Aging population and public pensions: theory and evidence

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Abstract

Rapidly aging population in high-income countries has exerted additional pressure on the sustainability of public pension expenditure. We present a formal 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 the rise of net replacement rate. We provide and examine an empirical model of old-age expenditure in a panel of 33 countries in the period 1998–2008. Our results indicate that increases in total fertility rate and effective retirement age would reduce age-related expenditure substantially. While higher net replacement rate would alleviate the risk of old-age poverty, it would endanger long-term sustainability of public finance by imposing additional pressure on deficit and public debt.

JEL classification: H55, J11, C54.

Keywords: public pensions, aging, social security, replacement rate, life expectancy.

1. Introduction

The 2010 edition of *World Population Prospects* (Population Division 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 *panacea* to 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 the 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 the widespread adoption after Bismarckian revolution in 19th 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 Samuelson (1958), and Cass and 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 necessary 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 the retirement age, well-discussed in the microeconomic literature (*cf.* Jappelli and Modigliani 1998; Quinn *et al*. 1998; Canegrati 2007), 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 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 20th and 21st century developed world created numerous adverse consequences. The decrease in effective retirement age resulted in continuous increases in overall and marginal tax rates while the net replacement ratio was already high in high-income OECD countries since, according to Gruber and 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 (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 the 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. Although the negative consequences of adverse shocks, such as 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 the 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 the fiscal sustainability of expenditure on public pensions in the long-term. In fact, the irreversibility of public pension expenditure under high replacement rates is 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 and demographic determinants for the period 1998–2008 on 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 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.

From the empirical perspective, we examine direction and strength of the relationship between public pension expenditure and a sequence of demographic and macroeconomic determinants. In particular, we focus on the effect of old-age dependency ratio, effective retirement age, fertility rate, gross savings, net replacement 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 2, we present a brief overview of the literature, emphasizing the theoretical framework of public pensions and the relevant cross-country evidence on the evaluation of the costs and fiscal implications of aging. In

Section 3, we provide a theoretical framework, building on establishing rigorous neoclassical assumptions of our model and deriving the equilibrium conditions for the hypothesis stated. In Section 4, we outline the data sources exploited in this article. In Section 5, we briefly present the methodology and then focus on empirical evidence and the interpretation of results. Section 6 concludes with the main findings and some policy implications.

2. 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 the 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 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.

Feldstein and Liebman (2001) assessed theoretical and empirical implications of the transition from current PAYG schemes into fully funded pension schemes based on 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 Barr and Diamond (2009), Bovenberg and Knapp (2005), and Dutta *et al*. (2000). The equilibrium implications of the intergenerational redistribution within various birth cohorts suggest the finding, later reinforced by Feldstein (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 the literature identified early retirement policies as the major cause of the budgetary imbalances concerning fiscal implications of aging.

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.

Herbertsson and Orszag (2001) provided the theoretical framework to assess to 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, Blöndal and 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 decision, as cross-country differences in effective retirement age are closely related to the extent of the disincentives to work at older ages.

Baker *et al*. (2003) studied the effects of systemic incentives in Canadian Income Security System (CIS) on early retirement. Overall, their findings suggest stronger responses to Income Security system in Canada compared to the U.S. In earlier studies, Coile and Gruber (2007) established the significance of future entitlements on retirement decision 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 decision substantially.

The incidence of early retirement in transition countries had been documented by Svejnar (1996), Verbič (2007), and Polanec *et al.* (2010). 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 since high-income transition countries (Slovenia, Czech Republic) resembled the OECD average more than lower-income countries in Eastern Europe.[1] The period of transition

[1] Given the enormous variation in pensions-to-GDP ratio in transition countries, the average pension tax wedge across transition countries represented 25.5 percent compared to 16.6 percent in the OECD. The highest pension tax wedge in the early stage of transition was found in Hungary (35 percent), Slovenia (31 percent), and Poland (30 percent).

in Central and Eastern Europe was characterized by deteriorating labour market conditions (Blanchflower and 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 Czech Republic and notional defined contributions in Poland and Hungary leaned towards mitigating adverse shocks of aging population on public pension expenditure.

