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WORKING PAPER

Heterogeneous ability and the effects of fiscal policy on employment, income and welfare in general equilibrium

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Abstract

We construct an overlapping generations model for an open economy where hours worked, human capital accumulation, income and welfare are all endogenous. Within each generation we distinguish individuals with high, medium or low innate ability. These differences in ability explain inequality in income and welfare. The composition of fiscal policy plays a central role in our model. The government sets tax rates on labor, capital and consumption. It spends its revenue mainly on goods, non-employment benefits and pensions. We find that our calibrated model's predictions match the main facts quite well in a sample of 13 OECD countries. We then use the model to investigate optimal changes in taxes and non-employment benefits if the objective is not only to improve aggregate equilibrium employment, output (income) and welfare, but also to reduce intergenerational and intragenerational welfare inequality. Our results strongly prefer an overall reduction of non-employment benefits to finance a combined decrease of labor tax rates on older workers and on all low-wage earners.

Key words: heterogeneous ability, employment by age, human capital, fiscal policy, welfare inequality, overlapping generations

JEL Classification: E62, H5, I28, J22, J24

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0. Introduction

Rising pressure on the welfare state due to ageing forces all OECD countries to develop effective employment and growth policies. The need to raise employment is particularly pressing among older and lower skilled workers. Concern for employment and growth is not new, however. They have been high on the agenda of both policy makers and researchers since at least two decades. In more recent years, increasing sensitivity to the problem of inequality has made the challenge for policy makers only larger. Not only efficiency, but also equity and fairness demand attention.

Many researchers have demonstrated the major influence of fiscal policy composition on employment. Most contributions focus on aggregate employment (e.g. Prescott, 2004; Rogerson, 2007; Dhont and Heylen, 2008; Ohanian, Raffo and Rogerson, 2008; Olovsson, 2009; Berger and Heylen, 2011). In more recent work, however, Rogerson and Wallenius (2009), Ludwig, Schelkle and Vogel (2012) and Wallenius (2013) also pay attention to life cycle patterns in labor supply and to employment differences across age groups. Erosa, Fuster and Kambourov (2012) and Alonso-Ortiz (2014) focus particularly on the influence of social security programs and taxes on labor supply late in the life cycle and on the retirement decision of older workers. Fiscal policy composition is also a central element in the 'capital accumulation' endogenous growth framework as initiated by Barro (1990) and King and Rebelo (1990). More recently, many fiscal policy models have introduced education and endogenous human capital as a major driver of output and possibly growth (e.g. Buiter and Kletzer, 1993; Glomm and Ravikumar, 1998; Docquier and Michel, 1999; Dhont and Heylen, 2009). Empirical work by e.g. Gemmell, Kneller and Sanz (2011) confirms the importance of fiscal policy for growth in OECD countries.

In Heylen and Van de Kerckhove (2013) we took this literature as far as we could. We studied the effects of fiscal policy in a general equilibrium OLG model for an open economy where the employment rate of young, middle aged and older individuals, the fraction of time that young individuals allocate to (tertiary) education, the retirement decision of older workers, and aggregate per capita growth are all endogenous. We introduced a rich specification of fiscal policy, with the government setting tax rates on labor, capital and consumption, and allocating its revenue to productive expenditures (mainly for education), consumption, pensions and non-employment benefits, including early retirement benefits. We calibrated the model and found that its predictions matched the facts remarkably well for all key variables in many OECD countries. We then used the model to investigate the effects of various fiscal policy shocks. Our simulations revealed a clear ranking of policy measures in their effectiveness to promote employment, human capital and growth. As to employment, we found the strongest effects from a reduction of non-employment benefit generosity, followed by labor tax cuts. The employment effects of other policy measures, e.g. capital tax cuts or a shift of taxes from labor to consumption, were also positive, but limited. Long-run output and growth were supported most by higher productive government expenditures, and by labor tax cuts targeted at middle-aged and older workers. The perspective of increased future hours of work at lower tax rates raises the lifetime utility gain from building human capital when young.

This encourages young individuals to study, which is a key condition for productivity and growth. By contrast, labor tax cuts targeted at younger workers imply lower future growth since they discourage the young to study.

An important weakness of our model in Heylen and Van de Kerckhove (2013), however, as well as in almost all related earlier literature, is that it assumes equal ability and capacity to build human capital for all people. Reality is different, however. Data reveal that in 2011 25% of the 25-64 year old population in the OECD had no upper secondary degree. About 44% had an upper secondary degree but no tertiary degree. The fraction of people with a tertiary degree was 32%. Among young cohorts (age 25 to 34), educational attainment is higher. Yet, the fraction that does not complete upper secondary education is still close to 20% on average (OECD, Education at a Glance, 2013, p. 39). 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. A second very important observation here is that these differences in school results feed through directly into labor market outcomes. On average in the OECD in 2011, the employment rate among people of age 25 to 34 with less than an upper secondary degree was only 58%. The employment rate among people with a tertiary degree was higher than 80% (OECD, Education at a Glance, 2013, p. 93).

In this paper we take our earlier OLG model as our starting point. We will, however, extend it by allowing heterogeneous abilities. More precisely, we define in each generation individuals who are born with high, medium or low innate ability. Individuals with higher ability enter the model with more human capital. They are also more productive in building additional human capital when they allocate time to (tertiary) education. This extension allows a richer and more realistic analysis of fiscal policy effects. Labor taxes and benefits may differ not only by the age of workers, but also by their ability (labor income). Moreover, in addition to aggregate welfare effects of policy changes, it will be possible to investigate welfare effects on specific age or ability groups. A discussion then becomes possible of the effects of policies on both intragenerational and intergenerational inequality. Next to an extension with heterogeneous abilities, this paper also brings a simplification in the model that we developed in Heylen and Van de Kerckhove (2013). In particular, we will adopt a simpler human capital production function, in the spirit of Lucas (1990), Glomm and Ravikumar (1998) and Docquier and Michel (1999). This simplification also brings a reduction in government spending categories to only non-employment benefits, pensions, general spending on goods and interest payments. In this paper we do not distinguish between government consumption and productive expenditures.

Our main findings are the following. First, we confirm some of our key results in Heylen and Van de Kerckhove (2013). We again identify labor taxes and (especially) non-employment benefits as the most effective policy variables with respect to employment. Again we observe that labor tax cuts targeted at older workers are far more effective than overall labor tax cuts. They have stronger employment effects. Moreover, they also promote human capital accumulation by individuals of high and medium ability and – as a consequence – productivity and output. Labor tax cuts targeted at young workers rather have the opposite effects. Second, however, a first new result in this paper is that if these policies are imposed, they also imply clearly differential welfare effects between the ability groups. Current and near future low ability individuals may experience significant relative welfare losses. Third, better overall employment effects and better welfare effects for low ability groups (implying reduced welfare inequality) are possible, at the cost of a slight loss of output, if one complements policies that cut labor taxes on older workers with labor tax cuts on all low-wage earners. In our model, the latter include all low ability individuals and the young medium-ability individuals. Their net wage income is less than two thirds of the average in the economy. The best effects on employment follow if this combined tax cut is financed by overall benefit cuts.

Several researchers have introduced heterogeneous abilities in life cycle / OLG models before. Some have done this to study the effects of fiscal policy on the incentives to accumulate human capital and on wage inequality (see e.g. Guvenen, Kuruscu and Ozkan, 2009). The way in which heterogeneity is introduced differs, however. Some authors model individuals with different human capital (or skill) levels when they enter the model (e.g. Sommacal, 2006; Fehr, Kallweit and Kindermann, 2013). Others introduce individuals with the same initial human capital, but different learning abilities (e.g. Docquier and Paddison, 2003). Another assumption to make is whether or not human capital and productivity are subject to idiosyncratic shocks during life, as for example in Fehr et al. (2013). In our model individuals with higher ability will have both higher initial human capital and be more productive in building additional human capital when they allocate time to (tertiary) education. Individuals with low ability enter the model with low human capital and have zero productivity to study and build additional human capital. We abstain, however, from shocks to individual human capital and productivity during individuals' life. This set of assumptions may offer the best match to recent findings by Huggett, Ventura and Yaron (2006, 2011) and Keane and Wolpin (2007) that heterogeneity in human capital endowment at young age and learning abilities, rather than shocks to human capital, account for most of the variation in lifetime utility. Our approach also matches findings that innate learning ability and human capital at the age of 23 are strongly positively correlated (Huggett et al., 2011). A final important element is the relationship between the human capital of subsequent generations. In the main part of this paper, we follow Ludwig et al. (2012) among others, and assume that human capital is predetermined and generation-invariant. Growth will then be exogenous. In a robustness section we will, however, assume that when people enter the model, they inherit a fraction of the human capital of the previous generation, as in Azariadis and Drazen (1990) and Heylen and Van de Kerckhove (2013). Individuals with higher ability inherit a larger fraction. Different generations then start with different (ability-specific) human capital, and growth becomes endogenous.

The structure of the paper is as follows. In Section 1 we document differences in employment by age and by educational attainment, education of the young, and the effective retirement age of older workers in 13 OECD countries before the financial crisis (1995-2007). Section 2 sets out our basic model with predetermined and generation-invariant human capital. In Section 3 we calibrate the model on actual data. Section 4 gives more insight into the reality behind the key fiscal policy parameters in our model. We report data for the same 13 OECD countries. In Section 5 we confront the model's predictions with the facts described in Section 1. Our procedure is as follows. We impose common technology and preference parameters on all countries, but country-specific fiscal policy parameters. Simulating the model for each individual country we find that its predictions match the main facts in most countries. Section 6 includes the results of a wide range of policy simulations. In this section we discuss the steady state employment, education, output and welfare effects of fiscal policy changes. We study effects per generation and per ability (income) group. In Section 7 we investigate (and confirm) the robustness of our findings to allowing an intergenerational transfer of human capital and endogenous growth. Section 8 concludes the paper.

1. Cross-country differences in employment, retirement age and participation in tertiary education

Table 1 contains key data on employment and participation in tertiary education 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: n_1 for young persons (age 20-34), n_2 for middle aged persons (35-49), and n_3 for older persons (50-64). Potential hours are 2080 per person per year (52 weeks times 40 hours per week). The observed employment rate rises if more people in an age group have a job, and if the employed work more hours. The employment rate in the age group of 50 to 64 is also affected by the average age at which older workers withdraw from the labor force. We include the effective retirement age as the fourth data column in the Table. In most countries, this age is well below the official age to receive old-age pensions. The fifth column in Table 1 reports employment differences by ability. Since data on hours worked per person by ability level are not available (as far as we know), it is not possible to compute data that are comparable to the employment rates by age. We therefore focus on employment rates in persons, i.e. the fraction of people with a certain educational attainment who have a job. Concentrating on the upper and lower group, we present the ratio of the employment rate in persons among people with less than upper secondary education to the employment rate among those with a tertiary degree. If it can be assumed that hours worked per employed person are comparable, these data would act as a (rough) proxy for n_L/n_H. The education rate (e) in Table 1 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. We refer to Appendix A for details on the calculation of our data, and on the assumptions that we have to make.

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 across 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, especially employment rates among older workers. The Nordic countries take intermediate positions, although they are

Table 1

Employment rate in hours (n) by age and educational attainment, effective retirement age and education rate ($\boldsymbol{e}$) in 13 OECD countries (1995-2007)

	n_1 (20-34)	n_2 (35-49)	n_3 (50-64)	*Effective retirement age*	n_L/n_H	e
Austria	59.9	64.3	34.7	59.5	0.73	12.5
Belgium	51.1	56.8	29.3	57.9	0.67	14.1
France	48.7	60.3	38.0	58.8	0.72	14.9
Germany	49.7	55.2	34.9	61.1	0.64	17.2
Italy	50.1	61.9	33.8	60.1	0.88	12.6
Netherlands	50.8	54.6	34.2	60.0	0.77	14.7
Core euro area Average	**51.7**	**58.8**	**34.2**	**59.6**	**0.73**	**14.3**
Denmark	56.2	66.7	49.6	62.2	0.77	21.7
Finland	55.6	69.0	47.3	60.2	0.78	23.1
Norway	51.9	60.9	50.6	63.1	0.77	18.1
Sweden	53.6	66.1	55.4	63.4	0.80	17.7
Nordic Average	**54.3**	**65.6**	**50.7**	**62.2**	**0.78**	**20.2**
US	**65.6**	**74.2**	**59.6**	**64.2**	**0.74**	**12.8**
UK	60.8	68.4	49.4	62.0	0.72	12.3
Canada	60.9	69.5	50.4	62.1	0.72	13.6
Overall average	**55.0**	**63.7**	**43.6**	**61.1**	**0.75**	**15.8**

Data sources: OECD (see Appendix A); data description: see main text and Appendix A. The data for the employment rates n_1, n_2 and n_3 concern 1995-2007. The data for education and the effective retirement age averages for 1995-2006. All these data are in percent, except the retirement age. The data for the relative employment rate (in persons) among individuals of low education (below upper secondary degree) versus individuals of high education (tertiary degree) concern workers of age 25-34. The data are an average for 2000 and 2005 and have been taken from OECD, Education at a Glance (2013, Table A5.3a).

close to the core euro area for the younger generation. One of the main factors explaining differences in n_3 is variation in the effective retirement age 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). As to ability groups, we see in all countries lower employment rates among lower educated people than among people with a tertiary degree (n_L /n_H <1). On average over all countries in Table 1, the former is only about 75% of the latter. Again we observe significant cross-country differences, with the lowest numbers in countries like Belgium and Germany, and the highest in the Nordic countries and Italy. Young people's effective participation in education is also by far the highest in the Nordic countries. Austria, Italy, and the UK have the lowest participation in education among people of age 20 to 34.

