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First draft, 7 March 2012

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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 growth, are all endogenous. Within each generation we distinguish individuals with high, medium or low ability to build human capital. This extension allows to investigate also the effects of pension reform on the income and welfare levels of different ability groups. Particular attention goes to the income at old-age and the welfare level of low-ability individuals.

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 aggregate welfare, positive effects in a pay-as-you-go 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. Such a regime does, however, imply welfare losses for the current low-ability generations, and rising inequality in welfare. Complementing or replacing this 'intelligent' pay-as-you-go system by basic and/or minimum pension components promotes welfare of the current and (maybe) future low-ability generations, but is negative for aggregate welfare, employment and growth. Better is to maintain the tight link between individual labor income and the pension also for low-ability individuals, but to strongly raise their replacement rate.

Keywords: employment by age; endogenous growth; retirement; pension reform; heterogeneous abilities; overlapping generations

JEL Classification: E62; H55; J22; J24

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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; 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; Zhang and Zhang, 2003; Kaganovich and Meier, 2008; Le Garrec, 2012). 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.*, 2011). 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 (Buyse *et al.*, 2011).

The above mentioned literature has strongly improved our understanding of the effects of pension systems on employment, education and growth. Still, it is limited in some respects. First of all, about all existing 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]. Buyse *et al.* (2011) respond to this limitation and study pension reform in a general equilibrium four-period OLG model where 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 are all endogenous. Their model includes a public PAYG old-age pension system which pays out pensions to a fourth generation of retired. Their approach allows to take into account the many mutual relationships between key variables. For example, if policy can make 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 also encourage people to work longer since they will then get a higher return from their investment. Also, if pension reform discourages employment of the young, it may still be positive if this contributes to education and growth. Buyse *et al.* (2011) show that the final effects of pension reform depend on all these interactions. This also implies that it is very 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.

[1] Fougère *et al.* (2009) and Ludwig *et al.* (2011) 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.

Like most existing literature, the model developed by Buyse *et al.* (2011) is limited in another important aspect, however. It disregards differences in abilities and motivation of people to learn. With some exceptions (e.g. Azariadis and de la Croix, 2002), models with education and growth typically assume that everyone is able to study and succeed in education. Reality is different, however. Data reveal that in 2008 about 30% of the 25-64 year old population on average in the OECD has no upper secondary degree. About 44% has an upper secondary degree but no tertiary degree. The fraction of people with a tertiary degree therefore remains below 30%. Among young cohorts, educational attainment is higher. Yet, the fraction that does not complete upper secondary education is still about 20% on average. About 40% obtains an upper secondary degree, but no tertiary degree. More or less another 40% completes both secondary and tertiary education (OECD, Education at a Glance, Tables A1, A2.2, A3.2). The simple fact that innate ability as for example reflected by IQ varies across people, implies that one can never expect everyone to succeed at the secondary, let alone the tertiary level.

In this paper we extend the OLG model in Buyse *et al.* (2011) by allowing heterogeneous abilities. We make the assumption that within each generation three ability groups exist. These groups differ both in the degree to which they (when young) assimilate existing knowledge, i.e. inherit human capital from the middle aged generation, and in their productivity of schooling when they spend time studying. One group has low ability. They inherit relatively little human capital from the middle aged generation, and will never engage in tertiary education. They will only work or have 'leisure'. A second group has medium ability, a third group high ability. These groups inherit higher fractions of existing human capital, and do allocate time to tertiary education. Given the variation between them in the productivity of schooling, this amount of time will differ, however. All other features of the model are as in Buyse *et al.* (2011). We also have a public PAYG old-age pension system which pays out pensions to the retired. The statutory retirement age in the 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. They then receive early retirement benefits. Next to the pension system, we introduce a role for education quality as well as a rich fiscal policy block. 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), old-age pensions, and interest payments on outstanding debt. Our aim is then to investigate the effects of various parametric adjustments in the old-age PAYG pension system on the employment rate of young, middle aged and older workers, education, growth and welfare. 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.

The main advantage of realistically introducing heterogeneous abilities, and therefore the main contribution of this paper, is that we will be able to study differential effects of pension reform on the income and welfare levels of individuals with different abilities and human capital. Particular attention goes to the income at old-age and the welfare level of the low-ability individuals. The link to a major issue as old-age poverty (see e.g. Kidd and Whitehouse, 2009) is obvious.

Buyse *et al.* (2011) prefer an 'intelligent' PAYG system above a fully-funded private system. When it comes to promoting employment, human capital, growth, and aggregate welfare, they find positive effects in a PAYG system to be 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. 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. A key question is, however, what such a regime would imply for low-ability individuals, who cannot study and will earn low wages, and for inequality in welfare. We try to answer this question in this paper. Furthermore, if effects for low-ability individuals are negative, a second question is whether there are better ways to reform the pension system. We investigate various adjustments like complementing or replacing this 'intelligent' PAYG system by basic and/or minimum pension components.

Our main findings are as follows. Our results confirm Buyse *et al.* (2011) in preferring an 'intelligent' PAYG system above a fully-funded private regime. Their preferred PAYG model does, however, imply welfare losses for the current low-ability generations, and rising inequality in welfare. Complementing or replacing this 'intelligent' PAYG system by basic and/or minimum pension components promotes welfare of the current and (maybe some) future low-ability generations, but it is negative for aggregate welfare, employment and growth. Labor supply and employment among low-ability individuals in particular fall strongly. Better is to maintain the tight link between individual labor income and the pension also for low-ability individuals, but to significantly raise their replacement rate.

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 employment, education and growth effects of various reforms of the pension system. We also study welfare effects per generation and per ability group. Section 6 concludes the paper.

2. Cross-country differences in employment, 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). Comparable data for hours worked by ability type (skill level) are not available. 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 include the effective retirement age in the Table. 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 details on the calculation of our data, and on the assumptions that we have to make.

Table 1

Employment rate in hours (*n*) by age, 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 effective participation in education is also 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 effective 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 large literature has used OLG models to study the behavioral effects of the pension system on employment, either on employment assuming exogenous growth, or on human capital and growth, ignoring the labor-leisure choice and assuming exogenous employment. New in this paper is that we explain both employment by age, and human capital and growth as jointly endogenous variables, and that we realistically take into account differences in individuals' innate abilities.

We consider three active adult generations, the young, the middle aged and the older, and one generation of retired agents. Within each generation we assume three types of individuals with different ability a to build human capital: a group H with high ability, a group M with medium ability and a group L with low ability**.** The last group will never enter into tertiary education. We assume that the three ability types are of equal size, and so are the different generations. We normalize each ability group to 1, so that the size of a generation is 3, and total population is 12, and constant[2]. Individuals enter the model at age 20. Each period is modeled to last for 15 years. High and medium ability 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). Low ability young individuals and all middle aged and older workers do not study anymore, they only work or have 'leisure'. The statutory old-age retirement age in our model is 65. Individuals may however optimally choose to leave the labor force sooner in a regime of early retirement.

Output is produced by domestic firms which 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

[2] Assuming demography and population to be constant may seem strange given that ageing is a crucial factor behind pension reform in many countries. Note however that this assumption is not uncommon (see also Jaag *et al.*, 2010; Fisher and Keuschnigg, 2010; Buyse *et al.*, 2011). Moreover, and most importantly, it need not be a limitation to disentangle behavioral effects from different routes of pension reform.

Drazen (1990). Each young generation inherits a fraction of the average level of human capital of a middle aged generation. The higher an individual's ability, the larger the fraction he inherits. In what follows, we concentrate on the core elements of the model: the optimizing behavior of individuals, the production and inheritance 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 with ability *a* (*a=H,M,L*) reaching age 20 in period *t* maximizes an intertemporal utility function of the form:

$$u_a^t = \sum_{j=1}^{4} \beta^{j-1} \left(\ln c_{ja}^t + \gamma_j \frac{(\ell_{ja}^t)^{1-\theta}}{1-\theta} \right), \qquad \forall a = H, M, L \tag{1}$$

with $0<\beta<1$, $\gamma_j>0$, $\theta>0$ ($\theta\neq 1$) and where we shall impose that

$$\ell_{1a}^t = 1 - n_{1a}^t - e_a^t \tag{2}$$

$$\ell_{2a}^t = 1 - n_{2a}^t \tag{3}$$

$$\ell_{3a}^t = \Gamma\left(\mu\left(R_a^t (1-\tilde{n}_{3a}^t) \right)^{1-(1/\rho)} + (1-\mu)\left(1-R_a^t\right)^{1-(1/\rho)} \right)^{\rho/(\rho-1)} \tag{4}$$

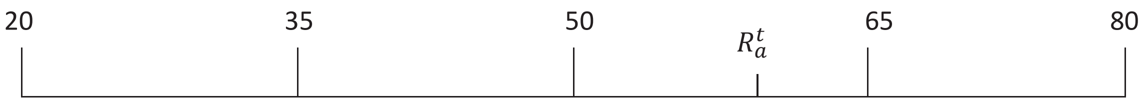
$\ell_{4a}^t = 1$ and $e_{1L}^t = 0.$

Superscript *t* indicates the period of youth, when the individual comes into the model. Subscript *j* refers to the *j*th period of life and *a* refers to the 'ability type'. Lifetime utility depends on consumption (c_{ja}) and 'leisure' (ℓ_{ja}) in each period of life. The intertemporal elasticity of substitution in consumption is 1, the intertemporal elasticity to substitute leisure $1/\theta$. Finally, β is the discount factor and γ specifies the relative value of 'leisure' versus consumption. The preference parameters θ, β and γ do not depend on ability type. Note, however, 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 of type a reaching age 20 in *t*. Individuals choose time devoted to work (n_{ja}) in the three active periods and education time (e_{1a}) 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_a 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; $(1-R_a)$ is then time in early retirement. We use n_{3a} to denote the fraction of time devoted to work between 50 and 65, and $\tilde{n}_{3a}$ 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_{3a} and $\tilde{n}_{3a}$ is as follows: $n_{3a} = R_a.\tilde{n}_{3a}$.

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 ($R_a(1-\tilde{n}_{3a})$), and time in early retirement after it *(1-R_a)*. 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, μ is a usual share parameter and Γ is added as a normalization constant such that the magnitude of ℓ_{3a} corresponds to the magnitude of total leisure time $1-n_{3a}$. 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. The main results in this paper are not in any way influenced by the magnitude of μ, Γ or ρ.

