



# **PUBLIC POLICY, EMPLOYMENT AND GROWTH IN OPEN ECONOMIES**

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# **Public policy, employment and growth in open economies**

by

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**DOCTORAL JURY**

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## **Nederlandstalige samenvatting**

Door de veroudering van de bevolking komt ons sociaal-zekerheidsstelsel en pensioensysteem onder druk te staan. De recente financiële en economische crisis hebben geleid tot lagere of stagnerende groei en tot het verlies van veel banen. De nood aan effectieve overheidsmaatregelen die werkgelegenheid en groei stimuleren is groot. Nochtans hoeft dit geen onmogelijke opdracht te zijn. We constateren dat er grote verschillen bestaan in werkgelegenheid en groei tussen Angelsaksische landen, West-Europese landen en Scandinavische landen, waaruit we kunnen leren. De verschillen zijn bijzonder groot voor de werkgelegenheid onder oudere werknemers. Er zijn recent heel wat studies gedaan naar de oorzaken van deze verschillen. Empirisch onderzoek bevestigt de rol van het begrotingsbeleid op werkgelegenheid en groei, m.a.w. de hoogte en structuur van belastingen en overheidsuitgaven spelen een grote rol. Andere studies beklemtonen de rol van onderwijs voor groei.

## **Algemene situering en bijdragen**

In een eerste studie van dit proefschrift (hoofdstuk 2) construeren we een theoretisch model waarmee we de effecten onderzoeken van overheidsbeleid – in de eerste plaats fiscaliteit en overheidsuitgaven – op de economische groei, de scholingsinspanning (tertiaire studie) van jongeren en de werkgelegenheid van drie leeftijdsgroepen (jongere werknemers, werknemers op middelbare leeftijd, en oudere werknemers).

We dragen hiermee bij tot de literatuur op drie manieren. Vooreerst zien we dat in de meeste theoretische modellen slechts één aspect van macro-economische prestaties aan bod komt: ofwel ligt de focus op werkgelegenheid ofwel ligt hij op groei. Er zijn weinig modellen die beide variabelen in rekening brengen, zodat de verbanden en onderlinge interactie tussen deze variabelen bij het onderzoek van de effecten van overheidsmaatregelen verloren gaan. Een tweede opmerking is dat men in de literatuur weinig studies vindt die rekening houden met de verschillen in werkgelegenheid tussen leeftijdsgroepen. Over het algemeen gaat het over één werkgelegenheidscijfer voor de gehele bevolking op actieve leeftijd. In de realiteit is het duidelijk dat mensen van middelbare leeftijd meer werken dan jongeren, die nog een deel van hun tijd besteden aan studeren, en ouderen. Ten derde is de modellering van het begrotingsbeleid in de meeste studies beperkt. Een rijke specificatie waarbij diverse categorieën belastingen (op arbeid, consumptie en kapitaal) en diverse categorieën overheidsuitgaven (productieve uitgaven, transfers aan wie niet werkt, pensioenen, en dergelijke) worden onderscheiden, en in hun effecten worden vergeleken, ontbreekt doorgaans.

Ons model in hoofdstuk 2 houdt rekening met deze tekortkomingen. In dit onderzoek wordt scholing, in het bijzonder hoger onderwijs, als een belangrijke determinant voor economische groei beschouwd. De assumptie is dat iedereen bekwaam en gemotiveerd is om met succes hogere studies te volgen. In de werkelijkheid is dit duidelijk niet zo. In het volgend hoofdstuk maken we het model nog meer waarheidsgetrouw door niet langer te veronderstellen dat alle individuen dezelfde studievaardigheden hebben. Mensen verschillen in hun bekwaamheid om bestaande kennis te

absorberen en nieuwe kennis op te bouwen. In hoofdstuk 3 houden we rekening met deze verschillen in studievvaardigheden tussen mensen. Hiermee leveren we een andere bijdrage tot de literatuur. Het meer realistisch en completer model van hoofdstuk 3 met verschillende 'bekwaamheidsgroepen' van individuen gebruiken we in een volgende studie (hoofdstuk 4) om de effecten van verschillende mogelijke hervormingen van het pensioensysteem op groei, scholing, en werkgelegenheid (globaal en naar leeftijd) te onderzoeken.

### **Onderzoeksaanpak en resultaten**

In de eerste studie (hoofdstuk 2 van het proefschrift) onderzoeken we dus de effecten van begrotingsbeleid op de economische groei, de scholing van de jongeren en de werkgelegenheid van drie leeftijdsgroepen. We construeren hiervoor een micro-economisch gefundeerd algemeen evenwichtsmodel (overlapping generations model) waarin de hoogte en de samenstelling van de ontvangsten en de uitgaven van de overheid een cruciale rol spelen. De overheid heft belasting op arbeid, kapitaal en consumptie. De uitgaven van de overheid omvatten overheidsconsumptie, productieve uitgaven en transfers naar structureel niet-werkenden. Productieve uitgaven zijn uitgaven hoofdzakelijk voor onderwijs en publieke infrastructuur. De tijd die jongeren besteden aan tertiaire studie is de hoofdcomponent van de endogene economische groei in het model. Naast de drie actieve generaties is er in het model ook één generatie van gepensioneerden. We tonen de empirische relevantie aan van het model voor een groep van 13 OESO landen (3 Angelsaksische landen, 6 West-Europese en de 4 Scandinavische landen) in de periode 1995-2007. We observeren opmerkelijke verschillen in werkgelegenheid per leeftijdsgroep, scholingsinspanning van de jongeren en groei tussen deze OESO landen. We illustreren dat de voorspellingen van het model voor deze 13 landen de actuele data heel goed voorspellen. Vervolgens gebruiken we het aan de realiteit geteste model om de effecten van verschillende beleidsmaatregelen die de werkgelegenheid en groei bevorderen te simuleren.

Resultaat van het onderzoek is dat verlaging van de belasting op arbeid en (vooral) verlaging van transfers aan structureel niet-werkenden het meest effectief zijn als we de werkgelegenheid willen bevorderen. Productieve uitgaven zijn het meest effectief voor de output en groei op lange termijn. Als één van de belangrijke onderzoeksresultaten vinden we dat belastingverlaging op arbeid effectiever is t.a.v. de groei en werkgelegenheid wanneer deze gericht is op oudere werknemers. Lastenverlaging op de arbeid van jongeren is veeleer negatief voor de lange termijn groei omdat deze de jongeren ontmoedigt om te blijven studeren.

Gebaseerd op deze studie kunnen we voor veel Europese landen de volgende beleidsaanbeveling doen om groei en werkgelegenheid te bevorderen, vooral onder de oudere werknemers. Een effectieve beleidsmaatregel is het verlagen van de transfers aan structureel niet-werkenden en het hierdoor vrijgekomen budget te gebruiken om de belasting op arbeid van oudere werknemers te verlagen en de uitgaven voor onderwijs en publieke infrastructuur te verhogen.

Ten opzichte van hoofdstuk 2 maken we in het derde hoofdstuk een meer realistische veronderstelling. Meer bepaald bouwen we in dat er in elke generatie verschillende bekwaamheidsgroepen zijn. We onderscheiden drie specifieke groepen met verschillende aangeboren studiebekwaamheid: laag, gemiddeld en hoog. De eerste groep neemt veeleer weinig van de bestaande kennis op wanneer ze jong zijn. Deze groep studeert ook niet verder. De tweede en de derde groep assimileren meer bestaande kennis, en zijn ook productiever in het opbouwen van nieuwe kennis door studie. De groep met de hoogste studiebekwaamheid studeert het langst en bouwt het meeste menselijk kapitaal op.

In ons derde hoofdstuk gaan we de implicaties na voor de conclusies uit het vorige hoofdstuk wanneer we rekening houden met heterogeniteit in studievasthouding. Minder lasten voor oudere werknemers, en dus een hoger nettoloon later, betekent dat de return op investering in scholing wanneer men jong is toeneemt, waardoor men eerder geneigd is om verder te gaan studeren. De vraag nu is of deze maatregel nog efficiënt is als men weet dat niet iedereen slaagt in hoger en zelfs niet in middelbaar onderwijs. In hoofdstuk 2 stelden we ook dat verlaging van belasting op arbeid van jongeren het studeren ontmoedigt, en dus slecht is voor de groei. Wat als men nu een belastingverlaging op arbeid enkel voor de lage inkomensgroepen doorvoert? Het model in hoofdstuk 3 laat toe dit te onderzoeken. De personen met laag inkomen zijn over het algemeen de laaggeschoolden, die niet verder gestudeerd hebben. In het model beschouwen we als lage inkomensgroepen diegenen die minder verdienen dan twee derde van het gemiddelde arbeidsinkomen. Verder vonden we in hoofdstuk 2 ook dat verhoging van productieve uitgaven, hoofdzakelijk voor onderwijs, het meest effectief is met betrekking tot groei. Maar zal dit geen ongelijkheidsverhogend effect hebben wanneer ongeveer een derde van de actieve bevolking geen baat heeft bij zulke maatregel omdat ze niet verder studeren? Of is deze groep op langere termijn toch beter af bij verhoogde productieve uitgaven, omdat ze ook genieten van de resulterende algemene productiviteitsverhoging?

Zoals ook in hoofdstuk 2 werd de empirische relevantie van dit uitgebreid model getoetst en werden de beleidssimulaties pas uitgevoerd nadat het model voldoende empirisch gevalideerd was. Het nieuwe model is eveneens in staat de beduidend lagere werkzaamheidsgraad onder laaggeschoolden te verklaren. En er wordt in het model ook rekening gehouden met het feit dat de verschillende types van arbeid (van laag, midden en hogeschoolden) niet perfect substitueerbaar zijn.

Onze conclusies zijn de volgende. Vooreerst bevestigen we de onderzoeksresultaten uit hoofdstuk 2. We vinden opnieuw dat verlaging van de belasting op arbeid en verlaging van de uitkeringen naar structureel niet-werkenden het meest effectief zijn om werkgelegenheid te bevorderen. Productieve uitgaven verhogen heeft opnieuw het positiefste effect op de lange termijn groei. Tevens blijkt ook nu dat een verlaging van de belasting op arbeid enkel gericht op oudere werknemers positief is voor de lange termijn groei. Opnieuw geldt het omgekeerde wanneer we een verlaging van de belasting

op arbeid doorvoeren voor jongeren. Vooral nieuw en belangrijk in deze studie was het bekijken van de welvaartseffecten van fiscale beleidsmaatregelen voor de drie verschillende bekwaamheidsgroepen (laag, gemiddeld en hoog). We vonden duidelijk verschillende effecten op de werkgelegenheid en verschillende welvaartseffecten voor deze drie groepen. Onder andere vonden we dat een gecombineerde maatregel van verlaging van de belasting op arbeid voor oudere werknemers, samen met een verlaging van de belasting op arbeid voor lage inkomensgroepen, welvaartsbevorderend was voor zowel laag-, midden- en hogeschoolden, en zowel bevorderend was voor de groei als voor de werkgelegenheid. Dit in tegenstelling tot een loutere belastingverlaging voor oudere werknemers, die de welvaart van de laaggeschoolden schaadde. De belangrijkste beleidsimplicatie van dit nieuwe hoofdstuk met heterogene individuen is: beperk de uitkeringen voor structureel niet-werkenden en gebruik het vrijgekomen budget voor hogere productieve uitgaven en lagere belasting op arbeid voor zowel lage inkomensgroepen als voor oudere werknemers.

In hoofdstuk 4 breiden we bovenstaand model uit met een publiek pensioensysteem en onderzoeken we, in een gezamenlijk werk met Tim Buyse, de effecten van pensioenhervormingen op werkgelegenheid, onderwijs, groei en welvaart. Deze studie is een uitbreiding van het model van Buyse, Heylen en Van de Kerckhove (*Journal of Population Economics*, 2013). In dit model ontwikkelen de auteurs een overlapping generations model met een repartitie pensioen systeem. De huidige actieve bevolking (3 generaties werkenden) betaalt de pensioenen van de oudere generatie. De wettelijke pensioenleeftijd is 65 jaar. Wettelijke pensioenen worden vanaf die leeftijd betaald. Maar oudere werknemers kunnen beslissen om vroeger te stoppen. Tot hun 65 jaar hebben ze recht op een vervroegd pensioen. De conclusie van Buyse et al. (2013) is dat een goed geconstrueerd repartitiesysteem beter kan presteren voor de macro-economische groei en werkgelegenheid dan een kapitalisatiestelsel. Wenselijk zijn een nauwe band tussen het pensioen en het eigen arbeidsinkomen, vooral het arbeidsinkomen dat verdiend is tussen 40 en 65 jaar.

Een tekortkoming van dit model is, dat de auteurs geen onderscheid maken tussen individuen en hun studiebekwaamheid. Ze gaan voorbij aan het gegeven dat een nauwe band tussen het pensioen en het eigen arbeidsinkomen ook sterk ongelijkheidsverhogend kan werken. Laaggeschoolden die een lager loon verdienen zullen in dit model ook een laag pensioen ontvangen en kunnen op oudere leeftijd in armoede belanden. Om deze problematiek en optimaal beleid dienaangaande te onderzoeken, maken we in hoofdstuk 4 opnieuw het model meer realistisch door ook hier de individuen op te splitsen in de drie specifieke bekwaamheidsgroepen. Vervolgens kunnen we de effecten van verschillende pensioensystemen en pensioenhervormingen (repartitiesysteem, eigen kapitalisatie, basispensioen, ...) op werkgelegenheid, scholing, economische groei en ongelijkheid in kaart brengen. Uit onze resultaten blijkt de voorkeur voor een 'intelligent' repartitiesysteem boven basispensioenen en pensioensystemen die vooral steunen op individueel pensioensparen.

We vinden de sterkste positieve effecten op werkgelegenheid, groei en geaggregeerde welvaart in een repartitiestelsel wanneer het verband tussen pensioen en individueel verdiende arbeidsinkomens hoog is en wanneer bij de berekening van de pensioenbasis veel gewicht wordt toegekend aan de inkomsten uit arbeid als oudere werknemer. Onze resultaten bevestigen aldus die van Buyse et al. (2013). We vinden echter ook – zoals verwacht - dat dit repartitiesysteem, wanneer het niet verder gecorrigeerd wordt, een sterke toename van ongelijkheid impliceert. Het beste om deze ongelijkheid te verminderen, is de strakke koppeling tussen individueel arbeidsinkomen en de pensioenbasis te handhaven, ook voor lage inkomensgroepen, maar anderzijds hun vervangingsratio aanzienlijk te verhogen. Dit vereist wel solidariteit van de hogere inkomensgroepen.



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**CHAPTER 1**  
**Introduction**

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# Introduction

## 1. General context and motivation

Rising pressure on social security and pension systems due to ageing, as well as the risk of persistent output and job losses because of the recent financial and economic crisis, have strengthened in all OECD countries the need to develop effective employment and growth policies. The need to raise employment is particularly pressing among older and lower skilled workers, in most countries of the euro area. At the same time, the observation of (much) higher employment and higher growth in some other countries reveals that low employment and growth are not accidents from nature.

The reasons for these cross-country differences have been the subject of intense discussion in the economic literature. In recent years the importance of finding convincing explanations for what drives employment and growth has only increased. Many researchers have demonstrated the major influence on employment of the composition of fiscal policy, i.e. the level and structure of government expenditures and taxes. More recently many fiscal policy models have introduced education expenditures/subsidies as a major component of productive government expenditures, enhancing effecting human capital accumulation and possibly growth. Empirical work confirms the importance of fiscal policy for growth in OECD countries. Others find evidence for a significant role of education for growth.

The literature is limited in some aspects. First, most of the studies focus on only one aspect of macro performance, either employment or growth. Second, most studies neglect life cycle patterns in labor supply and employment differences across age groups. The data, however, show that in all countries the middle aged work more hours than the young and the older. Third, most existing studies disregard differences in abilities and motivation of people to learn. An important observation here is that differences in school results feed through directly into labor market outcomes.

