries from the rates in Continental and Mediterranean Europe, where these have plummeted significantly below replacement rates. In addition, fertility rates are significantly negatively correlated with life expectancy at birth, suggesting the impact of demographic transition. On the other hand, partial correlation between life expectancy at age 65 and fertility rate is moderate (0.225), though highly significant. In addition, net replacement rates on average correlate highly with public pension expenditure (0.751) given a substantial cross-country variation, whereby lower-income countries tend to experience lower net replacement rates.

## 5. Macroeconometric Results

In this section, we report the results of IV-2SLS fixed-effect estimation of the panel-data model, represented by Equations (19)-(21) and taking into account the endogeneity, as described in Section 4. We provide the baseline results and results with lagged demographic effects separately. In Table 4, we report the baseline results, where both types of model specification, i.e. with and without interaction dummies are estimated, while in Table 5, we report the results with lagged demographic effects and with interaction dummies included. In particular, we set up a separate lag structure with three lags,  $p = 1, 2, 3$  and consider each lag in an independent model specification.

Focusing first on economic determinants, our estimates show that the average effective retirement age exerts an important influence on public pension expenditure as a share of GDP. The estimated coefficients suggest that increases in effective retirement age would facilitate a significant reduction in the size of public pensions in GDP, though in baseline specifications (Table 4) the estimated effect is considerably lower, compared to specifications with lagged demographic effects (Table 5). Taking into account the latter specifications, an increase in average effective retirement age by 1 year would reduce public pension expenditure as a share of GDP on average, *ceteris paribus*, by some 0.26-0.36 percentage points.

Conversely, the estimates concerning net replacement rates suggest that an increase in net replacement rate would raise the level of public pension expenditure. In particular, an increase by one percentage point would, on average, cause the rise of public pension expenditure in GDP by up to 0.02-0.03 percentage points in specifications without interaction dummies, holding demographic covariates, savings-to-GDP ratio and effective retirement age constant. When the interaction dummy variables are included, the value of the coefficient increases substantially. As will become clear shortly, interaction dummy variables capture very different institutional frameworks of pension systems with respect to the framework that is chosen as the benchmark.

**Table 4** Instrumental-Variable 2SLS Country Fixed-Effects Model Estimates of Public Pension Expenditure, Baseline Model Specifications

Explanatory variable	Model specification			
	(1)	(2)	(3)	(4)
<b>Macroeconomic determinants</b>				
Effective retirement age	-0.117* (0.060)	-0.184*** (0.056)	-0.187*** (0.057)	-0.001 (0.084)
Net replacement rate (NRR)	0.021* (0.012)	0.026* (0.015)	0.028* (0.015)	0.113*** (0.041)
Ratio of gross savings-to-GDP	-0.169*** (0.056)	-0.092* (0.053)	-0.088 (0.056)	-0.098* (0.055)
<b>Demographic controls</b>				
Old-age dependency ratio	0.144*** (0.038)	0.006 (0.054)	0.012 (0.063)	0.072** (0.028)
Total fertility rate	-1.708*** (0.554)	-2.694*** (0.576)	-2.618*** (0.558)	-2.906*** (0.568)
Life expectancy at birth	-	0.279*** (0.092)	-	-
Life expectancy at age 65	-	-	0.452** (0.216)	-
<b>Institutional interaction dummies</b>				
NRR × Continental European	-	-	-	-0.085** (0.041)
NRR × Nordic	-	-	-	-0.119** (0.042)
NRR × Mediterranean	-	-	-	-0.002 (0.004)
Observations	329	329	329	329
Instruments	13	13	13	13
R <sup>2</sup> (within)	0.170	0.331	0.335	0.368
R <sup>2</sup> (between)	0.384	0.645	0.667	0.125
R <sup>2</sup> (overall)	0.374	0.626	0.645	0.140
Wald test	62.50	85.16	85.47	89.32
p-value	0.000	0.000	0.000	0.000
Sargan-Hansen $\chi^2$ test	12.49	9.340	9.502	8.433
p-value	0.327	0.590	0.576	0.673

**Notes:** Constant term is omitted from the above presentation for brevity. Public pension expenditure as a percentage of GDP is the endogenous variable of the model in all four specifications. Robust standard errors are given in parentheses. Asterisks \*, \*\* and \*\*\* denote statistical significance at the 10 percent, 5 percent and 1 percent level, respectively.

**Source:** Authors' calculations.

The estimates further suggest that an increase in savings-to-GDP ratio would reduce public pension expenditure as the share of GDP, which is especially relevant for economies with a (partially or fully) funded pension system. The value of regression coefficient suggests that a one percentage point increase in savings-to-GDP ratio would decrease public pensions on average, *ceteris paribus*, by some 0.09-0.17 percentage points. Savings-to-GDP ratio thus offsets the increase in the size of public pension expenditure by only a small amount, compared to the magnitude of the effect of fertility rate.