The accuracy of estimating public pension expenditure in the future 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 Dang *et al*. (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 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.

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 (Kotlikoff and Leibfritz 1999). Van den Noord and Herd (1993) estimated the present value of net pension liabilities in OECD countries, defined as the present value of future income based on constant contribution rates. The findings suggest that in 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 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 the subject of intensive debate in Latin America following the introduction of individual savings accounts in Chile in 1981. Bravo and Uithoff (1999) presented the quantitative assessment of implicit pension debt in Latin America in 1990, suggesting significant transitional fiscal costs in shifting from unfunded PAYG schemes to individual savings accounts.[2]

3. Expenditure on public pensions: Theory and hypotheses

The aim of this section is to provide a theoretical framework to study the effects of changing demographic and macroeconomic parameters on the size of public pension

[2] Exploiting the differences in the implicit debt of PAYG pension systems in Latin America, the enormous variation in the size of the implicit debt, ranging from 305.4 percent of GDP in Argentina to 19 percent of GDP in Ecuador, the study emphasized the concurrent change in benefit and eligibility criteria in shifting towards contribution-defined pension schemes.

expenditure. Earlier attempts to provide a coherent theoretical framework include Samuelson (1958), Cass and Yaari (1966), Diamond (1965), Blanchard (1985), and Gertler (1999). In order to analyze long-run impact of fiscal policy and social security, we believe 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, $i = 1, ..., I$, with a horizon in discrete time t, $t = 1, ..., T$. As the representative agents in countries 1, ..., I discount the future by discount factor β_i, the net lifetime benefit of the representative agent, NB_{it}, can be written as (*cf.* Acemoglu 2005):

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

where y_t represents representative agent's lifetime earnings and e_t 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:

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

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, such as the quality of infrastructure, and α_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 τ_{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:

$$\mathrm{T}_{it} = \tau_{it} y_{it}. \tag{3}$$

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

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

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

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

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

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

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

Assume that the continuum of agents (citizens), consists of old and young agents. 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 θ_i to increase the share of G_i from time *t* to *j*. Hence, the elderly will maximize the utility of the lifetime consumption as discounted net present value of A_{it}, $W\left(A_{it}\right)$. The characterization of the lifetime consumption of the elderly can be written by a Bellman (1957) equation:

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

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:

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

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

Fertility and human capital

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

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

where c_i, n_i and w_i represent household consumption, number of children and the fraction of time devoted to goods production in country *i*, respectively. In addition, ϕ_i represents 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. Child-raising activity would involve an amount k_i of time per child. Hence, parents would spend an amount $1-k_i n_i$ of time producing goods. The budget constraint of the representative household can be written as:

$$c_i \leq h_i(1-k_i h_i). \tag{10}$$

In the Lucas-type model, human capital of the household grows at a constant rate, so that $h_{it+1} = \rho_i h_{it}$, where ρ_i represents the growth rate of human capital in country *i*. In the basic setup, the household solves the following Bellman equation:

$$f\left(h_i\right) = \max_{c_i, n_i} W\left(c_i, n_i, v(\rho_i h_i)\right), \tag{11}$$

where $v\left(\rho_i h_i\right)$ is the value function describing the best possible value of the objective as a function of the state h_{it+1}. The solution for equation (11) of the form $f\left(h_i\right) = D_i h_i$, will be given where the constant D_i satisfies:

$$D_i h_i = \max_{n_i} W\left(h_i(1-k_i n_i), n_i, D_i \rho_i h_i\right). \tag{12}$$

Considering the first-order conditions to solve (9) for n_i, denoting the number of children, would be given by (*cf.* Lucas 2002, p. 155):

$$k_i n_i = \frac{\phi_i}{1-\beta_i+\phi_i}. \tag{13}$$

The solution implies that technological change, captured by the exogenous growth rate ρ_i, would not alter fertility dynamics at all, suggesting that $D_i h_i$ is increasingly related to the rate of technological change.