In Chapter 2 of the dissertation we respond to the first and the second limitation that characterize most existing literature. We study the effects of fiscal policy in a general equilibrium OLG model on education, employment per age group, income, welfare and growth. In Chapter 3 we extend our OLG model by allowing for heterogeneity in learning abilities. In Chapter 4, we use the extended OLG model of Chapter 3 to investigate the effects of pension reform on the income and welfare levels of different ability groups.

## 2. Research questions, results, and contributions

In Chapter 2 “Employment by age, education, and economic growth : Effects of fiscal policy composition in general equilibrium” we build and parameterize a general equilibrium OLG model (Overlapping Generation Model) for an open economy that explains hours of work of young, middle aged and older individuals, education of the young, and aggregate growth, within one coherent

framework. The composition of fiscal policy, i.e. the level and structure of taxes and government expenditures, play a crucial role. The government sets tax rates on labor, capital and consumption. It allocates its revenue to productive expenditures (mainly for education and public infrastructure), consumption and non-employment benefits. Labor taxes and benefits may differ across age groups. In our four-period OLG model we consider three working generations and one retired generation and we evaluate the empirical relevance of our model on a group of 13 OECD countries in 1995-2007. We observe significant differences in employment by age, education of the young and per capita growth across these 13 OECD countries. We find that our model's predictions match the facts remarkably well for all key variables in many OECD countries and then use the model to investigate the effectiveness of various fiscal policy measures in promoting employment and growth. We also evaluate welfare effects for current and future generations.

Our key research question is what fiscal policy is most effective to promote employment, in particular among older workers, human capital formation, and per capita growth? What is the optimal composition of taxes, and of government expenditures? What are the employment and growth effects of changes in this composition? What is the realistic size of all these effects? What are the welfare effects on current and future generations?

We contribute to the literature in two possible ways. First, we tell one story explaining employment, and human capital and growth. Our approach allows to fully take into account the mutual relationships between all variables, which will matter for the size and possibly the sign of fiscal policy effects. Our second potential contribution is the careful parameterization of our model and we establish its empirical reliability before using the model for policy simulations.

The main results in this research are as follows. We identify cuts in labor taxes and non-employment benefits as the main policy variables promoting employment. Productive expenditures are the most effective with respect to long-run output and growth. We observed that output and growth may benefit from labor tax cuts targeted at middle-aged and older workers since these policies raise the return to investment in education when young. By contrast, labor tax cuts targeted at younger workers discourage the young to study and imply lower future output and growth. In general, the size of the effects that we obtain is well within the range of existing studies, although often at the lower end. A key policy implication of our results for many European countries searching higher growth and employment, mainly among older workers, would be to cut non-employment benefits and to reallocate these resources to labor tax cuts on older workers and to higher productive expenditures. From a welfare perspective, these policies are beneficial to current young and future generations, but only some are likely to support from current older and retired individuals.

In Chapter 2, we assume homogeneous individuals in each generation, and disregard obvious differences in abilities and motivation of people to learn. Everyone in the model is able to study and succeed at the tertiary level. Reality is different, however. Data reveal that in 2008 about 30% of the

25-64 year old population on average in the OECD has no upper secondary degree. About 44% has an upper secondary degree but no tertiary degree. About 40% obtains an upper secondary degree, but no tertiary degree. Cross-country variation in these data suggests that differences in the schooling system and government policies may have an important influence on these numbers. But the simple fact that innate ability as for example reflected by IQ varies across people implies that one can never expect everyone to exceed at the tertiary level.

In Chapter 3 “Heterogeneous abilities, and the effects and fiscal policies on employment and growth” we extend our OLG model by allowing for heterogeneous abilities. We make the assumption that within each generation three ability groups exist. These groups differ both in the degree to which they (when young) assimilate existing knowledge, i.e. inherit human capital from the middle aged generation, and in their productivity of schooling when they spend time studying. One group has low ability and will never engage in tertiary education. A second group has medium ability, a third group high ability. Both these groups inherit higher fractions of existing human capital, and will allocate time to tertiary education, but given the variation between them in the productivity of knowledge assimilation and schooling, the amount of time will differ. A high quality schooling system may to some extent counteract the effects of differences in innate ability. Our extensions allow for a richer analysis of policy.

Our main findings are the following. First, we confirm our earlier results in Chapter 2. We again identify labor taxes and (especially) ‘non-employment’ benefits as the main policy variables affecting employment. Productive government expenditures are the most effective with respect to long-run output and growth. Again we observe that output and growth may benefit also from labor tax cuts targeted at older workers. Second, however, a first new result in this study 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 welfare losses. Third, better overall employment effects and better welfare effects for low ability groups, at a slight cost in terms of growth, are possible if one complements policies that cut labor taxes on older workers with labor tax cuts on the low wage earners. The best effects on employment follow if this combined tax cut is financed by overall benefit cuts. 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, tax cuts on all the low wage earners, and higher productive expenditures.

In Chapter 4 “Pension reform in an OLG model with heterogeneous abilities” which is joint work with Tim Buyse, we study the effects of pension reform on employment, education, growth and welfare. This study is an extension of the model of Buyse et al. (2013). These authors develop an overlapping generations model which includes a public PAYG old-age pension system which pays out pensions to a fourth generation of retired. The statutory retirement age in the model is 65 and exogenous. Old-age pensions are paid from this age onwards. Individuals, however, may optimally choose a lower

effective (early) retirement age. They then receive early retirement benefits. The specification of pension benefits allows for both own-earnings related and flat-rate or basic components.

A shortcoming of this model is, however, that the authors do not explicitly model heterogeneity in skills or abilities. In the fourth chapter of this dissertation, we therefore introduce heterogeneous abilities, in order to assess the effects of the proposed pension reforms on inequality and welfare. Within each generation we distinguish individuals with high, medium or low ability to build human capital, which allows investigating also the effects of pension reform on the income and welfare levels of different ability groups. The government sets tax rates on labor, capital and consumption. It allocates its revenue to productive expenditures, consumption, pensions and non-employment benefits which include early retirement benefits. Our aim is to investigate the effects of various parametric adjustments in the old-age PAYG pension system on the employment rate of young, middle aged and older workers, education, growth and welfare. These parametric adjustments include changes in benefit levels, changes in the link between benefits and individual contributions, and changes in the weights of the three active periods in the computation of the old-age pension assessment base, i.e. earned labor income used to calculate pension benefits. We also consider the effects of moving to full private capital funding.

An advantage of realistically introducing heterogeneous abilities, and therefore an important contribution of this research, is that we will be able to study differential effects of pension reform on the income and welfare levels of individuals with different abilities and human capital. Particular attention goes to the income at old-age and the welfare level of the low-ability individuals. The link to major issue as old-age poverty is obvious.

Our results prefer an ‘intelligent’ pay-as-you-go (PAYG) system. We find the strongest positive effects on employment, growth and aggregate welfare in a PAYG system when it includes a tight link between individual labor income and the pension, and when it attaches a high weight to labor income earned as an older worker to compute the pension assessment base. Our results confirm those of Buyse et al. (2013). However, we find that their preferred system, when uncorrected, implies a strong increase of welfare inequality. Best is to maintain the tight link between individual labor income and the pension also for low-ability individuals, but to significantly raise their replacement rate. This requires some solidarity from high-ability individuals.

## References

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## **CHAPTER 2**

**Employment by age, education, and economic growth:  
Effects of fiscal policy composition in general equilibrium**

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# Employment by age, education, and economic growth: Effects of fiscal policy composition in general equilibrium

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## Abstract

We build and parameterize a general equilibrium OLG model that explains hours worked by three active generations, education by the young, the retirement decision of older workers, and aggregate per capita growth as functions of the level and structure of taxes and government expenditures. We find that our model's predictions match the facts remarkably well for all key variables in many OECD countries. We then use the model to investigate the effects of various fiscal policy shocks. To promote employment, especially among older workers, and economic growth, our results strongly prefer labor tax cuts targeted at older workers and higher productive government expenditures financed by a reduction of non-employment benefits and/or higher consumption taxes. We also evaluate the welfare effects for current and future generations of alternative policy changes.

**Key words:** employment by age, endogenous growth, taxes, fiscal policy, human capital production, overlapping generations

**JEL Classification:** E62, J22, O41

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## 1. Introduction

Rising pressure on the welfare state due to ageing, and growing concerns about the sustainability of public finances at times of high government debt, force all OECD countries to develop effective employment and growth policies. The need to raise employment is particularly pressing in the euro area, and most so among older workers. Concern for employment and growth is not new, however. They have been high on the agenda of both policy makers and researchers for at least two decades.

Many researchers have demonstrated the major influence on employment of the composition of fiscal policy, i.e. the level and structure of taxes and government expenditures including social security programs. 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). Recent work, however, has paid growing attention to life cycle patterns in labor supply and employment differences across age groups (e.g. Rogerson and Wallenius, 2009; Wallenius, 2009; Alonso-Ortiz, 2011; Erosa, Fuster and Kambourov, 2012). 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 expenditures/subsidies as a major component of productive government expenditures, enhancing human capital accumulation and possibly growth (e.g. Glomm and Ravikumar, 1992; Buiter and Kletzer, 1993; Docquier and Michel, 1999; Kaganovich and Zilcha, 1999; Dhont and Heylen, 2009). Empirical work confirms the importance of fiscal policy for growth in OECD countries (e.g. Kneller, Bleaney and Gemmell, 1999; Romero-Ávila and Strauch, 2008; Gemmell, Kneller and Sanz, 2011). Others find evidence for a significant role of education and/or public education expenditures (e.g. Barro, 2001; Nijkamp and Poot, 2004; de la Fuente and Doménech, 2006; Blankenau, Simpson and Tomljanovich, 2007)<sup>1</sup>. Hanushek and Woessmann (2009, 2011) emphasize the crucial role of education quality and the institutional features of the schooling system for growth.

The above mentioned literature has strongly improved our understanding of the effects of fiscal policy on employment, human capital, and growth. Still, it is limited in two respects.

First, most of the above mentioned studies focus on only one aspect of macro performance, either employment or growth. Most studies explaining employment disregard human capital and growth. At the same time, existing models explaining growth generally ignore the endogeneity of labor supply and the labor-leisure choice. Turnovsky (2000) and Dhont and Heylen (2009) are exceptions in this respect. They construct general equilibrium models with infinitely lived identical individuals and a rich specification of fiscal policy to study labor supply, employment and growth within one coherent framework. Some other researchers have built models with endogenous labor supply and endogenous human capital, but exogenous growth. Wallenius (2009) studies the influence of social security programs on life cycle labor supply in a general equilibrium context. She

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<sup>1</sup> Not all studies investigating the relationship between education and growth come up with significant positive results, however (e.g. Pritchett, 2001). De la Fuente and Doménech (2006) point at the low quality of schooling and human capital data as an important factor that may explain the mitigated results in many studies.

models human capital formation endogenously via a learning-by-doing mechanism. Fougère *et al.* (2009), Ludwig, Schelkle and Vogel (2012) and Guvenen, Kuruscu and Ozkan (2009) have also constructed models with endogenous employment over the life cycle and human capital formation. Here human capital is accumulated via the allocation of time to education or training à la Ben-Porath (1967). Second, the few studies that model labor supply and employment over the life cycle, and that have endogenous human capital, are relatively limited in the specification of the fiscal block and the number of fiscal policy instruments that they consider. Wallenius (2009) investigates the effects of the scale and eligibility rules of social security programs. Guvenen *et al.* (2009) study the effects of progressive taxation on human capital and before-tax wage inequality. Fougère *et al.* (2009) and Ludwig *et al.* (2012) do not investigate the impact of fiscal policy. All in all, the expenditure side in particular is underdeveloped in existing models. In this paper we want to make progress on these aspects.

Our main objectives in this paper are (i) to construct and parameterize a general equilibrium overlapping generations model for an open economy where hours worked by three active generations, education by the young, the retirement decision of older workers, and economic growth are all endogenous, and (ii) to use this model to study the effects of a rich set of fiscal policy shocks. The model is situated in the fiscal policy endogenous growth tradition, with growth being related to education and education quality. In line with most of this literature, we assume competitive markets. The government in our model sets tax rates on labor, capital and consumption. It allocates its revenue to productive expenditures (mainly for education), consumption, pensions, and non-employment benefits, including early retirement benefits. Our key research question is what fiscal policy is most effective to promote employment, in particular among older workers, human capital formation, and per capita growth? What is the optimal composition of taxes, and of government expenditures? What are the employment and growth effects of changes in this composition? What is the realistic size of all these effects? What are the welfare effects on current and future generations?

Although the questions that we ask are not new, we contribute to the literature in two possible ways. First, unlike existing studies, we tell one story explaining employment over the life cycle, and human capital and growth. Our approach allows to fully take into account the mutual relationships between all variables, which will matter for the size and possibly the sign of fiscal policy effects. Various channels exist in our model where changes in employment, capital formation and growth reinforce each other. For example, if employment rises, so will the marginal productivity of physical capital and the incentive to invest. Also, if people expect to retire later and work more hours as older worker, the return to investment in education when young will rise, and so may human capital and growth. Conversely, policies that promote education will encourage people to work longer since they will then get a higher return from their investment. Our model also contains channels where employment and growth move in opposite directions. One channel follows from the possible tradeoff between employment of the young and education. Policies that promote employment of the young may hinder growth when they discourage the young to study. From these examples it can easily be derived that a realistic modeling of all the linkages between labor supply in different

periods of life, human capital formation, and growth, is crucial for a correct analysis of the effects of fiscal policy changes. The long-run effects of labor tax cuts for example will be very different in a model where the endogeneity of human capital formation is taken into account rather than neglected. Also, the long-run effects of labor tax cuts may be very different when these tax cuts are targeted at older workers rather than young individuals.

Our second contribution is our focus on comparative fiscal policy analysis. Taking as our starting point the need to raise growth and employment, most so among older workers, in many OECD countries, we investigate the relative effectiveness of various changes in fiscal policy composition. The question is what policies work best? It makes our perspective different from recent contributions in the literature, like those of Alonso-Ortiz (2011) and Erosa *et al.* (2012). A central aim of their work is to investigate to what extent differences in various social security programs and taxes between European countries and the US can explain differences in labor market performance between these countries. They find for example that differences in social security rules are more important than tax differences.

Reliable policy analysis requires a very careful parameterization of our model. Stokey and Rebelo (1995) have shown an extreme variation in the predictions of existing calibrated fiscal policy models. Results seem to be very sensitive to the choice of some parameters. Models with education may be particularly vulnerable due to a lack of robust evidence on the correct specification and parameterization of the human capital production function (Bouzahzah, de la Croix and Docquier, 2002). We learn from this that, before using a calibrated model for policy analysis, it is particularly useful to test its empirical validity. We here test our model for a group of 13 OECD countries. This group includes the US, the core countries of the euro area, the UK, Canada and the Nordic countries. Our procedure is as follows. We calibrate our model to match the data for one (small open) economy, Belgium. We then impose the obtained technology and preference parameters on all countries, together with country-specific fiscal policy parameters and education quality. Simulating the model for each country we require (and find) that its predictions match the main facts in most countries. These facts concern observed hours of work in three age groups (20-34, 35-49, 50-64), education of the young (20-34), the effective retirement age of older workers, and per capita growth in 1995-2007. We conclude that the model translates observable policy differences into performance differences which are roughly in line with observations in the data. This clearly raises confidence about the quantitative reliability of the model. Our approach also yields new evidence on the human capital production function. The data prefer a specification where effective human capital is produced from both private inputs (education time) and public inputs (productive government expenditures, mainly for education), with the degree of complementarity between them being much higher than in the Cobb-Douglas case. To match the data, it seems very important also to account for the quality of schooling.

