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Pension reform, employment by age, and long-run growth

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Abstract

We study the effects of pension reform in a four-period OLG model for an open economy where hours worked by three active generations, education of the young, the retirement decision of older workers, and aggregate per capita growth, are endogenous. Next to the characteristics of the pension system, our model assigns an important role to the composition of fiscal policy. We find that the model explains the facts remarkably well for many OECD countries.

Our simulation results prefer an intelligent pay-as-you-go pension system above a fully-funded private system. When it comes to promoting employment, human capital, growth, and welfare, positive effects in a PAYG system are the strongest when it includes a tight link between individual labor income (and contributions) and the pension, and when it attaches a high weight to labor income earned as an older worker to compute the pension assessment base.

Key words: employment by age, endogenous growth, retirement, pension reform, overlapping generations

JEL Classification: E62, H55, J22, O41

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1. Introduction

Concern for the long-run financial viability of public pension systems has put pension reform high on the agenda of policy makers and researchers. The past two decades have seen a wave of reforms in many countries (Whitehouse et al., 2009). At the same time the literature on pension economics has grown rapidly (see e.g. Lindbeck and Persson, 2003; Fenge and Pestieau, 2005; Barr, 2006; and many recent papers that we refer to below).

To face the pension challenge, there seems to be general agreement on the need for higher employment, especially among older individuals, and higher productivity growth. Many studies have documented how the pension system may affect the incentives of individuals of different ages to work (e.g. Auerbach *et al.*, 1989; Gruber and Wise, 2002; Cremer *et al.*, 2008; Sánchez Martín, 2010; Börsch-Supan and Ludwig, 2010; Fisher and Keuschnigg, 2010; Jaag *et al.*, 2010; de la Croix *et al.*, 2010). Others have investigated the relationship between the pension system and investment in human capital formation, as a major determinant of productivity growth (e.g. Zhang, 1995; Kemnitz and Wigger, 2000; Docquier and Paddison, 2003; Zhang and Zhang, 2003; Kaganovich and Meier, 2008; Hachon, 2010; Le Garrec, 2011). Still others have demonstrated the crucial role of human capital formation to counteract the negative effects of population ageing on per capita output (e.g. Docquier and Michel, 1999; Fougère *et al.*, 2009; Ludwig *et al.*, 2010). Consensus on what pension reform would serve the goals of higher employment, productivity growth, and welfare best, has however not been reached. The results in some papers support parametric adjustments in the pay-as-you-go (PAYG) system that most countries rely on. Other papers prefer a gradual move to an actuarially neutral fully-funded private system. Often, differences in the particular specification of the model economy that is used for the analysis may explain the differences in results.

In this paper we construct and parameterize a general equilibrium four-period OLG model for an open economy. The model explains hours of work of young, middle-aged and older individuals, education and human capital formation of the young, the retirement decision of the older generation, and aggregate per capita growth. It includes a public PAYG old-age pension system which pays out pensions to a fourth generation of retired. The statutory retirement age in our model is 65 and exogenous. Old-age pensions are paid from this age onwards. Individuals, however, may optimally choose a lower effective (early) retirement age. The government in the model sets tax rates on labor, capital and consumption. It allocates its revenue to productive expenditures (mainly for education), consumption, 'non-employment' benefits (including early retirement benefits) and old-age pension benefits. Our aim is to investigate the effects of various parametric adjustments in the early retirement regime and in the old-age PAYG pension system. These parametric adjustments include changes in benefit levels, changes in the link between benefits and individual contributions, and changes in the weights of the three active periods in the computation of the old-age pension assessment base, i.e. earned labor income used to calculate pension benefits. We also consider the effects of moving to full private capital funding.

Our main contribution in this paper is to study the impact of pension systems on employment by age, the effective retirement decision, education and growth, and the welfare of current and future generations within one coherent framework, where all these variables are endogenous. Here we differ from the existing literature. The above mentioned studies either investigate incentives to work in a model with exogenous human capital and growth, or investigate human capital and growth while ignoring the labor-leisure choice and the endogeneity of labor supply[1]. Our approach allows to fully take into account the mutual relationships between all variables, which will matter for the size and possibly the direction of policy effects. Various channels exist in our model whereby the effects of changes in employment and changes in capital formation reinforce each other. For example, if employment rises, so will the marginal productivity of physical capital and the incentive to invest. Also, if people postpone retirement and work longer, the return to investment in education will rise, and so may human capital and growth. Conversely, policies that promote education will encourage people to work longer since they will then get a higher return from their investment. Our model also contains channels where employment and growth will move in opposite directions. One channel follows from the possible tradeoff between employment of the young and education. Pension reform which discourages employment of the young may still be positive if this contributes to education and growth. As we show in this paper, the final effects of pension reform depend on all these interactions. It will be important to have a realistic estimate of key parameters, for example in the specification of the human capital production function, or in labor supply by age.

Next to the endogeneity of all key variables, our model contains a number of other features which matter for the analysis of the effects of pension reform, but which are often ignored in the literature. The most important of these is a realistic modeling of the transition from work to retirement, and the role of early retirement regimes. These regimes play an important role in many countries. We explicitly distinguish the effective (early) retirement age, which is optimally chosen, and the statutory retirement age, which is exogenous (see also Heijdra and Romp, 2009; de la Croix *et al.*, 2010). Old-age pensions in our model are paid only from the statutory retirement age onwards. A key implication is that old-age pensions do not directly raise the opportunity cost of working in our model. Early retirement benefits do. In the literature this distinction is often not made (e.g. Hu, 1979; Börsch-Supan *et al.*, 2006; Jaag *et al.*, 2010; Fisher and Keuschnigg, 2010). It may obviously affect the evaluation of old-age pension reform. As a second feature, we allow individual pension benefits in the PAYG system to depend on accumulated individual labor income and contributions, rather than on average per capita labor income. Many countries have initiated reforms that strengthen this individual contributions - benefit link. Lindbeck and Persson (2003), Zhang and Zhang (2003) and Jaag *et al.* (2010) demonstrate the importance of taking this link into account. Others however ignore it when modeling a PAYG system, which may overstate the distortion induced by this system (e.g. Börsch-Supan and Ludwig, 2010; Ludwig *et al.*, 2010)[2]. Another characteristic which affects our results, is the assumption of an open economy. It has been shown that pension reform may have profound effects on international capital flows (e.g. Börsch-Supan *et al.*, 2006). In an open economy, changes in national savings need not feed through into investment in the domestic economy. Factor price changes may be much weaker than presumed in closed economy models. Clearly, this may affect employment and human capital formation. As a final feature, we assume that demography and population are constant in our model. Although ageing is obviously a crucial factor behind pension reform in many countries, this assumption need not be a limitation to disentangle behavioral effects from pension reform (see also Jaag *et al.*, 2010; Fisher and Keuschnigg, 2010).

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[1] Fougère *et al.* (2009) and Ludwig *et al.* (2010) also develop a model with endogenous employment by age and human capital, but they have exogenous growth. Moreover, Fougère *et al.* (2009) do not study pension reform.

[2] Long ago, Sheshinski (1978) already showed in a model that a pension system can encourage work and late retirement if benefits increase in the retirement date. This idea has been picked up also by Gruber and Wise (2002).

To study the effects of pension reform we parameterize, numerically solve, and simulate our model. Before we do that, however, we test its empirical validity for a group of 13 OECD countries. The countries that we consider include the US, the core countries of the euro area, the UK, Canada and the Nordic countries. Our main motivation for this test goes back to Stokey and Rebelo (1995), who find extreme variation in the predictions of existing calibrated models investigating the effects of public policy in the literature. Before using a parameterized theoretical model for policy simulations, we would therefore like to get at least some minimal evidence that the model's predictions are within reliable bands. Our procedure is as follows. We impose common technology and preference parameters on all countries, but country-specific fiscal policy and pension system parameters. Simulating the model for each country we find that its predictions match the main facts in most countries. These facts concern observed hours of work in three age groups (20-34, 35-49, 50-64), education of the young (20-34), the effective retirement age, and per capita growth since 1995. We conclude that the model translates observable policy differences into performance differences which are roughly in line with observations in the data.

Having established its empirical reliability, we then use the model for policy simulations. Our simulations assess to what extent pension reform may contribute to employment, growth and welfare. Our results speak in favor of an intelligent PAYG system. This system contains a close link between old-age pensions and individual labor earnings and contributions via a high pension replacement rate. Even more important is a high weight of labor income (i.e. hours worked and human capital) earned as an older worker in the pension assessment base. Pension reform in this direction encourages young individuals to study and build human capital, which promotes long-run growth. Furthermore, it encourages older workers to postpone retirement. Strengthening the link between one's future old-age pension, on the one hand, and one's human capital and labor supply when older, on the other, introduces strong financial incentives which may bring about important changes in behavior. Positive effects on employment, the effective retirement age, and growth, raise the government's resources, which makes it possible to finance a larger pension burden. Our results prefer a reform of the PAYG system along these lines above a movement to a fully funded private system, both from the perspective of employment, growth and welfare. We demonstrate the importance of the particular characteristics in our model that we have emphasized above. Finally, whereas our results show that old-age pension benefits may rise in an intelligent PAYG system, early retirement benefits must be reduced.

This paper confirms that the pension system can be a valuable policy instrument in its own right, as recently emphasized also by Cigno (2010). When it comes to employment, our results are in line with arguments for a change of the rules in actuarial direction as explained by Gruber and Wise (2002), Lindbeck and Persson (2003) and Cigno (2010) among others. Furthermore, our results demonstrate the importance of also taking into account possible effects on education, human capital and growth.

The structure of this paper is as follows. In Section 2 we document differences in employment by age, education of the young, the effective retirement age, and per capita growth across 13 OECD countries since 1995. Section 3 sets out our model. In Section 4 we calibrate the model on actual data and confront its predictions with the facts described in Section 2. Section 5 includes the results of a range of model simulations. We investigate the steady state effects of various reforms of the pension system. We also study transitional dynamics, and the welfare effects per generation. Section 6 concludes the paper.

2. Cross-country differences in employment by age, tertiary education and per capita growth

Table 1 contains key data on employment, education and growth in 13 OECD countries in 1995-2007. One would like a reliable model to match the main cross-country differences reported here. The employment rate in hours (*n*) indicates the fraction of potential hours that are actually being worked by the average person in one of three age groups (20-34, 35-49, 50-64). Potential hours are 2080 per person per year (52 weeks times 40 hours per week). The observed employment rate rises if more people in an age group have a job, and if the employed work more hours. The employment rate in the age group of 50 to 64 is also affected by the average age at which older workers withdraw from the labor force. We also include the effective retirement age in Table 1. In most countries, this age is well below the official age to receive old-age pensions (65 in most countries, 60 in France). The education rate (*e*) is our proxy for the fraction of time spent studying by the average person of age 20-34. It has been calculated as the total number of students in full-time equivalents, divided by total population in this age group. Our data for (average annual) real per capita growth concern real potential GDP per person of working age. We refer to Appendix 1 for further details on the calculation of all our data, and on the assumptions that we have to make.

Table 1
Employment rate in hours (*n*), effective retirement age, education rate (*e*) and per capita growth in OECD countries (1995-2006/7)

	n_1 (20-34)	n_2 (35-49)	n_3 (50-64)	*Effective retirement age*	*e*	*Annual real per capita growth*
Austria	59.9	64.3	34.7	59.5	12.5	2.06
Belgium	51.1	56.8	29.3	57.9	14.1	1.77
France	48.7	60.3	38.0	58.8	14.9	1.54
Germany	49.7	55.2	34.9	61.1	17.2	1.56
Italy	50.1	61.9	33.8	60.1	12.6	1.30
Netherlands	50.8	54.6	34.2	60.0	14.7	2.20
Core euro area Average	**51.7**	**58.8**	**34.2**	**59.6**	**14.3**	**1.74**
Denmark	56.2	66.7	49.6	62.2	21.7	1.81
Finland	55.6	69.0	47.3	60.2	23.1	2.72
Norway	51.9	60.9	50.6	63.1	18.1	2.29
Sweden	53.6	66.1	55.4	63.4	17.7	2.18
Nordic Average	**54.3**	**65.6**	**50.7**	**62.2**	**20.2**	**2.25**
US	**65.6**	**74.2**	**59.6**	**64.2**	**12.8**	**1.54**
UK	60.8	68.4	49.4	62.0	12.3	2.13
Canada	60.9	69.5	50.4	62.1	13.6	1.68
All country average	**55.0**	**63.7**	**43.6**	**61.1**	**15.8**	**1.91**

Data sources: OECD (see Appendix 1); data description: see main text and Appendix 1. The data for employment and growth concern 1995-2007, those for education 1995-2006. The effective retirement age is an average for 1995-2006. All data are in percent, except the retirement age.

As is well-known, middle-aged individuals work most hours, followed by the young. The older generation works the lowest number of hours. Average employment rates over all countries in these three age groups are 55.0%, 63.7% and 43.6% respectively. Furthermore, the data reveal strong cross-country differences. We observe the highest employment rates in each age group in the US. Employment rates are much lower in the core countries of the euro area. The Nordic countries take intermediate positions, although they are close to the core euro area for the younger generation. The latter, however, seems to be related to education. Young people's participation in education is by far the highest in the Nordic countries. These countries also show the highest potential per capita growth rates. On average, growth in the core euro area and the US was more than 0.5 percentage points lower in the period under consideration. The US and the other Anglo-Saxon countries tend to have the lowest participation in education among people of age 20 to 34. Finally, we note that the effective retirement age also varies across countries. The retirement age is quite low in Belgium (57.9) and France (58.8). By contrast, individuals in Nordic or Anglo-Saxon countries participate longer. Unsurprisingly, correlation between the effective retirement age and the employment rate among older workers (n_3) is very high (0.89).

3. The model

Our analytical framework consists of a computable four-period OLG model for a small open economy. We assume perfect international mobility of physical capital but immobile labor and human capital. Seminal work in the OLG tradition has been done by Samuelson (1958) and Diamond (1965). Auerbach and Kotlikoff (1987) initiated the study of public finance shocks in a computable OLG model. Buiter and Kletzer (1993) developed an open economy version of the model with endogenous growth, putting human capital at the centre. As we have documented in Section 1, a huge literature has used OLG models to study the behavioral effects of the pension system, either on employment, assuming exogenous growth, or on human capital and growth, assuming exogenous employment. New in our model is that employment by age, education and human capital, and growth, are jointly endogenous.

We consider three active adult generations, the young, the middle-aged and the older, and one generation of retired agents. All generations are of equal size, normalized to 1. Population is constant. Within each generation agents are homogeneous. Individuals enter the model at age 20. Each period is modeled to last for 15 years. Young people can choose either to work and generate labor income, to study and build human capital, or to devote time to 'leisure' (including other non-market activities). Middle-aged and older workers do not study anymore, they only work or have 'leisure'. The statutory old-age retirement age is 65. Individuals may however optimally choose to leave the labor force sooner in a regime of early retirement. Domestic firms act competitively and employ physical capital together with existing technology and effective labor provided by the three active generations. A final important assumption is that education generates a positive externality in the sense of Azariadis and Drazen (1990). The average level of human capital of a middle-aged generation is inherited by the next young generation.

In what follows, we concentrate on the core elements of the model: the optimizing behavior of individuals, the production of effective human capital, the behavior of domestic firms and the determination of aggregate output and growth, capital and wages.