As simultaneous human capital decisions set the course for technological change, the growth of human capital is endogenized when ρ_i is replaced by:

$$h_{it+1} = h_{it}\lambda\left(\upsilon_{it}\right), \tag{14}$$

where υ_{it} denotes the fraction of time endowment devoted to raising one child in the household, whereas λ_i represents the growth rate of human capital. The fraction of time devoted to child-raising, υ_{it}, is assumed to increase alongside the increase in the stock of human capital, which further implies an immediate reduction in the equilibrium number of children. In addition, υ_{it} enters the equation (14) exogenously. With a minimum amount k_i of time, the resource constraint of the representative household is:

$$c_i \leq h_i\left(1-(\upsilon_i+k_i)n_i\right). \tag{15}$$

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

$$f\left(h_i\right) = \max_{c_i,n_i,\upsilon_i} W\left(c_i, n_i, g\left(h_i\lambda\left(\upsilon_i\right)\right)\right), \tag{16}$$

subject to (15). Again, letting $D_i h_i = f\left(h_i\right)$, D_i must satisfy:

$$\max_{n_i,\upsilon_i} W\left(1-(\upsilon_i+k_i)n_i, n_i, D_i\lambda\left(\upsilon_i\right)\right). \tag{17}$$

Considering the two-first order condition for W with respect to n_i and w_i, and reverting to (10), the total time expenditure for child raising would be:

$$\frac{\phi_i}{n_i} = (\upsilon_i+k_i)\frac{1-\beta_i}{1-(\upsilon_i+k_i)n_i}. \tag{18}$$

Rearranging (18) would yield the following expression:

$$(\upsilon_i+k_i)n_i = \frac{\eta_i}{1-\beta_i+\eta_i}. \tag{19}$$

Compared to exogenous technological change in (13), the solution in (19) implies that fertility rate and human capital investment remain separately unaffected. Given the parametric solution, the first-order condition to solve (18) would become:

$$\beta_i\frac{\lambda'(\upsilon_i)}{\lambda(\upsilon_i)} = n_i\frac{\phi_i}{1-\beta_i+\phi_i}, \tag{20}$$

where, following the Becker *et al*. (1990) setting, we assume that dynamic human capital growth takes the exponential form:

$$\lambda(\upsilon_i) = \bar{\varsigma}_i \upsilon_i^{\vartheta_i}, \tag{21}$$

where $\bar{\varsigma}_i$ represents baseline fertility rate, whereas ϑ_i embodies the human capital growth parameter.

For human capital growth, rearranging (20) yields:

$$\beta_i \vartheta_i = \upsilon_i n_i \frac{1-\beta_i}{1-(\upsilon_i + k_i)n_i}. \tag{22}$$

Hence, to solve for the equilibrium values for n_i and υ_i in separate forms, we use (19) and (22) to yield:

$$n_i = \frac{1}{k_i}\frac{\eta_i - \beta_i \vartheta_i}{1+\eta_i - \beta_i}; \tag{23}$$

$$\upsilon_i = \frac{\beta_i \vartheta_i}{\eta_i - \beta_i \vartheta_i}. \tag{24}$$

The solution of (23) denotes the number of children. In our empirical framework, we modify the parameter to express total fertility rate. As $\bar{\varsigma}_i$ from expression (21) represents the baseline fertility rate, we henceforth denote $\varsigma_i = n_i / F_i$ as the total fertility rate, defined as the average number of children born to a woman over her lifetime, the number of women 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 $\bar{\varsigma}_i$ leave behavioural response to the stock of human capital unaltered. An increase in ϑ_i leads to greater amount of time υ_i endowed with human capital investment, and a corresponding reduction in equilibrium fertility rate.

Life expectancy and old-age dependence

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

$$\left(\frac{N_O}{N}\right)_{it} = \Gamma(l_{it}), \tag{25}$$

where N_i and N_{Oi} 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.

The utility of the elderly upon the effective retirement age a_i, u_{Oit}, can be subsumed in the utility function of the representative household (*cf.* Lucas 2002):

$$u_{Oit} = \sum_{a_i=1}^{L_i} e^{-\pi_i a_i} , \tag{26}$$

where π_i represents the discount factor populated through the years, $a_i \in \{1, 2, ..., L_i\}$, i.e. until the representative individual's life expectancy L_i. The discount factor is derived from the representative agent's lifetime utility function.