Having established its empirical reliability, we then use the model for policy simulations. Our main results are as follows. We identify cuts in labor taxes and non-employment benefits as the main policy variables promoting employment. Productive government expenditures are the most effective

with respect to long-run output and growth. Furthermore, we observe that output and growth may benefit from labor tax cuts targeted at middle-aged and older workers since these policies raise the return to investment in education when young. By contrast, labor tax cuts targeted at younger workers and non-employment benefit reductions imply lower future output and growth since they discourage the young to study. The net output and growth effects of overall labor tax cuts are positive, but quite small. Finding that (aggregate) employment, education and growth move in the same direction after some policy measures (labor tax cuts targeted at older workers), whereas they move in opposite directions after others (labor tax cuts for young workers, non-employment benefit cuts), underscores the importance of a model where all these variables are endogenous. Finally, we find that capital tax cuts have relatively strong positive and permanent effects on the level of output also, but almost negligible effects on long-run growth, and small effects on employment. In general, the size of the effects that we obtain is well within the range of existing studies, although often at the lower end.

A key policy implication of our results for many European countries searching higher growth and employment, mainly among older workers, would be to cut non-employment benefits and to reallocate these resources to labor tax cuts on older workers and to higher productive expenditures. The US would also benefit from higher productive expenditures. Non-employment benefits being low in the US, higher productive expenditures may be financed also by higher consumption taxes. From a welfare perspective, these policies are beneficial to current young and future generations, but only some are likely to get support from current older and retired individuals.

The paper is organized as follows. In Section 2 we document differences in employment by age, education of the young and per capita growth across 13 OECD countries since 1995. Section 3 sets out our model. In Section 4 we calibrate the model on actual data and confront its predictions with the facts described in Section 2. Sections 5 and 6 include the results of a wide range of model simulations. In Section 5 we discuss the long-run equilibrium effects of policy changes, in Section 6 the transitional dynamics, and the welfare effects per generation. Section 7 concludes the paper.

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

Table 1 contains key data on employment, education and growth in 13 OECD countries in 1995-2007. One would like a reliable model to match the main cross-country differences reported here. The employment rate in hours ( $n$ ) indicates the fraction of potential hours that are actually being worked by the average person in one of three age groups:  $n_1$  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 also include the effective retirement age in Table 1. In most countries, this age is well below the official age to receive old-age pensions (65 in most countries, 60 in France). The education rate ( $e$ ) is our proxy for the fraction of time spent studying by the average person of age 20-34. It has been

calculated as the total number of students in full-time equivalents, divided by total population in this age group. Our data for (average annual) real per capita growth concern real potential GDP per person of working age. We refer to Appendix 1 for further details on the calculation of all our data, and on the assumptions that we have to make.

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

**Table 1**

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

	$n_1$ (20-34)	$n_2$ (35-49)	$n_3$ (50-64)	<i>effective retirement age</i>	$e$	<i>annual real per capita growth</i>
Austria	59.9	64.3	34.7	59.5	12.8	2.06
Belgium	51.1	56.8	29.3	57.9	14.1	1.77
France	48.7	60.3	38.0	58.8	14.5	1.54
Germany	49.7	55.2	34.9	61.1	16.7	1.56
Italy	50.1	61.9	33.8	60.1	12.6	1.30
Netherlands	50.8	54.6	34.2	60.0	14.9	2.20
<b>Core euro area average</b>	<b>51.7</b>	<b>58.8</b>	<b>34.2</b>	<b>59.6</b>	<b>14.3</b>	<b>1.74</b>
Denmark	56.2	66.7	49.6	62.2	23.0	1.81
Finland	55.6	69.0	47.3	60.2	23.5	2.72
Norway	51.9	60.9	50.6	63.1	18.1	2.29
Sweden	53.6	66.1	55.4	63.4	17.8	2.18
<b>Nordic average</b>	<b>54.3</b>	<b>65.6</b>	<b>50.7</b>	<b>62.2</b>	<b>20.6</b>	<b>2.25</b>
<b>US</b>	<b>65.6</b>	<b>74.2</b>	<b>59.6</b>	<b>64.2</b>	<b>12.5</b>	<b>1.54</b>
UK	60.8	68.4	49.4	62.0	11.8	2.13
Canada	60.9	69.5	50.4	62.1	14.0	1.68
<b>All country average</b>	<b>55.0</b>	<b>63.7</b>	<b>43.6</b>	<b>61.1</b>	<b>15.9</b>	<b>1.91</b>

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

### 3. The model

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

We consider three active adult generations, the young, the middle-aged and the older, and one generation of retired agents. All generations are of equal size, normalized to 1. Population is constant. Within each generation agents are homogeneous. Individuals enter the model at age 20. In line with our data in the previous section, each period is modeled to last for 15 years. Per period,

individuals are endowed with one unit of time. Young people can choose either to work and generate labor income, to study and build human capital, or to devote time to ‘leisure’ (including other non-market activities). Middle-aged and older workers do not study anymore, they only work or have ‘leisure’. The statutory old-age retirement age is 65. Individuals may however optimally choose to leave the labor force sooner in a regime of early retirement. Domestic firms act competitively and employ physical capital together with existing technology and effective labor provided by the three active generations. A final important assumption is that education generates a positive externality in the sense of Azariadis and Drazen (1990). The average level of human capital of a middle-aged generation is inherited by the next young generation.

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

### 3.1. Individuals

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

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

with  $\gamma_j > 0$ ,  $\theta > 0$  ( $\theta \neq 1$ ) and where:

$$\ell_1^t = 1 - n_1^t - e^t \quad (2)$$

$$\ell_2^t = 1 - n_2^t \quad (3)$$

$$\ell_3^t = \Omega \left( \pi \left( R^t (1 - n_3^t) \right)^{1-(1/\rho)} + (1 - \pi) \left( 1 - R^t \right)^{1-(1/\rho)} \right)^{\rho/(\rho-1)} \quad (4)$$

$$\text{and } \ell_4^t = 1$$

Lifetime utility (1) depends on consumption ( $c_j$ ) and enjoyed ‘leisure’ ( $\ell_j$ ) in each period of life. Superscript  $t$  indicates the period of youth, when the individual comes into the model. Subscript  $j$  refers to the  $j$ th period of life. Furthermore,  $\beta$  is the discount factor ( $0 < \beta < 1$ ). The intertemporal elasticity of substitution in consumption is 1, the intertemporal elasticity to substitute leisure  $1/\theta$ . Finally,  $\gamma$  specifies the relative value of ‘leisure’ versus consumption. Note that  $\gamma$  may be different in each period of life. Except for the latter assumption, our specification of the instantaneous utility function is quite common in the macro literature (e.g. Rogerson, 2007; Erosa *et al.*, 2012).

Figure 1 shows the life-cycle of an individual reaching age 20 in  $t$ . Individuals choose time devoted to work ( $n_j$ ) in the three active periods and education time ( $e$ ) when young. Since individuals only

allocate time to education in their first period, we drop the subscript 1. Time endowment is normalized to 1 in each period. Following the approach in Buyse, Heylen and Van de Kerckhove (2013), the determination of early retirement is part of individuals' optimal choice of 'leisure' time in the third period of life (50-65). Individuals choose  $R$  which relates to the optimal effective retirement age and which is defined as the fraction of time between age 50 and 65 that the individual participates in the labor market;  $(1-R)$  is then time in early retirement. We use  $n_3$  to denote the fraction of time devoted to work between 50 and 65, and  $\tilde{n}_3$  as the fraction of time devoted to work before early retirement, but after 50. As labor market exit is irreversible and post-retirement employment is not allowed in our model, the relationship between  $n_3$  and  $\tilde{n}_3$  is as follows:  $n_3 = R \cdot \tilde{n}_3$ .

In the first two periods of active life, 'leisure' falls in labor supply and in education time (Equations 2 and 3). In the third period, 'leisure' time consists of two parts: non-employment time before the effective retirement age ( $R(1 - \tilde{n}_3)$ ), and time in early retirement after it  $(1-R)$ . Equation (4) then describes composite enjoyed 'leisure' of an older worker as a CES-function of both parts. Like Buyse *et al.* (2013) we assume imperfect substitutability between the two leisure types. The idea here is that 'leisure' time after and between periods of work is not the same as 'leisure' time in periods when individuals are not economically active anymore<sup>2</sup>. 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  $\rho$  is the constant elasticity of substitution,  $\pi$  is a usual share parameter and  $\Omega$  is added as a normalization constant such that the magnitude of  $\ell_3$  corresponds to the magnitude of total leisure time  $1-n_3$ .<sup>3</sup> The latter assumption allows to interpret  $\gamma_3$  as the relative value of 'leisure' versus consumption in the third period, comparable to  $\gamma_1$  and  $\gamma_2$ .

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

	20	35	50	65
	80			$R^t$
Period	$t$	$t+1$	$t+2$	$t+3$
Work	$n_1^t$	$n_2^t$	$n_3^t = R^t \tilde{n}_3^t$	0
Study	$e_1^t$	0	0	0
'Leisure' time	$1 - n_1^t - e_1^t$	$1 - n_2^t$	$R^t(1 - \tilde{n}_3^t) + (1 - R^t)$	1

<sup>2</sup> Think of the former as time to relax and time to spend on personal activities of short duration. Think of the latter as time to enjoy activities that last longer and that ask for longer term commitment (e.g. long journeys, non-market activity as a volunteer).

<sup>3</sup> The main results in this paper are not in any way influenced by the magnitude of  $\pi$ ,  $\Omega$  or  $\rho$ .

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

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

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

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

$$(1 + \tau_c) c_4^t = (1 + r_{t+3}) a_3^t + p p_4^t + z_{t+3} \quad (8)$$

$$\text{with: } h_1^t = h_2^{t-1} \quad (9)$$

$$h_3^t = h_2^t = (1 + \psi(e^t, g_y, q)) h_1^t \quad \psi > 0, \psi'(\cdot) > 0 \quad (10)$$

$$p p_4^t = b_4 \sum_{j=1}^3 \frac{1}{3} (w_{t+j-1} h_j^t n_j^t (1 - \tau_j)) \quad (11)$$

$$n_3^t = R^t n_3^t \quad (12)$$

The LHS of Equations (5)-(8) shows that individuals allocate their disposable income to consumption (including consumption taxes,  $\tau_c$ ) and the accumulation of non-human wealth  $a$ . We denote by  $a_j^t$  the stock of wealth that an individual who enters the model at time  $t$  holds at the end of his  $j$ th period of life. Note in Equation (8) that the retired only consume.

During the three periods of active life disposable income at the RHS includes after-tax labor income, non-employment benefits, interest income and lump sum transfers. In the Equations (5)-(8)  $w_k$  stands for the real wage per unit of effective labor at time  $k$ ,  $r_k$  is the exogenous (world) real interest rate at time  $k$ , and  $z_k$  is the lump sum transfer that the government pays out to all individuals at time  $k$ . Effective labor of an individual depends on hours worked ( $n_j^t$ ) and effective human capital ( $h_j^t$ ). Since young individuals allocate a fraction  $n_1^t$  of their time to work, and pay a tax rate on labor income  $\tau_1$ , they earn an after-tax real wage equal to  $w_t h_1^t n_1^t (1 - \tau_1)$ . After-tax labor income of middle-aged and older workers in equations (6) and (7) is determined similarly. Note that the government has the possibility to levy different tax rates on the different age groups. A young worker inherits his effective human capital from the middle-aged generation, as shown in Equation (9). During the second and third period, workers supply more units of effective human capital. It is our assumption in Equation (10) that  $h$  rises in education time when young ( $e$ ), productive government spending in percent of GDP ( $g_y$ , mainly education) and the quality of education ( $q$ ). We specify and discuss the effective human capital production function in Section 3.2. Individuals take  $g_y$  and  $q$  as

exogenous. We also assume in Equation (10) that human capital remains unchanged between the second and third period. We have in mind that learning by doing in work counteracts depreciation<sup>4</sup>.

For the fraction of time that young, middle-aged and older individuals are inactive, they receive a non-employment benefit from the government. Older workers may be eligible to two kinds of benefits: standard non-employment benefits (analogous to what young and middle-aged workers receive) as long as they are on the labor market, and early retirement benefits after having withdrawn from the labor market. All benefits are defined as a proportion of the after-tax wage of a full-time worker. The replacement rate for standard non-employment benefits is  $b_j$  with  $j=1,2,3a$ , for early retirement benefits it is  $b_{3b}$ .<sup>5</sup> Like taxes, replacement rates may differ across age groups.

After the statutory retirement age (65) individuals have no labor income and no non-employment benefits anymore. They then receive an old-age pension benefit ( $pp$ ) and the lump sum transfer. Equation (11) describes the old-age pension. We assume a public PAYG pension system in which pensions in period  $k$  are financed by contributions (labor taxes) from the active generations in that period  $k$  (see below). Individual pension benefits are related to earlier labor income. Individuals earn a net pension which is a fraction of their so-called pension base. The latter is equal to the average of net labor income in each of the three active periods of life. The net replacement rate is  $b_4$ . The pension rises in the individual's hours of work  $n_j^t$  and his human capital  $h_j^t$ . It will be lower when the individual retires early (lower  $R^t$ ). Fourth generation individuals consume their pension and the lump sum transfer, as well as their accumulated wealth from the third period plus interest (Equation 8). They leave no debts, nor bequests.

Substituting Equations (2)-(4) for  $l_j^t$  and (5)-(8) for  $c_j^t$  into Equation (1), and maximizing with respect to  $a_1^t, a_2^t, a_3^t, n_1^t, n_2^t, \tilde{n}_3^t, e^t$  and  $R^t$ , yields eight first order conditions for the optimal behavior of an agent entering the model at time  $t$ . Equation (13) expresses the law of motion of optimal consumption over time. Equations (14.a), (14.b) and (14.c) describe the optimal labor-leisure choice in each period of active live. In each period, individuals supply labor up to the point where the marginal utility of leisure equals the marginal utility gain from work. The latter consists of two parts. Working more hours in a particular period raises additional resources for consumption both in that

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<sup>4</sup> Our assumptions imply a constant hourly wage profile in the third period. Although the consensus view in labor economics is that the wage profile is hump-shaped, and declines around the age 50-55, our assumptions are fully in line with recent micro evidence from the US Panel Study of Income Dynamics which challenges this consensus view (Rupert and Zanella, 2010).

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

period and when retired. The marginal utility gain from work is higher when initial consumption is lower, and when an extra hour of work yields more extra consumption. Higher human capital (and its underlying determinants), lower taxes on labor, lower taxes on consumption and lower non-employment benefits contribute to the gain from work. Extra consumption during retirement rises in the pension replacement rate ( $b_4$ ).