3.1. Individuals

An individual reaching age 20 in *t* maximizes an intertemporal utility function of the form:

$$u^t = \sum_{j=1}^{4} \beta^{j-1} \left(\ln c_j^t + \gamma_j \frac{\ell_j^{t\,1-\theta}}{1-\theta} \right) \tag{1}$$

with γ_j>0, θ>0 *(*$\theta \neq$1) and where:

$$\ell_1^t = 1 - n_1^t - e^t \tag{2}$$

$$\ell_2^t = 1 - n_2^t \tag{3}$$

$$\ell_3^t = \Omega\left(\pi \left(R^t (1 - \tilde{n}_3^t) \right)^{1-(1/\rho)} + (1-\pi)\left(1 - R^t\right)^{1-(1/\rho)} \right)^{\rho/(\rho-1)} \tag{4}$$

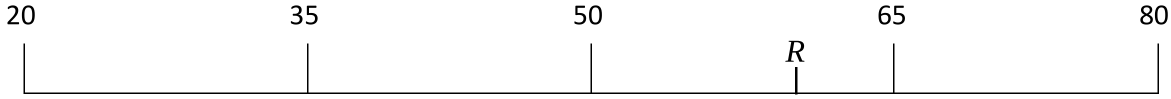
and $\ell_4^t = 1$

Lifetime utility (1) depends on consumption (c_j) and enjoyed 'leisure' (ℓ_j) in each period of life. Superscript *t* indicates the period of youth, when the individual comes into the model. Subscript *j* refers to the *j*th period of life. Furthermore, β is the discount factor (0<β<1). The intertemporal elasticity of substitution in consumption is 1, the intertemporal elasticity to substitute leisure 1/θ. Finally, γ specifies the relative value of 'leisure' versus consumption. Note that γ may be different in each period of life. Except for the latter assumption, our specification of the instantaneous utility function is quite common in the macro literature (e.g. Benhabib and Farmer, 1994; Rogerson, 2007).

Figure 1 shows the life-cycle of an individual reaching age 20 in *t*. Individuals choose time devoted to work (n_j) in the three active periods and education time (e_1) when young. Since individuals only allocate time to education in their first period, we drop the subscript 1 in what follows. Time endowment is normalized to 1 in each period. The determination of early retirement is part of individuals' optimal choice of 'leisure' time in the third period of life (50-65). Individuals choose *R* which relates to the optimal effective retirement age and which is defined as the fraction of time between age 50 and 65 that the individual participates in the labor market; *(1-R)* is then time in early retirement. We use n_3 to denote the fraction of time devoted to work between 50 and 65, and $\tilde{n}_3$ as the fraction of time devoted to work before early retirement, but after 50. As labor market exit is irreversible and post-retirement employment is not allowed in our model, the relationship between n_3 and $\tilde{n}_3$ is as follows: $n_3 = R.\tilde{n}_3$.

In the first two periods of active life, 'leisure' falls in labor supply and in education time (Equations 2 and 3). In the third period, 'leisure' time consists of two parts: non-employment time before the effective retirement age ($R(1-\tilde{n}_3)$), and time in early retirement after it *(1-R).* Equation (4) then describes composite enjoyed 'leisure' of an older worker as a CES-function of both parts. We assume imperfect substitutability between the two leisure types. The idea here is that 'leisure' time after and between periods of work is not the same as 'leisure' time in periods when individuals are not economically active anymore[3]. Equation (4) expresses that individuals prefer to have a balanced combination of both rather than an ‘extreme’ amount of one of them (and very little of the other). In this equation ρ is the constant elasticity of substitution, π is a usual share parameter and Ω is added as a normalization constant such that the magnitude of ℓ_3 corresponds to the magnitude of total leisure time $1\text{-}n_3$.[4] The latter assumption allows to interpret γ_3 as the relative value of ‘leisure’ versus consumption in the third period, comparable to γ_1 and γ_2.

Figure 1. Life-cycle of an individual of generation *t*



Period	*t*	*t+1*	*t+2*	*t+3*
Work	n_1^t	n_2^t	$n_3^t = R^t\tilde{n}_3^t$	*0*
Study	e_1^t	*0*	*0*	*0*
‘Leisure’ time	$1 - n_1^t - e_1^t$	$1 - n_2^t$	$R(1-\tilde{n}_3^t) + (1-R)$	*1*

Individuals will choose consumption, labor supply, education and their effective retirement age to maximize Equation (1), subject to Equations (2)-(4) and the constraints described in (5)-(12).

$$(1+\tau_c)c_1^t + a_1^t = w_t h_1^t n_1^t (1-\tau_1) + b_1 w_t h_1^t (1-\tau_1)(1-n_1^t - e^t) + z_t \tag{5}$$

$$(1+\tau_c)c_2^t + a_2^t = w_{t+1} h_2^t n_2^t (1-\tau_2) + b_2 w_{t+1} h_2^t (1-\tau_2)(1-n_2^t) + (1+r_{t+1})a_1^t + z_{t+1} \tag{6}$$

$$\begin{aligned}(1+\tau_c)c_3^t + a_3^t = {} & w_{t+2} h_3^t R^t \tilde{n}_3^t (1-\tau_3) + b_{3a} w_{t+2} h_3^t (1-\tau_3) R^t (1-\tilde{n}_3^t) \\ & + b_{3b} w_{t+2} h_3^t (1-\tau_3)(1-R^t) + (1+r_{t+2})a_2^t + z_{t+2}\end{aligned} \tag{7}$$

$$(1+\tau_c)c_4^t = (1+r_{t+3})a_3^t + pp_4^t + z_{t+3} \tag{8}$$

with: $$h_1^t = h_2^{t-1} \tag{9}$$

$$h_3^t = h_2^t = \left(1+\psi(e^t, g_y, q)\right) h_1^t \qquad \psi>0,\ \psi'(.)>0 \tag{10}$$

and: $$pp_4^t = b_{4a}\sum_{j=1}^{3}\left(p_j w_{t+j-1} h_j^t n_j^t (1-\tau_j) \prod_{i=j}^{3} x_{t+i-1} \right) + b_{4b}\frac{1}{3}\sum_{j=1}^{3}\left(w_{t+3} h_j^{t+4-j} n_j^{t+4-j} (1-\tau_j) \right) \tag{11}$$

[3] The former may be particularly valuable from the perspective of relaxation and time to spend on personal activities of short duration. The latter may be valuable to enjoy activities which take more time and ask for longer term commitment (e.g. long journeys, non-market activity as a volunteer).
[4] The results in this paper are not in any way influenced by the magnitude of π, Ω or ρ (see Section 4.1.).

$$\text{with : } \begin{array}{l} 0 \le p_j \le 1, \\ \sum_{j=1}^{3} p_j = 1, \\ x_t = 1 + \psi(e^t, g_y, q), \\ \text{and } n_3^t = R^t \tilde{n}_3^t \end{array} \qquad (12)$$

The LHS of Equations (5)-(8) shows that individuals allocate their disposable income to consumption (including consumption taxes, τ_c) and the accumulation of non-human wealth *a*. We denote by a_j^t the stock of wealth that an individual who enters the model at time *t* holds at the end of his *j*th period of life. During the three periods of active life disposable income at the RHS includes after-tax labor income, non-employment benefits, interest income and lump sum transfers. In each equation, w_k stands for the real wage per unit of effective labor at time *k*, r_k is the exogenous (world) real interest rate at time *k*, and z_k is the lump sum transfer that the government pays out to all individuals at time *k*. Effective labor of an individual depends on hours worked (n_j^t) and effective human capital (h_j^t). Since young individuals allocate a fraction n_1^t of their time to work, and pay a tax rate on labor income τ_1, they earn an after-tax real wage equal to $w_t h_1^t n_1^t (1-\tau_1)$. After-tax labor income of middle-aged and older workers in equations (6) and (7) is determined similarly. A young worker inherits his effective human capital from the middle-aged generation, as shown in Equation (9). During the second and third period, workers supply more units of effective human capital. It is our assumption in Equation (10) that *h* rises in education time when young (*e*), productive government spending in percent of GDP (g_y, mainly education) and the quality of education (*q*). We specify and discuss the effective human capital production function in Section 3.2. Individuals take g_y and *q* as exogenous. We assume that human capital remains unchanged between the second and third period. We have in mind that learning by doing in work may counteract depreciation.

For the fraction of time that young, middle-aged and older individuals are inactive, they receive a non-employment benefit from the government. Older workers may be eligible to two kinds of benefits: standard non-employment benefits (analogous to what young and middle-aged workers receive) as long as they are on the labor market, and early retirement benefits after having withdrawn from the labor market. All benefits are defined as a proportion of the after-tax wage of a full-time worker. The replacement rate for standard non-employment benefits is b_j with *j*=1,2,3a, for early retirement benefits it is b_{3b}.[5] After the statutory retirement age (65) individuals have no labor income and no non-employment benefits anymore. They then receive an old-age pension benefit (*pp*) and the lump sum transfer. Equation (11) describes the old-age pension. We assume a public PAYG pension system in which pensions in period *k* are financed by contributions (labor taxes) from the active generations in that period *k* (see below). Individual net pension benefits consist of two

[5] Our approach to model early retirement benefits as a function of a worker's last labor income, similar to standard non-employment benefits, reflects regulation and/or common practice in many countries. In some countries (e.g. Belgium, the Netherlands) workers can enter the early retirement regime only from employment, with their benefits being linked to the last wage. In other countries (e.g. Denmark) there is only access from unemployment, with the early retirement benefit being linked to the unemployment benefit (Salomäki, 2003). As to common practice, Duval (2003) confirms that in many countries, unemployment-related or disability benefits can be used *de facto* to bridge the time between the effective retirement age and old-age pension eligibility. Again there is a link between benefits and former wages.

components. A first one is related to the individual's earlier net labor income. It is a fraction of his so-called pension base, i.e. a weighted average of *revalued* net labor income in each of the three active periods of life. The net replacement rate is b_{4a}. The parameters p_1, p_2 and p_3 represent the weights attached to each period. This part of the pension rises in the individual's hours of work n_j^t and his human capital h_j^t. It will be lower when the individual retires early (lower R^t). Thanks to revaluation, this part of the net pension is adjusted to increases in the overall standard of living between the time that workers build their pension entitlements and the time that they receive the pension. We assume that past earnings are revalued in line with economy-wide wage growth x and hence follow practice in many OECD countries (OECD, 2005; Whiteford and Whitehouse, 2006).[6] The second component of the pension is a flat-rate or basic pension. Every retiree receives the same amount related to average net labor income in the economy at the time of retirement. This assumption assures that also basic pensions rise in line with productivity. Here, the net replacement rate is b_{4b}. Fourth generation individuals consume their pension and the lump sum transfer, as well as their accumulated wealth from the third period plus interest. They leave no debts, nor bequests.

Substituting Equations (2)-(4) for l_j^t and (5)-(8) for c_j^t into Equation (1), and maximizing with respect to $a_1^t, a_2^t, a_3^t, n_1^t, n_2^t, \tilde{n}_3^t, e^t$ and R^t, yields eight first order conditions for the optimal behavior of an agent entering the model at time *t.* Equation (13) expresses the law of motion of optimal consumption over time. Equations (14.a), (14.b) and (14.c) describe the optimal labor-leisure choice in each period of active live. In each period, individuals supply labor up to the point where the marginal utility of leisure equals the marginal utility gain from work. The latter consists of two parts. Working more hours in a particular period raises additional resources for consumption both in that period and when retired. The marginal utility gain from work is higher when initial consumption is lower, and when an extra hour of work yields more extra consumption. Higher human capital (and its underlying determinants), lower taxes on labor, lower taxes on consumption and lower non-employment benefits contribute to the gain from work. Extra consumption during retirement rises in the own-income-related pension replacement rate (b_{4a}), in the weight attached to the relevant period when computing the pension base (p_j), and in the revaluation parameters.

$$\frac{c_{j+1}^t}{c_j^t} = \beta\left(1+r_{t+j}\right) \qquad \forall\, j=1, 2, 3 \tag{13}$$

$$\frac{\gamma_1}{\left(\ell_1^t\right)^\theta}\frac{-\partial\ell_1^t}{\partial n_1^t} = \frac{w_t h_1^t\left(1-\tau_1\right)\left(1-b_1\right)}{c_1^t\left(1+\tau_c\right)} + \beta^3\frac{b_{4a}p_1 w_t h_1^t\left(1-\tau_1\right)x_t x_{t+1}x_{t+2}}{c_4^t\left(1+\tau_c\right)} \tag{14.a}$$

$$\begin{aligned}\frac{\gamma_2}{\left(\ell_2^t\right)^\theta}\frac{-\partial\ell_2^t}{\partial n_2^t} &= \frac{w_{t+1}\left(1+\psi\left(e^t, g_y, q\right)\right)h_1^t\left(1-\tau_2\right)\left(1-b_2\right)}{c_2^t\left(1+\tau_c\right)} \\ &\quad + \beta^2\frac{b_{4a}p_2 w_{t+1}\left(1+\psi\left(e^t, g_y, q\right)\right)h_1^t\left(1-\tau_2\right)x_{t+1}x_{t+2}}{c_4^t\left(1+\tau_c\right)}\end{aligned} \tag{14.b}$$

[6] We explain economy wide wage growth in Section 3.3. Individuals take it as exogenous.

$$\frac{\gamma_3}{\left(\ell_3^t\right)^{\theta}} \frac{-\partial \ell_3^t}{\partial \tilde{n}_3^t} = \frac{w_{t+2}\left(1+\psi\left(e^t, g_y, q\right)\right) h_1^t \left(1-\tau_3\right) R^t \left(1-b_{3a}\right)}{c_3^t\left(1+\tau_c\right)} + \beta \frac{b_{4a} p_3 w_{t+2}\left(1+\psi\left(e^t, g_y, q\right)\right) h_1^t R^t \left(1-\tau_3\right) x_{t+2}}{c_4^t\left(1+\tau_c\right)} \tag{14.c}$$

Equations (14.a)-(14.c) highlight positive substitution effects from the pension replacement rate b_{4a}. To the extent that higher replacement rates raise individuals' consumption possibilities (c_j), they also cause adverse income effects on labor supply. Basic pensions (b_{4b}) do not directly occur in Equations (14), but they do affect employment via this income effect.