When it comes to data in this paper, one further point of clarification may be useful. As we have done in Table 1 for n_L and n_H, we will use data for people with below upper secondary education as a proxy for the low ability group, data for people with an upper secondary but no tertiary degree as a proxy for the medium ability group, and data for people with a tertiary degree as a proxy for the high ability group. Considering the distribution of these degrees within the population, and even within young cohorts (as we have mentioned in the introduction), the match between these data and our model with three equal sized ability groups is close. The median low ability individual in our model would be at the 17th percentile, the median medium ability individual at the 50th percentile and the median high ability person at the 83th percentile. In the data individuals at the 17th percentile have no upper secondary degree in most countries. Individuals at the 83th percentile have a tertiary degree.

2. The model with exogenous growth

Our analytical framework borrows heavily from Heylen and Van de Kerckhove (2013). It consists of a computable four-period OLG-model for a small open economy with endogenous employment and human capital. New in this paper is that we realistically take into account differences in individuals' innate abilities.

2.1. Basic set-up and demographics

We consider three active adult generations, the young, the middle aged and the older, and one generation of retired agents. Individuals enter the model at age 20. Each period of life is modeled to last 15 years. Within each generation we assume three types of individuals with different ability: a group H with high ability, a group M with medium ability and a group L with low ability. We normalize each ability group to 1, so that the size of a generation is 3, and total population is 12, and constant. Consistent with findings by Huggett et al. (2006, 2011), differences in ability are reflected both in the amount of human capital with which individuals enter the model and in their productivity of schooling (at the tertiary level) when young. Low ability individuals enter with the lowest human capital and will never go into tertiary education. They only work or have 'leisure' (including other non-market activities). High and medium ability young people enter the model with more human and will also invest a fraction of their time in tertiary education. Middle aged and older individuals do not study anymore. Whatever their innate ability, 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 acting on competitive markets. These firms employ physical capital together with existing technology and effective labor provided by the three active generations. In the spirit of Buiter and Kletzer (1993), physical capital is internationally mobile, whereas labor and human capital are immobile.

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

2.2. Individuals: preferences and time allocation

An individual with ability a ($a = H, M, L$) reaching age 20 in period t maximizes an intertemporal utility function of the form:

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

with $0 < \beta < 1, \gamma_j > 0, \theta > 0$ $(\theta \neq 1)$. 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 ability. Lifetime utility depends on consumption (c_{ja}^t) and enjoyed leisure (ℓ_{ja}^t) in each period of life. The parameters β, γ and θ define the discount factor, the relative value of leisure versus consumption, and the inverse of the intertemporal elasticity to substitute leisure. These parameters are common across ability types. The preference parameter γ may, however, 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. Rogerson, 2007; Erosa et al., 2012).

Figure 1 shows the individuals' time allocation over the life cycle. Equations (2)-(5) describe how this is reflected in enjoyed leisure ℓ_{ja}^t. Time endowment in each period is normalized to 1.

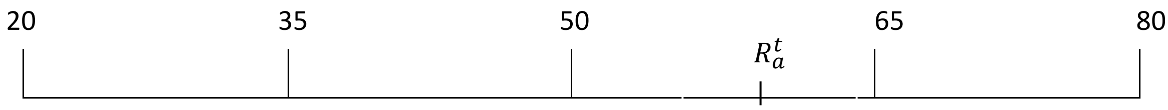
$$\ell_{1a}^t = 1 - n_{1a}^t - e_{1a}^t, \quad \text{with } e_{1L}^t = 0. \tag{2}$$

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

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

$$\ell_{4a}^t = 1 \tag{5}$$

Figure 1. Life cycle of an individual of generation *t* and ability *a*



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*

Note: $e_{1L}^t = 0$.

In the first period of active life (Equation 2), leisure falls in labor supply (n_{1a}^t) and in education time (e_{1a}^t). Only the low ability individuals do not study ($e_{1L}^t = 0$). In the second and third period, no one studies. Individuals only work or have leisure (Equations 3 and 4). Following the approach in Buyse *et al.* (2013), part of the individuals' optimal choice of leisure in the third period of their life concerns the determination of early retirement. Individuals choose R_a^t 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; $(1 - R_a^t)$ is the fraction of time in early retirement. Assuming that labor market exit is irreversible and post-retirement employment is not allowed, the relationship between the fraction of time devoted to work between 50 and 65 (n_{3a}^t) and the fraction of time devoted to work before early retirement but after 50 ($\tilde{n}_{3a}^t$), is as follows: $n_{3a}^t = R_a^t . \tilde{n}_{3a}^t$. Leisure time in the third period therefore consists of two parts: non-employment time before the effective retirement age $R_a^t(1 - \tilde{n}_{3a}^t)$, and time in early retirement after it $(1 - R_a^t)$. Equation (4) then describes composite enjoyed leisure of an older worker as a CES-function of both parts. Like Buyse *et al.* (2013), we assume imperfect substitutability between the two leisure types. The idea 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.[1] 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 ζ 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}^t corresponds to the magnitude of total leisure time $(1 - n_{3a}^t)$. The latter assumption allows us 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 ζ.

2.3. Individuals: budget constraints

Equations (6)-(9) describe the main budget constraints that individuals are subject to. The LHS shows that individuals allocate their disposable income to consumption (including consumption taxes, τ_c) and to the accumulation of non-human wealth. We denote by Ω_{ja}^t the stock of wealth held by a type a individual of generation *t* at the end of the *j*th period of his life. Individuals start adult life with zero assets. As is clear from Equation (9), they also finish life with zero assets. During the three periods of active life, disposable income at the RHS includes after-tax labor income and non-employment benefits. From the second to the fourth period, it may also include interest income. We denote by $w_{a,k}$ the real wage per unit of effective labor supplied at time *k* by an individual with ability *a* and by r_k the exogenous (world) real interest rate at time *k*.

Effective labor of an individual with ability a depends on hours worked (n_{ja}^t) and human capital (h_{ja}^t). Given the tax rate on labor income τ_w, young individuals earn an after-tax real wage

[1] 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 that take more time and ask for longer term commitment (e.g. long journeys, non-market activity as a volunteer).

$$(1+\tau_c)c_{1a}^t + \Omega_{1a}^t = w_{a,t}h_{1a}^t n_{1a}^t(1-\tau_w) + bw_{a,t}h_{1a}^t(1-\tau_w)(1-n_{1a}^t - e_{1a}^t) \qquad (6)$$

$$(1+\tau_c)c_{2a}^t + \Omega_{2a}^t = w_{a,t+1}h_{2a}^t n_{2a}^t(1-\tau_w) + bw_{a,t+1}h_{2a}^t(1-\tau_w)(1-n_{2a}^t)$$

$$+(1+r_{t+1})\Omega_{1a}^t \qquad (7)$$

$$(1+\tau_c)c_{3a}^t + \Omega_{3a}^t = w_{a,t+2}h_{3a}^t R_a^t \tilde{n}_{3a}^t(1-\tau_w) + bw_{a,t+2}h_{3a}^t(1-\tau_w)R_a^t(1-\tilde{n}_{3a}^t)$$

$$+b_{er}w_{a,t+2}h_{3a}^t(1-\tau_w)(1-R_a^t) + (1+r_{t+2})\Omega_{2a}^t \qquad (8)$$

$$(1+\tau_c)c_{4a}^t = (1+r_{t+3})\Omega_{3a}^t + pp_a^t \qquad (9)$$

$$pp_a^t = \rho_{wa}\sum_{j=1}^{3}\left(p_j w_{a,t+j-1}h_{ja}^t n_{ja}^t(1-\tau_w)\right)$$

$$+\rho_{fa}\left(\frac{1}{9}\right)\sum_{j=1}^{3}\sum_{a=H,M,L}\left(w_{a,t+3}h_{ja}^{t+4-j}n_{ja}^{t+4-j}(1-\tau_w)\right) \qquad (10)$$

with: $0 \le p_j \le 1$

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

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

equal to $w_{a,t}h_{1a}^t n_{1a}^t(1-\tau_w)$. After-tax labor income of middle aged and older workers in Equations (7) and (8) is determined similarly. For the fraction of time that young, middle aged and older individuals are inactive, they receive a non-employment benefit from the government. Older individuals 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, for early retirement benefits it is b_{er}[2].

After the statutory retirement age (65) individuals have no labor income and no non-employment benefits anymore. They earn interest income from accumulated non-human wealth, and they receive an old-age pension benefit (pp_a^t). We assume a public PAYG pension system in which pensions in period *k* are basically financed by contributions from the active generations in that period *k* (see below). As described by Equation (10), 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 net labor income in each of the three active periods of life. The net replacement rate is ρ_{wa}. 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

[2] As explained in greater detail by Buyse *et al.* (2013, footnote 5), the 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.

capital h_{ja}^t. It will be lower when the individual retires early (lower R_a^t). 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. Here, the net replacement rate is ρ_{fa}.

Note that we allow ability-specific pension replacement rates ρ_{wa} and ρ_{fa}. This specification is in line with the data in many countries. The importance of own-income related versus flat components may be very different depending on people's earned income, and therefore ability (see Section 4 and Table 5 below). For other policy variables like labor tax rates such differences are much smaller (Heylen and Van de Kerckhove, 2013).

2.4. Individuals: human capital formation

Individuals enter our model at the age of 20 with a predetermined level of human capital. This level is generation-invariant, but it rises in innate ability. The latter reflects for example the positive overall effects of higher intelligence, and the fact that higher innate ability makes it easier for individuals to learn and accumulate knowledge at primary and secondary school. In Equation (11) we normalize the human capital of a young individual with high ability to h_0. A young individual with medium ability enters the model with only a fraction ε_M of this. A young worker with low ability enters with an even lower fraction ε_L. These fractions will be calibrated.

$$h_{1a}^t = \varepsilon_a h_0 \qquad \forall\, a = H, M, L \tag{11}$$

with $0 < \varepsilon_L < \varepsilon_M < \varepsilon_H = 1$.

During youth, individuals with high and medium ability will invest a fraction of their time to expand their human capital, making them more productive in the second and third period. We adopt in Equation (12.a) a human capital production function similar to Lucas (1990), Glomm and Ravikumar (1998), Bouzahzah *et al.* (2002) and Docquier and Paddison (2003). The production of new human capital by these individuals rises in the amount of time they allocate to education (e_{1a}^t) and in their initial human capital (h_{1a}^t). We assume a common elasticity of time input (σ) and a common efficiency parameter (ϕ) for both ability types. Individuals with low innate ability do not study. In Equation (12.b) their human capital remains constant. Finally, we assume in Equation (13) that the human capital of all individuals remains unchanged between the second and the third period. We have in mind that learning by doing in work may counteract depreciation. The same assumption explains the lack of depreciation in Equation (12). In no way does this assumption affect our main results in this paper.

$$h_{2a}^t = h_{1a}^t (1 + \phi (e_{1a}^t)^\sigma) \qquad \forall a = H, M \tag{12.a}$$

$$h_{2L}^t = h_{1L}^t \tag{12.b}$$

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

with $0 < \sigma \leq 1, \phi > 0$.

2.5. Individuals: optimization and the influence of fiscal policy

Individuals will choose consumption, labor supply in each period of active life, education when young (for the medium and high ability individuals), and their effective retirement age to maximize Equation (1), subject to Equations (2)-(13). Substituting Equations (2)-(5) for ℓ_{ja}^{t} and (6)-(9) 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_{1a}^{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, and consequently promote labor supply. Extra consumption during retirement rises in the own-income-related pension replacement rate (ρ_{wa}) and in the weight attached to the relevant period when computing the pension base (p_j). Equations (15.a)-(15.c) highlight positive substitution effects from the pension replacement rate ρ_{wa}. To the extent that higher replacement rates raise individuals' consumption possibilities (c_{ja}^{t}), they also cause adverse income effects on labor supply. Basic pensions (ρ_{fa}) do not directly occur in Equations (15), but they do affect employment via this income effect.