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

$$\frac{\gamma_1}{(\ell_1^t)^\theta} \frac{-\partial \ell_1^t}{\partial n_1^t} = \frac{w_t h_1^t (1-\tau_1)(1-b_1)}{c_1^t (1+\tau_c)} + \frac{\beta^3 b_4 w_t h_1^t (1-\tau_1)}{3 c_4^t (1+\tau_c)} \quad (14.a)$$

$$\begin{aligned} \frac{\gamma_2}{(\ell_2^t)^\theta} \frac{-\partial \ell_2^t}{\partial n_2^t} &= \frac{w_{t+1} (1+\psi(e^t, g_y, q)) h_1^t (1-\tau_2)(1-b_2)}{c_2^t (1+\tau_c)} \\ &+ \frac{\beta^2 b_4 w_{t+1} (1+\psi(e^t, g_y, q)) h_1^t (1-\tau_2)}{3 c_4^t (1+\tau_c)} \end{aligned} \quad (14.b)$$

$$\begin{aligned} \frac{\gamma_3}{(\ell_3^t)^\theta} \frac{-\partial \ell_3^t}{\partial n_3^t} &= \frac{w_{t+2} (1+\psi(e^t, g_y, q)) h_1^t (1-\tau_3) R^t (1-b_{3a})}{c_3^t (1+\tau_c)} \\ &+ \frac{\beta b_4 w_{t+2} (1+\psi(e^t, g_y, q)) h_1^t R^t (1-\tau_3)}{3 c_4^t (1+\tau_c)} \end{aligned} \quad (14.c)$$

Equation (15) describes the first order condition for the optimal effective retirement age. The LHS represents the utility loss from postponing retirement. Later retirement reduces enjoyed leisure as early retiree, but raises enjoyed leisure in between periods of work for given work time  $\tilde{n}_3$ . The RHS shows the marginal utility gain from postponing retirement. This marginal gain follows from consuming the extra labor income (vis-à-vis the early retirement benefit) in the third period, and the higher future old-age pension after 65. The latter effect rises in  $b_4$ .

$$\begin{aligned} \frac{\gamma_3}{(\ell_3^t)^\theta} \frac{-\partial \ell_3^t}{\partial R^t} &= \frac{w_{t+2} (1+\psi(e^t, g_y, q)) h_1^t (1-\tau_3) (n_3^t + b_{3a} (1-n_3^t) - b_{3b})}{c_3^t (1+\tau_c)} \\ &+ \frac{\beta b_4 w_{t+2} (1+\psi(e^t, g_y, q)) h_1^t n_3^t (1-\tau_3)}{3 c_4^t (1+\tau_c)} \end{aligned} \quad (15)$$

Finally, equation (16) imposes that the marginal utility loss from investing in human capital when young equals the total discounted marginal utility gain in later periods from having more human capital. Individuals will study more the higher future versus current after-tax real wages and the

higher the marginal return of education to human capital ( $\partial\psi/\partial e$ ). Labor taxes during youth therefore encourage individuals to study, whereas labor taxes in later periods of active life discourage them. Notice also that high benefit replacement rates in later periods ( $b_2, b_{3a}, b_{3b}$ ) and a high income-related pension replacement rate ( $b_4$ ) will encourage young individuals to study. The reason is that any future benefits and the future pension rise in future labor income, and therefore human capital. A final interesting result is that young people study more – all other things equal – if they expect to work harder in later periods ( $n_2, n_3=R.\tilde{n}_3$ ).

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

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

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

$$\frac{\partial c_3^t}{\partial e^t} = \frac{\partial\psi(e^t, g_y, q)}{\partial e^t} \cdot \frac{w_{t+2} h_1^t (1 - \tau_3) \left[ R^t \left( n_3^t (1 - b_{3a}) + b_{3a} - b_{3b} \right) + b_{3b} \right]}{1 + \tau_c}.$$

$$\frac{\partial c_4^t}{\partial e^t} = \frac{b_4}{3} \frac{\partial\psi(e^t, g_y, q)}{\partial e^t} \cdot \frac{\sum_{j=2}^3 (n_j^t w_{t+j-1} h_1^t (1 - \tau_j))}{1 + \tau_c}$$

### 3.2. Production of effective human capital

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

Our specification also includes education time of young individuals and education expenditures by the government. We see these variables as indicators for the quantity of invested private and public

resources. Compared to most of the literature, however, we differ in three respects. First, we adopt a more flexible CES functional form, allowing the elasticity of substitution to differ from 1. Second, we take recent empirical evidence seriously that the quality of education and the schooling system is very important (Hanushek and Woessmann, 2009, 2011). Better quality implies higher cognitive abilities for the same allocation of resources. As a proxy for quality we will use OECD PISA science scores (see Section 4.2 for further discussion). As a third extension, our definition of relevant (productive) government expenditures includes more than education. It also includes expenditures for training in the context of active labor market policy, public R&D expenditures and public fixed investment. This approach goes back to our use of the broader concept of *effective* human capital. As in Dhont and Heylen (2008, 2009), effective human capital and worker productivity rise not only in accumulated schooling or training, but also in the productive efficiency of accumulated schooling. Education and training expenditures directly contribute to more human capital being accumulated, public R&D and fixed investment expenditures will mainly raise the productive efficiency of accumulated human capital.

All these arguments find their way in Equation (17). The *growth rate* of effective human capital is a flexible CES function of education time when young ( $e$ ) and productive government expenditures in % of output ( $g_y$ ). In steady state both determinants are constant, which will imply constant steady state growth. We add the quality of education ( $q$ ) in a multiplicative way. We allow  $q$  to vary across countries in later sections. Next to  $q$  we introduce (constant, common) technical parameters:  $\phi$  is a positive efficiency parameter,  $\sigma$  a scale parameter,  $\nu$  is a share parameter and  $\kappa$  the elasticity of substitution. These parameters will be calibrated.

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

Due to lack of existing empirical evidence, an ex-ante assessment of our specification is difficult. In Section 4.3., however, we confront our model's predictions with the facts about education and growth in 13 OECD countries. This confrontation reveals that our specification of the human capital production function performs better than alternative ones without quality, with a narrower definition of government expenditures, or with a Cobb-Douglas functional form.

### 3.3. Domestic firms, output and factor prices

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

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

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

with:  $x_{t-1} = 1 + \psi(e^{t-1}, g_y, q)$  and  $n_3^{t-2} = R^{t-2} n_3^{t-2}$ , and where we use Equations (9) and (10).

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

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

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

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

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

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

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

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

### 3.4. Government

Equation (23) describes the government's budget constraint. Productive expenditures  $G_{yt}$ , consumption  $G_{ct}$ , benefits related to non-employment  $B_t$  (including early retirement benefits), old-age pension benefits  $PP_t$ , lump sum transfers  $Z_t$ , and interest payments  $r_t D_t$  at time  $t$  are financed by taxes on labor  $T_{nt}$ , taxes on capital  $T_{kt}$ , and taxes on consumption  $T_{ct}$ , and/or by new debt  $\Delta D_{t+1}$ . We define  $D_t$  as outstanding public debt at beginning of period  $t$ .

$$\Delta D_{t+1} = D_{t+1} - D_t = G_{yt} + G_{ct} + B_t + PP_t + Z_t + r_t D_t - T_{nt} - T_{kt} - T_{ct} \quad (23)$$

with:

$$\begin{aligned} G_{yt} &= g_y Y_t \\ G_{ct} &= g_c Y_t \\ B_t &= (1 - n_1^t - e^t) b_1 w_t h_1^t (1 - \tau_1) + (1 - n_2^{t-1}) b_2 w_t h_2^{t-1} (1 - \tau_2) \\ &\quad + R^{t-2} (1 - n_3^{t-2}) b_{3a} w_t h_3^{t-2} (1 - \tau_3) + (1 - R^{t-2}) b_{3b} w_t h_3^{t-2} (1 - \tau_3) \\ PP_t &= b_4 \sum_{j=1}^3 \left( w_{t+j-4} h_j^{t-3} n_j^{t-3} (1 - \tau_j) \right) / 3 \\ Z_t &= 4 z_t \\ T_{nt} &= \sum_{j=1}^3 n_j^{t+1-j} w_t h_j^{t+1-j} \tau_j \\ T_{kt} &= \tau_k [\alpha Y_t - \delta_k K_t] \\ T_{ct} &= \tau_c \sum_{j=1}^4 c_j^{t+1-j} \end{aligned}$$

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

### 3.5. Aggregate equilibrium and the current account

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

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

$$\begin{aligned} F_t &= A_t - K_t - D_t \\ \text{with: } CA_t &= F_{t+1} - F_t = \Delta A_{t+1} - \Delta K_{t+1} - \Delta D_{t+1} \\ I_t &= \Delta K_{t+1} + \delta_k K_t \end{aligned}$$

## 4. Parameterization and empirical relevance of the model

The economic environment described above allows us to simulate the transitory and steady state growth and employment effects of various fiscal policy changes. This simulation exercise requires us first to parameterize and solve the model. In Section 4.1 we discuss our choice of preference and technology parameters. Starting from actual cross-country fiscal policy data in Section 4.2, we compare in Section 4.3 our model's predictions with the employment and growth differences that we have reported in Table 1. This comparison provides a first and simple test of our model's empirical relevance. In Section 5 we consider long-run equilibrium effects of policy changes. Section 6 discusses transitional dynamics, and welfare effects per generation. To solve the model and to perform the simulations, we choose an algorithm that preserves the non-linear nature of our model. We follow the methodology basically proposed by Boucekkine (1995) and implemented by Juillard (1996) in the program Dynare.

### 4.1. Preference and technology parameters

Table 2 contains an overview of all parameters. Following among others Barro (1990), we set the rate of time preference equal to 2% per year. Considering that periods in our model consist of 15 years, this choice implies a discount factor  $\beta$  equal to 0.74. With respect to effective labor, we assume a share coefficient  $1-\alpha$  equal to 0.7. This value is well in line with the literature. For example, King and Rebelo (1990) also model goods production as a function of effective labor (human capital) and

physical capital. They assume a value for  $1-\alpha$  equal to  $2/3$ . There is more controversy in the literature about the value of the intertemporal elasticity of substitution in leisure ( $1/\theta$ ). Micro studies often reveal very low elasticities. However, given our macro focus, these studies may not be the most relevant ones (Rogerson and Wallenius, 2009; Fiorito and Zanella, 2012). Rogerson (2007) also adopts a macro framework. He puts forward a reasonable range for  $\theta$  from 1 to 3 (Rogerson, 2007, p. 12). In line with this, we impose  $\theta$  to be equal to 2. The world real interest rate is assumed constant and equal to 3% per year, which is approximately the average real return on 10 year US government bonds in the last decade. Considering a period of 15 years, this implies that  $r = 0.558$ . Finally, we set the physical capital depreciation rate to 8% per year, which implies  $\delta_k=0.714$ . This value is also within the range of existing studies (see e.g. Heijdra and Romp, 2009).

A second series of parameters have been determined by calibration: three taste for leisure parameters ( $\gamma_1, \gamma_2, \gamma_3$ ), two parameters in the human capital production function (the efficiency parameter  $\phi$  and the scale parameter  $\sigma$ ), and the elasticity of substitution ( $\rho$ ) in the composite leisure function in Equation (4). We have calibrated these parameters to Belgium. We choose this country since it is one of the most open economies in the set of countries that we focus on. Moreover, the calculation of non-employment benefits and public pension benefits in Belgium fits exactly within the way we model it<sup>6</sup>. The parameters  $\gamma_1, \gamma_2, \gamma_3, \phi, \sigma$  and  $\rho$  have been determined such that with observed levels of the policy variables (tax rates, benefit replacement rates, pension replacement rate, etc.) and the observed level of schooling quality ( $q$ )<sup>7</sup> in Belgium, the model correctly predicts Belgium's employment rates ( $n_1, n_2, n_3$ ), per capita growth rate, education rate ( $e$ ) and effective retirement age ( $R$ ) in 1995-2007. Underlying performance and policy data are reported in Tables 1, 3 and 4. We find that the taste for leisure rises with age ( $\gamma_1=0.059, \gamma_2=0.110, \gamma_3=0.204$ ). Furthermore, we observe decreasing returns in human capital production ( $\sigma=0.837$ ), and a stronger degree of substitutability than in the Cobb-Douglas case between the two types of leisure for older workers ( $\rho = 1.60$ ).

Finally, we had no strong ex ante indication on two parameters in the human capital production function: the share parameter  $\nu$  and the elasticity of substitution parameter  $\kappa$ . We could assign sensible values to these parameters thanks to a sensitivity analysis on the results that we report in the next section. There we evaluate the capacity of our fiscal policy model to explain six important macro variables in 13 OECD countries. Although the influence of  $\nu$  and  $\kappa$  on the explanatory power of our model is very limited, our guideline to pin down specific values for these parameters (within a sensible range) was to minimize the deviation of our model's predictions from the true data<sup>8</sup>. This

<sup>6</sup> See footnote 5 for early retirement benefits. As to public pensions in Belgium, these are proportional to average annual labor income earned over a period of 45 years, with equal weights to all years (OECD, 2005).

<sup>7</sup> And with the values of two parameters in the human capital production function ( $\nu, \kappa$ ) that we discuss below (see also footnote 8).

<sup>8</sup> From our model's predictions and the true data for 13 countries we computed for each variable ( $n_1, n_2, n_3, e, R, growth$ ) the root mean squared error normalized to the mean. We minimized the average normalized RMSE over all six variables. More precisely, we adopted the following iterative procedure. We chose values for  $\nu$  and  $\kappa$  and then calibrated the efficiency parameter  $\phi$  and the scale parameter  $\sigma$ . The values for  $\nu$  and  $\kappa$  had no

procedure implied  $\nu=0.25$  and  $\kappa = 0.55$ . The result for  $\kappa$  reveals a higher degree of complementarity between private education time and government expenditures than in the Cobb-Douglas case. The result for  $\nu$  demonstrates relatively high importance for human capital formation of private education time versus productive public expenditures. Neither did we have an ex ante indication on the remaining parameters in the composite leisure function in Equation (4). We impose equal weight for both leisure types ( $\pi=0.5$ ). The normalisation parameter  $\Omega$  equals 2. The size of this parameter has no impact at all on our country predictions or simulation results.

**Table 2** Basic parameterization: preference and technology parameters

Production parameters (output)	$1 - \alpha = 0.7$
Effective human capital	$\phi = 3.553, \nu = 0.25, \kappa = 0.55, \sigma = 0.837$
Preference parameters	$\beta = 0.74, \theta = 2, \gamma_1 = 0.059, \gamma_2 = 0.110, \gamma_3 = 0.204$ $\pi = 0.5, \rho = 1.60, \Omega = 2$
World real interest rate	$r = 0.558$
Capital depreciation rate	$\delta_k = 0.714$

#### 4.2. Fiscal policy and education quality

Tables 3 and 4 describe key characteristics of fiscal policy in 1995-2001/2004. Our proxy for the tax rate on labor income concerns the total tax wedge, for which we report the marginal rate in %. The data cover personal income taxes, employee and employer social security contributions payable on wage earnings and payroll taxes. The OECD publishes these marginal tax data for eight family and income situations. Our data for  $\tau$  in Table 3 are the average of all these situations. We take this tax rate as a measure for all three active age groups. 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 simplifying 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.

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influence on the calibration results for  $\gamma_j$  and  $\rho$ . Given the obtained values for  $\phi$  and  $\sigma$ , we computed the average normalized RMSE over all six variables. We then checked whether changes in  $\nu$  and  $\kappa$ , and a recalibration of  $\sigma$  and  $\phi$ , could further reduce this statistic. We did this until no further reduction was possible.

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. 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 60<sup>th</sup> 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<sup>9</sup>. The data are expressed in

**Table 3** Fiscal policy (tax rates and government debt)

	tax rate on labor income (%)	consumption tax rate (%)	tax rate on capital income (%)	Government debt (% of GDP)
<b>Proxy for :</b>	$\tau_1, \tau_2, \tau_3$	$\tau_c$	$\tau_k$	$D/Y$
Austria	54.9	13.2	17.3	69.6
Belgium	67.2	13.4	27.1	117.4
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
<b>Overall country average</b>	52.5	14.3	22.1	70.6

Note: Labor tax rates are data for the total tax wedge, marginal rate (OECD, Taxing Wages). Data are for 2000-04. Earlier data are not available. For details, see Appendix 1. Capital tax rates are effective marginal corporate tax rates (Institute for Fiscal Studies, their EMTR; data for 1995-2001, see also Devereux et al., 2002). Consumption tax rate: see Dhont and Heylen (2009). Data for 1995-2001.

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 1). We take the outcome of this computation as a measure for all three active age groups, before early retirement. 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. The data are again expressed in percent of after-tax final wages. To assess the generosity of early retirement we integrate the information available via  $b$  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).

<sup>9</sup> 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](http://www.oecd.org/els/social/workincentives), Benefits and Wages, country specific files).

For details, see Appendix 1. We observe the most generous early retirement regimes in Belgium and Finland, whereas net early retirement benefits in Anglo-Saxon countries are much lower.