We assume that the individuals in country *i* and 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. The expression can be written as:

$$l_{65i} = \sum_{t=1}^{T} l_{it} \left(1 - d_{ni}\right)\left(1 + d_{pi}\right), \tag{27}$$

where d_{ni} and d_{pi} capture negative and positive externalities to life expectancy during the course of individual's lifetime.[3] The net replacement ratio is defined as the ratio between real pension earnings and pre-retirement earnings in time $t \in \{1, ..., T_i'\}$. The ratio is defined as:

$$\frac{r_i}{y_i} = \omega_i \left[\sum_{t=1}^{T_i'} y_t \left(1 - \tau_{it}\right) \right], \tag{28}$$

where y_i represents agent's earnings, which are then adjusted for effective tax rate τ_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. The distribution parameter ω_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. Let K_{it} represent the stock of human capital accumulated over time *t* in country *i*. 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, denoted ψ_i, can be written as discounted over *T* periods of time:

$$\psi_i = K_{Hi} - K_{Li} = \sum_{t=1}^{T} \frac{B_{Hit}}{1 + g_{Bi}} - \sum_{t=1}^{T} \frac{B_{Lit}}{1 + g_{Bi}} , \tag{29}$$

[3] See Acemoglu and Johnson (2007) for a thorough and rigorous theoretical discussion of the overall effect of life expectancy on economic growth by including baseline differences across countries.

where B_{Hit} and B_{Lit} represent the benefits of human capital accumulation over the life cycle of the representative individual with high and low endowment of human capital, respectively, whereas g_{Bi} represents the appropriate discount rate. Hence, adjusting net replacement rate for differences in human capital return yields the aggregate net replacement rate:

$$\frac{r_i}{y_i} = \omega_i \left[\sum_{t=1}^{T_i'} y_{it} \left(1 - \tau_{it}\right) \right]^{\frac{1}{1-\psi_i}}, \tag{30}$$

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 ratio r_i / y_i is, as an instantaneous relationship, determined by the old-age dependency ratio. We derive the constraint as:

$$\frac{r_i}{y_i} = \sum_{t=1}^{T} \mu_i \frac{N_{Ai}}{N_{Oi}}, \tag{31}$$

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

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 demographic and macroeconomic determinants.

Among the demographic determinants, we assume that the level of expenditure responds negatively to the increase in total fertility rate ς_{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.

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

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

$$G_{it} = \gamma_1 + \gamma_2 \left(\frac{N_0}{N}\right)_{it} + \gamma_3 a_{it} + \gamma_4 l_{0it} + \gamma_5 l_{65it} - \gamma_6 \varsigma_{it} - \gamma_7 s_{it} + \gamma_8 \left(\frac{r}{y}\right)_{it} + v_{it}, \tag{32}$$

where $\gamma_j, j = 1,...,8$ are the parameters of the model[4] to be estimated by an appropriate econometric technique, and $v_{it} \sim IID(0, \Sigma)$ is the disturbance term.

4. Data sources

To analyze the relationship between public pension spending and demographic and macroeconomic indicators, we utilize the data available from national statistics and various other sources of data, as described below. Although we are aware of the potential measurement error 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 the relationship between public pension spending and demographic determinants.

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.[5] 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 country's 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 2011b), while the relevant data for EU countries were reported by Eurostat's *Pension Expenditure Database* (Eurostat 2011).

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.[6] The data on old-age dependency ratio for OECD member states were reported in *Pensions at a Glance* (OECD 2011a) while the data for Cyprus, Estonia, Malta and Slovenia for the period 1998–2008 were obtained from Eurostat.

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.* Filer

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[4] The sign of any given coefficient $\gamma_j, j = 1,...,8$ in expression (32) represents the expect direction of effect of that determinant on public pension expenditure (to be examined hereinafter).

[5] 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).