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

$$\frac{\gamma_1}{\left(\ell_{1a}^{t}\right)^{\theta}} \frac{-\partial \ell_{1a}^{t}}{\partial n_{1a}^{t}} = \frac{w_{a,t} h_{1a}^{t}(1-\tau_w)(1-b)}{c_{1a}^{t}(1+\tau_c)} + \beta^3 \frac{\rho_{wa} p_1 w_{a,t} h_{1a}^{t}(1-\tau_w)}{c_{4a}^{t}(1+\tau_c)} \tag{15.a}$$

$$\begin{aligned}\frac{\gamma_2}{\left(\ell_{2a}^{t}\right)^{\theta}} \frac{-\partial \ell_{2a}^{t}}{\partial n_{2a}^{t}} &= \frac{w_{a,t+1}\left(1+\phi\left(e_{1a}^{t}\right)^{\sigma}\right) h_{1a}^{t}(1-\tau_w)(1-b)}{c_{2a}^{t}(1+\tau_c)} \\ &\quad + \beta^2 \frac{\rho_{wa} p_2 w_{a,t+1}\left(1+\phi\left(e_{1a}^{t}\right)^{\sigma}\right) h_{1a}^{t}(1-\tau_w)}{c_{4a}^{t}(1+\tau_c)}\end{aligned} \tag{15.b}$$

$$\begin{aligned}\frac{\gamma_3}{\left(\ell_{3a}^{t}\right)^{\theta}} \frac{-\partial \ell_{3a}^{t}}{\partial \tilde{n}_{3a}^{t}} &= \frac{w_{a,t+2}\left(1+\phi\left(e_{1a}^{t}\right)^{\sigma}\right) h_{1a}^{t} R_{a}^{t}(1-\tau_w)(1-b)}{c_{3a}^{t}(1+\tau_c)} \\ &\quad + \beta \frac{\rho_{wa} p_3 w_{a,t+2}\left(1+\phi\left(e_{1a}^{t}\right)^{\sigma}\right) h_{1a}^{t} R_{a}^{t}(1-\tau_w)}{c_{4a}^{t}(1+\tau_c)}\end{aligned} \tag{15.c}$$

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 $\tilde{n}_{3a}^{t}$. 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. We observe again positive effects from lower taxes on labor and lower consumption taxes. High standard non-employment benefits b also raise the gain from continued work. High early retirement benefits, by contrast, do exactly the opposite. Last but not least, Equation (16) reveals the role of the pension system. A tight relationship (via ρ_{wa} and p_3) between the pension and labor income earned between the age of 50 of 65 will encourage individuals to retire later.

$$\frac{\gamma_3}{\left(\ell_{3a}^{t}\right)^{\theta}}\frac{-\partial\ell_{3a}^{t}}{\partial R_a^t} = \frac{w_{a,t+2}\left(1+\phi\left(e_{1a}^{t}\right)^{\sigma}\right)h_{1a}^{t}(1-\tau_w)(\tilde{n}_{3a}^{t}+b(1-\tilde{n}_{3a}^{t})-b_{er})}{c_{3a}^{t}(1+\tau_c)}$$

$$+\beta\,\frac{\rho_{wa}p_3 w_{a,t+2}\left(1+\phi\left(e_{1a}^{t}\right)^{\sigma}\right)h_{1a}^{t}\tilde{n}_{3a}^{t}(1-\tau_w)}{c_{4a}^{t}(1+\tau_c)} \qquad (16)$$

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 ($\sigma\phi(e_{1a}^{t})^{\sigma-1}$). Labor taxes during youth therefore encourage individuals to study, whereas labor taxes in later periods of active life discourage them. Notice also that high benefit replacement rates in later periods, and a high income-related pension replacement rate (ρ_{wa}), 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}^{t}, $n_{3a}^{t} = R_a^t.\tilde{n}_{3a}^{t}$).

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

with: $\frac{\partial c_{1a}^{t}}{\partial e_{1a}^{t}} = -\frac{b w_{a,t} h_{1a}^{t}(1-\tau_w)}{1+\tau_c}$

$$\frac{\partial c_{2a}^{t}}{\partial e_{1a}^{t}} = \sigma\phi\left(e_{1a}^{t}\right)^{\sigma-1}\frac{w_{a,t+1}h_{1a}^{t}(1-\tau_w)\left[n_{2a}^{t}+b\left(1-n_{2a}^{t}\right)\right]}{1+\tau_c}$$

$$\frac{\partial c_{3a}^{t}}{\partial e_{1a}^{t}} = \sigma\phi\left(e_{1a}^{t}\right)^{\sigma-1}\frac{w_{a,t+2}h_{1a}^{t}(1-\tau_w)\left[R_a^t\left(\tilde{n}_{3a}^{t}(1-b)+b-b_{er}\right)+b_{er}\right]}{1+\tau_c}$$

$$\frac{\partial c_{4a}^{t}}{\partial e_{1a}^{t}} = \rho_{wa}\sigma\phi\left(e_{1a}^{t}\right)^{\sigma-1}\frac{\sum_{j=2}^{3}\left(p_j n_{ja}^{t} w_{a,t+j-1}h_{1a}^{t}(1-\tau_w)\right)}{1+\tau_c}$$

2.6. 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 (18). Production exhibits constant returns to scale in aggregate physical capital *(K_t)* and labor in efficiency units ($A_t H_t$), so that profits are zero in equilibrium. Technology A_t is growing at an exogenous and constant rate x: $A_{t+1} = A_t(1+x)$. Equation (19) 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 $\eta_H = 1 - \eta_M - \eta_L$.

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

$$H_t = \left(\eta_H H_{H,t}^{1-\frac{1}{s}} + \eta_M H_{M,t}^{1-\frac{1}{s}} + \eta_L H_{L,t}^{1-\frac{1}{s}}\right)^{\frac{s}{s-1}} \tag{19}$$

Equation (20) specifies effective labor per ability group. Within each ability group we assume perfect substitutability of labor supplied by the different age groups.

$$\begin{aligned} H_{a,t} &= n_{1a}^{t} h_{1a}^{t} + n_{2a}^{t-1} h_{2a}^{t-1} + n_{3a}^{t-2} h_{3a}^{t-2} \\ &= (n_{1a}^{t} + n_{2a}^{t-1}\,\psi_a^{t-1} + n_{3a}^{t-2}\,\psi_a^{t-2})\varepsilon_a h_0 \qquad \forall a = H, M, L \end{aligned} \tag{20}$$

To derive Equation (20) we make use of Equations (12) and (13) where we define:

$$1 + \phi(e_{1a}^{t})^{\sigma} \equiv \psi_a^{t}\text{, where } \psi_L^{t} = 1 \tag{21}$$

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

Furthermore, we exploit the result that

$$h_{1a}^{t} = h_{1a}^{t-1} = h_{1a}^{t-2} = \varepsilon_a h_0 \tag{22}$$

Substituting Equation (20) for $a = H, M$ and L into (19), and recognizing differences in the capacity ε_a to inherit human capital as indicated by Equation (11), yields Equation (23).

$$H_t = \left[\textstyle\sum_{a=H,M,L} \eta_a \varepsilon_a^{1-\frac{1}{s}} (n_{1a}^{t} + n_{2a}^{t-1}\,\psi_a^{t-1} + n_{3a}^{t-2}\,\psi_a^{t-2})^{1-\frac{1}{s}}\right]^{\frac{s}{s-1}} h_0 \tag{23}$$

Competitive behavior implies in Equation (24) 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 (world) real interest rate being given, firms will install more capital when the amount of labor in efficiency units increases or the capital tax rate falls. In that case the net return to investment in the home country rises above the world interest rate, and capital flows in. Furthermore, perfect competition implies equality between the real wage and the marginal product of effective labor for each ability type (Equation 25). Workers of a particular ability type will earn a higher real wage when their supply is relatively scarce, when the level of technology is higher, and when physical capital per unit of aggregate effective labor is higher.

$$\left[\alpha\left(\frac{A_t H_t}{K_t}\right)^{1-\alpha} - \delta_k\right](1-\tau_k) = r_t \tag{24}$$

$$(1-\alpha)A_t^{1-\alpha}\left(\frac{K_t}{H_t}\right)^{\alpha}\eta_a\left(\frac{H_t}{H_{a,t}}\right)^{\frac{1}{s}} = w_{a,t} \quad \forall a = H, M, L \tag{25}$$

Our assumptions of constant population and of individuals entering the model with a predetermined and generation-invariant level of human capital imply that in steady state effective labor will be constant. Physical capital, output and real wages by contrast will all grow at the exogenous technology growth rate x.

2.7. Government

Equation (26) describes the government's budget constraint. Demand for goods G_t, benefits related to non-employment B_t (including early retirement benefits), old-age pension benefits PP_t, and interest payments $r_t D_t$ 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.

$$\Delta D_{t+1} = D_{t+1} - D_t = G_t + B_t + PP_t + r_t D_t - T_{nt} - T_{kt} - T_{ct} \tag{26}$$

with: $G_t = gY_t$

$$B_t = \sum_{a=H,M,L}\Big((1-n_{1a}^t - e_{1a}^t) b w_{a,t} h_{1a}^t (1-\tau_w) + (1-n_{2a}^{t-1}) b w_{a,t} h_{2a}^{t-1}(1-\tau_w)$$
$$+R_a^{t-2}(1-\tilde{n}_{3a}^{t-2}) b w_{a,t} h_{3a}^{t-2}(1-\tau_w) + (1-R_a^{t-2}) b_{er} w_{a,t} h_{3a}^{t-2}(1-\tau_w)\Big)$$

$$PP_t = \sum_{a=H,M,L}\Big(\rho_{wa}\sum_{j=1}^{3}\Big(p_j w_{a,t+j-4} h_{ja}^{t-3} n_{ja}^{t-3}(1-\tau_w)\Big)$$
$$+\rho_{fa}\left(\frac{1}{9}\right)\sum_{j=1}^{3}\sum_{a=H,M,L}\Big(w_{a,t} h_{ja}^{t+1-j} n_{ja}^{t+1-j}(1-\tau_w)\Big)\Big)$$

$$T_{n,t} = \tau_w \sum_{a=H,M,L}\Big(\sum_{j=1}^{3} n_{ja}^{t+1-j} w_{a,t} h_{ja}^{t+1-j}\Big)$$

$$T_{kt} = \tau_k(\alpha Y_t - \delta_k K_t)$$

$$T_{ct} = \tau_c \sum_{j=1}^{4}\Big(c_{jH}^{t+1-j} + c_{jM}^{t+1-j} + c_{jL}^{t+1-j}\Big)$$

Note our assumption that the government claims a given fraction g of output. Goods bought by the government have no effect on private sector productivity, nor do they directly affect individuals' utility. Non-employment benefits (B_t) are an unconditional source of income support related to inactivity (leisure) and non-market household activities as in Rogerson (2007) and Dhont and Heylen (2009). Although it may seem strange to have such transfers in a model without involuntary unemployment, there is 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.

2.8. Aggregate equilibrium and the current account

Optimal behavior by firms and households and government spending underlie aggregate domestic demand for 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 (27) describes aggregate equilibrium as it can be derived from the model's equations. The LHS of (27) represents national income. It is the sum of domestic output Y_t and net factor income from abroad $r_t F_t$, with F_t being net foreign assets at the beginning of *t.* The aggregate stock of wealth Z_t accumulates wealth held by individuals who entered the model in *t-1*, *t-2* and *t-3*. At the RHS of (27) CA_t stands for the current account in period *t.*

$$Y_t + r_t F_t = C_t + I_t + G_t + CA_t \tag{27}$$

with: $F_t = Z_t - K_t - D_t$

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

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

3. Parameterization

The economic environment described above allows us to simulate the effects on employment, education, output and welfare of various changes in the pension system. Our main contribution in this paper is that we model and assess differential effects for individuals with different ability. This simulation exercise requires us first to parameterize and solve the model. Table 2 contains an overview of all parameters. Many have been set in line with the existing literature. Others have been calibrated to match key data.