Equation (15) describes the first order condition for the optimal effective retirement age. The LHS represents the utility loss from postponing retirement. Later retirement reduces enjoyed leisure as early retiree, but raises enjoyed leisure in between periods of work for given work time $\tilde{n}_3$. The RHS shows the marginal utility gain from postponing retirement. This marginal gain follows from consuming the extra labor income (vis-à-vis the early retirement benefit) in the third period, and the higher future old-age pension after 65. The latter effect rises in b_{4a} and p_3.

$$\frac{\gamma_3}{\left(\ell_3^t\right)^{\theta}} \frac{-\partial \ell_3^t}{\partial R^t} = \frac{w_{t+2}\left(1+\psi\left(e^t, g_y, q\right)\right) h_1^t \left(1-\tau_3\right)\left(\tilde{n}_3^t + b_{3a}\left(1-\tilde{n}_3^t\right) - b_{3b}\right)}{c_3^t\left(1+\tau_c\right)} + \beta \frac{b_{4a} p_3 w_{t+2}\left(1+\psi\left(e^t, g_y, q\right)\right) h_1^t \tilde{n}_3^t \left(1-\tau_3\right) x_{t+2}}{c_4^t\left(1+\tau_c\right)} \tag{15}$$

Finally, equation (16) imposes that the marginal utility loss from investing in human capital when young equals the total discounted marginal utility gain in later periods from having more human capital. Individuals will study more the higher future versus current after-tax real wages and the higher the marginal return of education to human capital $(\partial \psi / \partial e)$. Labor taxes during youth therefore encourage individuals to study, whereas labor taxes in later periods of active life discourage them. Notice also that high benefit replacement rates in later periods (b_2, b_{3a}, b_{3b}) and a high income-related pension replacement rate (b_{4a}), combined with high weights p_2 and p_3, will encourage young individuals to study. The reason is that any future benefits and the future pension rise in future labor income, and therefore human capital. A final interesting result is that young people study more – all other things equal – if they expect to work harder in later periods (n_2, $n_3 = R.\tilde{n}_3$).

$$\frac{\gamma_1}{(\ell_1^t)^{\theta}} \frac{-\partial \ell_1^t}{\partial e^t} - \frac{1}{c_1^t} \frac{\partial c_1^t}{\partial e^t} = \beta \frac{1}{c_2^t} \frac{\partial c_2^t}{\partial e^t} + \beta^2 \frac{1}{c_3^t} \frac{\partial c_3^t}{\partial e^t} + \beta^3 \frac{1}{c_4^t} \frac{\partial c_4^t}{\partial e^t} \tag{16}$$

with: $$\frac{\partial c_1^t}{\partial e^t} = \frac{-b_1 w_t h_1^t \left(1-\tau_1\right)}{1+\tau_c}$$

$$\frac{\partial c_2^t}{\partial e^t} = \frac{\partial \psi\left(e^t, g_y, q\right)}{\partial e^t} . \frac{w_{t+1} h_1^t \left(1-\tau_2\right)\left[n_2^t + b_2\left(1-n_2^t\right)\right]}{1+\tau_c} .$$

$$\frac{\partial c_3^t}{\partial e^t} = \frac{\partial \psi\left(e^t, g_y, q\right)}{\partial e^t} \cdot \frac{w_{t+2} h_1^t \left(1-\tau_3\right)\left[R^t \left(\tilde{n}_3^t (1-b_{3a}) + b_{3a} - b_{3b}\right) + b_{3b}\right]}{1+\tau_c}.$$

$$\frac{\partial c_4^t}{\partial e^t} = b_{4a} \frac{\partial \psi\left(e^t, g_y, q\right)}{\partial e^t} \cdot \frac{\sum_{j=2}^{3} \left(p_j n_j^t w_{t+j-1} h_1^t \left(1-\tau_j\right) \prod_{i=j}^{3} x_{t+i-1} \right)}{1+\tau_c}$$

It will be obvious from the above discussion that (for a given way of financing) the specific organization of pension benefits may have strong effects on behavior in earlier periods of life. Both income and substitution effects occur. The latter are particularly rich when pensions are linked to individuals' own labor income. A higher replacement rate b_{4a} raises the return to working (n) and building human capital (e, h) in earlier periods. Changes in the particular weight attached to these earlier periods may modify these incentive effects. The return to education will rise in p_2 and p_3, but fall in p_1. The return to working in the third period will rise in p_3, etc. Policy makers may change all these parameters. We investigate the effects of policy interventions in Section 5.

3.2. Production of effective human capital

The specification and parameterization of the human capital production function is often a problem in numerical endogenous growth models. In contrast to goods production functions, there is not much empirical evidence and no consensus about the determinants of human capital growth, nor about the underlying functional form and parameter values (Bouzahzah *et al*, 2002, Arcalean and Schiopu, 2010). The literature shows a variety of functions, typically including one or two of the following inputs: individual time allocated to education, private expenditures on education by individuals themselves or by their parents, and government expenditures on education (e.g. Lucas, 1988, Glomm and Ravikumar, 1992; Docquier and Michel, 1999, Kaganovich and Zilcha, 1999; Bouzahzah et al., 2002; Fougère et al., 2009; Arcalean and Schiopu, 2010). In case of two inputs, the adopted functional form is very often Cobb-Douglas (e.g. Glomm and Ravikumar, 1992; Kaganovich and Zilcha, 1999; Docquier and Michel, 1999).

Our specification also includes education time of young individuals and education expenditures by the government. We see these variables as indicators for the quantity of invested private and public resources. However, our specification is broader than this. First, we take recent empirical evidence seriously that the quality of education and the schooling system is very important (Hanushek and Woessmann, 2009). Better quality implies higher cognitive skills for the same allocation of resources. As a proxy for quality we will use OECD PISA science scores (see Section 4.2 for further discussion). As a second extension, our definition of relevant (productive) government expenditures includes more than education. It also includes active labor market expenditures, public R&D expenditures and public fixed investment. This approach goes back to our use of the broader concept of *effective* human capital. As in Dhont and Heylen (2009), effective human capital (and worker productivity) rise not only in accumulated schooling or training, but also in the productive efficiency of accumulated schooling. Education and active labor market expenditures directly contribute to more human capital being accumulated, public R&D and fixed investment expenditures will mainly raise the productive efficiency of accumulated human capital. The hypothesis that public investment and infrastructure services may also matter for aggregate human capital, next to education expenditures, has been developed recently by Agénor (2008).

Equation (17) shows our specification for the growth rate of effective human capital. We adopt a flexible CES-specification in education time when young (*e*) and productive government expenditures in % of output (g_y). We add the quality of education (*q*) in a multiplicative way. We allow *q* to vary across countries in later sections. Next to *q* we introduce (constant, common) technical parameters: ϕ is a positive efficiency parameter, σ a scale parameter, *v* is a share parameter and κ the elasticity of substitution. These parameters will be calibrated.

$$\Psi(e, g_y, q) = \phi q \left(\nu g_y^{\,1-(1/\kappa)} + (1-\nu) e^{1-(1/\kappa)} \right)^{\sigma\kappa/(\kappa-1)} \tag{17}$$

Lack of existing empirical evidence makes an ex-ante assessment of our specification very difficult. In previous work, however, we have been able to verify that this specification performs better than alternative specifications without quality, with a narrower definition of government expenditures or with a different functional form (Heylen and Van de Kerckhove, 2010). In Section 4 we show that our model's predictions for education and per capita growth, which rely on (17), are fairly close to reality for most countries.

3.3. Domestic firms, output and factor prices

Firms act competitively on output and input markets and maximize profits. All firms are identical. Total domestic output is given by the production function (18). Technology exhibits constant returns to scale in aggregate physical capital *(K_t)* and effective labor (H_t), so that profits are zero in equilibrium. Equation (19) describes total effective labor supplied by young, middle-aged and older workers. Note our assumptions that each generation has size 1 and that young workers inherit the human capital of the middle-aged ($h_1^t = h_2^{t-1}$).

$$Y_t = K_t^{\alpha} H_t^{1-\alpha} \tag{18}$$

$$H_t = n_1^t h_1^t + n_2^{t-1} h_2^{t-1} + n_3^{t-2} h_3^{t-2} = \left(n_1^t + n_2^{t-1} + \frac{n_3^{t-2}}{x_{t-1}} \right) h_1^t \tag{19}$$

with: $x_{t-1} = 1 + \psi(e^{t-1}, g_y, q)$ and $n_3^t = R^t \tilde{n}_3^t$, and where we use Equations (9) and (10).

Competitive behavior implies in Equation (20) that firms carry physical capital to the point where its after-tax marginal product net of depreciation equals the world real interest rate (see also Backus et al., 2008). Physical capital depreciates at rate δ_k. Capital taxes are source-based: the tax rate τ_k applies to the country in which the capital is used, regardless of who owns it. The real interest rate being given, firms will install more capital when the amount of effective labor increases or the capital tax rate falls. In that case the net return to investment in the home country rises above the world interest rate, and capital flows in. Furthermore, perfect competition implies equality between the real wage and the marginal product of effective labor (Equation 21). Higher real wages follow from an increase in physical capital per unit of effective labor. Taking into account (20), real wages per unit of effective labor will therefore fall in the world real interest rate and in domestic capital tax rates.

$$\left[\alpha\left(\frac{H_t}{K_t}\right)^{1-\alpha}-\delta_k\right](1-\tau_k)=r_t \tag{20}$$

$$(1-\alpha)\left(\frac{K_t}{H_t}\right)^{\alpha}=w_t \tag{21}$$

Substituting (19) for H_t and (20) for K_t/H_t, we can rewrite (18) as

$$Y_t=\left(\frac{K_t}{H_t}\right)^{\alpha}H_t=\left(\frac{\alpha(1-\tau_k)}{r_t+\delta_k(1-\tau_k)}\right)^{\alpha/(1-\alpha)}\left(n_1^t+n_2^{t-1}+\frac{n_3^{t-2}}{x_{t-1}}\right)h_1^t.$$

If we finally recognize that in steady state r, τ_k, x, e, and n_j are constant, we obtain the long-run (per capita) growth rate of the economy as

$$ln\left(\frac{Y_t}{Y_{t-1}}\right)=ln\left(\frac{h_1^t}{h_1^{t-1}}\right)=ln\left(\frac{h_2^{t-1}}{h_1^{t-1}}\right)=ln\left(1+\psi(e,g_y,q)\right) \tag{22}$$

In line with earlier models (e.g., Lucas, 1988; Azariadis and Drazen, 1990; Buiter and Kletzer, 1993), the long-run (per capita) growth rate is positively related to the quality of schooling (q) and to the fraction of time that young people allocate to education (e). It is also positively related to the share of productive government expenditures (g_y), like in Barro (1990).

3.4. Government

The government runs a balanced budget. Productive expenditures, consumption, benefits related to non-employment (including early retirement benefits), old-age pension benefits, and lump sum transfers at time t are financed by taxes on labor, capital and consumption.

$$G_{yt}+G_{ct}+B_t+PP_t+Z_t=T_{nt}+T_{kt}+T_{ct} \tag{23}$$

with:

$$G_{yt}=g_yY_t$$

$$G_{ct}=g_cY_t$$

$$\begin{aligned}B_t&=(1-n_1^t-e^t)b_1w_th_1^t(1-\tau_1)+(1-n_2^{t-1})b_2w_th_2^{t-1}(1-\tau_2)\\&\quad+R^{t-2}(1-\tilde{n}_3^{t-2})b_{3a}w_th_3^{t-2}(1-\tau_3)+(1-R^{t-2})b_{3b}w_th_3^{t-2}(1-\tau_3)\end{aligned}$$

$$PP_t=b_{4a}\sum_{j=1}^{3}\left(p_jw_{t+j-4}h_j^{t-3}n_j^{t-3}(1-\tau_j)\right)\prod_{i=j}^{3}x_{t+i-4}+b_{4b}\frac{1}{3}\sum_{j=1}^{3}\left(w_th_j^{t+1-j}n_j^{t+1-j}(1-\tau_j)\right)$$

$$Z_t=4z_t$$

$$T_{nt}=\sum_{j=1}^{3}n_j^{t+1-j}w_th_j^{t+1-j}\tau_j$$

$$T_{kt}=\tau_k\left[\alpha Y_t-\delta K_t\right]$$

$$T_{ct}=\tau_c\sum_{j=1}^{4}c_j^{t+1-j}$$

Following Turnovsky (2000) and Dhont and Heylen (2009), we assume that the government claims given fractions g_y and g_c of output for productive expenditures and consumption. Non-employment benefits (B_t) are an unconditional source of income support related to inactivity ('leisure') and non-market household activities. Although it may seem strange to have such transfers in a model without involuntary unemployment, one can of course analyse their employment and growth effects as a theoretical benchmark case (see also Rogerson, 2007; Dhont and Heylen, 2008, 2009). Moreover, there is also clear practical relevance. Unconditional or quasi unconditional benefits to structurally non-employed people are a fact of life in many European countries. We further assume that the pension system is fully integrated into the government accounts. We do not impose a specific financing of the PAYG pension plan, the government can use resources from the general budget to finance pensions. Finally, as we have mentioned before, the government pays the same lump sum transfer z_t to all individuals living at time *t*.

3.5. Aggregate equilibrium and the current account

Optimal behavior by firms and households, and government spending for productive and consumption purposes, underlie aggregate domestic demand for consumption and investment goods in the economy. Our assumption that the economy is open implies that aggregate domestic demand may differ from supply and income, which generates international capital flows and imbalance on the current account. Equation (24) describes aggregate equilibrium as it can be derived from Equations (5)-(8), defined for all generations living at time *t*, Equations (18)-(21) and Equation (23). In Equation (24), F_t stands for net foreign assets at the beginning of *t*. The aggregate stock of wealth A_t accumulates wealth held by individuals who entered the model in *t-1*, *t-2* and *t-3*.

$$Y_t + r_t F_t = C_t + I_t + G_{ct} + G_{yt} + CA_t \tag{24}$$

with:

$$\begin{aligned} F_t &= A_t - K_t \\ CA_t &= F_{t+1} - F_t = \Delta A_{t+1} - \Delta K_{t+1} \\ I_t &= \Delta K_{t+1} + \delta K_t \end{aligned}$$

4. Parameterization and empirical relevance of the model

The economic environment described above allows us to simulate the transitory and steady state growth and employment effects of various changes in fiscal policy and the pension system. This simulation exercise requires us first to parameterize and solve the model. In Section 4.1 we discuss our choice of preference and technology parameters. Starting from actual cross-country policy data in Section 4.2, we compare in Section 4.3 our model's predictions with the employment and growth differences that we have reported in Table 1. This comparison provides a first and simple test of our model's empirical relevance. In Section 5 we consider both long-run equilibrium effects and transitional dynamics of policy changes. To solve the model and to perform our simulations, we choose an algorithm that preserves the non-linear nature of our model. We follow the methodology basically proposed by Boucekkine (1995) and implemented by Juillard (1996) in the program Dynare.

4.1. Preference and technology parameters

Table 2 contains an overview of all parameters. Following among others Barro (1990), we set the rate of time preference equal to 2% per year. Considering that periods in our model consist of 15 years, this choice implies a discount factor β equal to 0.74. With respect to effective labor, we assume a share coefficient 1-α equal to 0.7. This value is well in line with the literature. For example, King and Rebelo (1990) also model goods production as a function of effective labor (human capital) and physical capital. They assume a value for 1-α equal to 2/3. There is more controversy in the literature about the value of the intertemporal elasticity of substitution in leisure (1/θ). Micro studies often reveal very low elasticities. However, given our macro focus, these studies may not be the most relevant ones. Rogerson and Wallenius (2009) show that micro and macro elasticities may be unrelated. Rogerson (2007) also adopts a macro framework. He puts forward a reasonable range for θ from 1 to 3 (Rogerson, 2007, p. 12). In line with this, we impose θ to be equal to 2. The world real interest rate is assumed constant in steady state and equal to 4.25% per year. Considering a period of 15 years, this implies that r = 0.867. Finally, we set the physical capital depreciation rate to 7.5% per year, which implies δ_k=0.689. Our values for these parameters are within the range of existing studies.

Table 2 Preference and technology parameters

Production parameters (output)	$1-\alpha=0.7$
Effective human capital production	$\phi=4.48,\ \sigma=0.99,\ v=0.125,\ \kappa=0.375$
Preference parameters	$\beta=0.74,\ \theta=2,\ \gamma_1=0.063,\ \gamma_2=0.125,\ \gamma_3=0.189$
	$\pi=0.5,\ \rho=1.4,\ \Omega=2$
World real interest rate	$r=0.867$
Physical capital depreciation rate	$\delta_k=0.689$

A second series of parameters have been determined by calibration: three taste for leisure parameters (γ_1, γ_2, γ_3), two parameters in the human capital production function (the efficiency parameter ϕ and the scale parameter σ), and the elasticity of substitution (ρ) in the composite leisure function in Equation (4). We have calibrated these parameters to Belgium. We choose this country since in Belgium the calculation of pension benefits fits exactly within the way we model it. Public pensions are proportional to average annual labor income earned over a period of 45 years, with equal weights to all years. There is no basic pension (OECD, 2005). In our model this comes down to b_{4a}>0, b_{4b}=0 and p_1=p_2=p_3=1/3. The parameters γ_1, γ_2, γ_3, ϕ, σ and ρ have been determined such that with observed levels of the policy variables (tax rates, benefit replacement rates, pension replacement rate, etc.) and the observed level of schooling quality (q)[7] in Belgium, the model correctly predicts Belgium's employment rates (n_1, n_2, n_3), per capita growth rate, education rate (e) and effective retirement age (R) in 1995-2007. Underlying performance and policy data are reported in Tables 1, 3 and 4. We find that the taste for leisure rises with age (γ_1=0.063, γ_2=0.125, γ_3=0.189). Furthermore, we observe quasi constant returns in human capital production ($\sigma\approx 1$), and a stronger

[7] And with the values of two parameters in the human capital production function (v, κ) that we discuss below (see also footnote 8).

degree of substitutability than in the Cobb-Douglas case between the two types of leisure for older workers ($\rho = 1.4$).