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



Period	*t*	*t+1*	*t+2*	*t+3*
Work	n_{1a}^t	n_{2a}^t	$n_{3a}^t = R_a^t \tilde{n}_{3a}^t$	*0*
Study	e_{1a}^t	*0*	*0*	*0*
'Leisure' time	$1 - n_{1a}^t - e_{1a}^t$	$1 - n_{2a}^t$	$R_a^t(1-\tilde{n}_{3a}^t) +$ $(1-R_a^t)$	*1*

Individuals will choose consumption, labor supply and education to maximize Equation (1), subject to Equations (2)-(4) and the constraints described in (5)-(13). Equations (5)-(8) describe the individuals' dynamic budget constraints. The LHS of these equations shows that individuals allocate their disposable income to consumption (including consumption taxes, τ_c) and the accumulation of non-human wealth. In each equation we denote by Ω_{ja}^t the stock of wealth held by a type a individual who enters the model at time *t* at the end of his jth period of life. Equations (5) and (8) respectively indicate that individuals start

[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).

and finish adult life with zero assets. 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, $w_{a,k}$ stands for the real wage per unit of effective labor supplied at time k by an individual with ability a, 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 with ability a depends on hours worked (n^t_{ja}) and effective human capital (h^t_{ja}). Since young individuals with ability a pay a tax rate on labor income τ_{1a} [4], they earn an after-tax real wage equal to $w_{a,t}h^t_{1a}n^t_{1a}(1-\tau_{1a})$. After-tax labor income when middle aged and older in Equations (6) and (7) are determined similarly.

$$(1+\tau_c)c^t_{1a} + \Omega^t_{1a} = w_{a,t}h^t_{1a}n^t_{1a}(1-\tau_{1a}) + b_{1a}w_{a,t}h^t_{1a}(1-\tau_{1a})(1-n^t_{1a}-e^t_a) + z_t \tag{5}$$

$$\begin{aligned}(1+\tau_c)c^t_{2a} + \Omega^t_{2a} &= w_{a,t+1}h^t_{2a}n^t_{2a}(1-\tau_{2a}) + b_{2a}w_{a,t+1}h^t_{2a}(1-\tau_{2a})(1-n^t_{2a}) \\ &\quad + (1+r_{t+1})\Omega^t_{1a} + z_{t+1}\end{aligned} \tag{6}$$

$$\begin{aligned}(1+\tau_c)c^t_{3a} + \Omega^t_{3a} &= w_{a,t+2}h^t_{3a}R^t_a\tilde{n}^t_{3a}(1-\tau_{3a}) + b_{3a}w_{a,t+2}h^t_{3a}(1-\tau_{3a})R^t_a(1-\tilde{n}^t_{3a}) \\ &\quad + b_{4a}w_{a,t+2}h^t_{3q}(1-\tau_{3q})(1-R^t_a) + (1+r_{t+2})\Omega^t_{2a} + z_{t+2}\end{aligned} \tag{7}$$

$$(1+\tau_c)c^t_{4a} = (1+r_{t+3})\Omega^t_{3a} + pp^t_{4a} + z_{t+3} \tag{8}$$

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 net replacement rate for standard non-employment benefits is b_{ja} (with *j*=1,2,3 and *a*=*H,M,L*), for early retirement benefits it is b_{4a}[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

[4] The assumption of different labor tax rates (and different non-employment benefits) by ability reflects reality in many countries where low and high income earners may pay different tax rates.

[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.

lump sum transfer. Equation (9) 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 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_{5a}. 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_{ja}^t and his human capital h_{ja}^t. It will be lower when the individual retires early (lower R_a^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_{6a}. Fourth generation individuals consume their pension and the lump sum transfer, as well as their accumulated wealth from the third period plus interest (Equation 8). They leave no debts, nor bequests.

$$
\begin{aligned}
pp_{4a}^t &= b_{5a} \sum_{j=1}^{3} \left(p_j w_{a,t+j-1} h_{ja}^t n_{ja}^t (1-\tau_{ja}) \prod_{i=j}^{3} x_{t+i-1} \right) \\
&\quad + b_{6a} \frac{1}{9} \sum_{j=1}^{3} \sum_{a=H,M,L} \left(w_{a,t+3} h_{ja}^{t+4-j} n_{ja}^{t+4-j} (1-\tau_{ja}) \right)
\end{aligned} \tag{9}
$$

with : $0 \leq p_j \leq 1,$

$\sum_{j=1}^{3} p_j = 1,$

and $n_{3a}^t = R_a^t \tilde{n}_{3a}^t$

As we show in Equations (10) and (11), at the age of 20 a young worker with ability *H* inherits a fraction π of the average effective human capital of the middle aged generation. A young worker with ability *M* enters our model with only a fraction $\varepsilon_M \pi$, a young worker with ability *L* enters with an even lower fraction $\varepsilon_L \pi$. Lower ability may imply more difficulty to learn and accumulate knowledge at primary and secondary school. Lower ability individuals may as a result also be more likely to suffer from school fatigue. During their second and third period, workers supply more units of effective human capital. It is our assumption in Equation (12) that h_{2a}, and therefore labour productivity, rise in education time when young (e_a), productive government spending in percent of GDP (g_y, mainly education spending) and an overall quality of schooling parameter (q). Individuals take g_y and q to be exogenous. Note that the

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

human capital accumulation function itself (ψ_a) also depends on innate ability. We specify and discuss effective human capital production and human capital inheritance in greater detail in Section 3.2. Finally, we assume in Equation (13) that human capital remains unchanged between the second and the third period. We have in mind that learning by doing in work may counteract depreciation.

$$h_{1a}^{t} = \varepsilon_a \pi h_2^{t-1} = \varepsilon_a \pi \frac{\left(h_{2H}^{t-1} + h_{2M}^{t-1} + h_{2L}^{t-1}\right)}{3}, \forall a = H, M, L \tag{10}$$

$$0 < \pi,\ 0 < \varepsilon_L < \varepsilon_M < \varepsilon_H = 1 \tag{11}$$

$$h_{2a}^{t} = \left(1 + \psi_a(e_a^t, g_y, q)\right) h_{1a}^{t}, \qquad \psi_a > 0,\ \psi_a^{'}(.) > 0 \tag{12}$$

$$h_{3a}^{t} = h_{2a}^{t}, \quad \forall a = H, M, L \tag{13}$$

Substituting Equations (2)-(4) for ℓ_{ja}^t and (5)-(8) for c_{ja}^t into (1), and maximizing with respect to $\Omega_{1a}^t, \Omega_{2a}^t, \Omega_{3a}^t, n_{1a}^t, n_{2a}^t, \tilde{n}_{3a}^t, R_a^t$ and e_a^t, yields eight first order conditions for the optimal behavior of an individual with ability *a* entering the model at time *t.* Equation (14) expresses the law of motion of optimal consumption over the lifetime. Equations (15.a), (15.b) and (15.c) describe the optimal labor-leisure choice in each period of active live. 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 rises when the marginal utility of consumption $(1/c_{ja}^t)$ is higher, 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_{5a}), in the weight attached to the relevant period when computing the pension base (p_j), and in the revaluation parameters. Equations (15.a)-(15.c) highlight positive substitution effects from the pension replacement rate b_{5a}. To the extent that higher replacement rates raise individuals' consumption possibilities (c_{ja}), they also cause adverse income effects on labor supply. Basic pensions (b_{6a}) do not directly occur in Equations (15), but they do affect employment via this income effect.

$$\frac{c_{j+1,a}^{t}}{c_{ja}^{t}} = \beta\left(1 + r_{t+j}\right) \qquad \forall j = 1,2,3 \tag{14}$$

$$\frac{\gamma_1}{\left(\ell_{1a}^t\right)^{\theta}}\frac{-\partial \ell_{1a}^t}{\partial n_{1a}^t}=\frac{w_{a,t}h_{1a}^t\left(1-\tau_{1a}\right)\left(1-b_{1a}\right)}{c_{1a}^t\left(1+\tau_c\right)}+\beta^3\frac{b_{5a}p_1\,w_{a,t}h_{1a}^t\left(1-\tau_{1a}\right)x_t x_{t+1}x_{t+2}}{c_{4a}^t\left(1+\tau_c\right)} \tag{15.a}$$

$$\begin{aligned}\frac{\gamma_2}{\left(\ell_{2a}^t\right)^{\theta}}\frac{-\partial \ell_{2a}^t}{\partial n_{2a}^t}&=\frac{w_{a,t+1}\left(1+\psi_a\left(e_a^t,g_y,q\right)\right)h_{1a}^t\left(1-\tau_{2a}\right)\left(1-b_{2a}\right)}{c_{2a}^t\left(1+\tau_c\right)}\\&+\beta^2\frac{b_{5a}p_2w_{a,t+1}\left(1+\psi_a\left(e_a^t,g_y,q\right)\right)h_{1a}^t\left(1-\tau_{2a}\right)x_{t+1}x_{t+2}}{c_{4a}^t\left(1+\tau_c\right)}\end{aligned} \tag{15.b}$$

$$\begin{aligned}\frac{\gamma_3}{\left(\ell_{3a}^t\right)^{\theta}}\frac{-\partial \ell_{3a}^t}{\partial \tilde{n}_{3a}^t}&=\frac{w_{a,t+2}\left(1+\psi_a\left(e_a^t,g_y,q\right)\right)h_{1a}^t\left(1-\tau_{3a}\right)R_a^t\left(1-b_{3a}\right)}{c_{3a}^t\left(1+\tau_c\right)}\\&+\beta\frac{b_{5a}p_3w_{a,t+2}\left(1+\psi_a\left(e_a^t,g_y,q\right)\right)h_{1a}^tR_a^t\left(1-\tau_{3a}\right)x_{t+2}}{c_{4a}^t\left(1+\tau_c\right)}\end{aligned} \tag{15.c}$$

Equation (16) 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 $\tilde{n}_{3a}$. 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_{5a} and p_3.

$$\begin{aligned}\frac{\gamma_3}{\left(\ell_{3a}^t\right)^{\theta}}\frac{-\partial \ell_{3a}^t}{\partial R_a^t}&=\frac{w_{a,t+2}\left(1+\psi_a\left(e_a^t,g_y,q\right)\right)h_{1a}^t\left(1-\tau_{3a}\right)\left(\tilde{n}_{3a}^t+b_{3a}\left(1-\tilde{n}_{3a}^t\right)-b_{4a}\right)}{c_{3a}^t\left(1+\tau_c\right)}\\&+\beta\frac{b_{5a}p_3w_{a,t+2}\left(1+\psi_a\left(e_a^t,g_y,q\right)\right)h_{1a}^t\tilde{n}_{3a}^t\left(1-\tau_{3a}\right)x_{t+2}}{c_{4a}^t\left(1+\tau_c\right)}\end{aligned} \tag{16}$$

Finally, Equation (17) imposes for high and medium ability individuals 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 $(\partial \psi_a / \partial e_a)$. Labor taxes during youth therefore encourage individuals to study, whereas labor taxes in later periods of active life and net education costs discourage them. Notice also that high benefit replacement rates in later periods (b_{2a}, b_{3a}, b_{4a}) and a high income-related pension replacement rate (b_{5a}), 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_{2a}, $n_{3a}=R_a.\tilde{n}_{3a}$).

$$\frac{\gamma_1}{(\ell_{1a}^t)^\theta}\frac{-\partial \ell_{1a}^t}{\partial e_a^t}-\frac{1}{c_{1a}^t}\frac{\partial c_{1a}^t}{\partial e_a^t}=\beta\frac{1}{c_{2a}^t}\frac{\partial c_{2a}^t}{\partial e_a^t}+\beta^2\frac{1}{c_{3a}^t}\frac{\partial c_{3a}^t}{\partial e_a^t}+\beta^3\frac{1}{c_{4a}^t}\frac{\partial c_{4a}^t}{\partial e_a^t}, \quad \forall a=H,M \tag{17}$$

with: $$\frac{\partial c_{1a}^t}{\partial e_a^t}=\frac{-b_{1a}w_{a,t}h_{1a}^t(1-\tau_{1a})}{1+\tau_c}$$

$$\frac{\partial c_{2a}^t}{\partial e_a^t}=\frac{\partial \psi_a\left(e_a^t,g_y,q\right)}{\partial e_a^t}\cdot\frac{w_{a,t+1}h_{1a}^t(1-\tau_{2a})\left[n_{2a}^t+b_{2a}\left(1-n_{2a}^t\right)\right]}{1+\tau_c}.$$

$$\frac{\partial c_{3a}^t}{\partial e_a^t}=\frac{\partial \psi_a\left(e_a^t,g_y,q\right)}{\partial e_a^t}\cdot\frac{w_{a,t+2}h_{1a}^t(1-\tau_{3a})\left[R_a^t\left(\tilde{n}_{3a}^t(1-b_{3a})+b_{3a}-b_{4a}\right)+b_{4a}\right]}{1+\tau_c}.$$

$$\frac{\partial c_4^t}{\partial e_a^t}=b_{5a}\frac{\partial \psi_a\left(e_a^t,g_y,q\right)}{\partial e_a^t}\cdot\frac{\sum_{j=2}^{3}\left(p_j n_{ja}^t w_{a,t+j-1}h_{1a}^t\left(1-\tau_{ja}\right)\prod_{i=j}^{3}x_{t+i-1}\right)}{1+\tau_c}$$

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_{5a} raises the return to working (*n,* for all ability groups) and to building human capital (*e*, *h*, for high and medium-ability individuals) 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. Inheritance and production of effective human capital

Equations (10) and (11) above assume that when entering the model young workers with high ability inherit a fraction π of the average effective human capital of the middle aged generation. The value of π is to be calibrated. Individuals with medium and lower ability inherit less ($\varepsilon_L<\varepsilon_M<1$). OECD PISA scores leave no doubt. On average over the 13 countries that we focus on in this paper, the test scores for science of students at the 17th and the 50th percentiles are 67% and 84% respectively of the test score of students at the 83th percentile. We take these numbers as proxies for ε_L and ε_M (see also Section 4).