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

	Non-employment benefit (net replacement rate, %)	Early retirement benefit (net replacement rate, %)	Pension replacement rate (net, in %)	government consumption (% of GDP)	Government productive expenditure (% of GDP)	PISA – science (divided by 1000)	
Proxy for :	$b_1$ $b_2$ $b_{3a}$	$b_{3b}$	$b_4$	$g_c$	$g_y$ $educ$	$q$	
Austria	56.3	71.6	88.9	14.6	8.8	5.9	0.507
Belgium	59.6	79.0	63.1	16.9	7.9	5.5	0.505
France	46.0	63.8	68.8	18.3	10.2	5.9	0.502
Germany	64.7	70.8	71.8	15.3	7.9	4.7	0.502
Italy	17.0	55.7	88.8	14.3	7.8	4.8	0.480
Netherlands	55.0	68.1	84.1	18.4	8.9	5.0	0.525
Denmark	61.9	43.2	54.1	18.4	11.4	8.2	0.484
Finland	61.3	73.8	78.8	16.0	10.8	6.6	0.550
Norway	56.9	39.9	65.1	14.7	11.6	7.4	0.490
Sweden	55.4	39.0	68.2	20.0	12.6	7.9	0.507
UK	51.1	39.4	47.6	14.4	7.0	4.9	0.523
US	30.5	18.3	51.0	10.3	9.2	5.2	0.493
Canada	44.4	27.0	57.1	14.7	8.9	5.9	0.527
Overall average	52.2	53.8	68.3	15.9	9.5	6.0	0.507

Notes: A description of all variables is given in the main text. For more details, see Appendix 1. The data for the net benefit replacement rates are an average for 2001-2004 (earlier data are not available). The pension replacement rate concerns 2002 (OECD, 2005, p. 52). The data for government consumption and productive expenditures concern 1995-2001. The PISA science scores are an average for 2000, 2003 and 2006.

Our data for the net old-age pension replacement rate  $b_4$  concern an individual with mean earnings before retirement. The data include only (quasi-)mandatory pension programs, and are expressed in percent of this individual's average lifetime net labor income, as is the case in our Equation (11). Voluntary occupational pensions are not included. The overall average replacement rate is 68.3%, but there are strong cross-country differences (OECD, 2005, p. 52).

Our data for productive government expenditures ( $g_y$ ) in Table 4 include education, training as part of active labor market policy, government financed R&D and public investment. As can be seen, we also report education expenditures separately. On average, education expenditures constitute a little more than 60 % of total  $g_y$ . Government consumption includes wage and non-wage consumption, net of public education outlays going to wages and working-expenses. The latter are included in productive expenditures. As a final variable in Table 4 we include PISA science scores. We use these data as a proxy for the quality of schooling ( $q$ ) in the human capital production function (17). We concentrate on science scores given their expected closer link to growth (Barro, 2001). Although available PISA scores relate to secondary education, we do not see this as a weakness. PISA scores

may be very informative about the quality with which young people enter tertiary education. Quality at entrance should have a positive influence on people's capacity to learn and to raise human capital during tertiary education. Furthermore, PISA scores have been found empirically very significant for growth (Hanushek and Woessmann, 2009, 2011). Finally, these scores are easily available for all countries. Note that there is no correlation at all in Table 4 between productive government expenditures and the PISA score. Correlation is -0.07. Correlation between public education expenditures and the PISA score is -0.12. Both variables seem to tell different stories (see also Woessmann, 2003).

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

In this section we confront our model's predictions with the facts that we have reported in Table 1. The main idea is to test (and show) the model's empirical validity before using it for policy analysis. Even if this exercise is subject to various limitations<sup>10</sup>, it is important. A first reason goes back to Stokey and Rebelo's (1995) observation of an extreme variation in the predictions of existing calibrated fiscal policy models. Results seem to be very sensitive to the choice of some parameters. Careful calibration seems no guarantee for reliable predictions. We here do not want to add just another series of computed fiscal policy effects, even if they are derived from a model which explains all key variables endogenously within one framework. We also want additional evidence that these computed effects are realistic and reliable. A second motivation for this test is that, like most models, our model is highly stylized, and may miss potential determinants of growth or employment. For example, assuming perfect competition, we disregard differences in labor and product market institutions, which some authors consider of crucial importance (see e.g. Nickell, Nunziata and Ochel, 2005; Aghion and Howitt, 2006). Also, our model assigns a key role to investment in human capital for growth. However, despite the major role of the human capital production in a lot of work on growth, the literature provides no hard empirical evidence on this function and its determinants. Our specification of the effective human capital growth rate in Equation (17) as a CES function of education time and productive government spending in % of GDP, and with the quality of schooling (PISA) entering in a multiplicative way as an overall productivity parameter, is not standard in the literature. If our specifications or assumptions were flawed, or if crucial elements for an analysis of fiscal policy effects are missing in our model, one may expect a confrontation of the model's predictions with the true data to reveal this.

We proceed as follows. Our calibration implies that our model's prediction perfectly matches employment rates by age, the effective retirement age of older workers, education, and per capita growth in Belgium. A test of the model's validity is whether it can also match the data for the other countries, and cross-country differences. To obtain individual country predictions we impose the

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<sup>10</sup> For example, 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. Also, this exercise only concerns the last 15 years. Due to lack of data – especially with respect to marginal labor tax rates and non-employment benefits before the mid 1990s – it is impossible for us to relate changes in growth and employment to changes in policy within countries over longer time periods.

same preference and technology parameters, reported in Table 2, on all countries. Only fiscal policy variables and education quality differ<sup>11</sup>. As a part of fiscal policy, lump sum transfers also differ across countries. Underlying our model's predictions for each country, is the assumption of a constant debt to GDP ratio at the level reported for that country in Table 3. Lump sum transfers adjust endogenously in Equation (23) to obtain this equilibrium debt to GDP ratio.

Simulating the model for each individual country we find that its predictions match the main facts in most countries. We conclude that the model translates observable policy differences into performance differences which are roughly in line with observations in the data.

Figures 2 to 4 relate our model's predictions for three employment rates to actual observations for all countries. We add the 45°-line to assess the absolute differences between predictions and facts, as well as the coefficient of correlation between predictions and facts. Our model performs quite well. In each age group, it correctly predicts high employment rates in the US and Canada, and low employment in Germany. For young workers it also correctly predicts relatively low employment in most other countries of the core euro area, and in the Nordic countries. For older workers it has relatively high employment right in the Nordic countries. Overall correlation between the model's predictions and the actual data in Figure 1 is 0.31. If we drop Italy, for which there are good reasons<sup>12</sup>, this rises to 0.61. Correlation in Figure 2 is 0.52, in Figure 3 it is 0.78. Moreover, in each figure - again after dropping Italy from Figure 1 - the regression line (not shown) is close to the 45°-line, which suggests that our model correctly assesses the size of the employment effects of policy differences across countries. Next to Italy, there are a few other countries, where our model somewhat over- or underpredicts. The model's employment predictions tend to be too high for France, Italy and (except in Figure 1) the Netherlands. They tend to be too low in general for Finland. All in all, however, our model matches actual employment rates quite well for a large majority of countries. Given all underlying assumptions, we basically confirm earlier results of Ohanian *et al.* (2008), Dhont and Heylen (2008) and Erosa *et al.* (2012) that fiscal policy differences, rather than variation in taste for leisure or different market rigidities, are critical to explain cross-country variation in labor market performance.

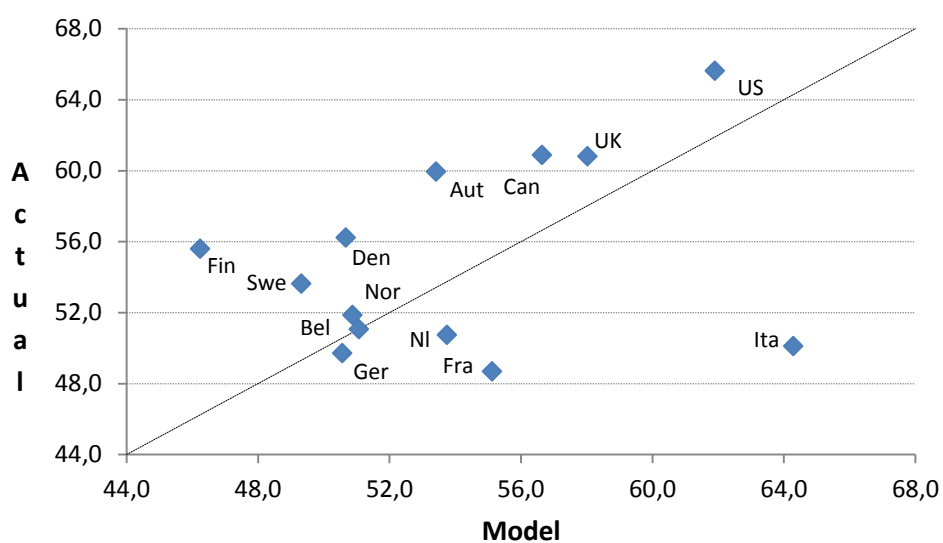
Figure 5 relates our model's predictions to the facts for the effective retirement age. The model again captures the large differences between countries. It predicts the highest retirement age in the Anglo-Saxon and Nordic countries and a much lower retirement age in core euro area countries. Correlation between actual data and the model's predictions is 0.91.

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<sup>11</sup> A similar approach has been adopted before by Dhont and Heylen (2008), Alonso-Ortiz (2011) and Erosa *et al.* (2012).

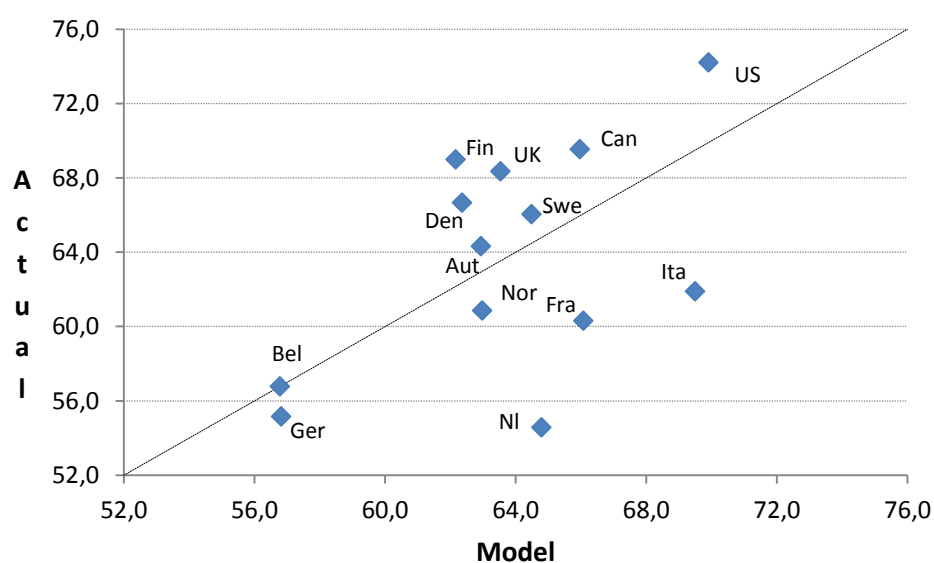
<sup>12</sup> A major element behind the deviation for this country seems to be underestimation of the fallback income position for structurally non-employed young workers. OECD data show very low replacement rates in Italy. However, as shown by Reyneri (1994), the gap between Italy and other European countries is much smaller than it seems. Reyneri (1994) points to the importance of family support as an alternative to unemployment benefits. Fernández Cordon (2001) shows that in Italy young people live much longer with their parents than in other countries. In 1995 for example about 56% of people aged 25-29 were still living with their parents in Italy. In about all other countries this fraction was below 23%. Of all non-working males aged 25-29 in Italy more than 80% were living with their parents. In France or Germany the corresponding numbers were close to 40%.

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



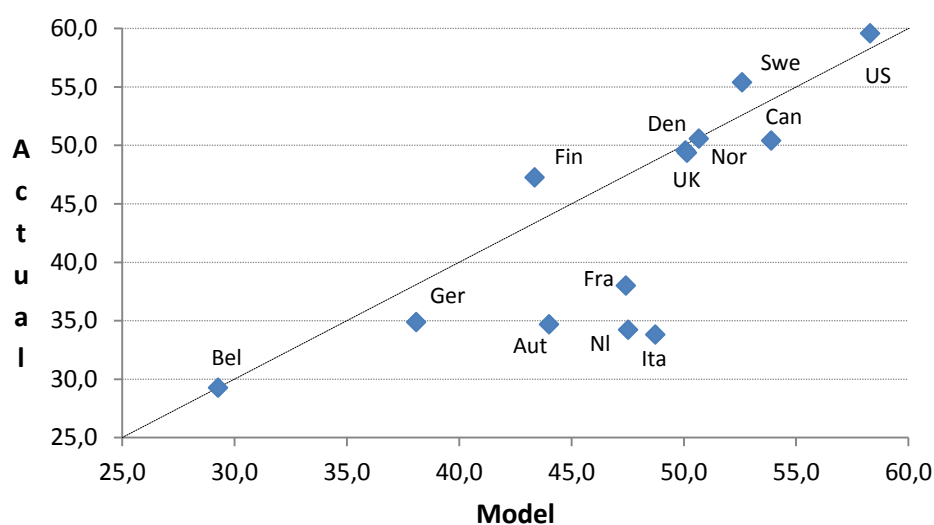
Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.31. Excluding Italy correlation rises to 0.61.

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



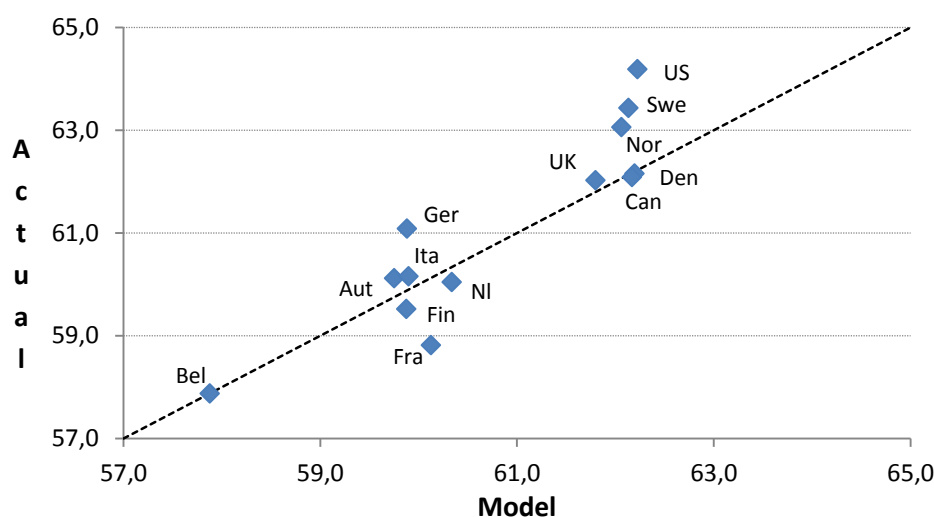
Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.52.

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



Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.78.

**Figure 5.** Effective retirement age, 1995-2006



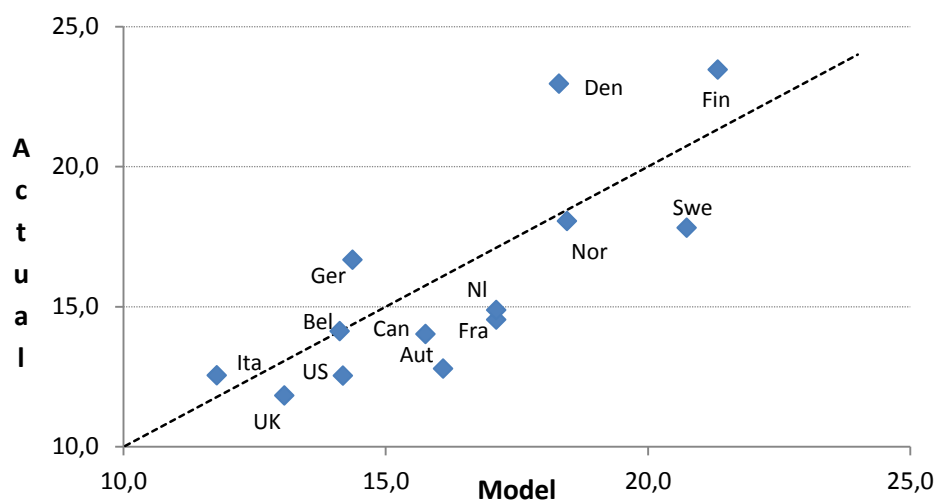
Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.91.