We had no ex ante indication on two parameters in the human capital production function: the share parameter v and the elasticity of substitution parameter κ. We could assign sensible values to these parameters thanks to a sensitivity analysis on the results that we report in the next section. There we evaluate the capacity of our model to explain six important macro variables in 13 OECD countries. Although the influence of v and κ on the explanatory power of our model is very limited, our guideline to pin down specific values for these parameters (within a sensible range) was to minimize the deviation of our model's predictions from the true data[8]. This procedure implied v=0.125 and κ= 0.375. The result for κ reveals a higher degree of complementarity between private education time and government expenditures than in the Cobb-Douglas case. The result for v demonstrates relatively high importance for human capital formation of private education time versus productive public expenditures. Neither did we have an ex ante indication on the remaining parameters in the composite leisure function in Equation (4). We impose equal weight for both leisure types (π=0.5). The normalisation parameter Ω equals 2. The size of this parameter has no impact at all on our country predictions or simulation results.

4.2. Fiscal policy, pensions and education quality

Tables 3 and 4 describe key characteristics of fiscal policy and the pension system in 1995-2001/2004. Reported data are averages of the available annual data in that period, unless indicated otherwise. Our description of the data here is short. For some variables we provide more detail in Appendix 1. Our proxy for the tax rate on labor income concerns the total tax wedge, for which we report the marginal rate in %. The data cover personal income taxes, employee and employer social security contributions payable on wage earnings and payroll taxes. The OECD publishes these tax data for several family and income situations. Considering that workers typically earn less when they are young (and have lower human capital) than when they are middle-aged, we calculated our τ_1 for each country as an average of marginal tax rates for lower to middle income families. Tax rates for middle-aged and older workers were computed from OECD data for middle to higher income families. As one can see in Table 3, however, differences within countries between τ_1 on the one hand and τ_2 and τ_3 on the other, are very small. Cross-country differences are much bigger. Belgium, Germany, Sweden and Finland have marginal labor tax rates above 55% or even 60%. The US and the UK have marginal labor tax rates below, or close to, 40%. Capital tax rates are effective marginal corporate tax rates reported by the Institute for Fiscal Studies (their EMTR, base case). Germany and Belgium have the highest rates. In contrast to labor (and consumption), capital is taxed relatively little in the Nordic countries. As to consumption taxes, we follow Dhont and Heylen (2009) in computing them as the ratio of government indirect tax receipts (net of subsidies paid) to total domestic demand net of indirect taxes and subsidies. Our simplifying assumption is that consumption tax rates correspond to

[8] From our model's predictions and the true data for 13 countries we computed for each variable (n_1, n_2, n_3, e, R, *growth*) the root mean squared error normalized to the mean. We minimized the average normalized RMSE over all six variables. We then adopted the following iterative procedure. Given chosen values for v and κ we calibrated the efficiency parameter ϕ and the scale parameter σ. The values for v and κ had no influence on the calibration results for γ_j. Given the values for ϕ and σ, we checked whether changes in v and κ could further improve the model's explanatory power. New values for v and κ led to a recalibration of σ and ϕ, etc.

aggregate indirect tax rates. The Nordic countries stand out with the highest consumption tax rates, the US with the lowest.

Table 3 Fiscal policy (Tax rates)

	tax rate on labor income when young (%)	tax rate on labor income when middle age and older (in %)	consumption tax rate (%)	tax rate on capital income (%)
Proxy for :	τ_1	τ_2, τ_3	τ_c	τ_k
Austria	56.5	53.0	13.2	17.3
Belgium	66.6	67.6	13.4	27.1
France	52.4	53.3	17.1	21.7
Germany	62.5	60.0	11.1	34.4
Italy	54.7	57.1	14.7	14.9
Netherlands	52.3	51.6	12.2	24.3
Denmark	46.4	51.2	18.9	22.5
Finland	55.6	57.9	15.2	17.2
Norway	49.6	52.6	16.4	22.1
Sweden	54.5	58.1	17.9	16.1
UK	39.8	41.6	14.5	21.2
US	34.2	36.9	7.2	23.6
Canada	46.8	47.6	14.5	24.8
Overall country average	51.7	52.9	14.3	22.1

Note: Labor tax rates are data for the total tax wedge, marginal rate (OECD, Taxing Wages). Data for 2000-04. For details on the calculation of tax rates by age group, see Appendix 1. Capital tax rates are effective marginal corporate tax rates (Institute for Fiscal Studies, their EMTR; data for 1995-2001, see also Devereux et al., 2002). Consumption tax rate: see Dhont and Heylen (2009). Data for 1995-2001.

Table 4 summarizes our data for the expenditure side of fiscal policy. A first variable is our proxy for the net non-employment benefit replacement rate b_j (j = 1,2,3a). Since in our model non-employment is a structural or equilibrium phenomenon, the data that we use concern net transfers received by structurally or long-term unemployed people. They include social assistance, family benefits and housing benefits in the 60th month of benefit receipt. They also include unemployment insurance or unemployment assistance benefits if these benefits are still paid, i.e. if workers can be structurally unemployed for more than five years without losing benefit eligibility[9]. The data are expressed in percent of after-tax wages. In line with our approach to determine labor tax rates by age group, we are again guided by the same family and income cases to determine b_1, b_2 and b_{3a} (see Appendix 1). Overall, the euro area and the Nordic countries pay the highest net benefits on average. Transfers to structurally non-employed people are by far the lowest in the US. A related variable is our proxy for the net early retirement benefit replacement rate b_{3b}.The data are again expressed in percent of after-tax final wages. To assess the generosity of early retirement we integrate the information available via b_{3a} and data for the implicit tax rate on continued work in the early retirement route as provided by Duval (2003) and Brandt *et al*. (2005). For details, see Appendix 1. We observe a very

[9] This is the case in Austria, Belgium, France, Germany, Finland, and the UK. Workers cannot be structurally non-employed and still receive unemployment benefits in the Netherlands, Italy, Denmark, Norway and the US (OECD, 2004, www.oecd.org/els/social/workincentives, Benefits and Wages, country specific files).

generous early retirement regime in Belgium and Finland, whereas net early retirement benefits in Anglo-Saxon countries are much lower.

Our data for productive government expenditures in Table 4 include education, active labor market expenditures, government financed R&D and public investment. Governments in the Nordic countries allocate by far the highest fractions of output to productive expenditures. Productive expenditures in percent of GDP are the lowest in the UK. The US and most core countries of the euro area take intermediate positions. Government consumption in percent of GDP is the highest also in the Nordic countries, followed at close distance by several countries of the core euro area[10]. In the US, government consumption is (much) lower.

Our data for the net pension replacement rates (b_{4a}, b_{4b}) concern an individual with mean earnings before retirement. The data include only (quasi-)mandatory pension programs, and are expressed as a percentage of this individual's average lifetime labor income (OECD, 2005)[11]. In the majority of countries individuals with mean earnings only receive earnings-related pensions (b_{4a}>0, b_{4b}=0). The overall average net replacement rate in these countries is around 70%, but there are strong cross-country differences. We observe the highest b_{4a} in Austria and Italy, and low rates in the US and Belgium. Differences exist also in the precise organization of the earnings-related system. Some countries have pure defined-benefit systems (e.g. Belgium, Finland, US), others have so-called point systems (Germany) or notional-account systems (Italy, Sweden). Although these three systems can appear very different, OECD (2005) shows that they are all similar variants of earnings-related pension schemes. A smaller group of countries combine earnings-related and (variants of) basic pension systems. Denmark, the Netherlands and the UK have the strongest non-earnings related components[12]. As a final important remark, we emphasize that the straightforward way in which the OECD computes the pension replacement rates, in percent of an individual's average lifetime labor income, comes down to assuming in our model that the weights p_1, p_2 and p_3 are all equal to 1/3. For reasons of consistency we will therefore make this assumption for all individual countries when we derive our model's predictions. We are aware however that equal weights do not fully match practice in all countries. Some deviate from this prototype, to varying degrees.[13] When we compare our model's predictions for these countries to the facts in the next section, we should take this into account. Assuming equal weights may slightly bias our predictions.

[10] Note that we calculate government consumption as total government consumption in % of GDP, diminished with the fraction of public education outlays going to wages and working-expenses. The latter are included in productive expenditures.

[11] In most countries mandatory programs are public. For Denmark, the Netherlands and Sweden the data also include benefits from mandatory private systems. These benefits are earnings-related. Voluntary, occupational pensions are not included in our data.

[12] For the sake of completeness, it should be mentioned that our proxy for b_{4b} also includes targeted and minimum pensions if they are relevant for a worker with mean income. Basic pensions pay the same amount to every retiree. Targeted plans pay a higher benefit to poorer pensioners and reduced benefits to better-off ones. Minimum pensions are similar to targeted plans. Their main aim is to prevent pensions from falling below a certain level (OECD, 2005, p. 22-23). Our main motivation to merge these three categories in our proxy for b_{4b} is that they are not (or even inversely) linked to earnings.

[13] In Austria, Norway and France earnings-related pensions are not calculated from average lifetime income but from average income during the final working years or a number of years with the highest earnings. Ideally, one would impose different weights p_1, p_2 and p_3, although exact data are often not available. Moreover, the OECD pension replacement rate would then no longer be reliable since it is based on the assumption of equal weights.

As a final variable in Table 4 we include PISA science scores. We use these data as a proxy for the quality of schooling (q) in the human capital production function (17). We concentrate on science scores given their expected closer link to growth. Although available PISA scores relate to secondary education, we do not see this as a weakness. PISA scores may be very informative about the quality with which young people enter tertiary education. Quality at entrance should have a positive influence on people's capacity to learn and to raise human capital during tertiary education. Furthermore, PISA scores have been found empirically significant for growth (Hanushek and Woessmann, 2009). Finally, these scores are easily available for all countries, which is not obvious for 'better' quality indicators. Finland scores best, followed by the Netherlands, Canada and the UK. Note that there is no correlation in Table 4 between productive government expenditures and the PISA score. Correlation is -0.04. There is no correlation either if we restrict productive expenditures to education only. Both variables seem to tell different stories (see also Woessmann, 2003).

Table 4 Fiscal policy (net transfer replacement rates, government consumption, productive expenditures), pension system, and PISA education score

	Non-employment benefit, young (net replacement rate, %)	Non-employment benefit, middle-aged and older (net replacement rate, %)	Early retirement benefits (net replacement rate, %)	Pension benefit (net replace-ment rate, %)	Basic pension (% of net average earnings)	Government consumption (% of GDP)	Government productive expenditure (% of GDP)	PISA – science (divided by 1000)
Proxy for :	b_1	b_2, b_{3a}	b_{3b}	b_{4a} [(a)]	b_{4b} [(a)]	g_c	g_y	q
Austria	60.8	50.9	69.9	88.9	0	14.6	9.1	5.07
Belgium	65.1	51.7	75.1	63.1	0	16.9	8.9	5.05
France	52.3	38.3	59.9	68.8	0	18.3	11.0	5.02
Germany	65.4	59.7	68.3	71.8	0	15.3	8.6	5.02
Italy	18.5	15.3	54.9	88.8	0	14.3	8.0	4.80
Netherlands	62.5	46.6	63.9	48.8	35.3	18.4	10.3	5.25
Denmark	67.8	55.4	40.0	19.5	34.6	18.4	12.5	4.84
Finland	68.4	54.4	70.4	78.8	0	16.0	11.4	5.50
Norway	64.8	49.4	36.2	46.2	18.9	14.7	12.1	4.90
Sweden	62.8	47.8	35.2	65.9	2.3	20.0	14.0	5.07
UK	57.8	44.4	36.0	13.8	33.8	14.4	7.3	5.23
US	34.3	26.6	16.3	51.0	0	10.3	9.3	4.93
Canada	49.7	39.5	24.6	39.4	17.7	14.7	9.3	5.27
Overall average	56.2	44.6	49.9	57.3	11.0	15.9	10.1	5.07

Notes: A description of all variables is given in the main text. For more details, see Appendix 1. The data for net non-employment benefit replacement rates are an average for 2001 and 2004 (earlier data are not available). The data for government consumption and productive expenditures concern 1995-2001. The PISA science scores are an average for 2000, 2003 and 2006. The pension replacement rates concern 2002 (source OECD, 2005, p. 52). To split up the OECD data into our b_{4a} and b_{4b} in countries where b_{4b} >0, we have used the information in OECD (2005, part II, Country studies). We derive b_{4b} from the fraction of the total net replacement rate that goes to basic, minimum or targeted pensions (see also our footnote 12).
(a) The weights p_i to compute the pension base (with j=1, 2, 3) are in all countries assumed equal to 1/3 (see motivation in the main text).

4.3. Predicted versus actual employment by age, education of young and growth in the OECD

Can our model match the facts that we have reported in Table 1. In this section we confront our model's predictions with the true data for 1995-2006/2007. Clearly, one should be aware of the serious limitations of such an exercise. First of all, our model is highly stylized and may (obviously) miss potential determinants of growth or employment. Second, even if we compute the true data in Table 1 as averages over a longer period, these averages need not be equal to the steady state. Countries may still be moving towards their steady state. Third, this exercise only concerns the last 15 years. Lack of data – especially with respect to marginal labor tax rates and non-employment transfers in the early 1990s – makes it impossible for us to execute the maybe most convincing test, which is to relate changes in growth and employment to changes in policy within countries over longer time periods. In spite of all this, if one considers the extreme variation in the predictions of existing calibrated models investigating the effects of fiscal policy in the literature (see Stokey and Rebelo, 1995), even a minimal test of the 'goodness of fit' of our model is informative.