After entering the model, young individuals may decide to study and accumulate more human capital. The specification and parameterization of the human capital production function $\psi_a(.)$ in Equation (12) 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. 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). 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 of the human capital production function also includes education time of young individuals and education expenditures by the government as indicators for the quantity of invested private and public resources. Compared to most of the literature, however, we differ in three respects. First, we adopt a more flexible CES functional form, allowing the elasticity of substitution to differ from 1. Second, our definition of relevant 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[7]. Our third extension is to take into account the quality of education and the schooling system. We recognize that better quality implies higher cognitive skills for the same allocation of resources. Young individuals' capacity to build human capital will then rise.

All these arguments find their way in Equations (18.a) and (18.b). The former shows the *growth* rate of effective human capital for high and medium ability individuals as a CES specification in education time when young (e_a) and productive government expenditures in % of output (g_y). In steady state both determinants are constant, which will imply constant steady state growth. We add the quality of the schooling system (q) in a multiplicative way. We will use country-specific PISA science scores at the 50th percentile as a proxy for q [8]. Next to q we introduce (constant common) technical parameters: ϕ_a is a positive efficiency parameter reflecting natural ability, σ a scale parameter, v a share parameter and κ the elasticity of substitution. These parameters will be calibrated. Note in Equation (18.b) that low ability individuals supply no education time, but they also enjoy positive effects on their effective human capital from productive government expenditures. The quality of received schooling *q* also plays a role here.

$$\Psi_a(e_a, g_y, q) = \phi_a q \left(\nu g_y^{1-(1/\kappa)} + (1-\nu) e_a^{1-(1/\kappa)} \right)^{\sigma\kappa/(\kappa-1)}, \forall a = H, M \quad (18.a)$$

$$\Psi_L(g_y, q) = \phi_L q g_y^{\sigma} \quad (18.b)$$

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 a specification like (18.a) performs better than alternative ones without quality, with a narrower definition of government expenditures, or with a different functional form (see Heylen and Van de Kerckhove, 2010; Buyse *et al.*, 2011).

---

[7] 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 contribute directly to more human capital being accumulated, public R&D and fixed investment expenditures will mainly raise the productive efficiency of accumulated human capital.

[8] Ideally, one would employ a quality indicator relating to tertiary education, but this is not (yet) available. Still, PISA scores may be very useful. They are informative about the quality that young people attain in secondary education, and with which some enter tertiary education. Quality at entrance should have a positive effect on people's capacity to learn and to raise human capital in tertiary education. Furthermore, PISA scores have been found empirically significant for growth (Hanushek and Woessmann, 2009).

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 (Y_t) is given by the production function (19). 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 (20) defines total effective labor as a CES aggregate of effective labor supplied by the three ability groups. In this equation s is the elasticity of substitution between the different ability types of labor and η_H, η_M and η_L are the input shares. We will impose that $\eta_H = 1-\eta_L-\eta_M$.

$$Y_t = K_t^{\alpha} H_t^{1-\alpha} \tag{19}$$

$$H_t = \left(\eta_H H_{H,t}{}^{1-(1/s)} + \eta_M H_{M,t}{}^{1-(1/s)} + \eta_L H_{L,t}{}^{1-(1/s)}\right)^{s/(s-1)} \tag{20}$$

Equation (21) specifies effective labor per ability group. Within each ability group we assume perfect substitutability of labor supplied by the different age groups.

$$\begin{aligned} H_{a,t} &= n_{1a}^{t} h_{1a}^{t} + n_{2a}^{t-1} h_{2a}^{t-1} + n_{3a}^{t-2} h_{3a}^{t-2} \\ &= \left(n_{1a}^{t} + n_{2a}^{t-1} \frac{x_a^{t-1}}{x_{t-1}} + n_{3a}^{t-2} \frac{x_a^{t-2}}{x_{t-1} x_{t-2}} \right) h_{1a}^{t}, \quad \forall a = H, M, L \end{aligned} \tag{21}$$

To derive Equation (21) we make use of Equations (12) and (13) where we define:

$$1 + \psi_a(e_a^t, g_y, q) \equiv x_a^t \tag{22}$$

It then follows that : $h_{3a}^{t-j} = h_{2a}^{t-j} = x_a^{t-j} h_{1a}^{t-j}, \quad \forall a = H, M, L.$

Furthermore, we exploit the result that[9] : $h_{1a}^{t} = x_{t-1} h_{1a}^{t-1} = x_{t-1} x_{t-2} h_{1a}^{t-2}$ (23)

where by definition: $x_t \equiv \pi \left(\dfrac{x_H^t + \varepsilon_M x_M^t + \varepsilon_L x_L^t}{3} \right).$

[9] Starting from Equation (10), and using (11), (12) and (22), it is easy to see that:

$$\begin{aligned} h_{1H}^{t} &= \pi \frac{h_{2H}^{t-1} + h_{2M}^{t-1} + h_{2L}^{t-1}}{3} = \pi \frac{x_H^{t-1} h_{1H}^{t-1} + x_M^{t-1} h_{1M}^{t-1} + x_L^{t-1} h_{1L}^{t-1}}{3} \\ &= \pi \frac{\left(x_H^{t-1} + \varepsilon_M x_M^{t-1} + \varepsilon_L x_L^{t-1} \right)}{3} h_{1H}^{t-1} = x_{t-1} h_{1H}^{t-1} \end{aligned}$$

Human capital of the lower ability individuals (a= M, L) will grow at the same rate ($\dfrac{h_{1a}^{t}}{h_{1a}^{t-1}} = \dfrac{\varepsilon_a h_{1H}^{t}}{\varepsilon_a h_{1H}^{t-1}} = \dfrac{h_{1H}^{t}}{h_{1H}^{t-1}}$) which explains the first part of Equation (23). Lagging this result by one period, generates the second part.

Substituting Equation (21) for *H*, *M* and *L* into (20), and recognizing differences in the capacity ε to inherit human capital as indicated by Equations (10) and (11), yields Equation (24).

$$H_t = \left[\sum_{a=H,M,L} \eta_a \varepsilon_a^{1-(1/s)} \left(n_{1a}^t + n_{2a}^{t-1} \frac{x_a^{t-1}}{x_{t-1}} + n_{3a}^{t-2} \frac{x_a^{t-2}}{x_{t-1}x_{t-2}} \right)^{1-(1/s)} \right]^{s/(s-1)} h_{1H}^t \quad (24)$$

Competitive behavior implies in Equation (25) that firms carry physical capital to the point where its after-tax marginal product net of depreciation equals the world real interest rate. 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 for each ability type equality between the real wage and the marginal product of effective labor (Equation 26). Workers of a particular ability type will earn a higher real wage when their supply is relatively scarce and when physical capital per unit of aggregate effective labor is higher. Taking into account (25), real wages per unit of effective labor will therefore fall in the world real interest rate and in domestic capital tax rates.

$$\left[\alpha \left(\frac{H_t}{K_t} \right)^{1-\alpha} - \delta_k \right] (1-\tau_k) = r_t \quad (25)$$

$$(1-\alpha) \left(\frac{K_t}{H_t} \right)^{\alpha} \eta_a \left(\frac{H_t}{H_{a,t}} \right)^{1/s} = w_{a,t} \quad \forall a = H, M, L \quad (26)$$

Substituting (24) for H_t and (25) for K_t/H_t, we can rewrite (19) as

$$Y_t = \left(\frac{K_t}{H_t} \right)^{\alpha} H_t$$
$$= \left[\frac{\alpha(1-\tau_k)}{r_t + \delta_k(1-\tau_k)} \right]^{\alpha/(1-\alpha)} \left[\sum_{a=H,M,L} \eta_a \varepsilon_a^{1-(1/s)} \left(n_{1a}^t + n_{2a}^{t-1} \frac{x_a^{t-1}}{x_{t-1}} + n_{3a}^{t-2} \frac{x_a^{t-2}}{x_{t-1}x_{t-2}} \right)^{1-(1/s)} \right]^{s/(s-1)} h_{1H}^t$$

If we finally recognize that in steady state r, τ_k, x_a, e_a and n_{ja} are constant, we obtain the long-run (per capita) growth rate of the economy as

$$ln\left(\frac{Y_t}{Y_{t-1}} \right) = ln\left(\frac{h_{1H}^t}{h_{1H}^{t-1}} \right) = ln(x_{t-1})$$
$$= ln\left(\pi . \frac{\left(1+\psi_H(e_H^{t-1}, g_y, q)\right) + \varepsilon_M \left(1+\psi_M(e_M^{t-1}, g_y, q)\right) + \varepsilon_L \left(1+\psi_L(g_y, q)\right)}{3} \right) \quad (27)$$

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). Growth will rise also if young individuals incorporate a larger fraction of average human capital of the middle aged generation (π, ε).