In comparison to earlier attempts to measure the impact of aging on public pensions, which do not incorporate demographic determinants as controls (*cf.* Disney 2000; John C. Caldwell, Pat Caldwell, and Peter McDonald 2002; John Bongaarts 2004), we tried to derive a framework that includes these relationships. The results from Table 4 suggest that old-age dependency ratio exerts a persistent effect on pub-

lic pensions as a share of GDP. The estimated effect suggests that a one percentage point increase in dependency ratio increases the share of public pensions in GDP (with various lags) at most by some 0.07-0.14 percentage points, holding all other factors constant. Although the literature suggests (*cf.* Ronald D. Lee and Ryan D. Edwards 2001; Meena Seshamani and Alastair Gray 2002; Kyrre Stensnes and Nils Martin Stølen 2007) that public pensions should respond strongly to the increases in old-age dependency ratio, our estimates suggest that this effect is only moderate after controlling for other determinants of public pension expenditure.

Conversely, higher fertility rates would significantly reduce the pension-to-GDP ratio (see Tables 4 and 5). An increase in fertility rate by one child per woman would reduce public pension expenditure as the share of GDP (with various lags) by up to 2.9 percentage points, holding all other factors constant. Although an increase in fertility rate by such an order of magnitude is highly unrealistic, the estimate suggests that increases in total fertility rates absorb much of the pressure generated either by aging or lower effective retirement age over the long term.

Increases in longevity and life expectancy at various ages and decreases in total fertility rate are causing a lasting pressure on public pension expenditure. In Bismarckian settings, keeping contribution rates unaltered would require a reduction of net replacement rate or an increase in fertility rate that would increase the share of working-age population. We tested the impact of life expectancy at birth (Specification 2 of Table 4 and entire Table 5) and at age 65 (Specification 3 of Table 4 and entire Table 5) on the size of age-related expenditure. Our estimates suggest that increases in life expectancy significantly affect the level of expenditure. An increase in life expectancy at birth by an additional year would raise the level of public expenditure by some 0.28-0.31 percentage points. Increases in life expectancy at age 65 have, according to our estimates, an even more profound effect (from 0.40 to 0.58 percentage points) than increases in life expectancy at birth.

**Table 5** Instrumental-Variable 2SLS Country Fixed-Effects Model Estimates of Public Pension Expenditure, Specifications with Lagged Demographic Effects

Explanatory variable	Model specification		
	(1) $\rho = 1$	(2) $\rho = 2$	(3) $\rho = 3$
<b>Macroeconomic determinants</b>			
Effective retirement age	-0.145 (0.099)	-0.259** (0.110)	-0.355** (0.150)
Net replacement rate (NRR)	0.152*** (0.051)	0.178** (0.073)	0.224** (0.115)
Ratio of gross savings-to-GDP	-0.143*** (0.056)	-0.168*** (0.053)	-0.129** (0.054)
<b>Demographic controls</b>			
Lagged old-age dependency ratio	0.009 (0.049)	0.006 (0.055)	0.012 (0.073)
Lagged total fertility rate	-2.350*** (0.577)	-0.999* (0.536)	-0.768 (0.653)
Lagged life expectancy at birth	0.312* (0.171)	0.139 (.159)	0.160 (.171)
Lagged life expectancy at age 65	0.396* (0.240)	0.417* (0.233)	0.582* (0.303)

	Institutional interaction dummies		
NRR × Continental European	-0.127** (0.051)	-0.157** (0.074)	-0.186* (0.119)
NRR × Nordic	-0.156*** (0.052)	-0.183** (0.074)	-0.228* (0.116)
NRR × Mediterranean	-0.001 (0.004)	-0.003 (0.004)	-0.001 (0.004)
Observations	300	270	240
Instruments	13	13	13
R <sup>2</sup> (within)	0.220	0.089	0.093
R <sup>2</sup> (between)	0.053	0.110	0.138
R <sup>2</sup> (overall)	0.042	0.098	0.128
Wald test	84.31	95.77	84.07
p-value	0.000	0.000	0.000
Sargan-Hansen $\chi^2$ test	13.60	12.23	9.42
p-value	0.192	0.201	0.309

**Notes:** Constant term is omitted from the above presentation for brevity. Public pension expenditure as a percentage of GDP is the endogenous variable of the model in all four specifications. Robust standard errors are given in parentheses. Asterisks \*, \*\* and \*\*\* denote statistical significance at the 10 percent, 5 percent and 1 percent level, respectively.

**Source:** Authors' calculations.

As already indicated, we also estimated our model by including vectors representing interaction dummies into our empirical relationship, as time-invariant dummies in the fixed-effects model are dropped and therefore cannot be estimated. We formed interaction dummies by multiplying time-invariant dummies and net replacement rate to account for the difference in the effect of institutional features of public pension systems on the level of public pension expenditure. We set Anglo-Saxon countries with Beveridgian pension system as the comparison group, to avoid the so-called “dummy trap” (perfect multicollinearity).