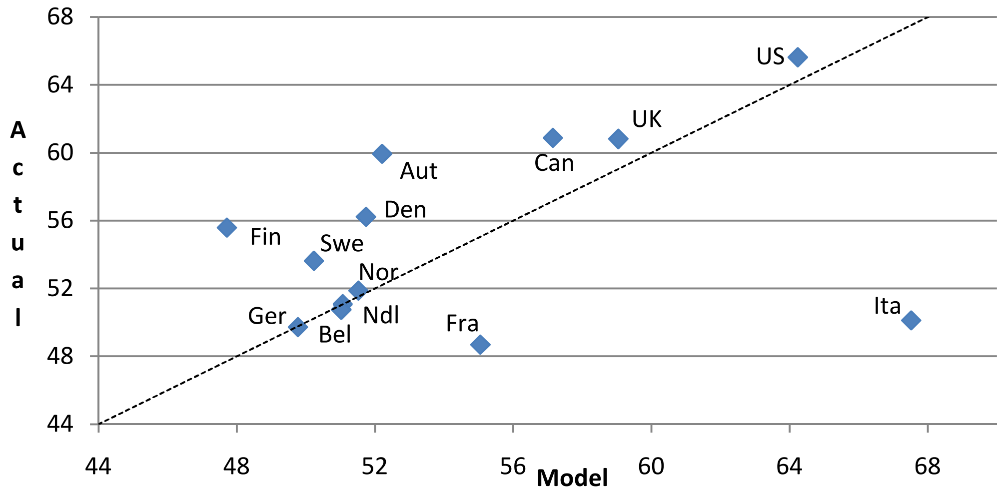
Our calibration implies that our model's prediction matches employment rates by age, the effective retirement age of older workers, education, and per capita growth in Belgium. A test of the model's validity is whether it can also match the data for the other countries, and the cross-country differences. Before one uses a model for policy analysis, one would like to see for example that the model does not overestimate, nor underestimate the performance differences related to observed cross-country policy differences. Our test is tough since we impose the same preference and technology parameters, reported in the upper part of Table 2, on all countries. Only fiscal policy variables, the pension replacement rate and education quality differ. Moreover, assuming perfect competition, we disregard differences in labor and product market institutions which some authors consider of crucial importance (e.g. Blanchard and Wolfers, 2000; Nickell *et al.*, 2005). Still, we find that the model matches the facts remarkably well for a large majority of countries. Basically, we here confirm earlier findings by e.g. Ohanian *et al.* (2008) and Dhont and Heylen (2008) that once one controls for fiscal policy differences, variation in taste for leisure or different market rigidities are not critical to explain cross-country variation in labor market performance.

Figures 2 to 4 relate our model's predictions for three employment rates to actual observations for all countries. We add the 45°-line to assess the absolute differences between predictions and facts, as well as the coefficient of correlation between predictions and facts. Our model performs quite well. In each age group, it correctly predicts high employment rates in the US and Canada and low employment in Germany. For young workers it also correctly predicts relatively low employment in most other countries of the core euro area, and in the Nordic countries. For older workers it has relatively high employment right in the Nordic countries and the UK. Overall correlation between the model's predictions and the actual data in Figure 2 is 0.31. If we drop Italy, for which there are good reasons[14], this rises to 0.71. Correlation in Figure 3 is 0.43, in Figure 4 it is 0.77. Moreover, in each

[14] A major element behind the deviation for this country seems to be underestimation of the fallback income position for structurally non-employed young workers. OECD data show very low replacement rates in Italy. However, as shown by Reyneri (1994), the gap between Italy and other European countries is much smaller than it seems. Reyneri (1994) points to the importance of family support as an alternative to unemployment benefits. Fernández Cordón (2001) shows that in Italy young people live much longer with their parents than in other countries. In 1995 for example about 56% of people aged 25-29 were still living with their parents in Italy. In about all other countries this fraction was below 23%. Of all non-working males aged 25-29 in Italy more than 80% were living with their parents. In France or Germany the corresponding numbers were close to 40%.

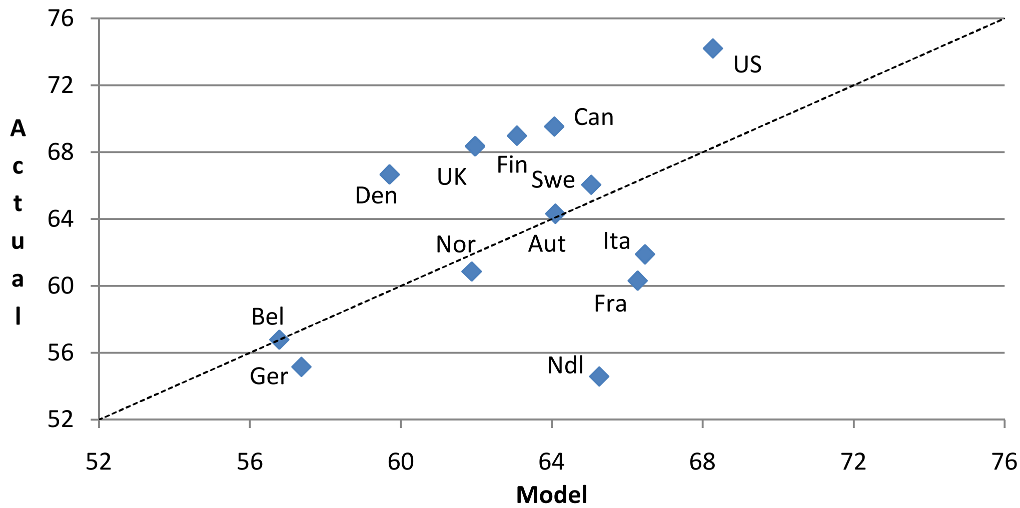
figure - again after dropping Italy from Figure 2 - the regression line (not shown) is close to the 45°-line, which suggests that our model correctly assesses the size of the employment effects of policy differences across countries. Next to Italy, there are a few other countries, where our model somewhat over- or underpredicts. The model's employment predictions tend to be too high for France, Italy and (except in Figure 2) the Netherlands. They tend to be too low in general for Denmark and Finland.

Figure 2. Employment rate in hours of young individuals (n_1), in %, 1995-2007



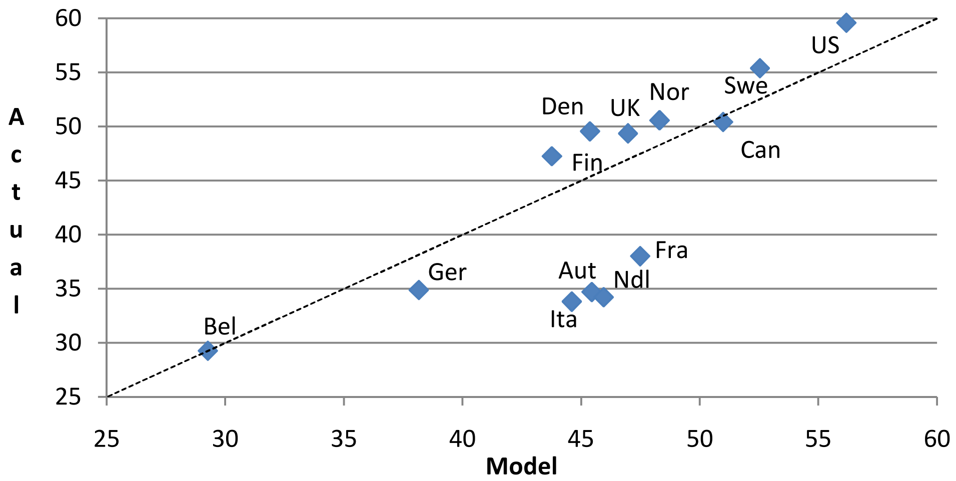
Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.33. Excluding Italy, correlation rises to 0.71.

Figure 3. Employment rate in hours of middle-aged individuals (n_2), in %, 1995-2007



Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.43.

Figure 4. Employment rate in hours of older individuals (n_3), in %, 1995-2007

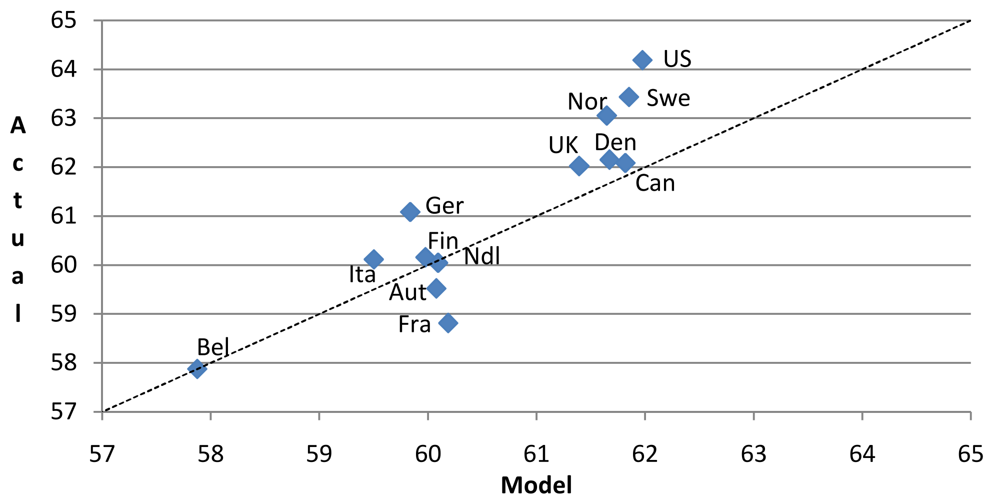


Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.77.

Figure 5 relates our model's predictions to the facts for the effective retirement age. The model again captures the large differences between countries. It predicts the highest retirement age in the Anglo-Saxon and Nordic countries and a much lower retirement age in core euro area countries. Correlation between actual data and the model's predictions is 0.90.

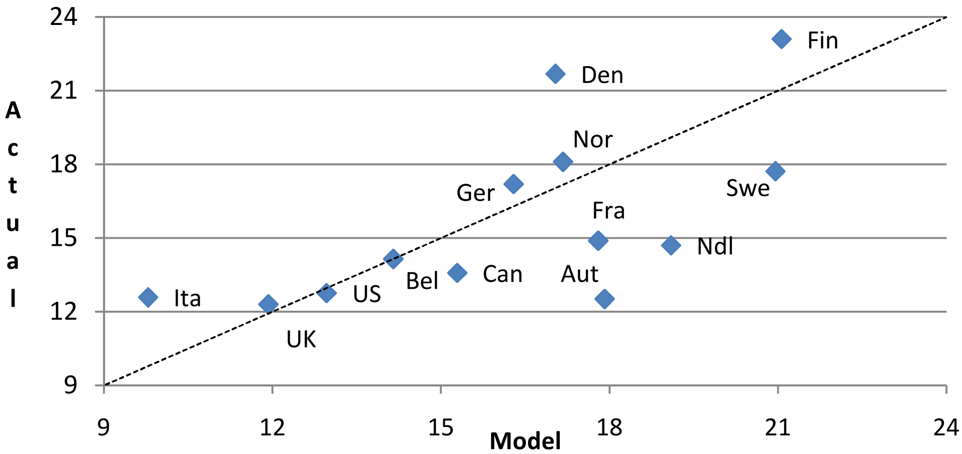
In Figures 6 and 7 we relate our model's predictions to the facts for education and growth. For education, the model correctly captures key differences between the Nordic countries on the one hand and countries like the UK, Italy and Belgium on the other. Predictions for education are quite close to the 45°-line for all individual countries except Austria, Denmark and the Netherlands. The model also has important cross-country differences right for growth. The model has difficulty however to explain observed growth for France and the UK. Correlation between the model's predictions and the true data is 0.63 for education and 0.70 for growth. Finally, in Figure 8, we relate our model's predictions to the facts for the annual current account balance (in % of GDP). Note that we have not done any calibration on these data. Our model predicts current account balances of about the right size (between -2 and +5% of GDP). It matches cross-country differences fairly well.

Figure 5. Effective retirement age, 1995-2006



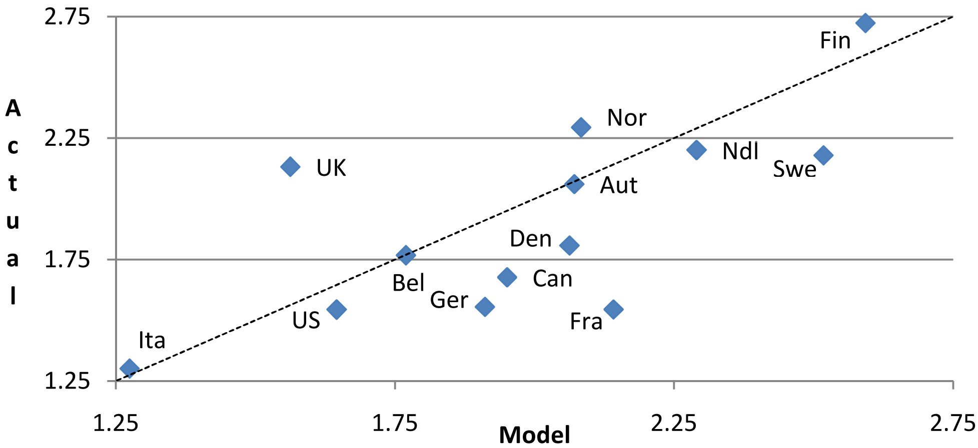
Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.90.

Figure 6. Tertiary education rate (*e*), in %, 1995-2006



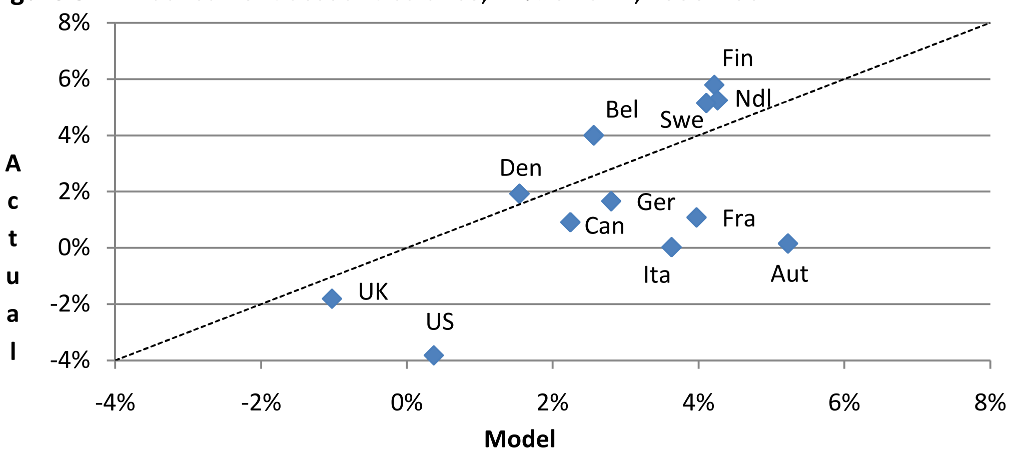
Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.63.

Figure 7. Annual per capita potential GDP growth, in %, 1995-2007



Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.70.

Figure 8. Annual current account balance, in % of GDP, 1995-2007



Note: The dotted line is the 45°-line. We have excluded Norway from this figure as Norway is a clear outlier in the current account data (10.7% of GDP). Correlation between actual data and the model's predictions is 0.61. When we include Norway, correlation drops to 0.44.

5. **Fiscal policy shocks and public pension reform.**

Having established the empirical relevance of our model, we now simulate a series of policy shocks. Our aim is to discover the (relative) effectiveness of various reforms of the pension system for the employment rate of three age groups, aggregate employment, education of the young, the effective retirement age, and growth. In Section 5.1 we consider steady state effects, in Section 5.2 transitional dynamics and welfare effects per generation. The particular pattern of transitory effects implies that subsequent generations' welfare may be affected differently. The benchmark from which we start, and against which all policy shocks are evaluated, is the average of the six core euro area countries in our sample.