We set the rate of time preference at 1.5% per year, the (exogenous and constant) world real interest rate at 4.5% per year and the physical capital depreciation rate at 8% per year. Considering that periods in our model last 15 years, this choice implies a discount factor β = 0.8, an interest rate r = 0.935 and physical capital depreciation δ_k = 0.714. In the production function for goods we assume a capital share coefficient α equal to 0.3. The elasticity of substitution s between the different ability types of effective labor is set equal to 1.5. Our values for the rate of time preference, the capital share and capital depreciation are well within the range of values imposed in the literature (e.g. Altig et al., 2001; Heijdra and Romp, 2009; Ludwig et al., 2012). So is the value for s. The empirical labor literature consistently documents values between 1 and 2 (see Caselli and Coleman, 2006). For the value of the intertemporal elasticity of substitution in leisure ($1/\theta$) we follow Rogerson (2007, p. 12).

He puts forward a reasonable range for θ from 1 to 3. In line with this, we impose θ to be equal to 2. This choice implies an elasticity of labor supply which is much higher than the very low elasticities typically found in micro studies. Given our macro focus, however, these micro studies may not be the most relevant ones (see Rogerson and Wallenius, 2009; Fiorito and Zanella, 2012).

Four parameters relate to human capital production. For the elasticity with respect to education time (σ) we choose a conservative value of 0.3. This value is within the range considered by Bouzahzah et al. (2002) and Docquier and Paddison (2003), but much lower than the elasticity of 0.80 that we see in Lucas (1990) or Glomm and Ravikumar (1998). The choice of a conservative value for σ excludes that our main findings in the next sections might be due to an overestimation of the returns to education[3]. The literature provides much less guidance for the calibration of the relative initial human capital of medium and low ability individuals (relative to the initial human capital of high ability individuals, ε_M and ε_L). To determine these parameters we rely on PISA science scores. These scores leave no doubt. In about all OECD countries the science test score of students at the 17th percentile varies between 65% and 69% of the test score of students at the 83th percentile, while the science test score of students at the 50th percentile varies between 82.5% and 85.5% of the test score of students at the 83th percentile[4]. The differences across countries in these relative scores are extremely small. We can take them as objective indicators of the relative cognitive capacity of low and medium ability individuals, and will correspondingly set ε_L equal to 0.67 and ε_M equal to 0.84. Last but not least, the efficiency parameter ϕ in the human capital production function has been determined by a calibration procedure that we discuss now.

We determined eight parameters by calibration. Next to the efficiency parameter in human capital production (ϕ), these are the exogenous technology growth rate (x), two share parameters in aggregate effective labor (η_M and η_L, where η_H follows as $1-\eta_L-\eta_M$), three taste for leisure parameters $(\gamma_1, \gamma_2, \gamma_3)$ and the elasticity of substitution (ζ) in the composite leisure function in Equation (4). The calibration target values are reported at the bottom of Table 2. Six of them concern Belgium: three employment rates, the effective retirement age, aggregate participation in tertiary education, and per capita growth. Our main reason for choosing Belgium is that it is a very small open economy and therefore matches key assumptions of our model[5]. The other two target values are the relative wages of young workers with below upper secondary education or with upper secondary education in the US compared to workers with tertiary education. 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.

[3] Imposing higher values for σ would only reinforce our main conclusions in this paper.

[4] The data that we report are averages of the PISA results for the years 2000, 2003 and 2006. Ideally, for our parameterization, we dispose of PISA test scores for students aged 19. The available data concern students aged 15.

[5] Moreover, in Belgium public pension benefits are calculated exactly as we model them. Public pensions are proportional to average annual labor income earned over a period of 45 years, with equal weight for all years. In our model this comes down to $\rho_{wa} > 0$, with $p_1 = p_2 = p_3 = 1/3$. Only individuals with labor income below about 75% of the mean receive an additional social assistance benefit, which in our model can be expressed as a 'basic pension' for the low ability individuals. So, $\rho_{fL} > 0$, while $\rho_{fM} = \rho_{fH} = 0$.

Table 2. Parameterization and benchmark equilibrium

Technology and preference parameters	
Goods production (output)	$\alpha = 0.30, s = 1.5, \eta_H = 0.48, \eta_M = 0.33, \eta_L = 0.19$
Exogenous technology growth	$x = 0.301$
Human capital	$\phi = 1.21, \sigma = 0.3$
Initial human capital	$\varepsilon_M = 0.84, \varepsilon_L = 0.67$
Preference parameters	$\beta = 0.80, \theta = 2, \gamma_1 = 0.074, \gamma_2 = 0.147, \gamma_3 = 0.258$
	$\mu = 0.5,\ \zeta = 1.54, \Gamma = 2$
World real interest rate	$r = 0.935$
Capital depreciation rate	$\delta_k = 0.714$

Fiscal policy and pensions policy parameters [(a)]

$\tau_w = 67.2\%,\ \tau_c = 13.4\%,\ \tau_k = 27.1\%,\ b = 59.6\%,\ b_{er} = 79.0\%,$
$\rho_{wL} = 55.4\%,\ \rho_{wM} = 63.1\%,\ \rho_{wH} = 42.7\%,\ \rho_{fL} = 17.2\%,\ \rho_{fM} = \rho_{fH} = 0\%$

Target values for calibration

Employment, education and growth [(b)]

n_1	n_2	n_3	R	e	*Annual per capita growth*
51.1%	56.8%	29.3%	57.9	14.1%	1.77%

Relative wages of young workers, US [(c)]

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

Notes: (a) Values for Belgium. For a detailed description of these policy parameters, see Section 4 in this paper;
(b) Values for Belgium, see Table 1 and Appendix A.
(c) 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 (with secondary education) in the US relative to earnings of workers with a tertiary degree. The data concern 2007. Data source: OECD Education at a Glance, 2009, Table A7.1a.

Certain parameters are clearly more than others linked to certain target values. The calibrated growth rate of technology (x) reflects total per capita output growth over a period of 15 years, annual growth in Belgium being 1.77%. The leisure parameters, including the elasticity of substitution in the composite leisure function (4), are basically determined so that with observed levels of the policy variables (tax rates, non-employment benefit replacement rates, pension replacement rates, etc.) in Belgium, the model correctly predicts Belgium's employment rates by age (n_1, n_2, n_3) and effective early retirement age (R). By the same approach the efficiency parameter in human capital production (ϕ) is mainly determined to correctly predict participation in education (e). We find that the taste for leisure rises with age ($\gamma_1 = 0.074, \gamma_2 = 0.147, \gamma_3 = 0.258$) and observe a stronger degree of substitutability than in the Cobb-Douglas case between the two types of leisure for older workers ($\zeta = 1.54$). The efficiency parameter ϕ turns out to be 1.21. Finally, 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.

They are determined so that with observed levels of the policy variables in the US, and given the whole set of other parameters, the model correctly predicts these relative wages. As shown by Equation (25), the share parameters are important determinants of the relative productivity of labor. 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 than in Europe, which explains the introduction here of US relative wages rather than Belgian ones. We provide more detail on our calibration procedure to obtain η_L and η_M in Appendix B. The results imply $\eta_L = 0.19, \eta_M = 0.33$ and $\eta_H = 0.48$.

Finally, we had no 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 normalization parameter Γ equals 2. The size of this parameter has no impact at all on our results.

4. Fiscal policy and pensions in 13 OECD countries

Tables 3 and 4 describe key characteristics of fiscal policy in 13 OECD countries in 1995-2001/2004. For details on the sources and construction of the data, we refer to Appendix A. Our proxy for the tax rate on labor income τ_w 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. Belgium, Germany, Italy, Sweden and Finland have marginal labor tax rates above 55% or even 60%. The US have marginal labor tax rates below 40%. Capital tax rates are effective marginal corporate tax rates reported by the Institute for Fiscal Studies (their EMTR, base case). Germany and Belgium have the highest rates. In contrast to labor (and consumption), capital is taxed relatively little in the Nordic countries. As to consumption taxes, we follow Dhont and Heylen (2009) in computing them as the ratio of government indirect tax receipts (net of subsidies paid) to total domestic demand net of indirect taxes and subsidies. Our assumption is that consumption tax rates correspond to aggregate indirect tax rates. 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.

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. 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. The data are expressed in percent of after-tax wages. In line with our approach to determine labor tax rates, we again compute the average of data reported by the OECD for a wide range of family and income cases to determine b (see Appendix A). Overall, the euro area countries and the Nordic countries pay the highest net benefits on average. Transfers to structurally non-employed people are by far the lowest in the US. A related variable is our proxy for the net early retirement benefit replacement rate b_{er}. The data are

Table 3 Fiscal policy: Tax rates and government debt

	tax rate on labor income (in %)	consumption tax rate (%)	tax rate on capital income (%)	Public debt (% of GDP)
Proxy for :	τ_w	τ_c	τ_k	D/Y
Austria	54.9	13.2	17.3	69.6
Belgium	67.2	13.4	27.1	111.7
France	52.9	17.1	21.7	68.9
Germany	60.4	11.1	34.4	63.1
Italy	55.2	14.7	14.9	122.1
Netherlands	52.0	12.2	24.3	68.2
Denmark	48.6	18.9	22.5	60.3
Finland	56.2	15.2	17.2	54.1
Norway	50.8	16.4	22.1	40.4
Sweden	56.0	17.9	16.1	67.2
UK	44.9	14.5	21.2	46.6
US	37.4	7.2	23.6	61.9
Canada	46.4	14.5	24.8	83.8
Overall average	52.5	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, see Appendix A. 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 Fiscal policy: net benefit replacement rates

	Non-employment benefit (net replacement rate, %)	Early retirement benefit (net replacement rate, %)
Proxy for :	b	b_{er}
Austria	56.3	71.6
Belgium	59.6	79.0
France	46.0	63.8
Germany	64.7	70.8
Italy	17.0	55.7
Netherlands	55.0	68.1
Denmark	61.9	43.2
Finland	61.3	73.8
Norway	56.9	39.9
Sweden	55.4	39.0
UK	51.1	39.4
US	30.5	18.3
Canada	44.4	27.0
Overall average	50.8	53.0

Notes: A description of both variables is given in the main text. For more details, see Appendix A. The data are an average for 2001-2004 (earlier data are not available).

again expressed in percent of after-tax final wages. To assess the generosity of early retirement we integrate the information available via b 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 A. We observe a very generous early retirement regime in Belgium and Finland, whereas net early retirement benefits in Anglo-Saxon countries are much lower.

Government spending on goods is the residual category in Equation (26). Its value is endogenously determined to satisfy the government budget constraint. The values that we obtain are in general very close to actual values of the sum of government consumption and productive government spending for 2001-04 as reported in Heylen and Van de Kerckhove (2013, their Table 4). For example, for the US we obtain an endogenous G equal to 19.1% of GDP, while Heylen and Van de Kerckhove report 19.5%. For the core euro area average the numbers are 26.8% and 24.9% respectively.

Table 5 contains our data for the pension policy parameters ρ_{wa} and ρ_{fa}, and shows how they may be different for people with low, medium and high earnings potential. The data have been taken or computed from OECD (2005). They include only (quasi-)mandatory pension programs. In line with our specification in Equation (10), ρ_{wa} is expressed as a percentage of an individual's average lifetime net labor income, while ρ_{fa} is expressed as a percentage of average economy-wide net labor

Table 5. Net pension replacement rates

	Net earnings-related pension replacement rate (% of average earned net labor income)			Net basic pension replacement rate (% of economy-wide average net labor income)		
Proxy for:	Low ρ_{wL}	Medium ρ_{wM}	High ρ_{wH}	Low ρ_{fL}	Medium ρ_{fM}	High ρ_{fH}
Austria	88.7	88.9	75.9	0.0	0.0	0.0
Belgium	55.4	63.1	42.7	17.2	0.0	0.0
France	62.9	68.8	59.2	23.2	0.0	0.0
Germany	60.4	71.8	67.0	0.8	0.0	0.0
Italy	89.3	88.8	89.1	0.0	0.0	0.0
Netherlands	0.0	42.1	62.9	46.4	42.1	36.2
Denmark	15.3	11.0	10.0	43.6	43.1	42.2
Finland	82.3	78.8	78.3	4.9	0.0	0.0
Norway	36.4	43.0	38.4	26.4	22.1	20.3
Sweden	64.6	65.9	74.3	13.6	2.3	0.0
UK	0.0	5.0	8.0	43.6	42.6	41.2
US	61.4	51.0	39.0	0.0	0.0	0.0
Canada	31.6	33.9	18.1	31.5	23.2	23.3
Overall average	49.9	54.8	51.0	19.3	13.0	12.6

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 A.

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. In the majority of countries individuals with mean or higher earnings only receive earnings-related pensions ($\rho_{wa} > 0, \rho_{fa} = 0$ for $a = M, H$). Among these countries, Austria and Italy pay the highest net replacement rates (ρ_{wM}>85%), Belgium and the US the lowest (ρ_{wM}< 65%). 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.