[6] In addition, the share of population aged 65+ could cause collinearity bias given the small size of the sample (Yamagata 2005).

and Honig 2005; Burtless and Quinn 2002; Coile and Gruber 2001). To fill in the missing gap, we collected cross-country data on average effective retirement age for the period 1998–2008. We obtained the data for effective retirement age from *Pensions at a Glance* (OECD 2011a) and Chomik and 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 (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) and *OECD Health Data* (OECD 2011) while, for Cyprus and Malta, the data were provided by Eurostat.

As discussed earlier, the impact of fertility on public pension expenditure is unambiguous (Barro and Becker 1989; Wigger 1999; Meier and Wrede 2010; Boldrin *et al*. 2005). 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 account 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* (U.S. Census Bureau 2011).

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*. Coronado 2002; Feldstein and Rangueleva 2001; Diamond 2005), we provide the 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 income distribution, there is no single international statistical source that would report the rates and enable a straightforward international comparison of net replacement rates. We therefore collected data on average net wages and average net old-age pensions to calculate replacement ratios. Table 1 reports statistical sources from which we calculated net replacement ratios for each country studied in the sample.

Table 1. Statistical sources for net replacement rates

Country	Statistical source
Australia	Australian Prudential Regulation Authority (2007)
Austria	Statistik Österreich (2011)
Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, UK	*Pensions at a Glance* (OECD 2011a)
Canada	Statistics Canada (2004)
Czech Republic	Czech Statistical Office (2011)
Greece	Hellenic Statistical Authority (2009)
Iceland	Statistics Iceland (2010); Eurostat (2010)
Japan	Japan Statistics Bureau and Statistics Center (2011)
Korea	National Pension Service (2009)
Malta	Schwarz *et al.* (2004); Human Development Group (2010)
Mexico	Instituto Nacional de Estadistica y Geografia (2010)
New Zealand	Statistics New Zealand (2010); New Zealand Superannuation Fund (2010)
United States	*Annual Statistical Supplement* (U.S. Social Security Administration 2010)

5. Methodology and empirical results

For our panel of 33 countries for the period 1998–2008, we estimated fixed-effects and random-effects empirical specifications of the model based on expression (32), using as regressors effective retirement age, savings-to-GDP ratio, and a vector of demographic variables. To check for the orthogonality of the common effects and regressors we performed Hausman's (1978) specification test for fixed versus random effects. It turned out that the test statistic was sufficiently high to reject random effects at negligible level of significance 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 expression (32) and estimated further in this section, takes the form:

$$G_{it} = \alpha_i + \mathbf{X}\boldsymbol{\gamma}_1 + \mathbf{Z}\boldsymbol{\gamma}_2 + \varepsilon_{it}\,, \tag{33}$$

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 explanatory variables, and vectors $\boldsymbol{\gamma}_1 \in \mathbb{R}^{k_1\times 1}$ 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 expression (32) can now be decomposed as $v_{it} = \alpha_i + \varepsilon_{it}$, where α_i captures time-invariant country-specific effects and $\varepsilon_{it} \sim IID(0,\Sigma)$.

As already indicated, four dummy variables were generated denoting country-specific characteristics based on the asymptotic behaviour of expenditure variances.

After having examined variance properties of old-age expenditure, we thus placed each country into Anglo-Saxon, Continental European, Nordic, or Mediterranean group[7]. 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, Gal (2010) also established the peculiar institutional originality of Mediterranean welfare states.

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 the sample coefficients could provide rigorous estimates of the differences in the impact of net replacement rates on public pension expenditure. Table 2 provides a detailed overview of the variables used in the empirical model specifications, together with the statistical sources of the data.