5.1. Numerical steady state effects.

The main part of Table 5 shows the steady state effects of six changes in key features of the pension system. Any effects on the government budget are neutralized by a change in lump sum transfers (*z*), spread equally among all generations. This change in lump sum transfers is indicated at the bottom of the table. Policy 1 raises the earnings-related net benefit replacement rate b_{4a} from 72% in the benchmark to 77%. This policy intervention is equivalent to an ex ante increase in pension expenditures by 0.5% of GDP. The policy implies a slight increase in employment, especially among older workers. It has only minor positive effects on education and a quasi negligible impact on growth. All in all, behavioral effects are small[15]. Financial effects are somewhat stronger. A rise in the replacement rate induces an increase in the pension burden and a (limited) deterioration of the government's financial balance. To maintain budget balance (as in the benchmark) the government has to reduce lump sum transfers by 0.39% of output. Policies 2 and 3 alter the calculation of the pension base, such that more weight is given to the net labor income of workers when they are 'older'. These policies involve an increase in p_3, and a fall in p_1. We assume that these reforms do not hold for the current generation of retirees as they are no longer able to adapt their behavior to these new pension weights. The higher (lower) marginal utility from work when older (young) makes it interesting to shift work from the first period of active life to the third, and to postpone effective retirement. Furthermore, young individuals are encouraged to study because the lifetime return to building human capital rises. This follows first from the perspective of working longer and second from the greater importance of effective human capital when old in the pension calculation. Extra schooling contributes to steady-state growth. Interestingly, the government budget does not deteriorate. For instance, policy 3 implies an improvement in the budget balance by 0.89% of GDP[16]. All in all, simple reforms like policies 2 and 3 succeed in strongly increasing the employment rate among older workers (+4.21%-points and +7.87%-points respectively) and their effective retirement age (up to almost +1 year in policy 3). The effect on the aggregate employment rate is limited due to the significant drop in employment of the young. Fortunately, more than half of the latter is substituted into tertiary education. We observe a substantial increase in the per capita growth rate (+0.23%-points in policy 3).

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[15] Effects are even (about 50%) smaller if labor taxes are adjusted to maintain budget balance.

[16] That is, to maintain budget balance (as in the benchmark) the government can raise lump sum transfers by 0.89% of output.

Policy 4 combines policies 1 and 3. We find that complementing the alternative calculation of the pension base proposed in policy 3, by an increase in the replacement rate, provokes the strongest rise in employment, education and growth. An increase in the pension burden notwithstanding, net effects on the government budget are positive (as lump sum transfers do not decline). An important element is that a higher pension replacement rate raises the return to working when middle-aged and older, and to building human capital when young. Policy 5 shows the effects of a shift from individual earnings-related pensions to 'basic' pensions. The ex ante budgetary effect of this shift is zero. As can be seen, overall employment, education and growth effects are negative. A key element is the fall in the return to working and studying when the pension replacement rate b_{4a} is reduced. Ex post effects on the government budget are also negative.

Table 5. Effects of pension reform – Effects for a benchmark of 6 core euro area countries (Austria, Belgium, France, Germany, Italy and the Netherlands).

Initial values: P_1=1/3 P_2=1/3 P_3=1/3 b_{4a}=0.72 b_{4b}=0.06	**Policy 1** b_{4a}=0.77	**Policy 2** P_1=1/6 P_2=1/3 P_3=3/6	**Policy 3** P_1=0 P_2=1/3 P_3=2/3	**Policy 4** P_1=0 P_2=1/3 P_3=2/3 b_{4a}=0.77	**Policy 5** b_{4a}=0.54 b_{4b}=0.24	**Policy 6** Fully Funded	**Policy 4b** (= policy 4, with e exoge-nous)	**Policy 6b**	**Policy 7** Δb_{3b} =-0.281
Effect [(a)]:									
Δn_1	0.08	-2.88	-6.13	-6.45	-0.17	0.47	-2.83	3.75	0.11
Δn_2	0.23	0.18	0.49	0.77	-0.63	-0.69	-0.02	0.88	-0.59
Δn_3	0.61	4.21	7.87	8.74	-2.00	-6.55	7.57	0.34	6.23
ΔR [(c)]	0.08	0.51	0.93	1.02	-0.26	-1.02	0.91	0.15	1.72
Δe	0.07	1.53	3.21	3.51	-0.22	-0.56	0.00	-1.50	-0.50
Δn [(a, b)]	0.29	0.31	0.38	0.63	-0.87	-2.00	1.23	1.70	1.63
$\Delta N/N$ [(d)]	0.54	0.57	0.69	1.15	-1.60	-3.66	2.25	3.12	2.98
Δannual growth rate[(a)]	0.01	0.11	0.23	0.25	-0.02	-0.04	0.00	-0.12	-0.04
ΔZ ex post [(e)]	-0.39	0.64	0.89	0.49	-0.44	-3.53	0.75	1.49	1.98

Notes: (a) difference in percentage points between new steady state and benchmark, except $\Delta N/N$ and R.
(b) change in (weighted) aggregate employment rate in hours, change in percentage points.
(c) change in optimal effective retirement age in years
(d) change in volume of employment in hours, in %.
(e) change in lump sum transfer (as a fraction of output) to maintain budget balance, in %-points.

Policy 6 is a gradual shift from the PAYG system in the benchmark to a system with full private capital funding. This policy completely abolishes old-age pension benefits (b_{4a}, b_{4b}). For the government it implies a drastic cut in pension expenditures. We assume that this drop in expenditures feeds through into lower social security contributions for all workers such that, ex ante, the decline in total labor tax receipts in % of GDP is exactly the same as the drop in pension expenditures.[17] We observe that this transition to a private fully-funded pension scheme is not beneficial for employment. The aggregate employment rate drops by 2%-points. An important element here is that a fully-funded system breaks the direct positive link between individual labor income and the pension, which exists in the PAYG system as we have modeled it. Growth decreases (-0.04%-points) as tertiary education is discouraged both by the fall in the pension replacement rate b_{4a}, and by the cut in labor taxes when young. The labor tax cut when middle-aged and older cannot neutralize the negative effect. Smaller accumulation of human capital also discourages work when older. As a final result, we also observe that a shift to a fully-funded system affects the government balance negatively (as lump sum transfers decline by 3.53% of GDP). The latter is explained by the decline in the tax base as hours of work decrease. Another element is that, although we also find that moving to a system with private capital funding encourages national savings (see e.g. Feldstein, 1974, 2005), this need not imply an increase in domestic physical capital formation (and capital taxes). If effective labor supply and employment fall, this reduces the marginal product of physical capital, and causes savings to be invested abroad (see below, current account).

Our main result in Table 5 is that an intelligent PAYG system may have positive effects on both employment, the effective retirement age, and growth. It may perform (much) better than a system with a strong basic pension component, or a system with full private funding. A key element is to have a tight link between individuals' own labor income (and therefore hours worked and human capital) in later years of the career and the pension. Such a policy stimulates labor supply when middle-aged and older, and education when young. Positive effects on human capital formation promote future productivity and earnings capacity, also for future generations.

Our conclusion is in line with some recent literature, but goes against other. Additional results may explain part of the differences. First, our findings support analytical results by Jaag *et al.* (2010) and Fisher and Keuschnigg (2010) among others that a *strong link between own contributions and the pension* strengthens incentives to work (see also Lindbeck and Persson, 2003; Cigno, 2010). Flat pension regimes imply lower overall employment. This is clear from policy 5, which establishes a stronger link between a retiree's pension and the average net labor income of working generations at the time of his retirement (and a weaker link with his own labor income). Second, our findings from policies 3 and 4 also support the positive effects on the effective retirement age and the labor supply of older workers from *letting the pension rise in labor income and contributions paid as an older worker*, as emphasized by Sheshinski (1978), Gruber and Wise (2002) and Lindbeck and Persson (2003). Highly similar effects on n_3 and R follow from reducing the net replacement rate in the early retirement regime (b_{3b}). Policy 7 brings down b_{3b} by 28%-points, i.e. a reduction from 65% in the euro area benchmark to 37%, which is the average for Denmark, Norway and Sweden. Note however that this policy reduces the return to education and human capital formation, since early retirement benefits rise in human capital. This result illustrates, as a third observation, the importance of *endogenous education and growth* in an analysis of pension reform. The role of endogenous

[17] In particular, the gradual decline in b_{4a} and b_{4b} is announced at time t=1 and implemented as follows. Pensions benefits are not reduced for retirees at the moment of policy implementation (t=1), since retirees are not able to react to a pension reduction. In t=2 and t=3 the replacement rates are respectively reduced to 2/3 and 1/3 of their initial rates. From t=4 onwards, b_{4a} and b_{4b} are zero. At each moment, overall labor tax rates are reduced to ex ante compensate for the decline in pension expenditures.

education also qualifies the importance of labor supply effects for young workers. We also find, like Jaag *et al.* (2010), that a higher weight attached to labor income as an older worker (p_3) may reduce labor supply of the young. In our model, however, this may have positive effects due to the endogeneity of human capital and growth. The endogeneity of human capital is crucial also in the comparison of a PAYG system with a fully-funded private capital system when it comes to growth. Our results are in line with findings by Kemnitz and Wigger (2000) and Kaganovich and Meier (2008) that a PAYG system can raise growth compared to a fully-funded scheme because it strengthens incentives to invest in education. A key element is that a PAYG system allows individuals to partially internalize the positive externalities of human capital formation. In Kemnitz and Wigger (2000), as in our approach, a PAYG system raises the return to education because of the close link between an individual's pension benefit and his/her own accumulated human capital. Kaganovich and Meier (2008) show higher growth in a flat pension system. Here, individuals will invest more in their children's education because their children's productivity determines their future pension. Policy 4b in Table 5 revisits policy 4 under the assumption of exogenous education and growth. Overall employment rises more than in policy 4, mainly thanks to a smaller shift from employment into education by young workers. Unlike the relatively limited effects here, we will see below much stronger welfare effects, especially for future generations.

Our results also go against some of the literature. Börsch-Supan and Ludwig (2010) and Ludwig *et al.* (2010) among others tend to find that economies are better able to face ageing with a fully-funded system. Furthermore, despite positive effects on employment from an intelligently designed PAYG system, many studies find the highest employment in a fully-funded system (e.g. Fisher and Keuschnigg, 2010). We learn from our simulations that the specific setup of the pension system in these papers may explain the difference. Some studies compare the fully-funded system with a flat PAYG system. Clearly, this approach is crucial for the results. If we reinforce the shift to a flat pension in our policy 5 by bringing b_{4a} to zero and by simultaneously raising b_{4b}, employment effects are indeed worse than in policy 6 (Δn in this extreme version of policy 5 would be -4 percentage points). Other studies neglect the difference between early retirement and old-age pension systems. Workers in these studies are free to choose the age at which they step from work into old-age retirement. A PAYG pension then directly raises the opportunity cost of working. Clearly, this setup is not very realistic. In most countries early retirement benefits raise the opportunity cost of work, old-age pensions don't. It is hard to quantify in our model the effects of moving from such a system (where workers optimally choose the age to go from work directly into old-age pensions) to a fully-funded system. Since such a PAYG system does not exist in most countries, it cannot establish a reliable benchmark. When, however, we quantify the effects of (i) moving from our current benchmark to such a PAYG system, and (ii) moving from our current benchmark to a fully-funded system without an early retirement regime, we find that the movement to a fully-funded system yields indeed better performance and welfare. This is in line with the literature, but - again - not a realistic setup or exercise.

Policy 6b highlights a third possible reason for why one may find in the literature that moving to a fully-funded system is better than an (intelligent) PAYG system. In this policy we treat non-employment benefits differently than in policy 6. More precisely, if moving to a fully-funded system implies a cut in taxes on labor, this may also raise net non-employment benefits, when these are proportional to net wages. The gain from work versus non-employment then remains unaffected. This is what happens in policy 6. In policy 6b, by contrast, we keep net non-employment benefits unchanged, such that the labor tax cut raises the relative gain from work. This setup is much more in line with the literature, where non-employment benefits are often disregarded. As one can see in Table 5, moving to a fully-funded system now implies a strong increase in aggregate employment. All age groups work more. It should be clear, however, that the main element here is not the shift in the pension regime, but the relative reduction in non-employment benefits. In Heylen and Van de Kerckhove (2010) we report highly similar employment effects from an absolute cut in non-employment benefits (b_j, with j=1,2,3a) for unchanged labor taxes, and a constant pension system. Moreover, the employment success of policy 6b also comes at a cost. The strong rise in the employment rate of the young runs parallel with a strong reduction in education, and the largest fall in steady state growth.

5.2. Transitional dynamics and welfare effects per generation.

We now describe the transitory adjustment path of key variables, including welfare, after the main pension reforms discussed in Table 5. Figure 9 shows the evolution of aggregate output, Figure 10 the evolution of the aggregate employment rate. Policy changes are introduced in period 1. We assume that these policy changes are unanticipated and permanent. In the 'short-run' we observe small output losses after most policies, except policies 7 and 4b. The latter two policies are the only ones that succeed in raising aggregate employment in the 'short-run'. Policies 5, 6 and 6b show the worst short-run output evolution, which is again mainly driven by the evolution of employment. In the long-run, differences between policies are much more pronounced. Rather than employment, the evolution of education and human capital is now crucial. (Remember that human capital also attracts physical capital in our model). The strongest 'long-run' output effects follow from policy 4 (+19.7% after 6 periods), followed by policies 3 and 2. These are also the policies that encourage education most. Note that under the assumption of constant participation in education (policy 4b), output effects in Figure 10 are much more limited. We also observe strong output growth during periods 2, 3 and 4 under policies 6 and 6b, but this growth is not persistent[18].

Figure 11 shows the welfare effects of these policy changes for current and future generations. We report on the vertical axis the welfare effect on the generation born in $t+k$, where k is indicated on the horizontal axis, and where t is the period when the (permanent, unanticipated) policy change is introduced. Our welfare measure is the (constant) percentage change in benchmark consumption in each period of remaining life that individuals should get to attain the same lifetime utility as after the policy shock (see also King and Rebelo, 1990). For example, concentrating on policy 3, a shift in the weights underlying the pension base in favor of the third period (p_3) implies a welfare gain for the current young (k=0), equal to 1.28% of benchmark consumption. The gain for the current middle-aged and retired (k = -1, -3) is slightly positive whereas the current old slightly lose welfare (-0.85% of benchmark consumption. All future generations ($k>0$) gain. For the generation that is young in period $t+2$, for example, policy 3 implies a welfare gain of almost 9% of benchmark consumption.

[18] The announcement of the transition to a fully-funded system, and the perspective of a gradual fall in labor taxes during periods 2, 3 and 4, as described in footnote 17, makes individuals work less when young (and work more in later periods – at lower tax rates). Young individuals therefore study more, which is good for the evolution of human capital, and output. As we report in Table 5, however, this positive education effect is not permanent (on the contrary).