3.4. Government

Equation (28) describes the government's budget constraint. Productive expenditures G_{yt}, consumption G_{ct}, benefits related to non-employment B_t (including early retirement benefits), old-age pension benefits PP_t,, lump sum transfers Z_t and interest payments r_tD_t are financed by taxes on labor T_{nt}, taxes on capital T_{kt}, and taxes on consumption T_{ct} and/or by new debt ΔD_{t+1}. We define D_t as outstanding public debt at the beginning of period t.

$$\Delta D_{t+1} = D_{t+1} - D_t = G_{yt} + G_{ct} + B_t + PP_t + Z_t + r_t D_t - T_{nt} - T_{kt} - T_{ct} \tag{28}$$

with:

$$\begin{aligned}
G_{yt} &= g_y Y_t \\
G_{ct} &= g_c Y_t \\
B_t &= B_{H,t} + B_{M,t} + B_{L,t} \\
PP_t &= PP_{H,t} + PP_{M,t} + PP_{L,t} \\
Z_t &= 12\ z_t \\
T_{nt} &= T_{nH,t} + T_{nM,t} + T_{nL,t} \\
T_{kt} &= \tau_k \left(\alpha Y_t - \delta_k K_t \right) \\
T_{ct} &= \tau_c \sum_{j=1}^{4} \left(c_{jH}^{t+1-j} + c_{jM}^{t+1-j} + c_{jL}^{t+1-j} \right).
\end{aligned}$$

And $\forall a = H, M, L$:

$$\begin{aligned}
B_{a,t} &= (1 - n_{1a}^{t} - e_a^{t}) b_{1a} w_{a,t} h_{1a}^{t} (1 - \tau_{1a}) + (1 - n_{2a}^{t-1}) b_{2a} w_{a,t} h_{2a}^{t-1} (1 - \tau_{2a}) \\
&\quad + R_a^{t-2} (1 - \tilde{n}_{3a}^{t-2}) b_{3a} w_{a,t} h_{3a}^{t-2} (1 - \tau_{3a}) + (1 - R_a^{t-2}) b_{4a} w_{a,t} h_{3a}^{t-2} (1 - \tau_{3a}) \\
PP_{a,t} &= b_{5a} \sum_{j=1}^{3} \left(p_j w_{a,t+j-4} h_{ja}^{t-3} n_{ja}^{t-3} (1 - \tau_{ja}) \right) \prod_{i=j}^{3} x_{t+i-4} \\
&\quad + b_{6a} \frac{1}{9} \sum_{j=1}^{3} \sum_{a=H,M,L} \left(w_{a,t} h_{ja}^{t+1-j} n_{ja}^{t+1-j} (1 - \tau_{ja}) \right) \\
T_{na,t} &= \sum_{j=1}^{3} n_{ja}^{t+1-j} w_{a,t} h_{ja}^{t+1-j} \tau_{ja}.
\end{aligned}$$

Note our assumption that each ability group has size 1 and that each generation has size 3. 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. Note also our assumption that the pension system is fully integrated into 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 (29) describes aggregate equilibrium as it can be derived from Equations (5)-(8), defined for all generations living at time *t*, Equations (19)-(21), (25)-(26) and (28). The LHS of (29) represents national income. It is the sum of domestic output Y_t and net factor income from abroad r_tF_t, with F_t being 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*. At the RHS of (29) CA_t stands for the current account in period *t.*

$$Y_t + r_t F_t = C_t + I_t + G_{ct} + G_{yt} + CA_t \tag{29}$$

with:

$$F_t = A_t - K_t - D_t$$

$$CA_t = F_{t+1} - F_t = \Delta A_{t+1} - \Delta K_{t+1} - \Delta D_{t+1}$$

$$I_t = \Delta K_{t+1} + \delta K_t$$

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 long-run equilibrium effects of policy changes, as well as welfare effects per generation and ability group. To solve the model and to perform the 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. We use Dynare 4.2.

4.1. Preference and technology parameters

Table 2 contains an overview of all parameters. We set the rate of time preference equal to 1.5% per year. Considering that periods in our model consist of 15 years, this choice implies a discount factor β equal to 0.8. In the production function we assume a capital share coefficient α equal to 0.285. Our values for the rate of time preference and the capital share are well within the range of values imposed in the literature (e.g. Docquier and Michel, 1999; Altig *et al.*, 2001; Heijdra and Romp, 2009). There is more controversy about the value of the intertemporal elasticity of substitution in leisure ($1/\theta$). 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 and equal to 4.5% per year. Considering a period of 15 years, this implies that r = 0.935. Finally, we set the physical capital depreciation rate to 8% per year, which implies δ_k=0.714. These values are also within the range of existing studies (see e.g. Heijdra and Romp, 2009).

Table 2 Basic parameterization and benchmark equilibrium

Technology and preference parameters	
Goods production (output)	$\alpha = 0.285, s = 1.5, \eta_H = 0.48, \eta_M = 0.30, \eta_L = 0.22$
Effective human capital	$\phi_H = 5.65,\ \phi_M = 4.83,\ \phi_L = 2.99,\ v = 0.125,\ \kappa = 0.375,\ \sigma = 0.60$
Human capital inheritance	$\pi = 0.83,\ \varepsilon_M = 0.837,\ \varepsilon_L = 0.673$
Preference parameters	$\beta = 0.80,\ \theta = 2,\ \gamma_1 = 0.05,\ \gamma_2 = 0.115,\ \gamma_3 = 0.159,$ $\mu = 0.5,\ \rho = 1.61,\ \Gamma = 2$
World real interest rate	$r = 0.935$
Capital depreciation rate	$\delta_k = 0.714$

Target values for calibration

Employment, growth and education [(a)]

n_1	n_2	n_3	R	*Per capita growth (annual)*	e
51.1%	56.8%	29.3%	57.9	1.77%	14.2%

Relative wages US [(b)]

$w_L h_{1L} / w_H h_{1H}$	$w_M h_{1M} / w_H h_{1H}$	$w_L h_{2L} / w_H h_{2H}$	$w_M h_{2M} / w_H h_{2H}$
0.43	0.63	0.38	0.58

Note: (a) Values for Belgium, see Table 1;
(b) As a proxy for the relative wage of low-ability (medium-ability) young workers, we use available data on earnings of workers of age 25-34 with below upper secondary education (secondary education) in the US relative to earnings of workers with a tertiary degree. For the relative wage of middle aged workers, we use the same kind of data. However, since middle age-specific data are missing, we use average values for the whole age group 25-64 as a proxy. Data for the age group 55-64 are about the same (0.38 and 0.55). Data source: OECD Education at a Glance, 2009, Table A7.1.

A second series of ten parameters have been determined by calibration: three taste for leisure parameters (γ_1, γ_2, γ_3), the human capital inheritance parameter (π), three efficiency parameters in the human capital production function (ϕ_H, ϕ_M and ϕ_L), the elasticity of substitution (ρ) in the composite leisure function in Equation (4) and two share parameters in aggregate effective labor (η_M and η_L, where η_H follows as $1-\eta_L-\eta_M$). The ten target values to which these parameters have been calibrated are reported at the bottom of Table 2. Six of them concern the employment rates, the effective retirement age, education, and growth for Belgium in our study. 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. In our model this comes down to $b_5>0$, $b_6=0$ and $p_1=p_2=p_3=1/3$ [10]. The other four target values are the relative wages of young and middle aged workers of low and medium ability in the US. Although in practice a whole system of simultaneous equations is solved in which each target value is important for each parameter to be calibrated, it may be useful for our exposition here to bring some more structure. Certain parameters are clearly more than others linked to certain target values. The leisure parameters, including the elasticity of substitution in the composite leisure function (4), are basically determined such that with observed average levels of the policy variables (tax rates, non-employment benefit replacement rates, pension replacement rates, etc.) and the observed level of schooling quality (q)[11] in Belgium, the model correctly predicts Belgium's employment rates by age (n_1, n_2, n_3) and effective early retirement age (R). We find that the taste for leisure rises with age ($\gamma_1=0.05$, $\gamma_2=0.115$, $\gamma_3=0.159$) and observe a stronger degree of substitutability than in the Cobb-Douglas case between the two types of leisure for older workers ($\rho = 1.61$). The human capital inheritance parameter is basically determined to match average per capita growth. We find an inheritance rate for the highest ability group of almost 85% ($\pi=0.83$). Taking into account the values for ε_M and ε_L that we have discussed in Section 3.2., we obtain inheritance rates for the medium ability and the low ability groups of about 69% (=0.83x0.837) and 56% (=0.83x0.673).

Calibration of the share parameters η_M and η_L is mainly driven by the values for relative wages of young workers in the US. As shown by Equation (26), these share parameters are important determinants of the relative productivity of labour. Actual wages are informative if a close link can be assumed between wages and productivity. This condition is much more likely fulfilled in the US, which explains the introduction here of US relative wages rather than those in Belgium (or in any other European country). We illustrate the key elements in our procedure to obtain values for η_L and η_M from these relative wage data in Appendix 2. The results imply $\eta_L=0.22$, $\eta_M=0.30$ and $\eta_H=0.48$. A similar procedure is applied to derive values for ϕ_L, ϕ_M and ϕ_H. These are basically determined such that the model correctly predicts relative wages of middle aged workers in the US, as well the target value for the education rate e (see also Appendix 2). We obtain $\phi_L=2.99$, $\phi_M=4.83$ and $\phi_H=5.65$.

Finally, we had no strong ex ante indication on three parameters in the human capital production function: the scale parameter σ, 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 the facts in 13 OECD countries that we reported in Table 1. Our guideline to pin down specific values for σ, v

[10] Only individuals with labor income below about 75% of the mean receive an additional social assistance benefit. We include this as 'basic pension' for the low ability individuals ($b_{6L}>0$, see Table 5, and our discussion there).

[11] And with the values of three parameters in the human capital production function (σ, v, κ) that we discuss below (see also footnote 12).

and κ was to minimize the deviation of our model's predictions from the true data[12]. This procedure implied σ=0.60, v=0.125 and κ=0.375. We observe decreasing returns in human capital growth. 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 (μ=0.5). The normalisation parameter Γ 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 in 1995-2001/2004. 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 marginal tax data for several family and income situations. We use OECD tax rates on low income earners as a proxy for labor tax rates on low skilled individuals and young medium skilled individuals in our model. In our benchmark economy, these categories of workers earn about 67% or less of the aggregate average wage. Along the same line, we use OECD tax rates on average wage earners as a proxy for middle aged and older medium skilled individuals, as well as young high skilled individuals in our model. These workers earn about 100% of the average wage in the model. Finally, we use OECD tax rates on high income earners as a proxy for middle aged and older high skilled individuals. For further details, see Appendix 1. As one can see in Table 3, however, differences within countries between these tax rates are very small. Cross-country differences are much bigger. Belgium has the highest marginal labor tax rates (> 65%), the US the lowest (< 40%). Capital tax rates are effective marginal corporate tax rates reported by the Institute for Fiscal Studies (their EMTR). Germany and Belgium have the highest rates. In contrast to labor (and consumption), capital is taxed relatively little in the Nordic countries. For consumption taxes, we use data from Dhont and Heylen (2009). The Nordic countries stand out with the highest consumption tax rates, the US with the lowest. The utter right column in Table 3 shows the average ratio of gross government debt to GDP in the period that we study. The data range from less than 50% in Norway and the UK to more than 100 % in Belgium and Italy.

[12] From our model's predictions and the true data for 13 countries we computed for each variable (n_1, n_2, n_3, R, e, *growth*) the root mean squared error normalized to the mean. We minimized the average normalized RMSE over all six variables. More precisely, we adopted the following iterative procedure. We chose values for σ, v and κ and then calibrated the other ten parameters (although it should be mentioned that the values for σ, v and κ hardly affected the calibration results for γ_j). Given the obtained values for the other parameters, we computed the average normalized RMSE over all six endogenous variables. We then checked whether changes in σ, v and κ, and a recalibration of the other parameters , could further reduce this statistic. We did this until no further reduction was possible.