In Figures 6 and 7 we relate our model's predictions to the facts for education and growth. For education, the model correctly captures key differences between the Nordic countries on the one hand and countries like the UK and Italy on the other. Predictions for education are quite close to the 45°-line for all individual countries except Denmark, Sweden and Austria. Our model also has important cross-country differences right for growth. It has difficulty, however, to explain observed growth for France and the UK. Correlation between the model's predictions and the true data is 0.78 for education, and 0.73 for growth. For both variables the regression line is again very close to the 45°-line.

The model's good performance for education and growth is strongly related to our specification of the effective human capital production in Equation (17). We have adopted various alternative

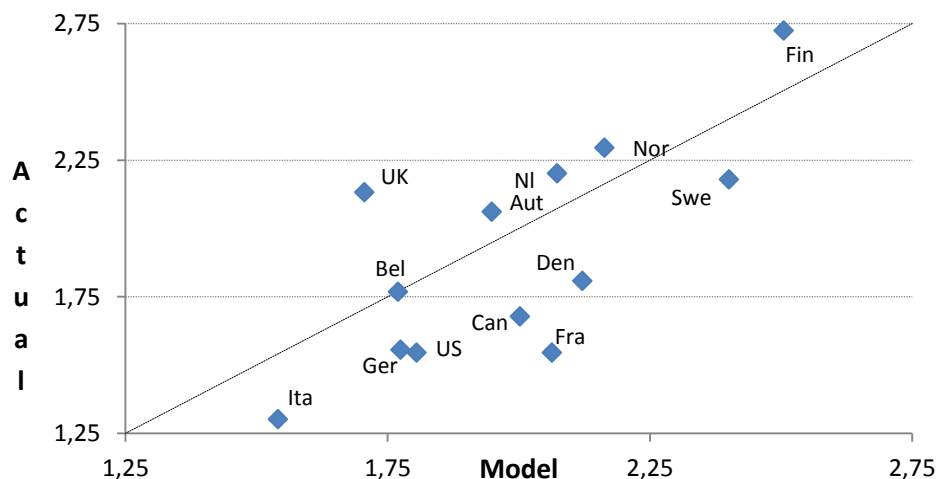
specifications where we (i) disregard differences in the quality of schooling (PISA) across countries (i.e. drop  $q$ ), (ii) impose a Cobb-Douglas human capital production function ( $\kappa \rightarrow 1$ ), (iii) include only education expenditures instead of total productive expenditures, and (iv) disregard productive government expenditures (i.e. impose  $v = 0$ ). Compared to the specification adopted in this paper, all these alternatives imply a match between predictions and facts which is (much) less good<sup>13</sup>. Explanatory power falls most in (iv) when we drop productive government expenditures and in (ii) when we move to a Cobb-Douglas specification. We also observe a significant fall in explanatory power for growth when we neglect quality of education differences. Here our results confirm Hanushek and Woessmann's (2009, 2011) findings.

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



Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.78.

**Figure 7.** Annual per capita potential GDP growth in 13 countries, in %, 1995-2007



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

<sup>13</sup> The (minimized) average root mean squared error normalized to the mean over our six endogenous variables of interest is always higher. See also footnote 8. More details are available upon request.

## 5. Numerical steady state 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 individual policy variables for the employment rate of three age groups, aggregate employment, and growth. In this section we focus on steady state effects. The next section discusses transitional dynamics as well as welfare effects per generation. The particular pattern of transitory effects implies that subsequent generations' welfare may be affected differently.

### 5.1. Basic setup

We consider the effects of reductions in tax rates on labor, consumption and capital, reductions in non-employment benefit replacement rates, and increases in government expenditures. All shocks are therefore expected to increase employment. Starting from budget balance, we impose in each scenario a permanent shock of the same size, equal to 2% of initial output. More precisely, if everything else remained unchanged, each single policy measure would have an effect on the government budget balance equal to 2% of GDP. The benchmark from which we start, and against which all policy shocks are evaluated, is the average for the six core euro area countries in our sample (see Table 1)<sup>14</sup>. Table 5 considers the effects of policy changes on steady state growth and employment, assuming that policy changes are financed by changes in lump sum transfers ( $z$ ) to maintain budget balance. The total change in lump sum transfers is indicated at the bottom of the table. It is spread equally among all living generations. In Table 6 we assume shocks to be compensated by a change in another fiscal policy variable. Throughout all our policy simulations the ratio of public debt to GDP remains constant.

### 5.2. Employment effects (lump sum financed policies)

Our results in Table 5 allow us to establish a ranking of individual policy measures in their steady state effects on employment. If we are guided by aggregate employment  $n$ , cuts in non-employment benefit replacement rates are by far the most effective. We find that an overall reduction of the net benefit replacement rate by 9.3%-points raises the aggregate employment rate in hours by 2.44%-points. Considering that the aggregate employment rate in hours in the benchmark is about 55%, the corresponding increase in the volume of hours worked ( $N$ ) is 4.45%. A more targeted approach where only particular age groups are affected by a change in benefits does not bring larger aggregate employment gains. Effects on the target group itself are stronger of course, but this stronger effect may be counteracted by a reduction of labor supply and employment among other age groups (intertemporal substitution). On the other hand, the particular need in many countries to encourage labor supply among older workers and postponement of retirement, may make more focus on this group crucial. Among all policy measures (of the same size) in Table 5, we observe the strongest

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<sup>14</sup> 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.

employment effect for the group of older workers ( $n_3$ ) from reducing both the standard non-employment benefit after the age of 50 ( $b_{3a}$ ) and the early retirement benefit ( $b_{3b}$ ). If an increase in the effective retirement age ( $R$ ) is the main goal, priority should be given to a reduction of early retirement benefits only, maintaining non-employment benefits at younger ages. This policy still has considerable aggregate employment effects. It would raise the aggregate employment rate in hours by 1.93%-points, total hours worked by 3.51%, and the effective retirement age by 2.35 years.

Second in our ranking of policies to promote employment, is a reduction of labor tax rates. Like a reduction of non-employment benefits, this also raises the marginal utility of work versus inactivity. A comparable overall labor tax rate cut by 2.9%-points would increase the aggregate employment rate by 0.87%-points, and the volume of hours worked ( $N$ ) by 1.59%. In the case of labor taxes, however, a targeted approach could be more effective than an overall change. Employment effects are the stronger when tax cuts are focused on young workers and older workers. Low actual employment among these age groups implies the lowest disutility from additional work. As to the size of tax effects, our results for overall labor tax cuts tend to be in the middle of existing studies. Effects are smaller than those obtained by Prescott (2004), Rogerson (2007) and Dhont and Heylen (2009), but larger than those of Turnovsky (2000). Our results are in the same range as those obtained by Coenen *et al.* (2008).

Lower consumption taxes and lower capital taxes also promote work in our model, but their effects are smaller than those of labor tax cuts (which is in line with the literature). A reduction of consumption taxes raises the return to working since the same wages buy more goods. The effect on employment will be smaller than in the case of labor tax cuts since also the non-employed fully enjoy the benefit of lower consumption taxes. A reduction of capital taxes stimulates the inflow of physical capital, which permanently raises labor productivity and wages. Higher wages introduce a positive substitution effect, which encourages individuals to supply labor. This positive effect will be partly offset however due to the income effect from permanently higher productivity, which raises demand for 'leisure'. Positive net employment effects in Table 5 are mainly due to the reduction in lump sum transfers imposed on workers by the government to finance the capital tax cuts. The same negative income effect caused by a reduction of lump sum transfers also explains the rise of labor supply and employment when the government raises public consumption.

The effects of higher productive expenditures on employment are comparable to those of a reduction in capital taxes. They induce higher productivity and have to be financed by a fall in lump sum transfers. The main difference is that higher productivity here is to an important extent dependent on, and related to, young workers' education. Higher productive expenditures encourage young individuals to study rather than work. They shift part of this work to later periods of life. In net terms we observe that a 2% of output increase in productive government expenditures implies a slight decline in the aggregate employment rate by 0.20%-points. The volume of hours worked would fall by 0.37%. These effects are less favorable than those obtained by Turnovsky (2000) and Dhont and Heylen (2009). In their models, however, individuals do not allocate time to education.

**Table 5.** Effects of fiscal shocks equal to 2% of output, compensated by changes in lump sum transfers (z) – benchmark: average of six core euro area countries

Change in policy variable <sup>(a)</sup>	$\Delta\tau_1=\Delta\tau_2=\Delta\tau_3=-2.9$	$\Delta\tau_1=-7.8$	$\Delta\tau_2=-6.8$	$\Delta\tau_3=-13.2$	$\Delta\tau_c=-4.1$	$\Delta\tau_k=-13.2$	$\Delta b_1=\Delta b_2$ $\Delta b_{3a}=\Delta b_{3b}=-9.3$	$\Delta b_1=-34.1$	$\Delta b_2=-27.7$	$\Delta b_{3a}=\Delta b_{3b}=-23.5$	$\Delta b_{3b}=-37.5$	$\Delta g_c=+2.0$	$\Delta g_y=+2.0$
Effect <sup>(b)</sup> :													
$\Delta n_1$	0.53	5.55	-2.53	-3.19	0.24	0.27	2.27	5.97	0.39	0.20	0.15	0.35	-2.70
$\Delta n_2$	0.84	-0.80	2.59	-0.02	0.47	0.54	1.82	-0.46	5.75	-0.72	-0.60	0.56	0.87
$\Delta n_3$	1.31	-1.24	-0.01	7.09	0.73	0.84	3.45	-0.71	-0.91	8.71	7.24	0.87	1.36
$\Delta R$ <sup>(c)</sup>	0.12	-0.12	0.00	0.67	0.07	0.09	0.46	-0.07	-0.09	1.08	2.35	0.08	0.13
$\Delta e$	0.14	-3.32	2.25	2.83	0.12	0.13	-0.60	-0.08	-0.77	-0.69	-0.56	0.09	2.83
$\Delta n$ <sup>(b, d)</sup>	0.87	1.23	0.10	0.96	0.47	0.53	2.44	1.65	2.00	2.33	1.93	0.58	-0.20
$\Delta N/N$ <sup>(e)</sup>	1.59	2.25	0.18	1.75	0.85	0.97	4.45	3.01	3.64	4.24	3.51	1.06	-0.37
$\Delta$ annual growth rate <sup>(b)</sup>	0.01	-0.22	0.13	0.16	0.01	0.01	-0.04	0.00	-0.05	-0.04	-0.03	0.01	0.27
$\Delta z$ ex-post <sup>(f)</sup>	-2.57	-2.98	-2.39	-3.05	-1.74	-1.99	2.83	2.36	2.32	2.62	2.17	-1.96	-1.47

Notes : (a) change in policy variable, in percentage points

(b) difference in percentage points between new steady state and benchmark, except  $\Delta N/N$

(c) change in optimal effective retirement age in years

(d) change in (weighted) aggregate employment rate in hours

(e) change in volume of employment in hours, in %. Approximately,  $\Delta N/N = \Delta n/n$  with N total hours worked (and assuming potential hours constant)

(f) change in lump sum transfer (as a fraction of output) to maintain budget balance, in %-points.

### 5.3. Education and growth effects (lump sum financed policies)

To promote long-run growth, three policy measures stand out as most effective: a cut in labor taxes on middle-aged workers, a cut in labor taxes on older workers, and an increase in productive government expenditures. Our results in Table 5 predict positive effects on the steady state annual growth rate of 0.13 to 0.16%-points in the first two cases and 0.27%-points in the third. Each of these policy measures raise hours worked and after-tax wages when middle-aged and older. Since these variables are key components of the lifetime return to investing in human capital when young, individuals will study more. The education rate among young individuals rises by about 2.3 to 2.8%-points. Thanks to the positive externalities caused by human capital accumulation, any increase of investment in education has permanent growth effects. An increase in productive government expenditures generates the strongest rise in growth since this measure also directly improves the productivity of education in Equation (17).

The effects from other policy measures on growth are much smaller or even negative. Most striking are the negative growth effects from labor tax cuts on the young generation. These tax cuts raise the opportunity cost of studying, which discourages human capital accumulation. The negative growth effects from labor tax cuts on the young also explain why overall (labor) tax cuts have only marginal

growth effects. Cuts in benefit replacement rates also have limited negative growth effects. The reason is that benefits in our model are linked to wages and effective human capital. A lower replacement rate especially in the second or the third period of active life then reduces the expected return to studying when young, and participation in education. Our model's prediction that overall changes in labor tax rates have only very limited growth effects, is in line with often cited empirical findings by Mendoza *et al.* (1997). Positive links between social security, education and growth have been demonstrated earlier by e.g. Zhang (1995) and Zhang and Zhang (2004).

The steady state growth effects of a reduction in capital tax rates are also positive, but almost negligible. Clearly, this does not exclude significant and permanent output *level* effects. As we show in the next Section, among all simulated policy shocks, we observe the strongest 'short-run' output gain when capital tax rates are cut. Capital inflow and rising employment explain this output gain. In the long run, output remains about 5% above the benchmark after a 13.2%-points capital tax rate cut. This increase is substantial, and larger than in a recent study by Bettendorf *et al.* (2009). It is smaller, however, than the strong effects reported by e.g. Arnold *et al.* (2011).

#### 5.4. Employment, education and growth effects from combined fiscal policy changes

In Table 6 we show the results of (maybe more realistic) combined fiscal policy changes. The size of the initial shock is again equal to 2% of output, but now it is financed by change in another fiscal policy variable. The results are in line with those reported in Table 5. To obtain a significant increase in employment, cuts in benefits seem unavoidable. A shift of taxes from labor to consumption has positive effects, but they are much more limited. So are the effects of a labor tax cut financed by lower government consumption (not shown in the Table).

However, to raise not only employment but also growth, it is of crucial importance how the government allocates the money that it saves by cutting benefits. Growth does not rise when savings are allocated to overall labor or consumption tax cuts. Overall benefit cuts have the strongest positive effects on employment, in particular among older workers, *and* growth when savings feed through into either tax cuts on older workers only, or higher productive expenditures. As to the latter, our simulations suggest that a budget neutral policy change involving an overall 9.3%-points cut in the net benefit replacement rate to finance higher productive expenditures would in the longer run imply an increase of average annual growth by 0.43%-points, an increase of the aggregate employment rate by 2.08%-points, and an increase of the employment rate among older workers by 5.73%-points. An important factor explaining the last result is the increase in the effective retirement age by 0.67 years. The long-run growth rate also rises strongly (+0.3%-points) when higher productive expenditures are financed by lower government consumption. In this case, however, aggregate employment falls moderately. Note that the same growth and employment effects follow when higher productive expenditures are financed by higher consumption taxes (not shown).