5. Our model's predictions and the facts in 13 OECD countries

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 employment or education. 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 10 to 15 years before the financial crisis. 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 performance 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 for example 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 simulations 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 and participation in education 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 and the pension replacement rates 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 most facts remarkably well for a large majority of countries. Only when it comes to the relative employment rate of low educated workers, the assumption of perfect competition may come at a cost. Another (minor) point is that our simplification of the human capital production function reduces the explanatory power of the model for education in the Nordic countries. We discuss both issues below.

To solve our model and to perform our simulations, we choose an algorithm that preserves the non-linear nature of the model. We follow the methodology basically proposed by Boucekkine (1995) and implemented by Juillard (1996) in the program Dynare. We use Dynare 4.4. 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. Government spending G adjusts endogenously in Equation (26) 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). Figure 5 compares predictions and facts for the effective retirement age. All in all, our model performs quite well. In each age group, it correctly predicts relatively high employment rates in the US and Canada and relatively low employment in Germany and the Netherlands. For young workers it also correctly predicts relatively low employment in the Nordic countries. For older workers it has relatively high employment right in Sweden, Norway and the UK. Overall correlation between the model's predictions and the actual data varies between 0.29 in Figure 2, 0.61 in Figure 4 and even 0.92 in Figure 5. We call these results quite good, all the more so since there are good reasons for the main deviations between predictions and facts. One of these deviations concerns Italy for employment. A major element behind the deviation for this country seems to be underestimation of the fallback income position for structurally non-employed workers, especially 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 when family support as an alternative to unemployment benefits is taken into account.[6] A second large deviation can be observed for Denmark and Finland in Figure 3 and – to a lesser extent – Figure 4. The main explanation here is related to our model's substantial underestimation of participation in tertiary education in these two countries. As we explain when we discuss Figure 7, again there are good reasons. The point here is that underestimating education among young people, the model will also underestimate the return to work when individuals are at middle age and older. It then comes as no surprise to see low predictions for n_2 and n_3 in these two countries[7].

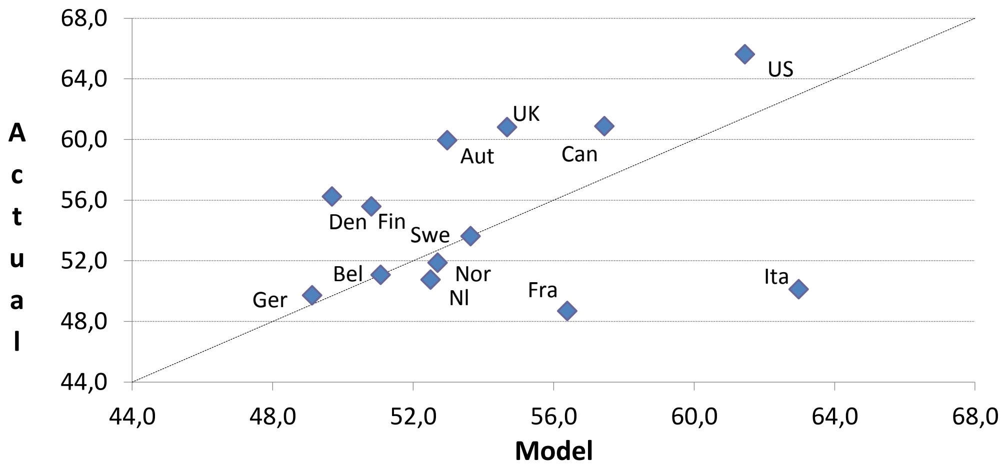
Figure 6 compares our model's predictions with the facts for the relative employment rate of low educated versus high educated individuals[8]. A first observation is that our model tends to overpredict relative employment among low educated individuals. Except for the Netherlands, all observations in Figure 6 are situated to the right of the 45°-line. The main explanation for this result is probably our assumption of perfect competition. In a recent paper, Boone and Heylen (2015) get a

[6] Fernández Cordón (2001) shows that in Italy young people live much longer with their parents than in other countries.

[7] Over all 13 countries the correlation between our model's prediction errors for e and n_2 (n_3) is 0.54 (0.68).

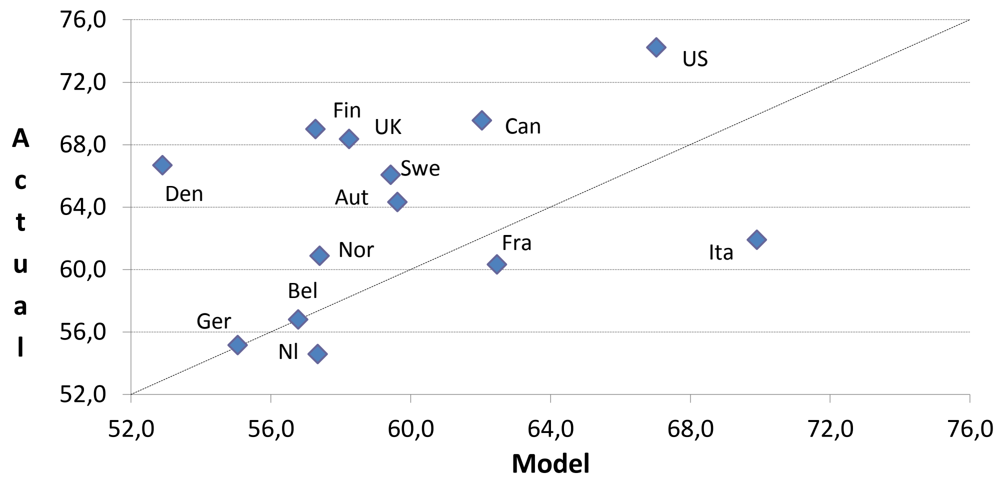
[8] We use the average of our model's relative employment predictions for the middle aged and the older groups. These two age groups have finished their education. We obtain quasi the same results when we use only our model's predictions for relative employment in the group of middle aged.

Figure 2. Employment rate in hours of young individuals in 13 countries, in %, 1995-2007



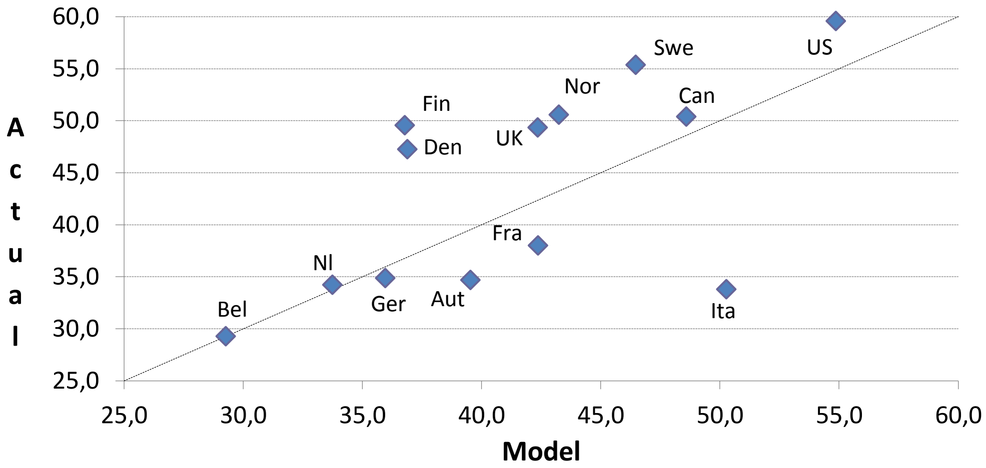
Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.29. Excluding Italy correlation rises to 0.60.

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



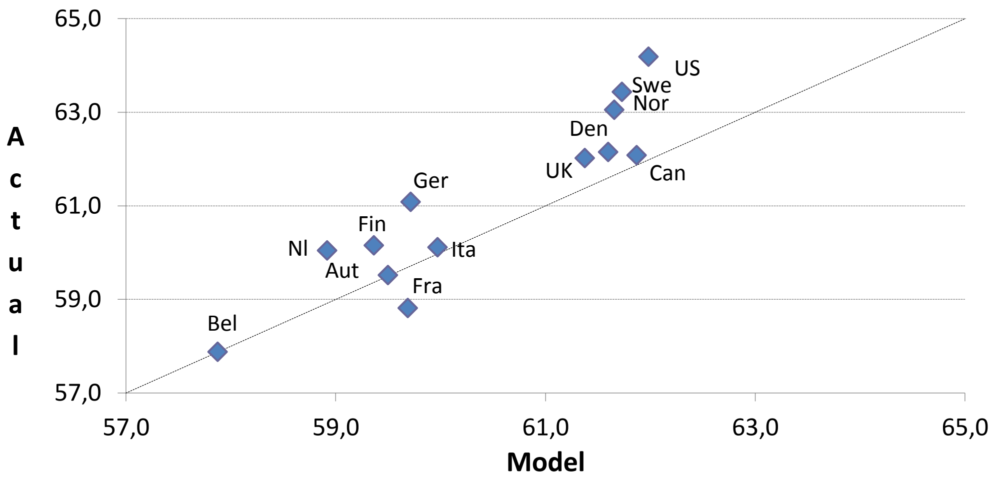
Note: Correlation between actual data and the model's predictions is 0.32. Excluding Italy correlation is 0.51.

Figure 4. Employment rate in hours of older individuals in 13 countries, in %, 1995-2007



Note: Correlation between actual data and the model's predictions is 0.61. Excluding Italy correlation is 0.81.

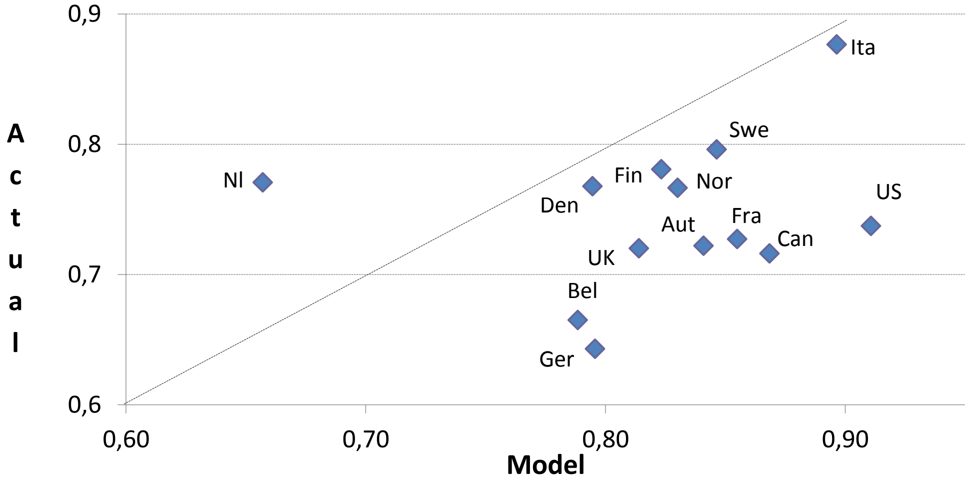
Figure 5. Effective retirement age in 13 countries, in %, 1995-2006



Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.92.

much better fit when they introduce union wage setting for low educated workers. By contrast, the assumption of perfect competition does not seem to affect the explanatory power of the model for employment among high educated workers. A second observation is that – again disregarding the Netherlands – our model seems to capture quite well the main drivers of cross-country differences in relative employment among the low educated. Without the Netherlands, correlation in Figure 6 is 0.51. The model also performs fairly well in its assessment of the size of the relative employment effects of cross-country policy differences. Without the Netherlands, the slope of the regression line in Figure 6 (not shown) would be 0.8. If we then turn to individual countries, our model seems to miss not only the Netherlands, but also the US. For the Netherlands the model seriously underestimates employment among low educated workers. The main reason is related to the pension system, more precisely the dominance of basic pension components for low-wage earners in the Netherlands (see Table 5). Absence of an own-income related component brings strong incentives against labor supply for low ability workers in our model. As to the US, our model is not the only one that overestimates the employment rate among low ability Americans. A large literature has tried to explain this (see for example The Economist, 2011).