Table 3 Fiscal policy: Tax rates and government debt

	tax rate on labor of low wage earners (%)	tax rate on labor of medium wage earners (%)	tax rate on labor of high wage earners (in %)	consumption tax rate (%)	tax rate on capital income (%)	Public debt (% of GDP)
Proxy for :	τ_{jL}, τ_{1M}	τ_{2M}, τ_{3M}, τ_{1H}	τ_{2H}, τ_{3H}	τ_c	τ_k	D/Y
Austria	55.9	57.2	49.0	13.2	17.3	69.6
Belgium	66.9	66.7	69.0	13.4	27.1	111.7
France	52.5	52.1	55.1	17.1	21.7	68.9
Germany	59.1	63.1	56.8	11.1	34.4	63.1
Italy	53.4	56.1	57.9	14.7	14.9	122.1
Netherlands	52.3	52.3	51.9	12.2	24.3	68.2
Denmark	45.0	47.8	55.6	18.9	22.5	60.3
Finland	54.4	56.7	59.0	15.2	17.2	54.1
Norway	44.3	55.1	55.1	16.4	22.1	40.4
Sweden	53.7	55.1	60.9	17.9	16.1	67.2
UK	39.8	39.8	43.4	14.5	21.2	46.6
US	34.3	34.3	39.6	7.2	23.6	61.9
Canada	47.9	46.0	43.2	14.5	24.8	83.8
Overall average	50.7	52.5	53.6	14.3	22.1	70.6

Notes: Labor tax rates are data for the total tax wedge, marginal rate (OECD, Taxing Wages). Data are for 2000-2004. Earlier data are not available. For details on the calculation of labor tax rates by age group, see Appendix 1. Capital tax rates are effective marginal corporate tax rates (Institute for Fiscal Studies, their EMTR, base case; data are for 1995-2001, see also Devereux *et al*., 2002). Consumption tax rates are from Dhont and Heylen (2009). Data are 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_{ja} (for j=1,2,3 and a=L,M,H). 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[13]. The data are expressed in percent of after-tax wages. In line with our approach to determine labor tax rates by skill level, we are again guided by the same income cases to determine b_{jH}, and b_{jM} and b_{jL} (see Appendix 1). Overall, the euro area and the Nordic countries pay the highest net benefits. The only exception is Italy. 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_{4a}.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 generous early

[13] In the period that we study, this is the case in Austria, Belgium, France, Germany, Finland, Ireland, and the UK. Workers cannot be structurally non-employed and still receive unemployment benefits in the Netherlands, Italy, Denmark, Norway, Sweden, Spain, Portugal, Switzerland and the US (OECD, 2004, www.oecd.org/els/social/workincentives, Benefits and Wages, country specific files).

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

Our data for productive government expenditures (g_y) in Table 4 include education, active labor market expenditures, government financed R&D and public investment, in percent of GDP. On average, education expenditures constitute close to 60% of total g_y. 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[14]. In the US, government consumption is (much) lower.

Table 4 Fiscal policy: net benefit replacement rates, consumption, productive expenditures

	Non-employment transfer, young, middle aged and older (net replacement rate, %) with income:			Early retirement benefit (net replacement rate, %) by income (ability):			government consumption (% of GDP)	government productive expenditures (% of GDP)
	Low	medium	high	Low	medium	high		
Proxy for :	b_{1L}, b_{2L} b_{1M}, b_{3L}	b_{2M}, b_{1H}, b_{3M}	b_{2H}, b_{3H}	b_{4L}	b_{4M}	b_{4H}	g_c	g_y
Austria	66.3	56.5	45.9	76.6	71.7	66.4	14.6	9.1
Belgium	73.5	58.9	46.3	86.0	78.7	72.4	16.9	8.9
France	60.8	44.7	32.3	71.2	63.2	57.0	18.3	11.0
Germany	71.8	61.7	60.5	74.3	69.3	68.7	15.3	8.6
Italy	20.0	17.1	13.8	57.2	55.8	54.1	14.3	8.0
Netherlands	72.0	53.0	40.1	76.5	67.1	60.6	18.4	10.3
Denmark	74.8	60.6	50.3	49.7	42.6	37.5	18.4	12.5
Finland	75.1	61.3	47.4	80.7	73.9	66.9	16.0	11.4
Norway	72.8	53.4	43.3	47.9	38.1	33.1	14.7	12.1
Sweden	71.5	53.5	41.3	47.0	38.0	31.9	20.0	14.0
UK	64.5	51.2	37.6	46.1	39.4	32.6	14.4	7.3
US	38.3	30.4	22.9	22.2	18.2	14.5	10.3	9.3
Canada	54.4	44.6	34.0	32.0	27.2	21.8	14.7	9.3
Overall average	62.8	49.8	39.7	59.0	52.6	47.5	15.9	10.1

Notes: A description of all variables is given in the main text. For more details, see Appendix 1. The data for net benefit replacement rates are an average for 2001-2004 (earlier data are not available). The data for government consumption and productive expenditures concern 1995-2001.

[14] Like Dhont and Heylen (2009) we calculate our data for government consumption as total government consumption in % of GDP, diminished with the fraction of public education outlays going to wages and working-expenses. We include the latter in productive expenditures.

Table 5 contains our data for the net pension replacement rates b_{5a} and b_{6a}. The data have been taken or computed from OECD (2005). They include only (quasi-)mandatory pension programs[15]. In line with our specification in Equation (9), b_{5a} is expressed as a percentage of an individual's average lifetime net labor income, while b_{6a} is expressed as a percentage of average economy-wide net labor income at the time of retirement. We consider individuals at 50 percent of mean earnings as representative for the low ability group, individuals with mean earnings as representative for the medium ability group, and individuals at twice the mean earnings as representative for the high ability group. Appendix 1 gives more details on the construction of the data. In the majority of countries individuals with mean or higher earnings only receive earnings-related pensions (b_{5a}>0, b_{6a}=0 for a=M,H). Among these countries, Austria and Italy pay the highest net replacement rates (b_{5M} >85%), Belgium and the US the lowest (b_{5M} < 65%)[16]. Five countries also pay basic pensions to individuals with mean or higher earnings: the Netherlands, Denmark, Norway, the UK and Canada. For individuals with low earnings, the situation is somewhat the opposite. Their pension includes a significant basic (or similar) component in most countries. Unsurprisingly, the Netherlands, Denmark and the UK pay the highest 'basic' amounts[17].

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[18]. 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.

A final variable in Table 5 is our indicator for education quality (q) in the human capital production function (12, 18). For each country we use PISA science scores. We concentrate on test results for science given their expected closer link to growth (Barro, 2001). The mean score is best in Finland, followed by the Netherlands, Canada and the UK. Education quality is relatively low in Italy, Denmark, Norway and the US. Note that there is no correlation between productive government expenditures in

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[15] 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 and included under b_{5a}. Voluntary, occupational pensions are not included in our data.

[16] Next to the pension level, 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.

[17] As we explain in Appendix 1, it should be mentioned that our proxy for b_{6a} also includes targeted and minimum pensions. 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_{6a} is that they are not (or even inversely) linked to earnings.

[18] 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. However, the pension replacement rate reported by the OECD would then no longer be reliable since it is based on the assumption of equal weights.

Table 4 and the PISA scores in Table 5. The coefficient of 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 5 Net pension replacement rates and PISA education score

	Net earnings-related pension replacement rate (% average earned net labor income)			Net basic pension replacement rate (% economy-wide average net labor income)			PISA science score (divided by 1000)
Proxy for :	Low b_{5L}	Medium b_{5M}	High b_{5H}	Low b_{6L}	Medium b_{6M}	High b_{6H}	q
Austria	88.7	88.9	75.9	0.0	0.0	0.0	0.507
Belgium	55.4	63.1	42.7	17.2	0.0	0.0	0.505
France	62.9	68.8	59.2	23.2	0.0	0.0	0.502
Germany	60.4	71.8	67.0	0.8	0.0	0.0	0.502
Italy	89.3	88.8	89.1	0.0	0.0	0.0	0.480
Netherlands	0.0	42.1	62.9	46.4	42.1	36.2	0.525
Denmark	15.3	11.0	10.0	43.6	43.1	42.2	0.484
Finland	82.3	78.8	78.3	4.9	0.0	0.0	0.550
Norway	36.4	43.0	38.4	26.4	22.1	20.3	0.490
Sweden	64.6	65.9	74.3	13.6	2.3	0.0	0.507
UK	0.0	5.0	8.0	43.6	42.6	41.2	0.523
US	61.4	51.0	39.0	0.0	0.0	0.0	0.493
Canada	31.6	33.9	18.1	31.5	23.2	23.3	0.527
Overall average	**49.9**	**54.8**	**51.0**	**19.3**	**13.0**	**12.6**	**0.507**

Notes: Pension replacement rates have been taken or computed from OECD (2005, p. 52 and part II). The data concern 2002. For more details, see Appendix 1. The PISA science scores are an average for 2000, 2003 and 2006.

4.3 Predicted versus actual employment by age, education of the 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 1995-2007. 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. Due to lack of data – especially with respect to marginal labor tax rates and non-employment benefits before the mid 1990s – it is impossible for us 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. This information is important to assess the value of the simulation results that we present in the next section, and their reliability for policy analysis. In most papers in the literature a test of the external validity of the model is missing.

Our calibration implies that our model's prediction matches the employment rates by age, the effective retirement age of older workers, education, and per capita growth in Belgium. The test of the model's validity is whether it can also match the data for the other countries, and 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, education costs and grants, 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. 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.

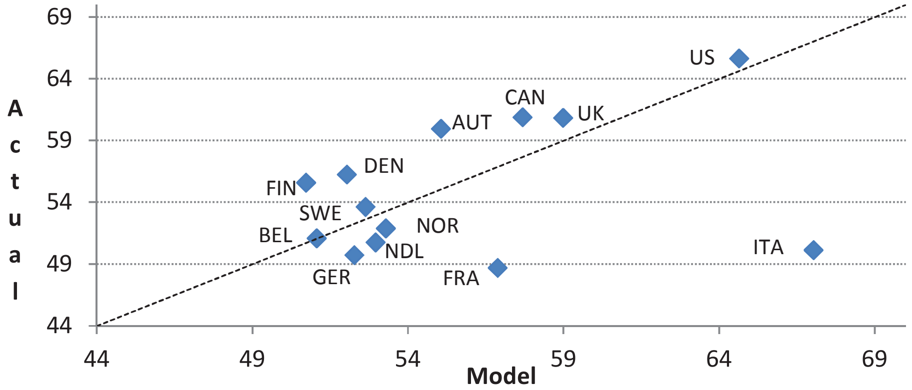
As a part of fiscal policy, lump sum transfers also differ across countries. Underlying our model's predictions for each country, is the assumption of a constant debt to GDP ratio at the level reported for that country in Table 3. Lump sum transfers adjust endogenously in Equation (28) to obtain this equilibrium debt to GDP ratio.

Figures 2 to 4 relate our model's predictions to actual observations for three employment rates by age (aggregated over the three ability groups). 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 0.34. If we drop Italy, for which there are good reasons[19], this rises to 0.71. Correlation in Figure 3 is 0.51, in Figure 4 it is 0.73. Moreover, in each 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 are too low in Figures 2 and 3 for Denmark and Finland.