**Table 6.** Fiscal shocks in the model equal to 2% of output, compensated by a change in another fiscal policy variable – benchmark: average of six core euro area countries

Change in policy variable <sup>(a)</sup>	$\Delta\tau_1=\Delta\tau_2$ $=\Delta\tau_3$ =-2.9	$\Delta\tau_3=$ -13.2	$\Delta b_1=\Delta b_2$ $\Delta b_{3a}=\Delta b_{3b}$ =-9.3	$\Delta b_1=\Delta b_2$ $\Delta b_{3a}=\Delta b_{3b}$ =-9.3	$\Delta b_1=\Delta b_2$ $\Delta b_{3a}=\Delta b_{3b}$ =-9.3	$\Delta b_1=\Delta b_2$ $\Delta b_{3a}=\Delta b_{3b}$ =-9.3	$\Delta g_y=$ +2.0
Compensating change <sup>(f)</sup>	$\Delta\tau_c=$ 6.1	$\Delta\tau_c=$ 7.4	$\Delta\tau_1=\Delta\tau_2$ $=\Delta\tau_3$ =-3.2	$\Delta\tau_3$ =-12.6	$\Delta\tau_c=$ -6.5	$\Delta g_y=$ 3.6	$\Delta g_c=$ -1.5
Effect <sup>(b)</sup> :							
$\Delta n_1$	0.09	-3.73	2.81	-0.74	2.72	-2.37	-2.95
$\Delta n_2$	0.14	-0.88	2.75	1.82	2.59	3.30	0.45
$\Delta n_3$	0.22	5.92	4.87	9.90	4.63	5.73	0.70
$\Delta R^{(c)}$	0.02	0.56	0.59	1.05	0.57	0.67	0.00
$\Delta e$	0.02	2.68	-0.42	2.10	-0.45	4.31	2.75
$\Delta n^{(b, d)}$	0.15	0.12	3.38	3.29	3.22	2.08	-0.63
$\Delta N/N^{(e)}$	0.27	0.22	6.17	6.00	5.87	3.79	-1.15
$\Delta$ annual growth rate <sup>(b)</sup>	0.00	0.15	-0.03	0.12	-0.03	0.43	0.27

Notes : (a) change in policy variable, in percentage points

(b) difference in percentage points between new steady state and benchmark, except  $\Delta N/N$ .

(c) change in optimal effective retirement age in years

(d) change in (weighted) aggregate employment rate in hours

(e) change in volume of employment in hours, in %

(f) compensating change, in percentage points

## 6. Transitional dynamics and welfare effects per generation

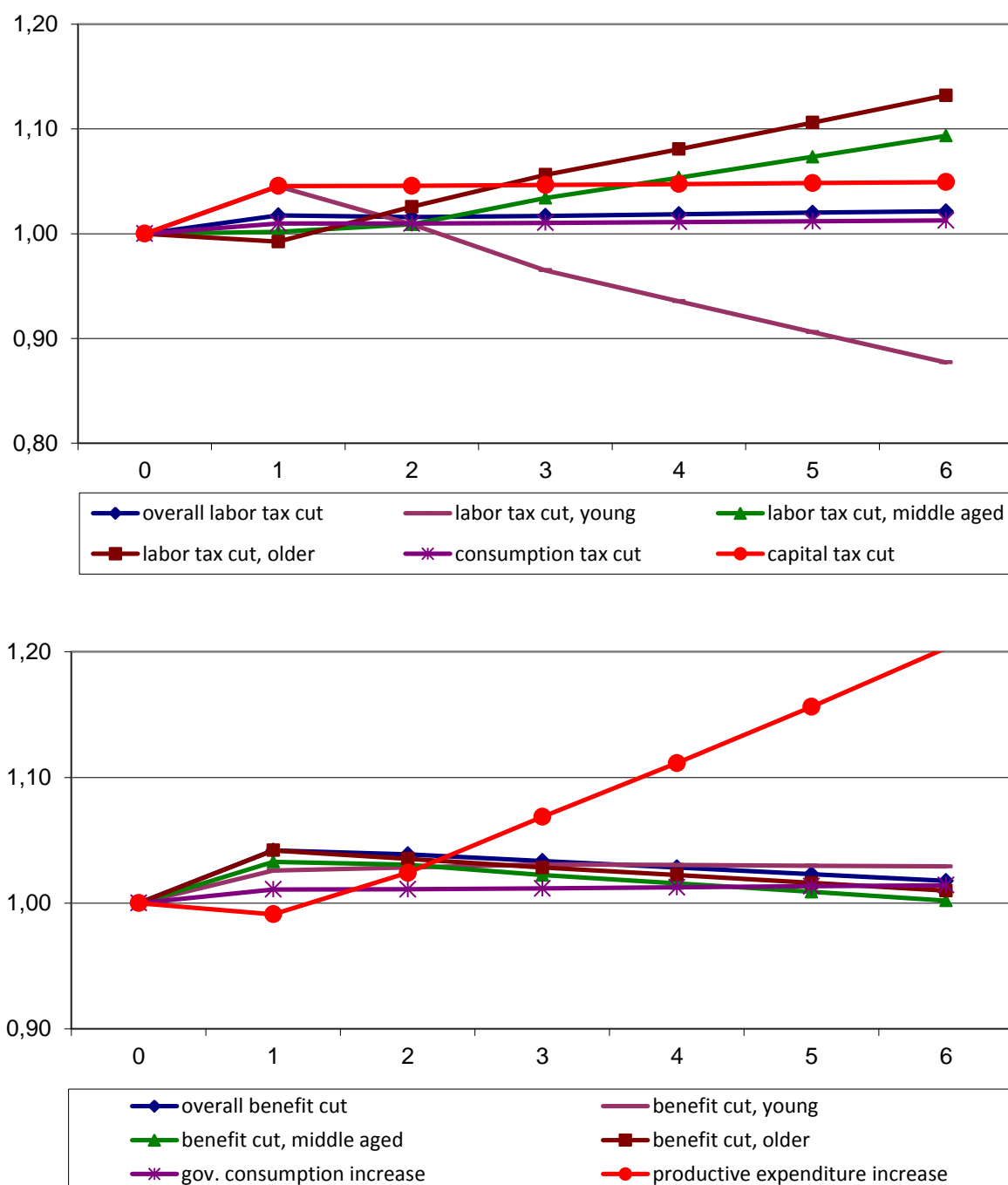
We now describe the transitory adjustment path of key variables, including welfare, after the fiscal policy changes discussed in the previous section. We assume that these policy changes are unanticipated and permanent.

Figure 8 shows the aggregate output level effects of the lump sum financed policy changes of Table 5. Policy measures are introduced at the beginning of period 1. As we have already mentioned, despite weak long-run growth effects, we observe the strongest output gain on impact when capital tax rates are cut. After one period (15 years) a 13.2%-point reduction of the capital tax rate raises output by about 5% compared to the benchmark. Long-run output gains are of the same size. The strongest ‘long-run’ output effects follow from an increase in productive expenditures. After 4 periods, output is 11% above the benchmark. After 5 periods that is almost 16% after. A cut in labor taxes on older workers follows next, with output being 11% higher after 5 periods. The ‘short-run’ output effects of these two policy changes are very close to zero, however. The reason is that they encourage the young to study, reducing employment in the short-run<sup>15</sup>. The opposite (i.e. a short-run output gain, but long-run output loss) occurs when labor tax rates on the young are cut. Finally,

<sup>15</sup> Employment effects after the policy changes reported in Table 5 are available upon request. In general, employment rates adjust to the new steady state reported in Table 5 quite rapidly.

despite strong employment gains, the output level effects of benefit reductions are very limited, both in the short and the long run. As we observed in Table 5, benefit reductions make all generations work more than in the benchmark, but human capital may be lower.

**Figure 8** Output level evolution after unanticipated and permanent lump sum financed policy shocks in period 1 (index, benchmark=1)



Figures 9 and 10 describe the evolution of the aggregate output level and the aggregate employment rate after more realistic, combined fiscal policy shocks (see Table 6). In line with the above, for strong output gains in the long-run, it is required either to increase productive expenditures or to cut labor taxes on older workers. The more effective way to finance these policies is to cut non-employment benefits. Figure 9 also shows that if these policies are financed by higher consumption taxes or lower government consumption, output may fall in the short run (period 1). The latter is related to the fall in employment (Figure 10).

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

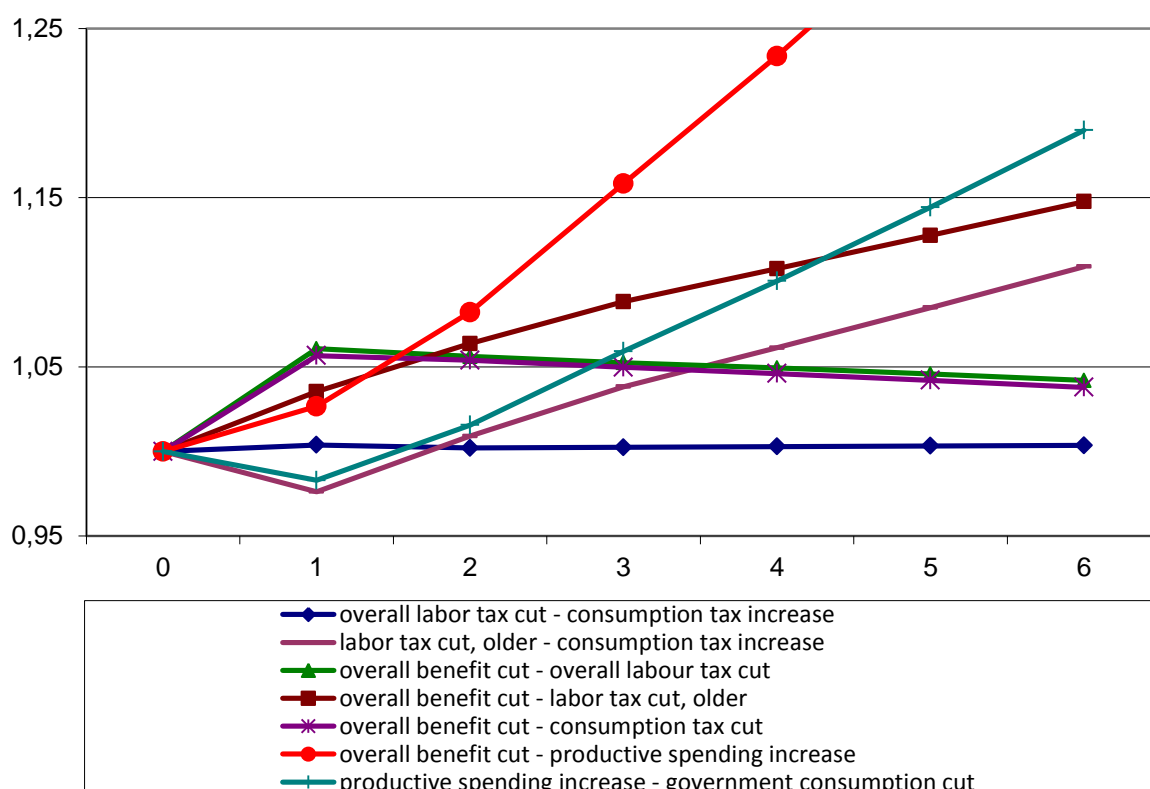
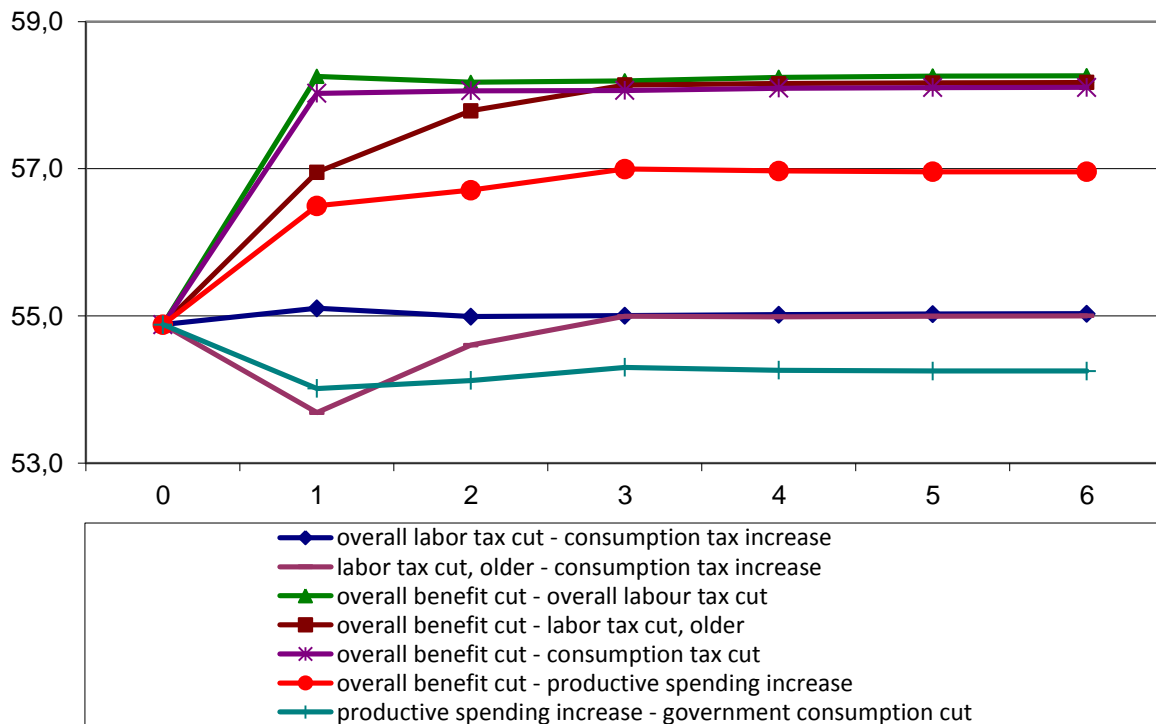


Figure 11 shows the welfare effects of these policy changes for current and future generations. We report on the vertical axis the welfare effect on the generation born in  $t+k$ , where  $k$  is indicated on the horizontal axis, and where  $t$  is the period when the (permanent, unanticipated) policy change is introduced. Our welfare measure is the (constant) percentage change in benchmark consumption in each period of remaining life that individuals should get to attain the same lifetime utility as after the policy shock (see also King and Rebelo, 1990). To compute this percentage change we keep employment rates at the benchmark. For example, concentrating on the first policy measure, an overall labor tax cut financed by higher consumption taxes implies welfare losses for the current retired ( $k=-3$ ) and older workers ( $k=-2$ ). The loss is equal to 4% of benchmark consumption for the retired and equal to 1% of benchmark consumption in each of the two remaining periods of life for the older workers. The current middle-aged ( $k=-1$ ) and young workers ( $k=0$ ) gain, but their gain is very limited (less than 1% of benchmark consumption). Future generations ( $k=+1, \dots, +4$ ) can also be expected to realize limited welfare gains. Considering the policy measures that contribute most to long-run output, we observe that these are also among the most favorable to the welfare of current