Table 2. Statistical sources for net replacement rates

Country	Statistical source
Australia	Australian Prudential Regulation Authority (2007)
Austria	Statistik Österreich (2011)
Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, UK	*Pensions at a Glance* (OECD 2011a)
Canada	Statistics Canada (2004)
Czech Republic	Czech Statistical Office (2011)
Greece	Hellenic Statistical Authority (2009)
Iceland	Statistics Iceland (2010); Eurostat (2010)
Japan	Japan Statistics Bureau and Statistics Center (2011)
Korea	National Pension Service (2009)
Malta	Schwarz *et al*. (2004); Human Development Group (2010)
Mexico	Instituto Nacional de Estadistica y Geografia (2010)
New Zealand	Statistics New Zealand (2010); New Zealand Superannuation Fund (2010)
United States	*Annual Statistical Supplement* (U.S. Social Security Administration 2010)

In Table 3, we provide descriptive statistics for our panel of data. The share of public pension expenditure in the GDP exerts a strong correlation with GDP per capita, although the tendency is not uniform in cross-country variation. Given 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%,

[7] Although alternative methods of country stratification prove plausible, the difficulty of stratification (choosing the relevant criteria) may lead to inconclusive estimates that could underestimate the extent of the effects discussed herein.

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 3. Descriptive statistics

Variable	Mean	Std Dev	Min	Max
Public pension expenditure (% of GDP)	8.91	3.60	0.60	14.97
Old-age dependency ratio	23.46	4.91	9.03	37.00
Effective retirement age	62.26	3.56	56.00	74.98
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 savings (% of GDP)	21.77	5.90	5.20	39.44
Net replacement rate (average net pension as % of full-time earnings)	60.8	23.9	13.9	120.9

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. Excluding Mexico as a middle-income country from our sample, 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 rate.

In Table 4, we report the results of fixed-effect estimation of the panel-data model, represented by expression (33). Both types of model specification, i.e. with and without interaction dummies are estimated and reported. First, our estimates suggest that the baseline level of public pension expenditure (the constant term, where statistically significant) ranges from 12.7% to 17.5% of GDP. The estimates further suggest that old-age dependency ratio exerts a persistent effect on public pensions as a share of GDP. The estimated effect suggests that 1 percentage point increase in dependency ratio increases the share of public pensions in GDP on average by about 0.11 percentage points, holding all other factors constant. Although the literature suggests (*cf.* Seshamani and Gray 2002; Lee and Edwards 2001; Stensnes and 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 the other determinants of public pension expenditure.

Our estimates show that 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 specification 1 the estimated effect is considerably lower, compared to specifications 2 and 3. Taking into account the latter two 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 0.18–0.22 percentage points.

Table 4. Fixed-effects model estimates of public pension expenditure

Explanatory variable	Model specification			
	(1)	(2)	(3)	(4)
Constant term	14.919*** (2.764)	5.006 (3.219)	17.484*** (2.774)	12.749*** (2.629)
Old-age dependency ratio	0.111*** (0.031)	0.013 (0.035)	0.038 (0.035)	0.105*** (0.029)
Effective retirement age	–0.082* (0.046)	–0.216*** (0.050)	–0.176*** (0.050)	–0.055 (0.043)
Total fertility rate	–1.552*** (0.340)	–2.119*** (0.342)	–2.001*** (0.350)	–1.573*** (0.320)
Ratio of gross savings to GDP	–0.101*** (0.014)	–0.086*** (0.014)	–0.090*** (0.014)	–0.088*** (0.014)
Net replacement rate (NRR)	0.019*** (0.004)	0.027*** (0.004)	0.024*** (0.004)	0.019*** (0.005)
Life expectancy at birth	–	0.265*** (0.049)	–	–
Life expectancy at age 65	–	–	0.289*** (0.072)	–
NRR × Anglo-Saxon	–	–	–	0.062*** (0.015)
NRR × Nordic	–	–	–	–0.036*** (0.009)
NRR × Mediterranean	–	–	–	0.030*** (0.014)
Observations	363	363	363	363
R^2 (within)	0.2610	0.3255	0.2965	0.3508
R^2 (between)	0.6604	0.6880	0.6909	0.1785
R^2 (overall)	0.6378	0.6702	0.6693	0.1827
F–test	22.96	25.67	22.75	21.75
p–value	0.0000	0.0000	0.0000	0.0000
Hausman test	74.03	58.26	295.28	56.04
p–value	0.0000	0.0000	0.0000	0.0000

Notes: Public pension expenditure as percentage of GDP is the endogenous variable of the model in all four specifications. Standard errors are given in parentheses. Asterisks *, ** and *** denote significance at the 10 percent, 5 percent and 1 percent level, respectively.