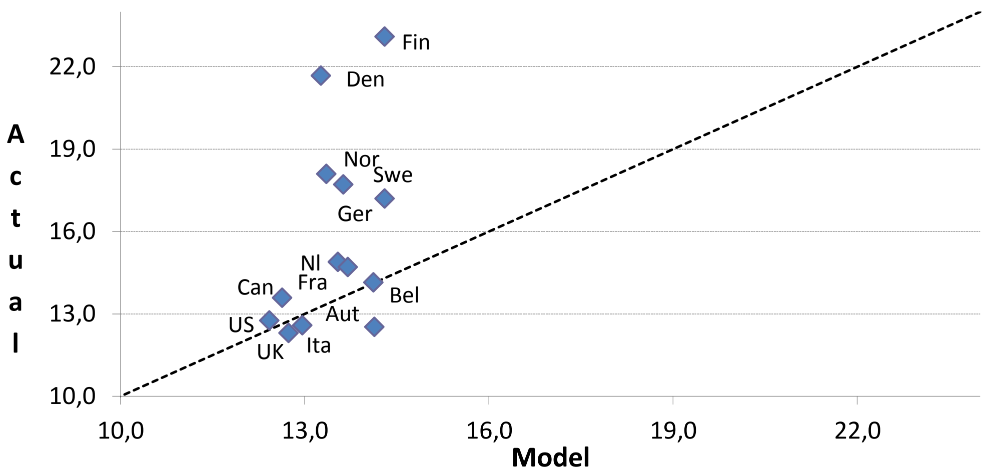
Figure 6. Relative employment rate among low versus high educated individuals (n_L/n_H) in 13 OECD countries.



Note: Correlation between actual data and the model's predictions is 0.20. Excluding the Netherlands, it rises to 0.51. Excluding both Italy and the Netherlands it is 0.30.

Finally, in Figure 7 we relate our model's predictions to the facts for education. While the model predicts the facts quite well in the core euro area and the Anglo-Saxon countries, it has major difficulty explaining high participation in tertiary education in the Nordic countries, especially Finland and Denmark. A comparison with results reported by Heylen and Van de Kerckhove (2013) reveals the main reason for this: our specification of the human capital production in this paper. In addition to individual time in education, Heylen and Van de Kerckhove also take into account government education spending (a fixed fraction of output) and the quality of education (proxied by country-specific PISA scores) as factors in the human capital production function. Moreover, they specify a more flexible CES function for human capital production. Their model predicts much higher participation rates of around 20% on average in the Nordic countries (see their Figure 6). We have deliberately chosen a simple human capital function. Moreover, we have adopted a conservative value for the elasticity of human capital with respect to education time (σ). The reason for these choices was to exclude that our main findings in the next two sections might be due to an overestimation of the returns to education. Given the lack of hard empirical evidence and no consensus about the determinants of human capital, nor about the underlying functional form and parameter values, caution was appropriate. Narrow cross-country variation in our model's predictions for *e* is therefore an expected result.

Figure 7. Participation rate in tertiary education in 13 countries, in %, 1995-2006



Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.42.

6. Numerical steady state and welfare effects of fiscal policy shocks

Having established the empirical relevance of our model, we now simulate a series of fiscal policy shocks. Our aim is to discover the (relative) effectiveness of changes in specific policy variables for the employment rate in three age groups, the employment rate in three ability groups, aggregate employment, older workers' retirement age, education of the young, and aggregate output (income). We report steady state effects. Furthermore, we pay particular attention to the welfare effects for current and future generations of individuals of high and low ability, and the evolution of welfare inequality.

Starting from budget balance, we impose permanent (and unanticipated) fiscal shocks equal to 2% of initial output. We consider reductions in the tax rates on labor and in the benefit replacement rates. The benchmark from which we start, and against which all policy shocks are evaluated, is the average of six core euro area countries as reported at the bottom of Table 6[9]. This table considers the steady state effects of policy changes assuming that these changes are compensated by a change in another fiscal variable. In six out of seven policies that we simulate, compensation is realized by adjusting the consumption tax rate.

Figure 8 shows the welfare effects of the policy measures described in Table 6 for the current and future generations of high and low ability individuals. Welfare effects for the individuals of

[9] The choice of 2% is arbitrary. Imposing smaller or larger shocks would not generate different results as far as the sign and the relative size of effects is concerned. Our main conclusions do not change either if we impose the same policy shocks on a different benchmark.

medium ability are in general close to those for the high ability group. We report on the vertical axis the welfare effect on individuals of the generation born *k* periods after the introduction of the policy reform, where *k* is indicated on the horizontal axis. So, the data at *k=0* for example concern the young in the period of the policy change. The data at *k=-3* concern the retirees in that period. Our welfare measure is the (constant) percentage change in benchmark consumption in each period of remaining life that individuals should get to attain the same lifetime utility as after the policy shock (see also King and Rebelo, 1990). 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 4% of their benchmark consumption. For the current older low ability individuals (k=-2) the gain is only equal to 1,5% of their benchmark consumption. In Table 7 we integrate the welfare effects induced by each policy reform into a single aggregate summary measure. For each individual we first compute the present discounted value of the total consumption change over life that is required in the benchmark to make him equally well off as under the policy reform. The basis of our computation is the data that we report in Figure 8. But now we also take into account differences in the length of remaining life. For young individuals the data in Figure 8 apply to four periods, whereas for retired individuals they only apply to one remaining period. Next, we impose that all those who lose under the new policy are compensated by the winners. Our summary measure is the present discounted value of the net aggregate consumption gain of all winners after having compensated the losers, in percent of initial GDP. The first row in Table 7 includes all current and four future generations of all three ability types into the computation. The second row includes only those generations that live at the moment the reform is introduced.

Our main findings are as follows:

(i) We confirm our earlier result in Heylen and Van de Kerckhove (2013) that the most effective policy to promote aggregate equilibrium employment should include an overall cut in non-employment benefits. In Table 6, policies 3 and 3B impose an overall reduction of the benefit replacement rate by almost 8 percentage points. In policy 3 this reduction (and the general equilibrium effects it induces) allow the government to cut the consumption tax rate by about 10 percentage points. In response to a strong increase in the relative marginal utility from work versus inactivity, all age and ability groups supply more labor. Aggregate hours worked would rise by more than 6%. So would output. Older and low ability individuals show the strongest reaction.

(ii) Overall labor tax cuts in policy 1 also bring about positive labor supply and employment effects among all age and ability groups, but these effects are in general only about half as large as those induced by policy 3. In Heylen and Van de Kerckhove (2013) we called it a much more effective strategy to target labor tax reductions at older workers. Our results in Table 6 for policy 2 fully confirm this. Policy 2 brings not only a stronger increase in aggregate hours worked than policy 1 (thanks to a strong rise in n_3 and R), it also promotes education by individuals of high and medium ability. The reason is that, by encouraging individuals to work longer (at lower tax

Table 6. Steady state effects of fiscal policy shocks (equal to 2% of output, ex ante) - Effects for a benchmark of 6 core euro area countries (Austria, Belgium, France, Germany, Italy, the Netherlands)

Change in policy variable	(1) $\Delta\tau_w$= -2.86 (for all j and a)	(2) $\Delta\tau_{w3}$= -9,33 (for all a)	(3) Δb= -7.95 (for all j and a)	(4) $\Delta\tau_{w,low}$= -13.0	(5) $\Delta\tau_{w3}$ = -7.52 $\Delta\tau_{w,low}$ = -2.5	(6) $\Delta\tau_{w1,low}$ = -21.2	(3b) Δb= -7.95 (for all j and a)
Compensating change[(e)]	$\Delta\tau_c$ = 1,44	$\Delta\tau_c$ = -1,01	$\Delta\tau_c$ = -10,42	$\Delta\tau_c$ = 4,23	$\Delta\tau_c$ = -0,72	$\Delta\tau_c$ = 6,68	$\Delta\tau_{w3}$ = -12.0 $\Delta\tau_{w,low}$ =-4.0
Effect [(a)]:							
Δn_1	1,08	-2,39	2,55	5,09	-0,54	7,65	0,44
Δn_2	1,08	-0,78	2,59	0,62	-0,39	-2,75	1,30
Δn_3	2,50	10,0	4,70	1,87	8,73	-4,27	9,22
ΔR [(c)]	0,36	1,23	0,57	0,32	1,10	-0,40	0,99
Δe	-0,15	1,60	-0,34	-2,29	0,66	-3,17	1,04
Δn [(a. b)]	1,49	1,80	3,19	2,50	2,21	0,34	3,30
Δ% total hours [(d)]	2,81	3,39	6,01	4,73	4,16	0,65	6,23
Δn_H	1,46	1,33	3,13	-0,01	1,20	-0,01	2,45
Δn_M	1,43	1,27	3,08	2,30	1,96	2,70	3,24
Δn_L	1,57	2,79	3,34	5,22	3,45	-1,66	4,22
Δ% per capita output [(d)]	2,90	6,24	6,05	0,55	5,55	-2,29	8,15

Notes: Initial steady state (benchmark): $n_1 = 55.1\%$, $n_2 = 61.3\%$, $n_3 = 39.9\%$, $R = 59.4$, e = 13.7%, $n = 53.0\%$, $n_H = 52.1\%$, $n_M = 52.2\%$, $n_L = 54.7\%$, $\tau_c = 13.6\%$, $\tau_w = 57.1\%$, $b = 49.8\%$.

(a) difference in percentage points between the new steady state and the benchmark, except for total hours worked, per capita output 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) difference in percent between new steady state and the benchmark.

(e) change in percentage points to keep the ratio of debt to GDP constant.

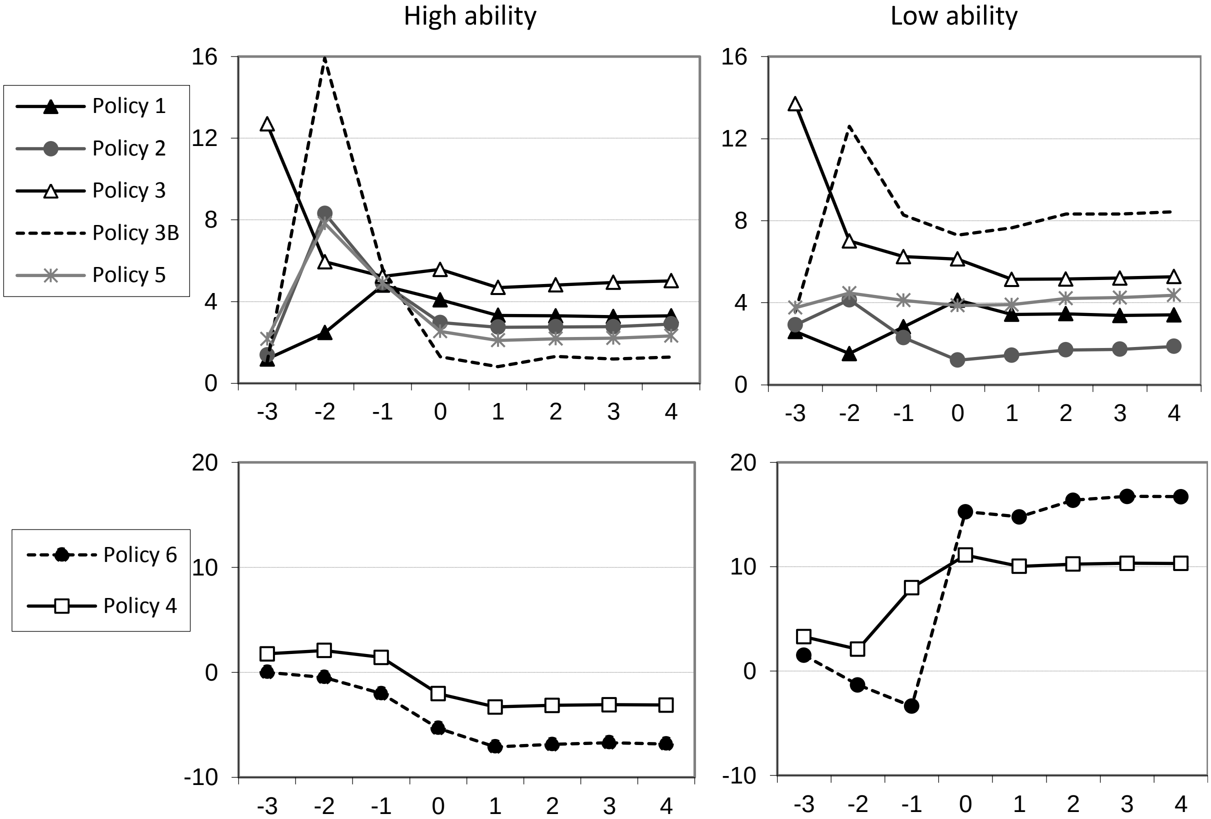
rates) during their third period of life, policy 2 also raises the marginal return to education. The growth in human capital induces higher productivity, which helps explaining why policy 2 brings the best output response of all policies in Table 6 that are compensated by an adjustment of the consumption tax.