As can be seen from Specification 4 of Table 4, the estimated interaction dummy coefficients suggest that raising the net replacement rates would disproportionately increase the level of public pension expenditure in Anglo-Saxon countries compared to Continental European and especially Nordic countries, whereas the group of Mediterranean countries does not seem to behave statistically significantly different in this respect. These findings are entirely robust to inclusion of various lags of demographic effects (see Table 5). Differences in the estimated impact of net replacement rate thus, depending on institutional characteristics of public pension schemes, arrive at magnitudes of different degree.

While in Bismarckian PAYG pension schemes long-term decline in total fertility rate would mean either increases in contribution rates or downward adjustment in replacement rates, increasing the level of public pension expenditure in Anglo-Saxon countries on the contributory basis would cause a disproportionate pressure on fiscal solvency of social security entitlements, had the level of expenditure increased. In fact, had the incidence of early retirement spread across countries with strict eligibility criteria for old-age and social security support, the increase in net replacement rate would probably cause greater relative rise of public pension expenditure, compared to those countries where the incidence of early retirement and lax eligibility conditions has been absorbed into higher baseline level of old-age expenditure.

Finally, in all model specifications the Sargan-Hansen test for overidentifying restrictions suggests non-rejection of the null hypothesis, indicating that the exclu-

sion restrictions are valid. Statistical significance of some lagged demographic variables largely disappears with time (see Table 5), which could in part be attributed to relatively short time span of our panel. Parametric tests on joint significance of demographic effects indicate that these are jointly significant and persist from zero-order to third-order lag. Furthermore, the institutional interaction controls are jointly significant in all model specifications.

## 6. Conclusion

In this article, we construct a theoretical model of public pension expenditure under endogenous human capital, which served as a basis for an empirical regression model, capturing the relationship between the level of public pension expenditure and key economic determinants with demographic controls. We then examined robust empirical specifications in a panel of 33 countries for the period 1998-2008.

Positive (positivist) implications of our empirical findings suggest that the aging population and diminishing fertility rates shall impose considerable pressure on long-term sustainability of public pension expenditure, measured as a percentage of GDP. The economic (and institutional) determinants of public pension expenditure seem to be much less powerful than crucial demographic controls, which is not a favourable signal for the success of current and future parametric policy measures in the pension systems.

Our estimates suggest that higher life expectancy was a significant feature behind higher old-age expenditure. Old-age dependency ratio further exerted a persistent pressure on public pensions, and declining fertility rates have led on average to negative real returns on PAYG pension schemes; however, they differed substantially in Anglo-Saxon countries from the rates in Continental and Mediterranean Europe, where these have plummeted significantly below replacement rates. Fertility rates were significantly negatively correlated with life expectancy at birth, suggesting the impact of demographic transition. In addition, our empirical estimates suggest that an increase in fertility rate would substantially decrease public pension expenditure. Although substantial shifts in fertility rates seem highly unrealistic at present, the estimates suggest the potential of a combination of economic and demographic policy measures in fighting the effects of aging and unpopular (often ostracized) parametric changes of pension systems.

Countries with lower effective retirement age either suffer from higher public pension expenditure or have poor prospects of future expenditure, whereas the phenomena of very low retirement age is confined to transition economies. Although we do not provide long-term forecasts (given the short time span of data), our estimates suggest, similarly to Verbič (2007), that raising the effective retirement age can significantly reduce the burden of public pensions.

We also found that net replacement rates correlated highly with public pension expenditure, where lower-income countries tend to experience lower net replacement rate. As the impact of an increase in net replacement rate depends on institutional characteristics of public pension schemes, we ran separate regressions to account for cross-country differentials in baseline and average replacement rates.

Our estimates suggest that increasing the net replacement rates would disproportionately hurt Anglo-Saxon countries, while the results do not suggest that public pension expenditure in these countries are inherently and disproportionately subverted by aging, relative to other countries. Obviously, one has to keep in mind that pension schemes in these countries are mostly based on the defined-contribution principle. Nonetheless, we are aware that even countries with similar institutional settings of the pension system may experience different types of pension system reforms, which leads to various effects on public pensions as a share of GDP. In this respect, a difference-in-difference approach to estimate the respective effects of public pension system reforms might be a fruitful direction for further research.

The normative implications of our findings are more difficult to ascertain. Since the majority of industrial countries live in the world of below-replacement fertility rates and persistently aging population, any decreases in effective retirement age and/or increases in net replacement rate on a permanent basis would substantially raise the level of public pension expenditure, reaching unsustainable levels. Higher spending on old-age entitlements would exert considerable burden on budget deficits and public debts, hence compromising macroeconomic stability and fiscal solvency of public pension systems.

Our results indicate that policy measures, aimed at tackling these issues (captured herein primarily in the form of economic determinants of public pension expenditure), even though separately inferior to all-embracing unfavourable demographic trends, can be effective, but have a chance of succeeding only if sufficient and consistently implemented in time in the form of pension reforms.



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