Source: Authors' calculations.

In comparison to the earlier attempts to measure the impact of aging on public pensions that do not incorporate the equilibrium fertility rate as a covariate (*cf.* Disney 2000; Caldwell *et al.* 2002; Bongaarts 2004), we tried to derive a framework that includes this relationship. The results suggest that higher fertility rates would significantly reduce the pension-to-GDP ratio (see Table 4). An increase in fertility rate by one child per woman would reduce public pension expenditure in the share of GDP on average by 1.55–2.12 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. Even half of the referred change would reduce public pension expenditure by as much as 1 percentage point.

Similarly, the increase in savings-to-GDP ratio would reduce public pension expenditure in 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 1 percentage point increase in savings-to-GDP ratio would decrease public pensions on average, *ceteris paribus*, by some 0.09 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.

Conversely, increases in longevity and life expectancy at various ages and decreases in total fertility rate caused 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. In Table 4 we tested the impact of life expectancy at birth (specification 2) and at age 65 (specification 3) 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 (specification 2) by additional year would raise the level of public expenditure on average by 0.26 percentage points. In specification 3, we netted out the impact life expectancy at birth and estimated the effect of higher life expectancy at age 65. The estimate then suggests that an increase in life expectancy at age 65 by additional year would raise the level of public pension expenditure on average by 0.29 percentage points.

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 1 percentage point would, on average, cause the rise of public pension expenditure in GDP by some 0.02–0.03 percentage points (specifications 1–3), holding demographic covariates, savings-to-GDP ratio and effective retirement age constant. As will become clear shortly, the estimates vary due to very different institutional frameworks of pension systems that make capturing the effect of net replacement rate on public pension expenditure in the panel-data framework less straightforward.

Consequently, we also estimated expression (33) 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 Continental European countries with Bismarckian welfare state as the comparison group, to avoid the so-called "dummy trap" (perfect multicollinearity).

As can be seen from specification 4 (Table 4), the estimated interaction dummy coefficients suggest that raising net replacement rates would disproportionally increase the level of public pension expenditure, especially in Anglo-Saxon countries and Mediterranean countries compared to Continental European countries, whereas for Nordic countries the estimated coefficient was negative. In particular, this suggests that an increase in net replacement rate by 1 percentage point would, on average, increase public pension expenditure in GDP by 0.06 percentage points more in the Anglo-Saxon countries, by 0.03 percentage points more in the Mediterranean countries and by 0.04

percentage points less in the Nordic countries, compared to the Continental European countries. 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 ratios, 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. Increasing the net replacement rate would disproportionately hurt Mediterranean countries compared to Continental Europe, given higher old-age dependency ratio and negligible fertility rates in Italy and Spain, as well as lower effective retirement age causing the incidence of early retirement. 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.

6. Conclusion

Over the last decades, industrialized countries experienced a continuous decline and convergence of fertility rates to the level below replacement rate. Lower effective retirement age for men and women that substantially deviate from statutory age reflects not only changing fertility patterns but, moreover, a persistent increases in life expectancy at age 65 and significant spikes in net replacement rates, which took place from 1980s onwards. Under the aging population, the Bismarckian PAYG pension system, founded on contributory basis, suffered from the setback of unfavourable demographic conditions and effective retirement age below the threshold that would incur a growing implicit PAYG debt. In particular, lower effective retirement age boosted the incidence of early retirement, which raised the present value of fiscal obligations to current and prospective generation of pensioners.

In this article, we provided a framework in which life expectancy at various ages is increasing due to the excess of positive externalities over negative externalities. We assumed that higher life expectancy leads to the income effect, causing an upward pressure on net replacement rates over time and increasing the level of age-related expenditure, whereas the baseline cross-country differential in the level of expenditure captures the baseline differences in life expectancy. Following Becker *et al*. (1990), we assumed that fertility rate is determined endogenously, where increases in human capital endowment reduce the equilibrium fertility rate and increase per capita amount of time for child raising while, on the other hand, causing a disproportionate rise in old-age dependency ratio. Based on these propositions, we constructed an empirical regression model capturing the relationship between the level of public pension expenditure and key economic and demographic determinants. We then examined robust empirical specifications in the panel of 33 countries for the period 1998–2008.