Figure 9. Output level evolution after permanent policy shocks introduced in period 1 (index, benchmark period=0, benchmark output level =1)

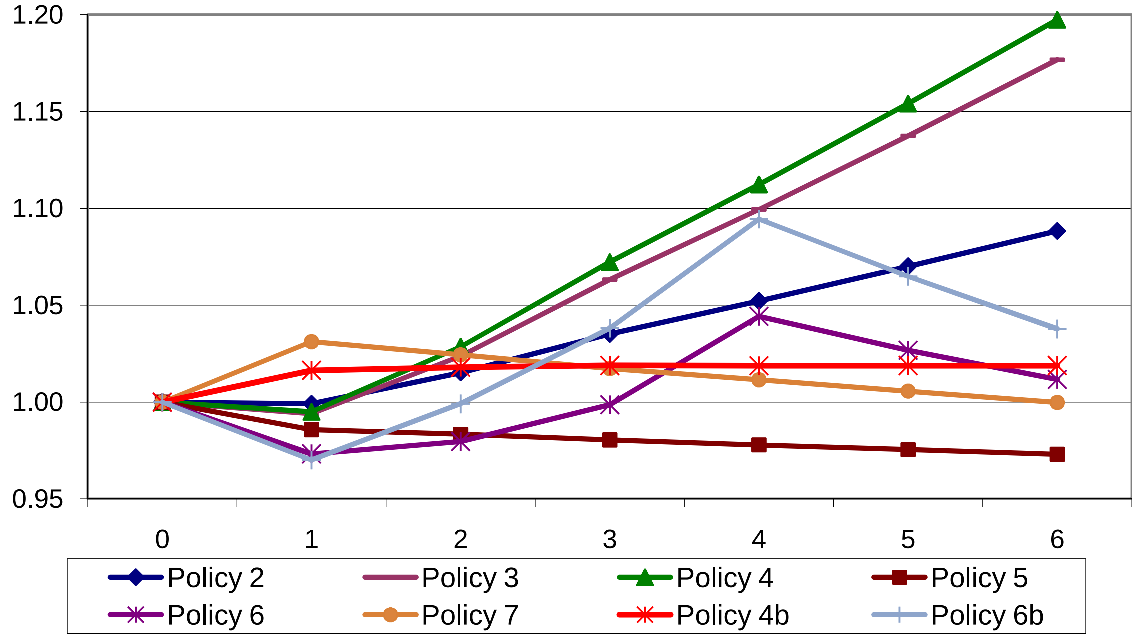
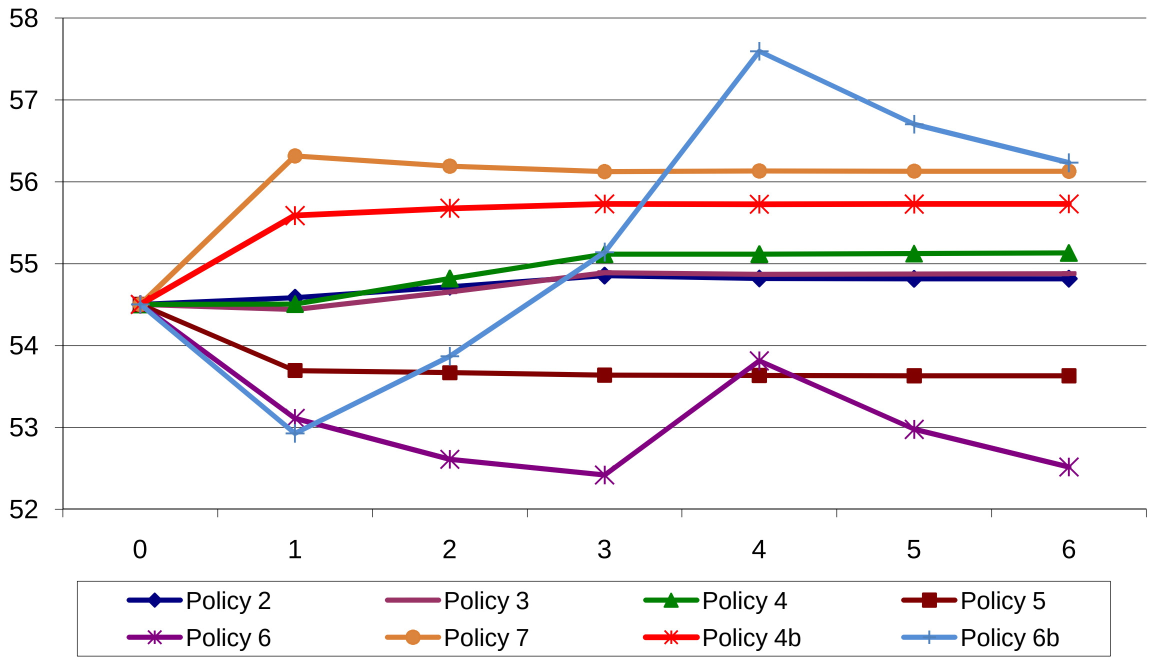
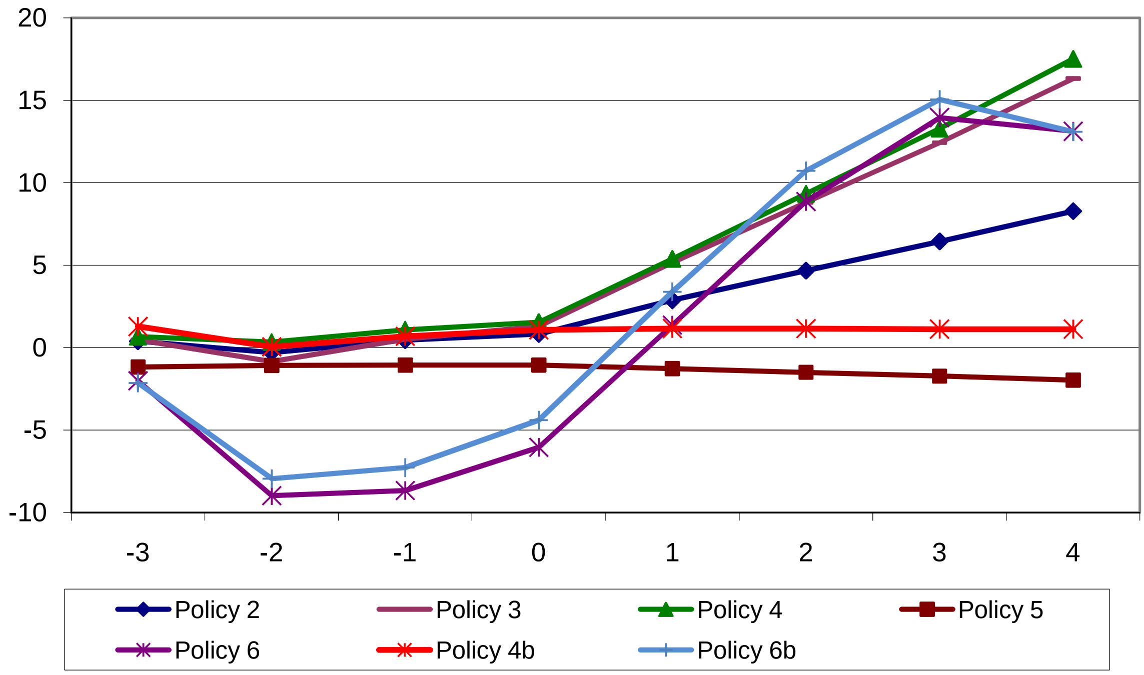


Figure 10. Aggregate employment rate in % after permanent policy shocks introduced in period 1 (benchmark period=0)



Our most interesting findings concern the overall welfare gain for current and (especially) future generations following the adoption of policy 4. An increase in the pension replacement rate, combined with a higher weight p_3 in the computation of the pension base, does not only have significant beneficial effects on employment and growth, but also on welfare. This reform results in the largest welfare gains when compared to our other policy measures. A comparison of welfare effects from policies 4 and 4b reveals, however, the crucial role of policy 4's strong positive effects on growth. This observation is important: neglecting possible effects of pension reform on human capital and growth may yield very different conclusions about welfare. The important role of endogenous human capital has recently been shown also by Ludwig *et al.* (2010). Finally, we observe the considerable overall welfare losses for current generations following the adoption of policy 6. The cost imposed on the transition generations is a well-known problem in policy proposals that consider to substitute a fully-funded private system for a PAYG model. Welfare effects on future generations are much more positive, however. A different treatment of non-employment benefits in policy 6b does not affect these conclusions. Finally, we observe consistently negative welfare effects on all generations from moving to basic pensions in policy 5.

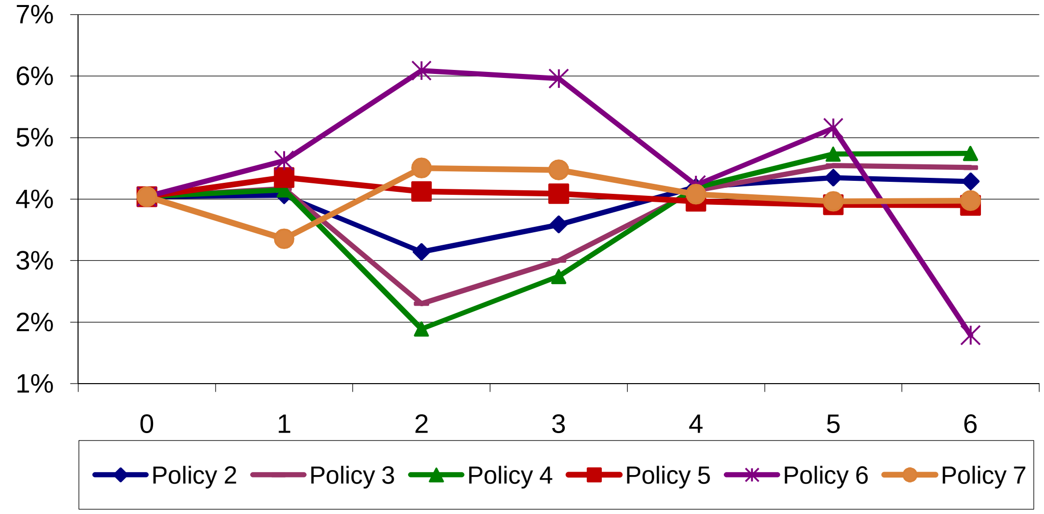
Figure 11. Welfare effects for current and future generations after pension reform



Note: The vertical axis indicates the welfare effect for the generation born in $t+k$, where t is when the policy change is introduced. The horizontal axis indicates k.
For a description of our welfare measure, see the main text.

Figure 12 shows the evolution of the current account under the different pension policies. In the first periods after the policy reform, it reveals strong capital outflows in policy 6, which is in line with the literature, and inflows in many other policies. In line with our earlier findings, changes in employment and human capital (which affect the productivity of physical capital) and savings can explain these movements. In later periods, capital flows under the fully-funded regime are reversed.

Figure 12. Current account balance (in % of GDP) after pension reform



6. Conclusions

Rising pressure on the welfare state due to ageing is forcing all OECD countries to develop effective employment and growth policies, and to reconsider pension and social security systems. This paper shows that both tasks are highly related. Pension reform can be an important policy instrument for higher employment (mainly of older workers), human capital and growth.

We build and parameterize a four-period OLG model for an open economy to study hours of work among young, middle-aged and older workers, education of the young, the effective retirement age of older workers, and aggregate per capita growth, within one coherent framework. We explain these endogenous variables as functions of various tax rates, various kinds of government expenditures, and key characteristics of the public PAYG pension system. Old-age pensions in our model are related to earned labor income over the three periods of active life, but the link between pension benefits and earlier labor income (and contributions) may be tight or loose. The government can also decide on the weight attached to each of the three active periods in the pension assessment base. Finally, we pay particular attention to a realistic modeling of the transition from work to retirement. Workers can optimally choose their effective retirement age, and receive early retirement benefits. However, the statutory retirement age after which old-age pensions are being paid, is exogenous.

We find that our model explains the facts remarkably well for many OECD countries. We then use the model to investigate the effects of various reforms of the pension system. Studying pension reform in a model where employment by age, education and human capital, and growth, are all endogenous is the main contribution of this paper.

Our simulation results prefer an intelligent PAYG pension system above a fully-funded private system. Key elements of an intelligent PAYG system include: (i) a close link between old-age pensions, and individual labor earnings and contributions, via a high pension replacement rate, (ii) a high weight of labor income (i.e. hours worked and human capital) earned as an older worker in the pension assessment base. Pension reform in this direction encourages young individuals to study and build human capital, which promotes long-run growth. Furthermore, it encourages older workers to postpone retirement. Strengthening the link between one's future old-age pension, on the one hand, and one's human capital and labor supply when older, on the other, introduces strong financial incentives which may bring about important changes in behavior. Policy reforms in this direction may also raise welfare levels of current and (especially) future generations. Furthermore, our results confirm that the partial abolishment of various early retirement regimes, through a reduction in the generosity of early retirement benefits or the introduction of more strict eligibility criteria for early retirement, substantially stimulates employment of older workers along both the intensive and extensive margin.

Our findings tend to support recent pension reforms in countries like Sweden and Finland. Sweden moved from a quite non-actuarial PAYG system to a quasi-actuarial system with individual notional accounts (Lindbeck and Persson, 2003; OECD, 2005). These accounts establish a close relationship between working hours, labor earnings and contributions on the one hand, and future pensions on the other, as in the case of a high replacement rate b_{4a} in our model (and a low b_{4b}). Finland introduced a system where the pension accrual rate rises with age, which corresponds to the case of a rising p_j as workers get older in our model (OECD, 2005). There is no support in our model for policy changes which imply an extension of the pension assessment base to those years when young people may optimally be studying.

We see various possibilities for future research. First, we assume in this paper a constant population structure and life length. The implementation of a birth and mortality rate and uncertain life length, is left for future research. Second, we assume in this paper homogeneous individuals in each generation. The implementation of different ability levels is also left for research in the near future. Welfare effects from the policy measures discussed in this paper may be very different for high and low ability (wage income) individuals. This may affect policy evaluation.

References

Agénor, P.-R. (2008) Fiscal policy and endogenous growth with public infrastructure, *Oxford Economic Papers*, 60, 57–87.

Arcalean, C. And Schiopu, I. (2010) Public versus private investment and growth in a hierarchical education system, *Journal of Economic Dynamics and Control*, 34, 604-622.

Auerbach, A. and Kotlikoff, L. (1987) *Dynamic Fiscal Policy*, Cambridge University Press, Cambridge.

Auerbach, A., Kotlikoff, L., Hagemann, P. and Nicoletti, G. (1989) The Economic Dynamics of an Ageing Population: The Case of Four OECD Countries, *OECD Economics Department Working Papers* 62, Economics Department

Azariadis, C. and Drazen, A. (1990) Threshold Externalities in Economic Development, *Quarterly Journal of Economics* 105, 501-526.

Backus, D., Henriksen, E. and Storesletten, K. (2008) Taxes and the global allocation of capital, *Journal of Monetary Economics*, 55, 48-61.

Barr, N. (2006) Pensions: Overview of the issue, *Oxford Review of Economic Policy*, 22, 1-14.

Barro, R.J. (1990) Government spending in a simple model of endogenous growth, *Journal of Political Economy*, 98, S103-125.

Benhabib, J. and Farmer, R. (1994) Indeterminacy and increasing returns, *Journal of Economic Theory*, 63, 19-41.

Blanchard, O. and Wolfers, J. (2000) The role of shocks and institutions in the rise of European unemployment: The aggregate evidence, *Economic Journal*, 110, C1-33.

Börsch-Supan, A., Ludwig, A. and Winter, J. (2006) Ageing, Pension Reform and Capital Flows: A Multi-Country Simulation Model, *Economica*, 73, 625-658

Börsch-Supan, A.H. and Ludwig, A. (2010) Old Europe ages: Reforms and Reform Backlashes, *NBER Working Paper*, N° 15744.

Boucekkine, R. (1995) An alternative methodology for solving non-linear forward-looking models. *Journal of Economic Dynamics and Control*, 19, 711–734.

Bouzahzah, M., de la Croix, D. and Docquier, F. (2002) Policy reforms and growth in computational OLG economies, *Journal of Economic Dynamics and Control*, 26, 2093–2113.

Brandt, N., Burniaux J.-M. and Duval, R. (2005) Assessing the OECD Jobs Strategy: Past developments and reforms, *Economics Department Working Paper,* No. 429 (annexes).

Buiter, W.H., and Kletzer, K.M. (1993) Permanent International Productivity Growth Differentials in an Integrated Global Economy, *Scandinavian Journal of Economics* 95, 467-493.

Cigno, A. (2010) How to avoid a pension crisis: a question of intelligent system design, *CESIfo Economic Studies*, 56, 21-37.