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 0.91. In Figures 6 and 7 we relate our

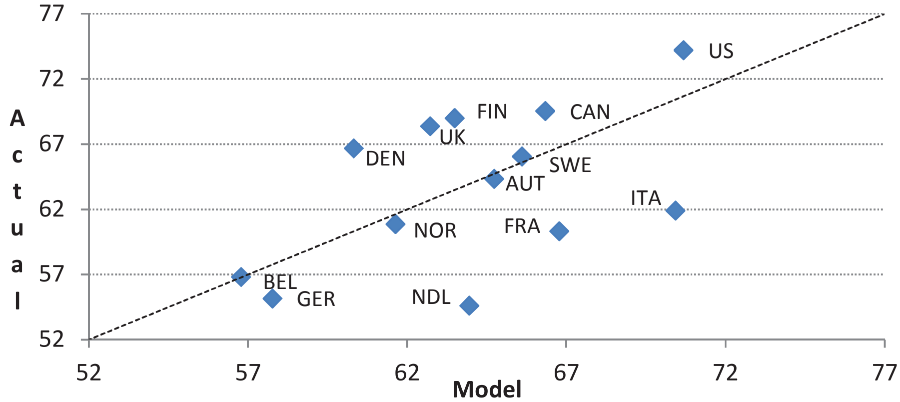
[19] A major element behind the deviation for this country seems to be underestimation of the fallback income position for structurally non-employed young workers. OECD data show very low replacement rates in Italy. However, as shown by Reyneri (1994), the gap between Italy and other European countries 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 2. Employment rate in hours of young individuals in 13 countries, in %, 1995-2007



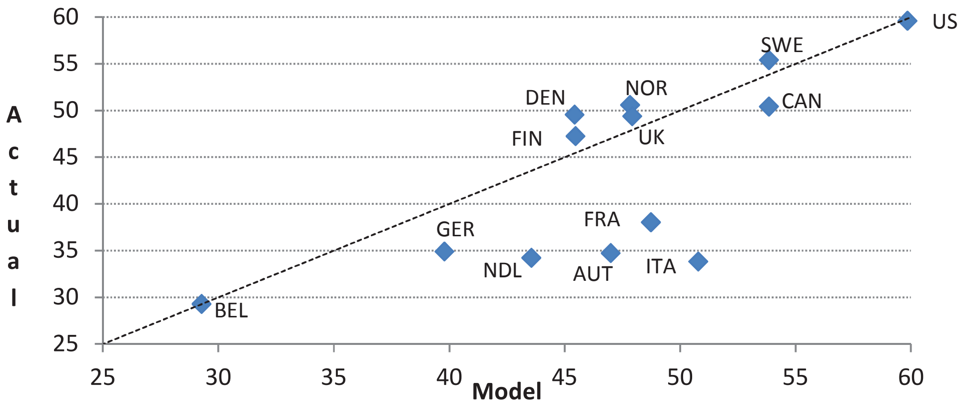
Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.34. Excluding Italy correlation rises to 0.71.

Figure 3. Employment rate in hours of middle aged individuals in 13 countries, in %, 1995-2007



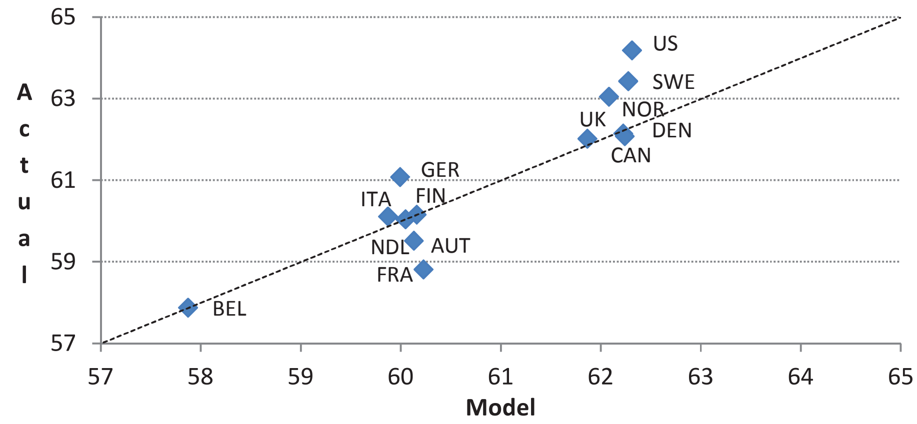
Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.51.

Figure 4. Employment rate in hours of older individuals in individual countries, in %, 1995-2007



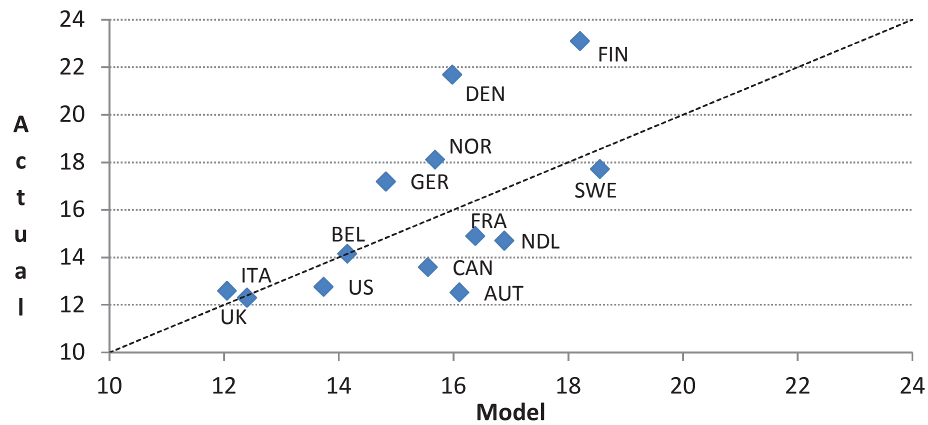
Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.73.

Figure 5. Effective retirement age, 1995-2006



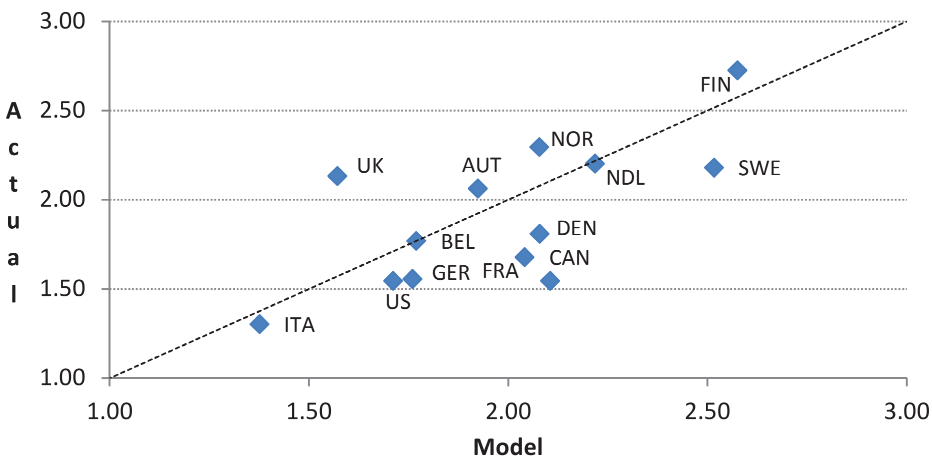
Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.91.

Figure 6. Tertiary education rate in individual countries, 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 13 countries, in %, 1995-2007



Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.69.

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 and Italy on the other. Predictions for education are quite close to the 45°-line for all individual countries except Austria and (especially) Denmark and Finland. The model does not match the high participation in education in the latter two countries. Finally, our model also has important cross-country differences right for growth. The model has some 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 0.69 for growth.

5. 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 and three ability groups, aggregate employment, education of the young, growth, and income at old-age (especially for the low-ability group). We report steady state effects, and welfare effects per generation and per ability group. We also show the pension level of low-ability retirees. Throughout all our policy simulations we assume that the government maintains a constant debt to GDP ratio in each period. To reach this goal, it adjusts lump sum transfers. The change in lump sum transfers is spread equally among all living generations.

Table 6 shows the steady state effects of seven reforms in key features of the pension system. It is our assumption that these reforms apply to everyone, except the generation of retirees at the moment of the introduction of the new policy, since they are no longer able to adapt their behavior[20]. 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. The parameters describing the benchmark pension system are indicated in the upper left corner of the table and in a first note below the table. Individual earnings-related replacement rates vary in the benchmark between 59% (b_{5L}) and 71% (b_{5M}). They are applied to a pension base where each active period has equal weight (p_{ja}=1/3). Basic pensions take values between 6% (b_{6H}) and 15% (b_{6L}) of aggregate average net labor income. No particular minimum level is imposed to the pension (MP=0). Changes in lump sum transfers to maintain a constant debt to GDP ratio are indicated at the bottom of the table.

Figure 8 shows the welfare effects of these policy changes for current and future generations of high and low-ability individuals. The results for medium-ability individuals are in general quite close to those for the high-ability group. 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. So, the data at $k=-3$ for example concern the retirees in the period of the policy change. 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

[20] Current retirees will therefore not experience a change in their pension replacement rate(s), nor in the rules behind the computation of their pension assessment base. Their income level can change, however, when the government adjusts lump sum transfers to keep the ratio of public debt to GDP constant, or when the aggregate average net wage (to which the basic pension replacement rate b_{6a} applies) changes.

as after the policy shock (see also King and Rebelo, 1990). To compute this percentage change we keep employment rates at the benchmark. For example, policy 1 implies a welfare gain for the current high-ability young (k=0) equal to 0.9% of benchmark consumption. It implies a welfare loss for the current older low-ability individuals (k=-2) equal to 2.5% of their benchmark consumption.

Given its importance for welfare at old-age, and the risk of old-age poverty, we focus in Figure 9 on the evolution of the pension level of low-ability retirees in the periods after a policy reform. Reported data at time 1 for example concern the pension level of those who were older at the time of introduction of the new policy. Data at time 3 concern those who were young at that time. All data are expressed relative to the benchmark.

The starting point of our discussion is policy 1, which introduces for each ability group an increase in p_3, and a fall in p_1, along the lines preferred by Buyse *et al.* (2011). To compute the pension base, the weight of labor income earned as an older worker rises to 2/3, the weight of labor income earned when young falls to 0. Our results confirm the important positive effects of such a reform for aggregate employment and growth. 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 (n_3 and R rise, n_1 falls). Furthermore, young individuals are encouraged to study (e increases) because the lifetime rate of return to building human capital rises. This follows first from the reduction of the opportunity cost of studying when young, second from the perspective of working longer, and third from the greater importance of effective human capital when old in the pension calculation. Extra schooling contributes to steady-state growth and reinforces incentives to work at older age. We observe an increase in the annual growth rate by 0.08 %-points. Note also that the employment rate rises in each ability group (n_H, n_M, n_L), but most so among low-ability individuals (Δn_L=1.44). These individuals can only respond to the new policy by working longer, they cannot study and enjoy higher human capital. Interestingly, the government budget does not deteriorate. It becomes possible to raise lump sum transfers while keeping the ratio of public debt to GDP constant (see bottom of Table 6). A quick comparison with the other policies in Table 6, to be discussed immediately, reveals that most of them are less effective when it comes to promoting (aggregate) employment and growth. The main disadvantage of policy 1, however, is the welfare loss that it imposes on most current generations of low-ability individuals (Figure 8, upper panel, RHS). While all high-ability groups and all future generations win, all current low-ability individuals lose (except those already retired). They work more, but can hardly consume more. They cannot respond positively to incentives to study. Even if policy 1 offers a convincing solution to the overall challenge of employment and growth in today's economies, and even if it may contribute to safeguard the welfare state in the future, it may worsen conditions for the current lower ability individuals. It may offer no solution to the problem of old-age poverty faced by many. Figure 9 shows an important fall relative to the benchmark in the pension level of many generations of low-ability individuals to come.