(iii) From a welfare perspective policy 3 comes out better than policies 1 and 2, both for current and future generations, and for low and high ability individuals[10]. A critical comment that one can raise, though (at times of intergenerational tensions due to ageing and high public debt), is that policy 3 is far from neutral across generations. Those who are retired when policy 3 is introduced, experience by far the largest gain. They can consume much more thanks to the drop in consumption taxes, without having to work more. Current young and future generations

[10] The only exception is the group of older high ability workers who are slightly better off with policy 2.

experience the smallest gains. Comparing policies 1 and 2, the latter has better aggregate welfare implications (Table 6). A disadvantage of policy 2, however, is that it enlarges intragenerational welfare inequality. High and medium ability individuals will benefit from the incentives to build human capital and to raise future productivity and wages. Low ability individuals cannot. For them policy 2 is the least beneficial of all policies that we consider in Table 6.

Figure 8. Welfare effects of fiscal policy shocks on current and future high and low ability individuals



Note: The vertical axis indicates the welfare effect for the generation born in *t+k*, where *t* is when the fiscal policy change is introduced. The horizontal axis indicates *k.*

Table 7. Net welfare effect after compensating welfare transfers (expressed as % of initial GDP)

Included generations	Policy 1	Policy 2	Policy 3	Policy 4	Policy 5	Policy 6	Policy 3B
All current + 4 future	3,12	3,53	5,89	1,85	3,73	0,21	5,28
All current	2,11	2,74	4,41	1,21	2,82	-0,43	4,26

Note: for a description of the computation of these data, see main text.

Policies 4, 5, 6 and 3B explore four alternative strategies to combine increased efficiency with progress in equity. Ideally, the latter includes an increase in aggregate welfare and a reduction in welfare inequality both within generations and between generations. Policy 4 targets the whole labor tax cut at low-income earners. These are all the low ability individuals and the young individuals of medium ability[11]. According to policy 4, they enjoy a reduction of the tax rate by 13 percentage points. Policy 5 extends policy 2's labor tax cut for all older workers to all low-income earners. Policy 6 targets the whole labor tax reduction at young low-income earners. A reduction of the labor tax rate by about 21 percentage points would be possible. Finally, policy 3B repeats the overall non-employment benefit reduction of policy 3. It differs from 3, however, by redirecting the gains from this benefit reduction to labor tax cuts for all older and all low-income earners (in line with policy 5). Observing our results, we draw the following conclusions:

(iv) Policies 4 and 6 are the best when the objective is to promote the welfare of young and future generations of low ability individuals. They fail, however, in their political economy consequences. Both policies imply negative welfare effects for most high ability individuals. They will have no chance politically. Policy 6 may even get no support from older generations of low ability individuals. Policy 6 also fails in its effects on overall efficiency. In the new steady state aggregate output and income will be more than 2% lower than initial output. Moreover, aggregate employment hardly rises following policy 6. The drastic rise in the consumption tax rate to finance this policy affects everyone's marginal gain from work negatively. Even the low ability individuals will not work more over their life cycle. They will just shift labor from their middle aged and older period to youth.

The employment effects of policy 4, by contrast, are much better. Employment rises strongly among all low ability generations and among the young individuals of medium ability. Considering all policies financed by an adjustment of the consumption tax rate, only policy 3 has better employment effects than policy 4. In this respect, our results are fully in line with empirical studies showing that labor tax cuts targeted at low-wage earners are more effective than overall labor tax cuts (e.g. OECD, 2011). At the same time, encouraging young individuals of medium ability to work more also comes at a significant cost. These individuals will then substitute work for education, which undermines future human capital and wages.

(v) Spreading the labor tax cut on both older and low-income earners, makes policy 5 better than policy 2 in most respects. It brings larger aggregate welfare gains than policy 2. Moreover, being more beneficial to low ability individuals, policy 5 also reduces intragenerational welfare inequality. And it has better aggregate employment effects. Only participation in education and aggregate output and income would rise more under policy 2 than under policy 5. (Note though that, relative to all other policies in Table 6, policy 5 is still among the better ones for education and aggregate output).

(vi) Among all policies that we discussed above policy 3 came out as best for aggregate welfare and employment. All generations of all ability types would gain. A critical point, however, was that policy 3 would imply higher intergenerational welfare inequality. Furthermore, it would not bring the positive effects of policies 2 and 5 on the participation in education by individuals of high and medium ability. Policy 3B deals with all these points of criticism. Rather than

[11] Ideally, only individuals of low innate ability should enjoy this labor tax cut. However, since the government cannot observe ability, its best alternative is to target the tax cut at all low-income earners.

redirecting the financial gains from cutting non-employment benefits to a reduction of consumption taxes, this policy uses these gains to reduce taxes on labor for older and low-income individuals. It combines the strongest aggregate output (income) and employment gains with a reduction in intragenerational inequality. For individuals of low ability policy 3B is by far the best among all feasible policies (i.e. policies that do not reduce other people's welfare). Moreover, policy 3B also brings a more equal intergenerational distribution of welfare gains than policy 3. Gains are more or less the same for all generations of workers of the same innate ability. Only third generation (older) workers stand out to gain much more. They capture the full gain of the reduction in τ_{w3} and do no longer carry the cost of lower non-employment benefits at younger age.

Policy 3B may thus deal with most of the comments raised against policy 3. In the end it should be recognized though, that for aggregate welfare in Table 7 policy 3 still performs best. In what follows, we show that our assumption of exogenous growth plays a key role for this outcome.

7. The model with endogenous growth

In this section, we extend the model presented above with an endogenous growth mechanism driven by education. Empirical research has shown that education is indeed one of the most important determinants of economic growth in the long run (see e.g. Hanushek and Woessmann, 2012). More specifically, we introduce the assumption that education generates a positive externality in the sense of Azariadis and Drazen (1990). Each young generation inherits a fraction of the average level of human capital of the middle aged generation. The higher an individual's ability, the larger the fraction he inherits. Equation (28) reflects this assumption. It replaces Equation (11). As a complement, technology is from now on assumed constant, i.e. A does not grow anymore.

$$h_{1a}^{t} = \varepsilon_a \pi (h_{2H}^{t-1} + h_{2M}^{t-1} + h_{2L}^{t-1})/3 \qquad \forall\, a = H, M, L \tag{28}$$

$$0 < \pi,\ 0 < \varepsilon_L < \varepsilon_M < \varepsilon_H = 1 \tag{29}$$

The value of π is to be calibrated. In line with the procedure described in Section 3, we also calibrate it to Belgium. The key target value in the calibration process is average per capita economic growth. We obtain an inheritance parameter π equal to 0.87. Individuals with medium and lower ability inherit less ($\varepsilon_L < \varepsilon_M < 1$). The values for ε_L and ε_M are unchanged. So are the elasticity of human capital with respect to education time (σ), which we keep at 0.30, and most of the other calibrated parameters[12]. The model generates endogenous growth, with the growth rate rising in the fraction of time that young people (of high and medium ability) allocate to education (e), the human capital inheritance parameter (π) and the fractions ε_L and ε_M. More exactly, we derive in Appendix D that:

$$ln\left(\frac{Y_t}{Y_{t-1}}\right) = ln\left(\pi \frac{\left(1+\phi\left(e_{1H}^{t-1}\right)^{\sigma}\right)+\varepsilon_M\left(1+\phi\left(e_{1M}^{t-1}\right)^{\sigma}\right)+\varepsilon_L}{3}\right) \tag{30}$$

[12] Appendix C reports all calibrated parameters.

Does allowing for an endogenous growth mechanism affect the main conclusions that we have drawn in the previous section? Tables 8 and 9 and Figure 9 bring the answer. All in all, it will be clear that most of our results are robust to the assumptions made about human capital formation and growth. When it comes to choosing policy 3 or 3B, however, we now observe better welfare effects for 3B in Table 9 as soon as we include the welfare effects on future generations. The reason is obvious and related to the effects of each policy on human capital formation. If at least part of the increase in human capital and productivity is passed on the next generation, policies that promote human capital formation tend to have the best long-run effects. Future generations of low ability individuals will then also benefit from investment in human capital by today's high ability individuals. The main difference between policy 3 and policy 3B is situated exactly here (see Tables 6 and 8). The former has negative effects on human capital formation and growth. The latter promotes them.

Table 8. Steady state effects of fiscal policy shocks (equal to 2% of output, ex ante) when growth is endogenous - Effects for a benchmark of 6 core euro area countries

Change in policy variable	(1) $\Delta\tau_w$= -2.86 (for all j and a)	(2) $\Delta\tau_{w3}$= -9,33 (for all a)	(3) Δb= -7.95 (for all j and a)	(4) $\Delta\tau_{w,low}$= -13.0	(5) $\Delta\tau_{w3}$ = -7.52 $\Delta\tau_{w,low}$ = -2.5	(6) $\Delta\tau_{w1,low}$ = -21.2	(3B) Δb= -7.95 (for all j and a)
Compensating change[e]	$\Delta\tau_c$ = 1,72	$\Delta\tau_c$ = -0,23	$\Delta\tau_c$ = -9,52	$\Delta\tau_c$ = 3,32	$\Delta\tau_c$ = -0,18	$\Delta\tau_c$ = 5,54	$\Delta\tau_{w3}$ = -13.0 $\Delta\tau_{w,low}$ =-4.0
Effect [a]:							
Δn_1	1,06	-1,95	2,52	5,00	-0,22	7,40	0,77
Δn_2	1,07	-0,53	2,57	0,50	-0,22	-3,38	1,51
Δn_3	2,49	10,31	4,68	1,74	8,96	-5,23	9,91
ΔR [c]	0,36	1,26	0,57	0,31	1,12	-0,50	1,05
Δe	-0,14	1,36	-0,32	-2,29	0,48	-3,17	0,87
Δn [a. b]	1,48	2,13	3,16	2,39	2,44	-0,25	3,69
Δ% total hours [d]	2,79	4,02	5,98	4,52	4,61	-0,48	6,98
Δn_H	1,42	1,63	3,06	-0,09	1,43	-0,13	2,81
Δn_M	1,39	1,57	3,01	1,92	2,12	2,10	3,50
Δn_L	1,61	3,19	3,43	5,34	3,78	-2,73	4,77
Δ annual growth rate [a]	-0,01	0,08	-0,02	-0,16	0,03	-0,23	0,06

Notes: Initial steady state (benchmark): $n_1 = 55.1\%$, $n_2 = 61.2\%$, $n_3 = 39.9\%$, $R = 59.3$, e $= 13.8\%$, $n = 52.9\%$, $n_H = 52.7\%$, $n_M = 52.8\%$, $n_L = 53.3\%$, $\tau_c = 13.6\%$, $\tau_w = 57.1\%$, $b = 49.8\%$.

(a) difference in percentage points between the new steady state and the benchmark, except for total hours worked, per capita output 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) difference in percent between new steady state and the benchmark.

(e) change in percentage points to keep the ratio of debt to GDP constant.

Figure 9. Welfare effects of fiscal policy shocks on current and future high and low ability individuals

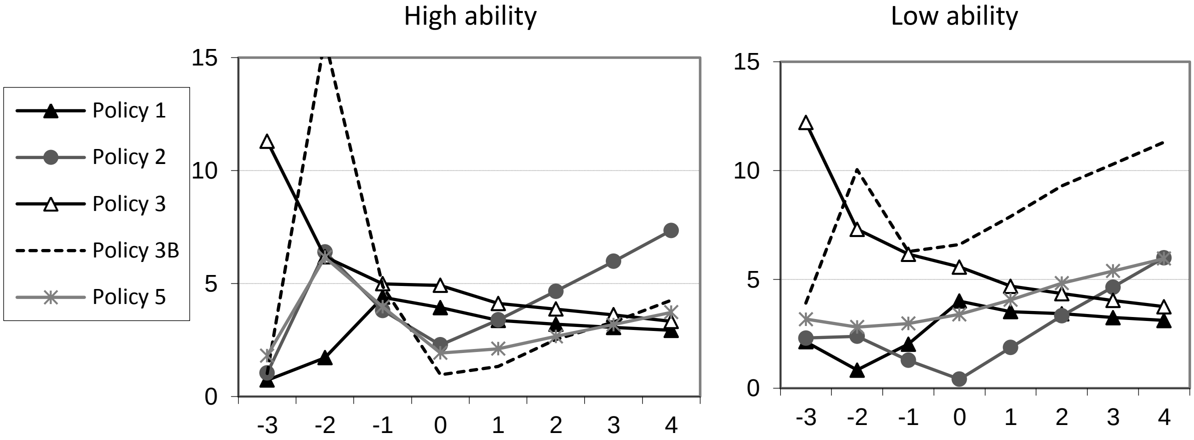


Table 9. Net welfare effect after compensating welfare transfers (expressed as % of initial GDP) when growth is endogenous

Included generations	Policy 1	Policy 2	Policy 3	Policy 4	Policy 5	Policy 6	Policy 3B
All current + 4 future	2,83	3,45	5,37	0,56	3,33	-1,43	5,42
All current	1,85	2,08	4,17	1,06	2,25	-0,42	3,98

Note: for a description of the computation of these data, see main text.