Cremer, H., Lozachmeur, J.-M. and Pestieau, P. (2008) Social Security and Retirement Decision : A Positive and Normative Approach, *Journal of Economic Surveys*, 22, 213-233.

de la Croix, D., Pierrard, O. and Sneessens, H.R. (2010) Aging and Pensions in General Equilibrium : Labor Market Imperfections Matter, *IZA Discussion Papers 5276.*

Devereux, M.P., Griffith, R. and Klemm, A. (2002) Corporate income tax reforms and international tax competition, *Economic Policy*, 35, 451-495.

Dhont, T. and Heylen, F. (2008) Why do Europeans work (much) less? It is taxes and government expenditures, *Economic Inquiry*, 46, 197-207.

Dhont, T. and Heylen, F. (2009) Employment and growth in Europe and the US: the role of fiscal policy composition, *Oxford Economic Papers*, 61, 538-565.

Diamond, P. (1965) National Debt in a Neoclassical Growth Model, *American Economic Review*, 55, 1126-1150.

Docquier, F. and Michel, P. (1999) Education subsidies, social security and growth: The implications of a demographic shock, *Scandinavian Journal of Economics*, 101, 425-440.

Docquier, F. and Paddison, O. (2003) Social security benefit rules, growth and inequality, *Journal of Macroeconomics*, 25, 47-71.

Duval, R. (2003) The Retirement Effects of Old-Age Pension and Early Retirement Schemes in OECD Countries, *OECD Economics Department Working Papers*, No. 370.

Feldstein, M. (1974) Social Security, Induced Retirement, and Aggregate Capital Accumulation, *Journal of Political Economy*, 82, 905-926.

Feldstein, M. (2005). Rethinking Social Insurance, *American Economic Review*, 95, 1-24.

Fenge R. and Pestieau, P. (2005) *Social Security and Early Retirement*, MIT Press, Cambridge.

Fernandez Cordon, J.A. (2001) Youth as a transition to full autonomy, *Family Observer,* No. 3, 4-11.

Fisher, W.H. and Keuschnigg, C. (2010) Pension reform and labor market incentives, *Journal of Population Economics*, 23, 769-803.

Fougère, M., Harvey, S., Mercenier, J. and Mérette, M. (2009) Population ageing, time allocation and human capital: a general equilibrium analysis for Canada, *Economic Modelling*, 26(1), p. 30-39

Glomm, G. and Ravikumar, G. (1992) Public vs. private investment in human capital: Endogenous growth and income inequality, *Journal of Political Economy*, 100, 818-834.

Gruber, J. and Wise, D. (2002) Social Security Programs and Retirement around the World: Microestimation, *NBER Working Paper*, N° 9407.

Hachon, C. (2010) Do Beveridgian pension systems increase growth, *Journal of Population Economics*, 825-831.

Hanushek, E.A. and Woessmann, L. (2009) Do better schools lead to more growth? Cognitive skills, economic outcomes, and causation, *NBER Working Paper*, N° 14633.

Heijdra, B. and Romp, W. (2009) Retirement, pensions and ageing, *Journal of Public Economics*, 93, 586-604.

Heylen, F. and Van de Kerckhove, R. (2010) Fiscal policy, employment by age, and growth in OECD economies, *Paper presented at the 25th Annual Congress of the European Economic Association*, Glasgow, August 2010 (www.sherppa.be).

Hu, S.C. (1979) Social security, the supply of labor and capital accumulation, *American Economic Review*, 69(3), 274-283.
Jaag, C., Keuschnigg, C. and Keuschnigg, M. (2010) Pension reform, retirement, and life-cycle unemployment, *International Tax and Public Finance,* 17, 556-585.
Juillard, M. (1996) Dynare: A program for the resolution and simulation of dynamic models with forward variables through the use of a relaxation algorithm*. Working Paper*, N° 9602, CEPREMAP.
Kaganovich, M. and Meier, V. (2008) Social security systems, human capital, and growth in a small open economy, *CESifo Working Paper*, N° 2488.
Kaganovich, M. and Zilcha, I. (1999) Education, social security and growth, *Journal of Public Economics*, 71, 289-309.
Kemnitz, A. and Wigger, B.U. (2000) Growth and social security: the role of human capital, *European Journal of Political Economy*, 16, 673-683.
King, R.G. and Rebelo, S. (1990) Public policy and economic growth: developing neoclassical implications, *Journal of Political Economy*, 98, S126-150.
Le Garrec, G. (2011) Social security, income inequality and growth, *Journal of Pension Economics and Finance*, forthcoming.
Lindbeck, A. and M. Persson (2003) The gains from pension reform, *Journal of Economic Literature*, 41, 74-112.
Ludwig A., Schelkle T. and Vogel E. (2010) Demographic Change, Human Capital and Welfare, *MEA Discussion Paper nr. 196-2010*
Lucas, R.E. (1988) On the mechanics of economic development, *Journal of Monetary Economics*, 22, 3-42.
Nickell, S., Nunziata, L., and Ochel, W. (2005) Unemployment in the OECD since the 1960s. What do we know?, *Economic Journal*, 115, 1-27.
OECD (2005) *Pensions at a Glance: Public policies across OECD countries*, OECD, Paris.
Ohanian, L., Raffo, A., and Rogerson, R. (2008) Long-term changes in labor supply and taxes: Evidence from OECD countries, 1956-2004, *Journal of Monetary Economics*, 55, 1353-1362.
Reyneri, E. (1994) Italy: A long wait in the shelter of the family and of safeguards from the State in: O. Benoit-Guilbot and D. Gaillie (eds.), *Long-term Unemployment*, London, Pinter, 97-110.
Rogerson, R. (2007) Taxation and market work: Is Scandinavia an outlier?, *NBER Working Paper*, N° 12890.
Rogerson, R. and Wallenius, J. (2009) Micro and macro elasticities in a life cycle model with taxes, *Journal of Economic Theory*, 144, 2277-2292.
Salomäki, A. (2003) Remain in or withdraw from the labour market? A comparative study on incentives, *European Economy Economic Papers*, N° 193.
Samuelson, P.A. (1958) An Exact Consumption-Loan Model of Interest, With or Without the Social Contrivance of Money, *Journal of Political Economy*, 66, 467-482.
Sánchez Martín, A. (2010) Endogenous Retirement and Public Pension System Reform in Spain, *Economic Modelling*, 27, 336-349.
Sheshinski, E. (1978) A Model of Social Security and Retirement Decisions, *Journal of Public Economics*, 10, 337-360.
Stokey, N.L. and Rebelo, S. (1995) Growth effects of flat-rate taxes, *Journal of Political Economy*, 103, 519-550.
Turnovsky, S.J. (2000) Fiscal policy, elastic labor supply, and endogenous growth, *Journal of Monetary Economics*, 45, 185-210.
Whiteford, P. and Whitehouse, E. (2006) Pension Challenges and Pension Reforms in OECD Countries, *Oxford Review of Economic Policy*, 22(1), 78-94.
Whitehouse, E., D'Addio, A., Chomik, R. And Reilly, A. (2009) Two decades of pension reform: What has been achieved and what remains to be done, *The Geneva Papers*, 34, 515-535.
Woessman, L. (2003) Schooling resources, educational institutions and student performance: the international evidence, *Oxford Bulletin of Economics and Statistics*, 65, 117-170.
Zhang, J. (1995) Social security and endogenous growth, *Journal of Public Economics*, 58, 185-213.
Zhang, J. and Zhang, J. (2003) Long-run effects of unfunded social security with earnings-dependent benefits, *Journal of Economic Dynamics and Control*, 28, 617-641.

Appendix 1: Construction of data and data sources

In this appendix we provide more detail on the construction of some of our performance variables and policy variables.

Employment rate in hours *(in one of three age groups, 1995-2007)*
Definition: total actual hours worked by individuals in the age group / potential hours worked.
Actual hours worked = total employment in persons x average hours worked per week x average number of weeks worked per year
Potential hours = total population in the age group x 2080 (where 2080 = 52 weeks per year x 40 hours per week)
Data sources:
* Total employment in the age group / total population in the age group: OECD Stat, Labour Force Statistics by Sex and Age. Data are available for many age groups, among which 20-24, 25-34, 35-44, 45-49, 50-54, 55-64. We constructed the data for our three age groups as weighted averages.
* Average hours worked per week: OECD Stat, Labour Force Statistics, Average usual weekly hours worked on the main job. These data are available only for age groups 15-24, 25-54, 55-64. We use the OECD data for the age group 15-24 as a proxy for our age subgroup 20-24, the OECD data for the age group 25-54 as a proxy for our age (sub)groups 25-34, 35-49 and 50-54.
* Average number of weeks worked per year: Due to lack of further detail, we use the same data for each age group. The average number of weeks worked per year has been approximated by dividing average annual hours actually worked per worker (total employment) by average usual weekly hours worked on the main job by all workers (total employment). Data source: OECD Stat, Labour Force Statistics, Hours worked.

Education rate of young *(age group 20-34, 1995-2006)*
Definition: total hours studied by individuals of age 20-34 / potential hours studied
As a proxy we have computed the ratio: $\left(fts_{20-34} + 0.5\, pts_{20-24} + 0.25\, pts_{25-34} \right) / \; pop_{20-34}$
with: *fts* the number of full-time students in the age group 20-34
pts the number of part-time students in the age groups 20-24 and 25-34.
pop total population of age 20-34
Full-time students are assumed to spend all their time studying. For part-time students of age 20-24 we make the assumption (for all countries) that they spend 50% of their time studying, part-time students of age 25-34 are assumed to spend 25% of their time studying. Due to the limited number of part-time students, these specific weights matter very little.
Data sources:
* Full-time students in age groups 20-24, 25-29, 30-34: OECD Stat, Education and Training, Students enrolled by age (all levels of education, all educational programmes, full-time)
* Part-time students in age groups 20-24, 25-29, 30-34: OECD Stat, Education and Training, Students enrolled by age (all levels of education, all educational programmes). We subtracted the data for full-time students from those for 'full-time and part-time students'.
Data are available in 1995-2006. However, for many countries (quite) some years are missing. Period averages are computed on the basis of all available annual data.

Average effective retirement age (1995-2006)
Definition: The average effective age of retirement is calculated as a weighted average of (net) withdrawals from the labor market at different ages over a 5-year period for workers initially aged 40 and over.
Data sources:
* OECD, Ageing and Employment Policies – Statistics on average effective age of retirement

Annual real potential per capita GDP growth rate *(aggregate, 1995-2007)*
Definition: Annual growth rate of real potential GDP per person of working age
Data sources:
* real potential GDP: OECD Statistical Compendium, Economic Outlook, supply block, series GDPVTR.
*population at working age: OECD Statistical Compendium, Economic Outlook, labour markets, series POPT.

Tax rate on labor income *(τ_1, τ_2, τ_3)*
Definition: Total tax wedge, marginal tax rate in %. The data cover personal income taxes, employee and employer social security contributions payable on wage earnings and payroll taxes.
Data source: OECD, Statistical Compendium, Financial and Fiscal Affairs, Taxing Wages, Comparative tax rates and benefits (new definition).
The OECD publishes these tax data for several family and income situations. We computed τ_1 as the average of marginal tax rates for (i) a one-earner married couple at 100% of average earnings (2 children), (ii) a two-earner married couple, one at 100% of average earnings and the other at 33 % (2 children), (iii) a single person at 67% of average earnings (no child) and (iv) a single person at 100% of average earnings (no child). We computed τ_2 and τ_3 as the average of tax rates for (i) a one-earner married couple at 100% of average earnings (2 children), (ii) a two-earner married couple, one at 100% of average earnings and the other at 67 % (2 children), (iii) a single person at 100% of average earnings (no child) and (iv) a single person at 167% of average earnings (no child). The reported data concern 2000-2002.

Net benefit replacement rates *(b_1, b_2, b_{3a})*
Definition: The data concern net transfers received by long-term unemployed people and include social assistance, family benefits and housing benefits in the 60th month of benefit receipt. They also include unemployment insurance or unemployment assistance benefits if these benefits are still paid, i.e. if workers can be structurally unemployed for more than five years without losing benefit eligibility. The data are expressed in % of after-tax wages. The OECD provides net replacement rates for six family situations and three earnings levels. In line with our assumptions for labor tax rates (see above), we computed b_1 as the average of the net benefit replacement rates for 'families' with earnings levels corresponding to 67% and 100% of the average worker's wage (AW). We computed b_2 as the average of the net benefit replacement rates for 'families' with earnings levels corresponding to 100% and 167% of the average worker's wage. The reported data are averages for 2001 and 2004. We assume b_{3a} to be equal to b_2.
Data source: OECD, Tax-Benefit Models, www.oecd.org/els/social/workincentives
Data adjustment: Original OECD data for Norway include the so-called "waiting benefit" (ventestønad), which a person could get after running out of unemployment benefits. Given the conditional nature of these "waiting benefits", they do not match our definition of benefits paid to structurally non-employed individuals. We have therefore deducted them from the OECD data in earlier years, which led to a reduction of net replacement rates by about 19 percentage points. For example, recipients should demonstrate high regional mobility and willingness to take a job anywhere in Norway. The "waiting benefit" was terminated in 2008. We thank Tatiana Gordine at the OECD for clarifying this issue with us.

Early retirement replacement rates *(b_{3b})*
To calculate our proxy for b_{3b} we have focused on the possibility for older workers in some countries to leave the labor market along fairly generous early retirement routes. Duval (2003) and Brandt *et al.* (2005) provide data for the so-called implicit tax rate on continued work for five more years in the early retirement route at age 55 and age 60. The idea is as follows. If an individual stops working (instead of continuing for five more years), he receives a benefit (early retirement, disability…) and no longer pays contributions for his future pension. A potential disadvantage is that he may receive a

lower pension later, since he contributed less during active life. Duval (2003) calculated the difference between the present value of the gains and the costs of early retirement, in percent of gross earnings before retirement. We use his data as a proxy for the gross benefit replacement rate for older workers in the early retirement route. To compute the net benefit replacement rate, we assume the same tax rate on early retirement benefits as on unemployment benefits. We call this net benefit replacement rate r_3. However, these implicit tax rates are only very rough estimates of the real incentive to retire embedded in early retirement schemes and are subject to important caveats (Duval, 2003). *"First, the focus on a single "early retirement route" leaves aside the participation effects of a number of other social transfer programs that may actually be used as early retirement devices. Second, the actual strictness of eligibility criteria for these programs is imperfectly reflected in the calculations. For instance, even in those countries for which it has been assumed that retirement on account of disability is not* […] *an available option, due to the official strictness of eligibility criteria, the share of disability benefit status in non employment actually grew significantly during the second half of the 1990s (e.g. Sweden, United States: see OECD 2003e)."* (Duval, 2003, p. 15). In sum, the available implicit tax rates take into account neither the strictness of eligibility criteria nor the presence of alternative social transfer programs that may de facto be used as early retirement devices. Our assumption will be that a realistic replacement rate for the early retirement route (b_{3b}) will be a weighted average of r_3 and b_{3a}, where we take the latter as a proxy for the replacement rate in alternative social transfer programs. If $r_3 > b_{3a}$, older workers will aim for the official early retirement route, but they may not all meet eligibility criteria and have to fall back on alternative programs. If $r_3 < b_{3a}$, workers will aim for the alternative, but again they may not be eligible. We propose that $b_{3b} = \xi b_{3a} + (1-\xi)r_3$. Underlying the data in Table 4 is the assumption that $\xi=0.5$. Correlation between b_{3b} and r_3 is 0.95. Cross-country differences roughly remain intact. Clearly, our results in the main text do not depend in any serious way on this assumption for ξ.

Data Source: OECD, Tax-Benefit Models, www.oecd.org/els/social/workincentives, Duval (2003), Brandt et al. (2005).

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