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

Although increasing life expectancy has been at the forefront of arguments for higher effective retirement age, there is a considerable gap in the economic literature in documenting the overall impact of higher life expectancy on public pension expenditure. We provided a model in which positive externalities account for the increasing life expectancy, whereas continuous externalities at later age exert additional pressure on net replacement ratio and thus on the overall share of public pension expenditure in GDP. Our estimates suggest that higher life expectancy was a significant feature behind higher old-age expenditure. In particular, a one-year improvement in life expectancy increased the public pension expenditure on average by 0.28 percentage points per year, keeping all other determinants unchanged.

Declining fertility rates have led on average to negative real return 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. Our empirical estimates suggest that an increase in fertility rate by one child per woman would decrease public pension expenditure on average by 1.8 percentage points, neglecting (first and foremost) the impact of other demographic covariates. Although such shifts seem highly unrealistic at present, the estimate suggests 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.

Moreover, our estimates suggest that old-age dependency ratio exerted a persistent effect on public pensions as a share of GDP. Namely, a one percentage point increase in dependency ratio increased the share of public pensions in GDP on average by about 0.11 percentage points, controlling for the other determinants. We thus found a relationship that, even though expected and statistically significant, is considerably weaker than usually suggested by economic literature.

Even though effective retirement age increased in 26 out of 33 countries studied in our panel, it is still significantly lower in the long-term perspective as documented by Chomik and Whitehouse (2010). 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. We calculated average effective retirement age for each country as an unweighted average of male and female effective retirement age. Although we have not provided the long-term impact of lower retirement age (given the lack of reliable data), our estimates suggest that raising the effective retirement age by 1 year can reduce the burden of public pensions as a share of GDP on average by as much as 0.22 percentage point per year, keeping all other determinants unchanged.

We also computed the net replacement rate as a ratio of average pensionable income and average earnings prior to withdrawal from the labour market and established that they correlated highly with public pension expenditure, where lower-income countries tended to experience lower net replacement rate. Our article provides direct estimates of effects of changing net replacement rates on public pension expenditure, which suggest that raising the net replacement rate by 1 percentage point would increase annual public pension expenditure in the share of GDP by some 0.02–0.03 percentage points, holding everything else constant.

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 ratios. Our estimates suggested that increasing net replacement rates would disproportionally hurt Anglo-Saxon countries, while the results do not suggest that public pension expenditure in these countries are inherently and disproportionally subverted by aging relative to other countries. Obviously, one has to keep in mind that pension schemes in these countries are mostly based on defined-contribution principle. On the other hand, comparing countries with Bismarckian PAYG pension system, we arrive at the conclusion that Mediterranean countries, facing "benign" fertility rates and rapidly aging population, would suffer disproportionately from an increase in net replacement rate, whereas the observed effect for Nordic countries relative to Bismarckian welfare states of the Continental Europe would be reduced substantially, partly reflecting above-average fertility rates that absorb adverse shocks, such as an increase in net replacement rates to mitigate the risk of old-age poverty.

As a consequence, the share of public pension expenditure in the GDP exerted on average a strong correlation with GDP per capita; however, countries with stronger fully funded pension systems have experienced stable or falling ratio of public pensions-to-GDP over time, with mild upward tendencies. Increasing aggregate savings had a favourable effect on public pension expenditure, which is especially relevant for economies with a funded pension system. The effects was relatively small, though; a one percentage point increase in aggregate savings as a share of GDP would reduce on average the share of public pensions in the GDP by 0.09 percentage points per year, keeping all other determinants unchanged.

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 given that expected increase in life expectancy would remain unaltered. Higher spending on old-age entitlements, measured as a fraction of GDP, would exert considerable burden on budget deficits and public debt, hence compromising macroeconomic stability and fiscal solvency of public pension system, as unfunded pension liabilities already give rise to considerable tensions regarding the stability of public finance across high-income countries.

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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