8. Conclusions

Rising pressure on the welfare state due to ageing forces all OECD countries to develop effective employment and growth policies. The need to raise employment is particularly pressing among older and lower ability workers. In more recent years, increasing sensitivity to the problem of inequality has made the challenge for policy makers only larger. Not only efficiency, but also equity and fairness demand attention.

In this paper we investigate the most effective composition of fiscal policy to face this whole challenge. We construct a general equilibrium model that explains hours of work of young, middle aged and older individuals, education of the young and human capital, and aggregate output (income) and welfare within one coherent framework. The government in the model sets tax rates on labor, capital and consumption. It spends its revenue mainly on goods, non-employment benefits and pensions. Moreover, to allow a realistic analysis of welfare and welfare inequality, not only across generations but also within generations, we introduce heterogeneity in individuals' ability to build human capital. Some individuals enter our model with high human capital, and have a high capacity to learn. Others enter with low human capital, and have very low learning ability.

We carefully calibrate our model and check its empirical reliability for 13 OECD countries before using it for policy simulations.

From these policy simulations we learn the following. First, we confirm our earlier result in Heylen and Van de Kerckhove (2013) that the most effective policy to promote aggregate equilibrium employment should include an overall reduction in non-employment benefits. Second, overall labor tax cuts also bring about sizeable positive labor supply and employment effects among all age and all ability groups, but these effects are (much) smaller than those induced by reducing non-employment benefits. A much more effective tax strategy is to target labor tax reductions at older workers. This also confirms our earlier result. The reason is that, by encouraging individuals to work longer (at lower tax rates) during their third period of life, this also raises the return to education when young. Growth in human capital then induces higher productivity, income and welfare. Third, however, a first new result in this paper is that policies that include non-employment benefit reductions and labor tax cuts on older workers – next to an improvement of aggregate efficiency and welfare – also imply clearly differential welfare effects between the ability groups. Current and future low ability individuals will experience relative welfare losses. Welfare inequality rises. Fourth, higher aggregate efficiency, employment and welfare, as well as a reduction of intragenerational and intergenerational welfare inequality, are possible if one complements policies that cut labor taxes on older workers with labor tax cuts on all the low-wage earners. The best effects on employment follow if this combined tax cut is financed by overall non-employment benefit cuts. Alternative policies to promote the relative welfare of low ability individuals, like labor tax cuts targeted only at the low-wage earners, or targeted only at the young low-wage earners, are clearly inferior. We derived these results in a setting with exogenous growth. If we alternatively model growth to be endogenous via an intergenerational transfer of human capital, this only reinforces our conclusions.

A key policy implication of our results for many European countries would be to cut non-employment benefits, and to reallocate these resources to tax cuts on older workers and tax cuts on the low-wage earners. For a proper interpretation it is important to emphasize, though, that our model abstracts from demand side effects and the business cycle. Our results are to be seen as long-run effects for economies at potential output.

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Appendix A: 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 and total population by 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'.
For those countries where data for specific years are missing, we computed period averages 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 effective age of retirement.

***Annual real potential per capita GDP growth rate** (aggregate, 1995-2007)*
Definition: Average 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_w)*
Definition: Total tax wedge, marginal tax rate in % of gross wage earnings. The data cover personal income taxes and social security contributions paid by employees on their wage earnings as well as social security contributions and payroll taxes paid by employers.
Data source: OECD, Statistical Compendium, Financial and Fiscal Affairs, Taxing Wages, Comparative tax rates and benefits (new definition).
The OECD publishes marginal labor tax rates for several family and income situations: single persons at 67%, 100% and 167% of average earnings (no children), single persons at 67% of average earnings (two children), one-earner married couples at 100% of average earnings (two children), two-earner married couples, one at 100% of average earnings and the other at 33 % (no children, 2 children), two-earner married couples, one at 100% of average earnings and the other at 67 % (2 children). Our data in Table 3 are the averages of these eight cases. Data for 2000-04.

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

***Net benefit replacement rate when young, middle aged and older before early retirement** (b)*

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[13]. The data are expressed in % of after-tax wages. The OECD provides net replacement rates for six family situations and three earnings levels. Our data in Table 4 are the averages of these 18 cases. Data 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.

***Net early retirement replacement rates** (b_{er})*

To calculate our proxy for b_{er} 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_{er}. 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_{er}) will be a weighted average of r_{er} and b, where we take the latter as a proxy for the replacement rate in alternative social transfer programs. If $r_{er} > b$, older workers will aim for the official early retirement route, but they may not all meet eligibility criteria and have to fall back on

[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).

alternative programs. If $r_{er} < b$, workers will aim for the alternative, but again they may not be eligible. We propose that $b_{er} = \xi b + (1-\xi)r_{er}$. Underlying the data in Table 4 is the assumption that ξ=0.5. Correlation between b_{er} and r_{er} lies around 0.92. 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 (ρ_{wa} and ρ_{fa} 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 ρ_{wa} includes all earnings-related pensions and mandatory occupational pensions when they depend on wages or hours worked. Note that the precise organization of the earnings-related system may differ across countries. 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. Our proxy for ρ_{fa} 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 ρ_{fa} is a percentage of the average net wage in the economy (Equation 10), 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 ρ_{fa}. This ratio can be derived from the 'pension modelling' tables in the individual country studies, at various multiples of average earnings.

As a final remark, we bring to the attention 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 also make this assumption for all individual countries when we derive our model's predictions in Section 5. Equal weights do not fully match practice in all countries, however. Some deviate from this prototype, to varying degrees[14]. When we compare our model's predictions for these countries to the facts, we should take this into account. Assuming equal weights may slightly bias our predictions.

[14] 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.

Appendix B: Details on the calibration procedure to determine $\boldsymbol{\eta_a}$ (with $\boldsymbol{a = L, M, H}$)

Given the data for US relative wages in Table 2, 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 (25) that $\frac{w_{L,t}}{w_{H,t}} = \frac{\eta_L}{\eta_H}\left(\frac{H_{H,t}}{H_{L,t}}\right)^{\frac{1}{S}}$, which implies for the US:

$$\frac{\eta_L}{\eta_H}\left(\frac{H_{H,t}}{H_{L,t}}\right)^{\frac{1}{S}} = \frac{0.43}{\varepsilon_L} = \frac{0.43}{0.67} = 0.64.$$

Similarly, it is easy to obtain for the medium ability group: $\frac{\eta_M}{\eta_H}\left(\frac{H_{H,t}}{H_{M,t}}\right)^{\frac{1}{S}} = \frac{0.63}{\varepsilon_M} = \frac{0.63}{0.84} = 0.75.$

If we finally take into account that $\eta_H = 1 - \eta_M - \eta_L$, 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, education rates, σ and ϕ, it is easy to see that we have three remaining equations in three unknowns (η_H, η_M, η_L) that can be solved.

Appendix C: Model with endogenous growth: parameterization.

Technology and preference parameters	
Goods production (output)	$\alpha = 0.30, s = 1.5, \eta_H = 0.49, \eta_M = 0.33, \eta_L = 0.18$
Human capital	$\phi = 1.72, \sigma = 0.3$
Initial human capital	$\pi = 0.87, \varepsilon_M = 0.84, \varepsilon_L = 0.67$
Preference parameters	$\beta = 0.80, \theta = 2, \gamma_1 = 0.085, \gamma_2 = 0.145, \gamma_3 = 0.196$
	$\mu = 0.5,\ \zeta = 1.54, \Gamma = 2$
World real interest rate	$r = 0.935$
Capital depreciation rate	$\delta_k = 0.714$

Fiscal policy and pensions policy parameters [(a)]

$\tau_w = 67.2\%,\ \tau_c = 13.4\%,\ \tau_k = 27.1\%,\ b = 59.6\%,\ b_{er} = 79.0\%,$
$\rho_{wL} = 55.4\%,\ \rho_{wM} = 63.1\%,\ \rho_{wH} = 42.7\%,\ \rho_{fL} = 17.2\%,\ \rho_{fM} = \rho_{fH} = 0\%$

Target values for calibration

Employment, education and growth [(b)]

n_1	n_2	n_3	R	e	*Annual per capita growth*
51.1%	56.8%	29.3%	57.9	14.1%	1.77%

Relative wages of young workers, US [(c)]

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

Notes: See Table 2.

Appendix D: Derivation of Equation (30)

Starting point to derive our equation for the endogenous economic growth rate are Equations (18) and (19), where we now assume A to be constant.

Effective labor per ability group now becomes:

$$H_{a,t} = n_{1a}^{t} h_{1a}^{t} + n_{2a}^{t-1} h_{2a}^{t-1} + n_{3a}^{t-2} h_{3a}^{t-2}$$
$$= \left(n_{1a}^{t} + n_{2a}^{t-1} \frac{\psi_a^{t-1}}{x_{t-1}} + n_{3a}^{t-2} \frac{\psi_a^{t-2}}{x_{t-1} x_{t-2}} \right) h_{1a}^{t} \qquad \forall a = H, M, L \tag{31}$$

To obtain (31) we again define:

$$1 + \phi (e_{1a}^{t})^{\sigma} \equiv \psi_a^{t} \text{, with } \psi_L^{t} = 1 \tag{21}$$

so that $h_{3a}^{t-j} = h_{2a}^{t-j} = \psi_a^{t-j} h_{1a}^{t-j} \qquad \forall a = H, M, L.$

Furthermore, assuming an intergenerational transfer of human capital according to Equation (28), we no longer use (22), but[15] :

$$h_{1a}^{t} = x_{t-1} h_{1a}^{t-1} = x_{t-1} x_{t-2} h_{1a}^{t-2}, \tag{32}$$

where by definition: $x_t \equiv \pi \left(\frac{\psi_H^{t} + \varepsilon_M \psi_M^{t} + \varepsilon_L}{3} \right)$.

Substituting Equation (31) for $a = H, M$ and L into (19), and recognizing differences in the capacity ε_a to inherit human capital as indicated by Equation (29), yields Equation (33).

$$H_t = \left[\sum_{a=H,M,L} \eta_a \varepsilon_a^{1-\frac{1}{s}} \left(n_{1a}^{t} + n_{2a}^{t-1} \frac{\psi_a^{t-1}}{x_{t-1}} + n_{3a}^{t-2} \frac{\psi_a^{t-2}}{x_{t-1} x_{t-2}} \right)^{1-\frac{1}{s}} \right]^{\frac{s}{s-1}} h_{1H}^{t} \tag{33}$$

Substituting (33) for H_t and (24) for K_t / AH_t, we can rewrite (18) as

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

If we finally recognize that in steady state $r, \tau_k, \psi_a, e_{1a}$ and n_{ja} are constant, we obtain the long-run (per capita) growth rate of the economy as

$$ln\left(\frac{Y_t}{Y_{t-1}}\right) = ln\left(\frac{h_{1H}^{t}}{h_{1H}^{t-1}}\right) = ln(x_{t-1}) = ln\left(\pi \frac{\left(1+\phi\left(e_{1H}^{t-1}\right)^{\sigma}\right) + \varepsilon_M \left(1+\phi\left(e_{1M}^{t-1}\right)^{\sigma}\right) + \varepsilon_L}{3}\right)$$

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[15] Starting from Equation (28), and using (21) and (29), it is easy to see that:

$$h_{1H}^{t} = \pi \frac{h_{2H}^{t-1} + h_{2M}^{t-1} + h_{2L}^{t-1}}{3} = \pi \frac{\psi_H^{t-1} h_{1H}^{t-1} + \psi_M^{t-1} h_{1M}^{t-1} + h_{1L}^{t-1}}{3} = \pi \frac{(\psi_H^{t-1} + \varepsilon_M \psi_M^{t-1} + \varepsilon_L)}{3} h_{1H}^{t-1} = x_{t-1} h_{1H}^{t-1}.$$

Human capital of the lower ability individuals ($a = M, L$) will grow at the same rate $\frac{h_{1a}^{t}}{h_{1a}^{t-1}} = \frac{\varepsilon_a h_{1H}^{t}}{\varepsilon_a h_{1H}^{t-1}} = \frac{h_{1H}^{t}}{h_{1H}^{t-1}}$ which explains the first part of Equation (32). Lagging this result by one period generates the second part.