Policies 2 and 3 focus on the problem of low pensions for low-ability individuals. Policy 2 maintains all benchmark replacement rates, but also introduces a minimum pension. Individuals are sure of a pension equal to at least 60% of average net labor income per worker in the economy. In practice the latter implies a strong increase in the pension level for the low-ability group (see also Figure 9), but no ex-ante change for the other two groups. Their optimal behavior given all policy variables implies a pension that is above 60% of the average net wage from the beginning. We remind that none of the policy reforms that we discuss apply to the retired at the moment of the introduction of the reform, so they are not eligible to the minimum pension. As shown by Figure 8, all low-ability individuals except the retired (*k=-3*) experience welfare increases up to almost 5% under policy 2. For the welfare of all other individuals, however, these policies have very negative effects. A key element is the drastic drop in the employment rate among low-ability individuals. The perspective of a minimum pension introduces a strong disincentive for them to work. The implied fall in aggregate employment and its negative effects on the government's budget, force the latter to cut lump sum transfers for all. Furthermore, medium and higher ability individuals can also expect a fall in their wage per unit of effective labor due to the reduction of low-ability labor supply[21].

Policy 3 imposes a shift from own-earnings related pensions to 'basic' pensions on all individuals. Every retiree gets a basic pension equal to 75% of average net labor income per worker in the economy. In our model b_5 goes to zero for all ability groups, b_6 becomes 0.75. This policy basically goes one step further than policy 2. It breaks the relationship between the pension and an individual's human capital and labor supply also for the high and medium-ability groups. The fall in the return to studying and to working also for these groups is at the basis of an overall and strong fall in employment, education time and growth. Figure 8 reveals negative welfare effects almost across the board, especially for higher ability individuals and all future generations. Only current and middle aged low-ability individuals gain. They benefit most from higher pensions. Due to lower growth, this gain will not persist for the future low-ability generations however.

Policies 4, 5 and 6 search for ways to combine the efficiency of policy 1 with the objective to reduce the risk of old-age poverty for low-ability individuals. Policy 4 extends policy 1 with a minimum pension equal to 60% of the average net wage, like in policy 2. This policy is most beneficial for the welfare of all low-ability individuals (except the retired). They enjoy both an immediate increase in their pension, for which they have to work less, and the benefits from increased human capital formation by the high and medium-ability groups. The latter immediately contributes to higher wages per person, also for the lower ability individuals, and to increased levels of inherited human capital for all future generations. Like policy 2, however, policy 4 also imposes significant welfare losses on the current generations of high and medium-ability individuals, which drastically reduces its chances politically.

Policy 5 tackles the problem of low income at old-age for the low-ability group by significantly raising their individual earnings-related pension replacement rate to 85% (Δb_{5L} = 25.6%-points). This policy combines the efficiency gains from policy 1 with strong incentives for the low-ability group to work more and longer. In contrast to the disincentives induced by basic or minimum pensions, policy 5 raises the return to work since it yields more future pension. Among all the policies that we discuss in Table 6, not one has more favorable effects on aggregate employment. Higher pensions can as a result be paid without the need for the government to reduce lump-sum transfers. Given the strong rise in aggregate output, the absolute amount of lump sum transfers will also rise. Compared to policy 1, welfare effects for the low-ability group are better, without hurting the medium and high-ability groups.

Policy 6 reconsiders the basic choice made in policy 1 to raise the weight of labor income earned

[21] As a narrow alternative to policy 2, we also investigated the introduction of a minimum pension combined with an abolishment of all basic pensions. All effects were very similar. Only the required reduction in lump sum transfers was smaller, since the government could save money from b_{6a} going to 0.

as an older worker in the computation of the pension assessment base, and to reduce the weight of labor income earned as a young worker. One of the main advantages of this choice is that it promotes education and human capital formation. Given that low-ability individuals will never continue education at the tertiary level, however, one may question this change in weights for them. Policy 6 therefore maintains the much higher individual earnings-related replacement rate for the low-ability group (b_{5L}=85%), but combines this with equal weights p_j=1/3 for this group. The shift to p_1=0, p_2=1/3 and p_3=2/3 only applies to medium and high-ability individuals. Employment and growth effects from policy 6 are better than, or at least as good as, those from policy 1. For the low-ability individuals, who work the highest fraction of their time while they are young, maintaining p_1 at 1/3 in policy 6 implies a further increase in their pension benefit compared to policy 5. This further increase in pensions will force the government to cut lump sum transfers. All in all, however, the welfare effects from policy 6 are among the best for the low-ability individuals, with quasi no cost imposed on the others.

Table 6. 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_{1a}=1/3 P_{2a}=1/3 P_{3a}=1/3 MP=0	**Policy 1** P_{1a}=0 P_{2a}=1/3 P_{3a}=2/3	**Policy 2** MP=0.6	**Policy 3** b_{5a}=0 b_{6a}=0.75	**Policy 4** P_{1a}=0 P_{2a}=1/3 P_{3a}=2/3 MP =0.6	**Policy 5** P_{1a}=0 P_{2a}=1/3 P_{3a}=2/3 b_{5L}=0.85	**Policy 6** P_{1MH}=0 P_{2MH}=1/3 P_{3MH}=2/3 b_{5L}=0.85	**Policy 7** Fully Funded
Effect [(a)]:							
Δn_1	-3.83	-0.43	-0.84	-3.38	-3.91	-2.71	0.46
Δn_2	-0.02	-1.05	-2.43	-0.99	0.44	0.54	-0.53
Δn_3	6.86	-3.82	-9.44	0.35	8.43	5.44	-6.20
ΔR [(c)]	0.84	-0.52	-1.32	0.00	1.01	0.68	-1.00
Δe	1.40	0.03	-0.44	1.44	1.41	1.42	-0.31
Δn [(a. b)]	0.68	-1.64	-3.92	-1.42	1.28	0.85	-1.84
$\Delta N/N$ [(d)]	1.22	-2.93	-7.01	-2.53	2.28	1.53	-3.28
Δn_H	0.24	0.20	-2.55	0.50	0.29	0.36	-1.37
Δn_M	0.37	0.36	-3.99	0.83	0.47	0.58	-1.95
Δn_L	1.44	-5.49	-5.23	-5.58	3.08	1.63	-2.21
Δ annual growth rate [(b)]	0.08	0.00	-0.03	0.08	0.08	0.08	-0.02
Δz [(e)]	0.39	-1.07	-2.21	-1.04	0.07	-0.29	-3.47

Notes: Initial values: b_{5L}=59.4, b_{5M}=70.6, b_{5H}=66.1, b_{6L}=14.6, b_{6M}=7.0, b_{6H}=6.0.
(a) difference in percentage points between new steady state and benchmark. except ΔN/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 (in % of output) to keep the ratio of debt to GDP constant.

Figure 8. Welfare effects for current and future generations after pension reform

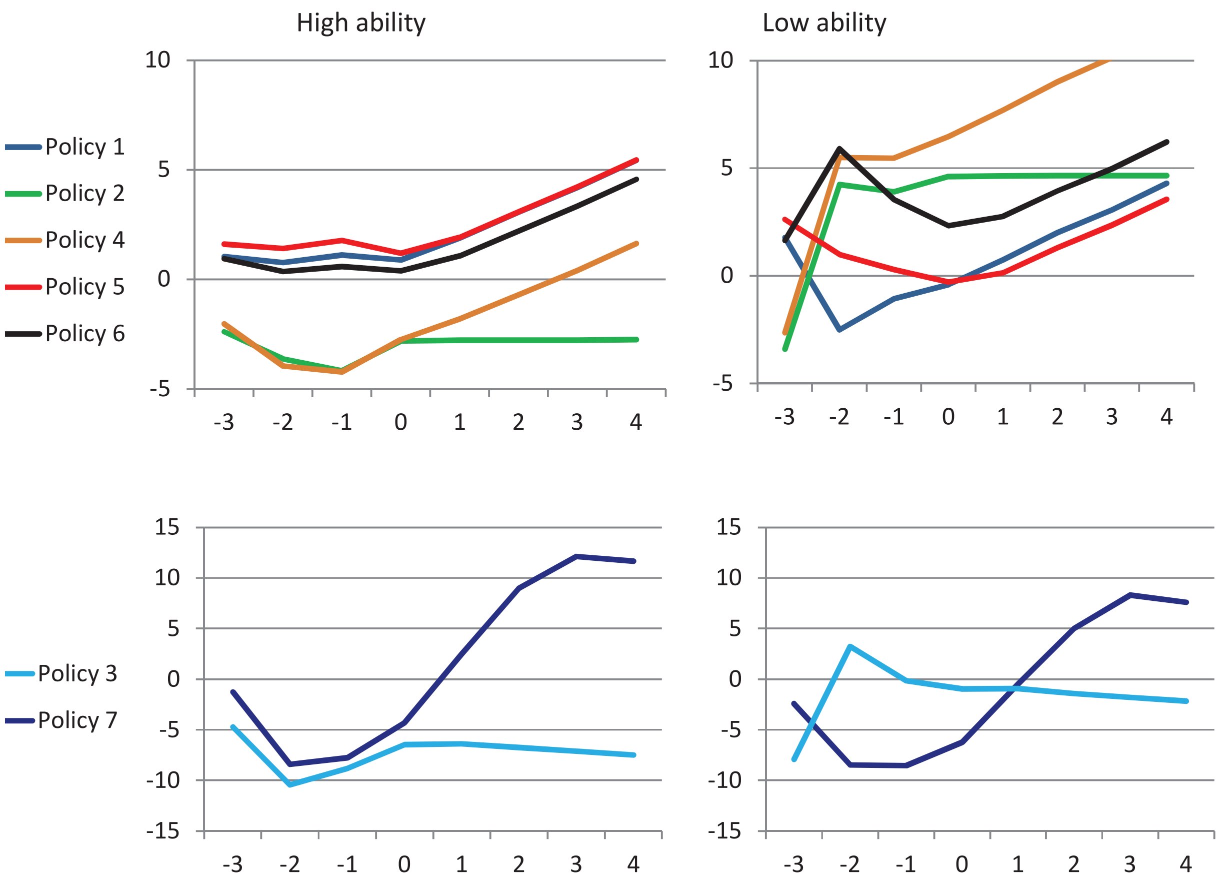
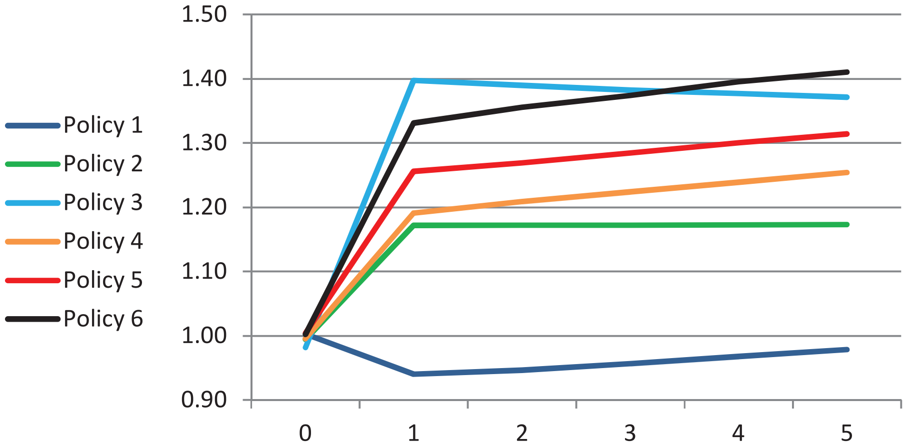


Figure 9. Pension level (relative to benchmark) of low-ability retirees at time t (where t=0 is when the policy reform is introduced)



Note: Policy 7 is not included. This policy implies a gradual reduction of public pensions to zero.

Policy 7 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_{5a} , b_{6a}). 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.[22] We observe in Table 6 that this transition to a private fully-funded pension scheme is not beneficial for employment. The new steady state shows lower hours worked among all ability groups and all age groups. The fall in employment is the strongest among older workers. The aggregate employment rate drops by about 1.8%-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. Time allocated to education also falls, slightly. So does growth (-0.02%-points). Furthermore, we observe that a shift to a fully-funded system affects the government balance negatively (as lump sum transfers have to decline by about 3.5% of GDP). The latter is mainly due to 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, so will the marginal product of physical capital, which causes savings to be invested abroad. Figure 8 reveals a strong intertemporal trade-off in the welfare effects from moving to a fully-funded system. Future generations gain, but current, transitional generations experience large welfare losses[23]. This result is well-known in the literature. Although the future gains in Figure 8 are relatively strong when compared to those from e.g. policy 6, it should also be recognized that in the more distant future (*k>5*) a fully-funded system will bring less gains. A key element is that it lacks the incentives to promote human capital formation and growth inherent in policies 1, 5 and 6.

The possibility that a fully-funded pension system has lower growth than a PAYG model has been shown before by Kemnitz and Wigger (2000), Zhang and Zhang (2003), and Kaganovitch and Meier (2008). The endogeneity of education and human capital is crucial for that result also in their models. The inferior employ-ment effects from a shift to a fully-funded system may, however, be surprising from the perspective of recent work by e.g. Börsch-Supan and Ludwig (2010), Ludwig *et al*. (2011) and Fisher and Keuschnigg (2010). For a discussion of this issue we refer to Buyse *et al.* (2011). A major element is that the existing literature generally compares a fully-funded system with a specific PAYG system which is less 'intelligent' than in our policies 5 or 6. Either one assumes for example a 'flat' PAYG system where

[22] In particular, the gradual decline in b_{5a} and b_{6a} is announced at time *t*=1 and implemented as follows. Pension 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_{5a} and b_{6a} are zero. At each moment, overall labor tax rates are reduced to ex ante compensate for the decline in pension expenditures.

[23] The explanation for the welfare loss of current generations in our model is as follows. 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 22, makes individuals shift hours worked to the future. During transition the young will study more, but total effective labor falls. Since this reduces the marginal productivity of physical capital, it will also discourage investment. Capital flows out. The economy experiences a strong drop in aggregate output (and tax revenue), which will force the government to reduce lump sum transfers. In later periods the economy enjoys the benefits from having accumulated more human capital during transition, but increased education efforts are not permanent (on the contrary).

individuals' pensions do not depend on their own human capital and labor earnings (as in our policy 3), or one models the public old-age pension system as an immediate alternative to work, neglecting the reality of early retirement systems.

6. Conclusions

Concern for the long-run financial viability of public pension systems has put pension reform high on the agenda of policy makers and researchers. In recent work, Buyse *et al.* (2011) show that an 'intelligent' PAYG system may have positive effects on both employment, the effective retirement age, education, and aggregate growth. These positive effects are the strongest when the PAYG system 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. Such a system stimulates individuals' labor supply when they are middle aged and older, and education when they are young. Positive effects on human capital formation promote future productivity and earnings capacity, also for future generations. An 'intelligent' PAYG system may perform (much) better than a system with a strong basic pension component, or a system with full private funding.

Like most existing literature, the model developed by Buyse *et al.* (2011) is limited in an important aspect. It disregards differences in people's abilities to learn and build human capital. The contribution of this paper is that we now introduce within each age group individuals with high, medium or low ability to build human capital. As a generalization, one may think of different capacities to study, which may not only depend on ability, but for example also on (differences in) credit availability. Our main findings are as follows. Basically, we confirm the main conclusions in Buyse *et al.* (2011). We see, however, that their preferred PAYG model implies welfare losses for the current low-ability generations, and rising inequality in welfare. We study various alternatives to maintain the benefits of an 'intelligent' PAYG system for aggregate employment and growth, while at the same time contributing to higher income at old-age and welfare for all individuals. Most promising is to maintain the tight link between individual labor income and the pension also for low-ability individuals, but to strongly raise their replacement rate. Such a system performs much better economically, and may expect to receive much more support politically, than basic or minimum pension components to promote the income of low-ability individuals. A tight link between individual labor income and the pension, combined with a high replacement rate, is a very effective way to promote labor supply. Basic and minimum pension models by contrast have strong negative effects on labor supply of low-ability individuals. A second welfare increasing adjustment to the preferred system in Buyse *et al.* (2011) would be to maintain equal weights in the pension assessment base for low-ability individuals. Since these individuals cannot study at the tertiary level, it is not optimal to give a lower weight to the labor income they earn when young.

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_5 in our model (and a low b_6). 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). Our results support this policy, except for individuals with low capacity to study at the tertiary level.

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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 the 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: Average age of all persons (being 40 or older) withdrawing from the labor force in a given period.
Data source: 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_{ja} for j=1,2,3 and a=L,M,H)
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 tax rates on low income individuals in our model (τ_{1L}, τ_{2L}, τ_{3L} and τ_{1M}) as the average of marginal tax rates for (i) a single person at 67% of average earnings (no children) and (ii) a one-earner married couple at 100% of average earnings (two children). We computed tax rates on medium income individuals in our model (τ_{2M}, τ_{3M}, τ_{1H}) as the average of tax rates for (i) a single person at 100% of average earnings (no children) and (ii) a two-earner married couple, one at 100% of average earnings and the other at 33 % (2 children). We computed tax rates on high income individuals in our model (τ_{2H}, τ_{3H}) as the average of tax rates for (i) a single person at 167% of average earnings (no children) and (ii) a two-earner married couple, one at 100% of average earnings and the other at 67 % (2 children).

Government debt *(D_t)*
Definition: General government gross financial liabilities.
Data source: OECD Statistical Compendium, Economic Outlook, N° 89, Government Accounts.

Net benefit replacement rates when young and middle aged *(b_{ja}* for j=1,2,3 and a=L,M,H*)*
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_{jL} with j=1,2,3 and and b_{1M} as the average of the net benefit replacement rates for 'families' with earnings levels corresponding to 67% the average worker's wage (AW). We computed b_{2M}, b_{3M} and b_{1H} as the average of the net benefit replacement rates for 'families' with earnings levels corresponding to 100% of the average worker's wage, and b_{2H} and b_{3H} as the average of the net benefit replacement rates for 'families' with earnings levels corresponding to 167% of the average worker's wage. The reported data are averages for 2001-2004.
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, 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_{4a} for a=L,M,H)

To calculate our proxy for b_{4a} 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. (A problem is however that these data are not differentiated by income (skill) level. We have to assume that they are valid proxies for all skill levels). 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, p. 15). 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_{4a}) 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 $b_{4a} = \xi b_{3a} + (1-\xi)r_3$. Underlying the data in Table 4 is the assumption that ξ=0.5. Correlation between b_{4a} and r_3 lies around 0.92 for all skill levels. Cross-country differences roughly remain intact. 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).

Net pension replacement rates (b_{5a} and b_{6a} for a=L,M,H)

OECD (2005, p. 52) presents net pension replacement rates for individuals at various multiples of average individual earnings in the economy. We consider the data for individuals at 50% of average earnings as representative for the low ability group, individuals with average earnings as representative for the medium ability group, and individuals with twice average earnings as representative for the high ability group. Country studies in OECD (2005, part II) show the composition (sources) of this net replacement rate. This composition may be different for individuals with different income levels. Our proxy for b_{5a} includes all earnings-related pensions and mandatory occupational pensions when they depend on wages or hours worked. Our proxy for b_{6a} includes basic pensions, minimum pensions, targeted pensions, and old-age social assistance benefits, i.e. all categories that are not (or even inversely) related to individual earnings.

Since in our model b_{6a} is a percentage of the average net wage in the economy (Equation 9), whereas the above described OECD data are in percent of an individual's net wage, we multiply the OECD data with the ratio of the replacement in percent of average earnings to the replacement rate in percent of individual earnings to obtain our b_{6a}. This ratio can be derived from the 'pension modelling' tables in the individual country studies, at various multiples of average earnings.

Appendix 2: Detail on calibration procedure to determine η_a and ϕ_a (with *a*=L, M, H)

Given the data for US relative wages, we have for the low ability group that:

$$\frac{w_{L,t}h_{1L}^{t}}{w_{H,t}h_{1H}^{t}} = \frac{w_{L,t}\varepsilon_L h_{1H}^{t}}{w_{H,t}h_{1H}^{t}} = \frac{w_{L,t}}{w_{H,t}}.\varepsilon_L = 0.43\,.$$

We also know from Equation (26) that $\frac{w_{L,t}}{w_{H,t}} = \frac{\eta_L}{\eta_H}\left(\frac{H_{H,t}}{H_{L,t}}\right)^{1/s}$ which implies for the US:

$$\frac{\eta_L}{\eta_H}\left(\frac{H_{H,t}}{H_{L,t}}\right)^{1/s} = \frac{0.43}{\varepsilon_L} = \frac{0.43}{0.673} = 0.66\cdot$$

Similarly, it is easy to obtain for the medium ability group: $\frac{\eta_M}{\eta_H}\left(\frac{H_{H,t}}{H_{M,t}}\right)^{1/s} = \frac{0.63}{\varepsilon_M} = \frac{0.63}{0.837} = 0.76\cdot$

If we finally take into account that $\eta_H = 1-\eta_L-\eta_M$, and we introduce values for $H_{H,t}/H_{M,t}$ and $H_{H,t}/H_{L,t}$ which we simultaneously obtain elsewhere in the calibration (as functions of the employment rates and x_L, x_M and x_H, which themselves depend on ϕ_L, ϕ_M and ϕ_H), it is easy to see that we have three remaining equations in three unknowns (η_H, η_L, η_M) that can be solved.

Along the same line of reasoning, we obtain values for ϕ_L, ϕ_M and ϕ_H such that our model matches the relative wages of middle aged low and medium ability workers for the US, as well as the target value for education (*e*) over all 13 countries. The direct link between ϕ_L, ϕ_M, ϕ_H and education, and these relative wages, is obvious from the following two equations:

$$\frac{w_{L,t}h_{2L}^{t-1}}{w_{H,t}h_{2H}^{t-1}} = \frac{w_{L,t}x_L^{t-1}\varepsilon_L h_{1H}^{t-1}}{w_{H,t}x_H^{t-1}h_{1H}^{t-1}} = \frac{w_{L,t}x_L^{t-1}}{w_{H,t}x_H^{t-1}}0.673 = 0.38$$

$$\frac{w_{M,t}h_{2M}^{t-1}}{w_{H,t}h_{2H}^{t-1}} = \frac{w_{M,t}x_M^{t-1}\varepsilon_M h_{1H}^{t-1}}{w_{H,t}x_H^{t-1}h_{1H}^{t-1}} = \frac{w_{M,t}x_M^{t-1}}{w_{H,t}x_H^{t-1}}0.837 = 0.58$$

where we know that x_L, x_M and x_H are functions of ϕ_L, ϕ_M and ϕ_H respectively and e_M and e_H. Furthermore, also w_L/w_H and w_M/w_H depend on these parameters via H_H/H_L and H_H/H_M as we have shown above.

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