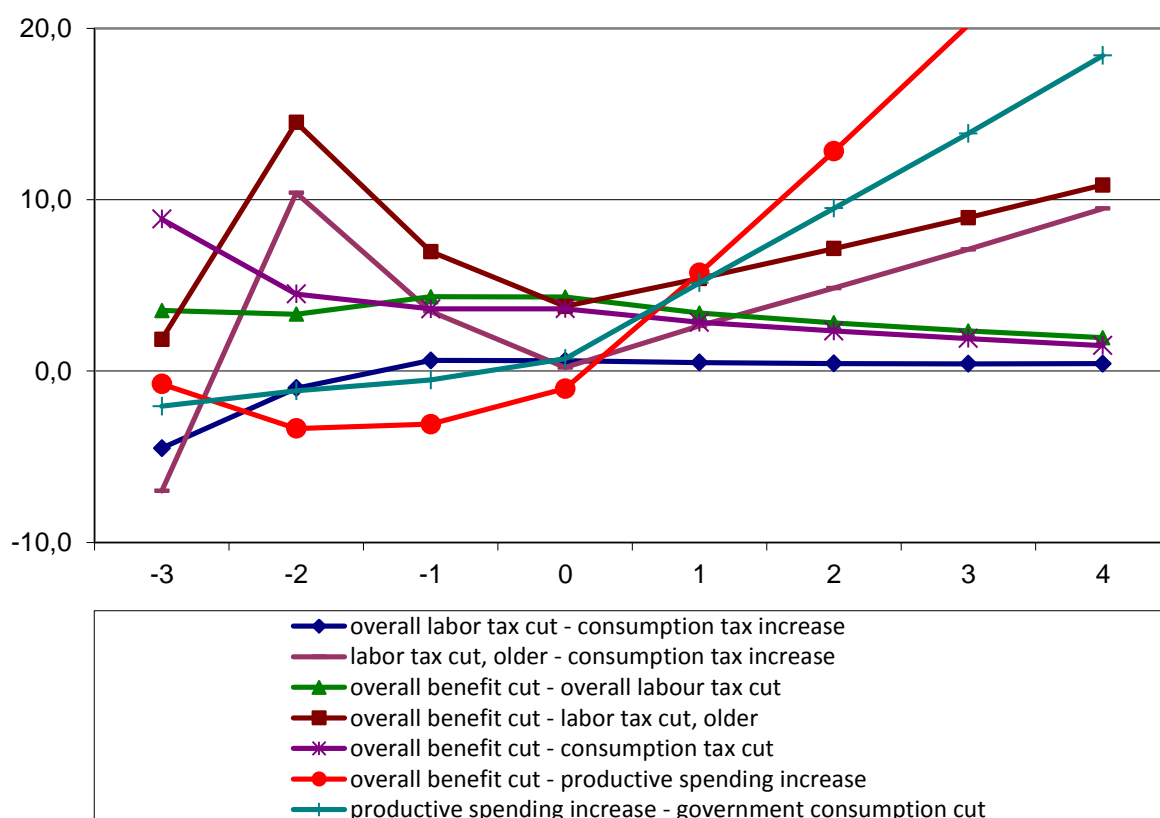
young and future generations. Labor tax cuts on older workers, financed by overall benefit reductions, are most likely to obtain support from the representative individual in each generation. Tax cuts on older workers financed by consumption taxes also raise the lifetime utility of current middle-aged and older workers, but they imply a strong welfare reduction for retired individuals. An increase of productive expenditures financed by overall benefit reductions, by lower government consumption or (not shown) by higher consumption taxes, is less likely to get support from current generations, despite its very positive long-run output effect. Current retired and older generations see no, or only a very small gain.<sup>16</sup>

**Figure 10.** Aggregate employment rate (in hours) after permanent policy shocks in period 1 (benchmark in period 0 is the initial steady state)



<sup>16</sup> Current young and future generations experience strong gains from substituting productive government spending for public consumption ( $\Delta g_y > 0$ ,  $\Delta g_c < 0$ ). Note, however, that this result partly reflects our assumption that public consumption is not useful to the individuals. Turnovsky (2000) and Dhont and Heylen (2009) do include public consumption in the individuals' utility function. In that case, welfare effects of substituting  $g_y$  for  $g_c$  are still positive, but much smaller than in the case where productive spending is financed by overall benefit cuts.

**Figure 11.** Welfare effects for current and future generations after fiscal policy changes



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  $k$ .

## 7. Conclusions

We study the effects of changes in the composition of fiscal policy in an open economy OLG model which explains hours of work among young, middle-aged and older workers, human capital formation by the young, and aggregate per capita growth, within one coherent framework. The government sets tax rates on labor, capital and consumption. It allocates its revenue to productive expenditures (mainly for education), consumption, non-employment benefits and pensions. Labor taxes and benefits may differ across age groups. Studying fiscal policy effects in a model where employment by age, education and human capital, and growth, are all endogenous, is the main contribution of this paper. Existing models explaining employment generally disregard growth, some exceptions notwithstanding. Models explaining education and growth generally disregard the labor-leisure choice and labor supply (by age).

We check the validity of our model and our calibration by simulating the model for 13 OECD countries and comparing its results with the true data. Imposing common technology and preference parameters but country-specific policy parameters, we find that the predictions of our model match the main facts quite well. A confrontation with the facts, in particular for education and growth, also allows us to reduce the uncertainty in existing literature about the human capital production function. The data prefer a specification where effective human capital is produced from both private

inputs (education time) and public inputs (productive government expenditures, mainly for education), with the degree of complementarity between them being much higher than in the Cobb-Douglas case. To match the data, it is very important also to account for the quality of schooling.

Our policy simulations reveal a clear ranking of policy measures in their effectiveness to promote employment and growth. As to employment, a reduction of non-employment benefit generosity has the strongest effects, followed by labor tax cuts. The employment effects of other policy measures, e.g. capital tax cuts or productive expenditure increases, are (much) more limited. Shifting taxes from labor to consumption has positive effects on employment, but these are very limited. Long-run output and growth are supported most by higher productive government expenditures. Furthermore, output and growth may benefit from 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 growth. By contrast, labor tax cuts targeted at younger workers and non-employment benefit reductions, imply lower future growth since they discourage the young to study. Finally, a reduction of capital tax rates has relatively strong positive and permanent effects on the level of output also, but almost negligible effects on long-run growth.

Rising pressure on the welfare state due to ageing, and the need to bring down high public debt to GDP ratios, force all OECD countries to develop effective employment and growth policies. The need to raise employment is particularly pressing in the euro area, and most so among older workers. A key implication of our results for fiscal policy in these countries is to cut non-employment benefits and to reallocate these resources to labor tax cuts on older workers and to higher productive expenditures (tertiary education, infrastructure). The US would also benefit strongly from higher productive expenditures. Non-employment benefits being low in the US, higher productive expenditures may be financed also by higher consumption taxes. From a welfare perspective, these policies are beneficial to current young and future generations, but only some are likely to get support from current older and retired individuals.

This paper gives room to various extensions, which we are currently exploiting. First, our results and policy implications have been derived under the assumption of homogeneous individuals per generation, each working the same hours, having the same talent to study, etc. Distributional issues between those within a generation who have high ability and those who have not, or between those who work a lot and those who live more on benefits, are therefore inexistent. In Van de Kerckhove and Heylen (2012) we allow for individuals with heterogeneous ability to build human capital. Second, we plan to pay more attention to important differences in school systems between countries, e.g. differences in tuition fees, study grants, and education quality. The empirical importance of such differences has been demonstrated most clearly recently by Hanushek and Woessmann (2011).

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## Appendix 1: Construction of data and data sources

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

### ***Employment rate in hours (in one of three age groups, 1995-2007)***

*Definition:* total actual hours worked by individuals in the age group / potential hours worked.

Actual hours worked = total employment in persons x average hours worked per week x average number of weeks worked per year

Potential hours = total population in the age group x 2080 (where 2080 = 52 weeks per year x 40 hours per week)

*Data sources:*

\* Total employment in the age group / total population in the age group: OECD Stat, Labour Force Statistics by Sex and Age. Data are available for many age groups, among which 20-24, 25-34, 35-44, 45-49, 50-54, 55-64. We constructed the data for our three age groups as weighted averages.

\* Average hours worked per week: OECD Stat, Labour Force Statistics, Average usual weekly hours worked on the main job. These data are available only for age groups 15-24, 25-54, 55-64. We use the OECD data for the age group 15-24 as a proxy for our age subgroup 20-24, the OECD data for the age group 25-54 as a proxy for our age (sub)groups 25-34, 35-49 and 50-54.

\* Average number of weeks worked per year: Due to lack of further detail, we use the same data for each age group. The average number of weeks worked per year has been approximated by dividing average annual hours actually worked per worker (total employment) by average usual weekly hours worked on the main job by all workers (total employment). Data source: OECD Stat, Labour Force Statistics, Hours worked.

### ***Education rate of the young (age group 20-34, 1995-2007)***

*Definition:* total hours studied by individuals of age 20-34 / potential hours studied

As a proxy we have computed the ratio:  $(fts_{20-34} + 0.5pts_{20-24} + 0.25pts_{25-34}) / pop_{20-34}$

with: *fts* the number of full-time students in the age group 20-34

*pts* the number of part-time students in the age groups 20-24 and 25-34.

*pop* total population of age 20-34

Full-time students are assumed to spend all their time studying. For part-time students of age 20-24 we make the assumption (for all countries) that they spend 50% of their time studying, part-time students of age 25-34 are assumed to spend 25% of their time studying. Due to the limited number of part-time students, these specific weights matter very little.

*Data sources:*

\* Full-time students in age groups 20-24, 25-29, 30-34: OECD Stat, Education and Training, Students enrolled by age (all levels of education, all educational programmes, full-time)

\* Part-time students in age groups 20-24, 25-29, 30-34: OECD Stat, Education and Training, Students enrolled by age (all levels of education, all educational programmes). We subtracted the data for full-time students from those for 'full-time and part-time students'.

Data are available in 1995-2007. However, for several countries (quite) some years are missing. Period averages are computed on the basis of all available annual data.

***Average effective retirement age (1995-2006)***

*Definition:* Average age of all persons (being 40 or older) withdrawing from the labor force in a given period.

*Data sources:*

\* OECD, Ageing and Employment Policies – Statistics on average effective age of retirement

***Annual real potential per capita GDP growth rate (aggregate, 1995-2007)***

*Definition:* Annual growth rate of real potential GDP per person of working age

*Data sources:*

\* real potential GDP: OECD Statistical Compendium, Economic Outlook, supply block, series GDPVTR.

\* population at working age: OECD Statistical Compendium, Economic Outlook, labour markets, series POPT.

***Tax rate on labor income ( $\tau_j$  for  $j=1,2,3$ )***

*Definition:* Total tax wedge, marginal tax rate in % of gross wage earnings. The data cover personal income taxes, employee and employer social security contributions payable on wage earnings and payroll taxes.

*Data source:* OECD, Statistical Compendium, Financial and Fiscal Affairs, Taxing Wages, Comparative tax rates and benefits (new definition).

The OECD publishes 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 rates ( $b_j$  for  $j=1,2,3a$ )***

*Definition:* The data concern net transfers received by long-term unemployed people and include social assistance, family benefits and housing benefits in the 60<sup>th</sup> month of benefit receipt. They also include unemployment insurance or unemployment assistance benefits if these benefits are still

paid, i.e. if workers can be structurally unemployed for more than five years without losing benefit eligibility. The data are expressed in % of after-tax wages. The OECD provides net replacement rates for six family situations and three earnings levels. Our data in Table 4 are the averages of these 18 cases. Data for 2001-04.

*Data source:* OECD, Tax-Benefit Models, [www.oecd.org/els/social/workincentives](http://www.oecd.org/els/social/workincentives)

*Data adjustment:* Original OECD data for Norway include the so-called “waiting benefit” (ventestønad), which a person could get after running out of unemployment benefits. Given the conditional nature of these “waiting benefits”, they do not match our definition of benefits paid to structurally non-employed individuals. We have therefore deducted them from the OECD data, which led to a reduction of net replacement rates by about 19 percentage points. For example, recipients should demonstrate high regional mobility and willingness to take a job anywhere in Norway. The “waiting benefit” was terminated in 2008. We thank Tatiana Gordine at the OECD for clarifying this issue with us.

### **Early retirement replacement rates ( $b_{3b}$ )**

To calculate our proxy for  $b_{3b}$  we have focused on the possibility for older workers in some countries to leave the labor market along fairly generous early retirement routes. Duval (2003) and Brandt *et al.* (2005) provide data for the so-called implicit tax rate on continued work for five more years in the early retirement route at age 55 and age 60. The idea is as follows. If an individual stops working (instead of continuing for five more years), he receives a benefit (early retirement, disability...) and no longer pays contributions for his future pension. A potential disadvantage is that he may receive a lower pension later, since he contributed less during active life. Duval (2003) calculated the difference between the present value of the gains and the costs of early retirement, in percent of gross earnings before retirement. We use his data as a proxy for the gross benefit replacement rate for older workers in the early retirement route. To compute the net benefit replacement rate, we assume the same tax rate on early retirement benefits as on unemployment benefits. We call this net benefit replacement rate  $r_{er}$ . 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 ( $b_{3b}$ ) will be a weighted average of  $r_{er}$  and  $b_{3a}$ , where we take the latter as a proxy for the replacement rate in alternative social transfer programs. If  $r_{er} > b_{3a}$ , older workers will aim for the official early retirement route, but they may not all meet eligibility criteria and have to fall back on alternative programs. If  $r_{er} < b_{3a}$ , workers will aim for the alternative, but again they may not be eligible. We propose that  $b_{3b} = \xi b_{3a} + (1-\xi)r_{er}$ . Underlying the data in Table 4 is the assumption that  $\xi=0.5$ . Correlation between  $b_{3b}$  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  $\xi$ .

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

***Net pension replacement rates ( $b_4$ )***

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 with average earnings.

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### **CHAPTER 3**

## **Heterogeneous ability and the effects of fiscal policies on employment and growth**

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# Heterogeneous ability and the effects of fiscal policies on employment and growth

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## Abstract

We build and parameterize a general equilibrium OLG model for an open economy to jointly study hours of work of young, middle aged and older individuals, education of the young, and aggregate growth. We distinguish within each age group three types of individuals, with high, medium or low ability to build human capital. The composition of taxes and government expenditures plays a crucial role in our model. The government sets tax rates on labor, capital and consumption. It allocates its revenue to productive expenditures (mainly to promote human capital accumulation), study grants, consumption and ‘non-employment’ benefits. Labor taxes and benefits may differ across age groups and across ability types. We find that our model’s predictions match the facts well for key variables in many OECD countries. We then use the model to investigate the effectiveness of various fiscal and educational policy measures in promoting employment and growth. We also evaluate welfare effects for current and future generations. Our main results support a reduction of labor taxes on older workers and on low-wage earners, as well as an increase of productive expenditures, financed by a reduction of ‘non-employment’ benefits.

**Key words:** heterogeneous abilities, employment by age, endogenous growth, fiscal policy, human capital, overlapping generations

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

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## 1. 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.

Many researchers have demonstrated in theoretical and/or empirical work the major influence on employment of the composition of fiscal policy, i.e. the level and structure of government expenditures and taxes (e.g. Prescott, 2004; Rogerson, 2007; Dhont and Heylen, 2008; Ohanian, Raffo and Rogerson, 2008; Olovsson, 2009; Berger and Heylen, 2011). 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 expenditures/subsidies as a major component of productive government expenditures, enhancing effective human capital accumulation and possibly growth (e.g. Glomm and Ravikumar, 1992; Buiter and Kletzer, 1993; Docquier and Michel, 1999; Kaganovich and Zilcha, 1999; Bouzahzah, de la Croix and Docquier, 2002; Dhont and Heylen, 2009). Empirical work by e.g. Kneller, Bleany and Gemmell (1999) and Romero-Ávila and Strauch (2008) confirms the importance of fiscal policy for growth in OECD countries. Others find evidence for a significant role of education and/or public education expenditures (e.g. Barro, 2001; Nijkamp and Poot, 2004; de la Fuente and Doménech, 2006; Blankenau, Simpson and Tomljanovich, 2007)<sup>1</sup>. Hanushek and Woessmann (2009) emphasize the crucial role of education quality and the institutional features of the schooling system for growth.

The above mentioned literature has strongly improved our understanding of employment and growth. Still, it is limited in some respects. First, most of the above mentioned studies focus on only one aspect of macro performance, either employment or growth. Most studies explaining employment disregard human capital and/or growth, whereas models explaining education and growth generally ignore the endogeneity of labor supply and the labor-leisure choice. Turnovsky (2000) and Dhont and Heylen (2009) are exceptions in this respect. Second, a few recent exceptions notwithstanding (e.g. Rogerson and Wallenius, 2009; Fougère *et al.*, 2009; Ludwig, Schelkle and Vogel, 2012), most studies neglect life cycle patterns in labor supply and employment differences across age groups. The data, however, show that in all countries the middle aged work more hours than the young and the older. Third, most existing studies disregard differences in abilities and motivation of people to learn. With some exceptions (e.g. Azariadis and de la Croix, 2002), models with education and growth typically assume that everyone is able to study and succeed in education. Reality is different, however. Data reveal that in 2008 about 30% of the 25-64 year old population on average in the OECD has no upper secondary degree. About 44% has an upper secondary degree but no tertiary degree. The fraction of people with a tertiary degree therefore remains below 30%.

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<sup>1</sup> Not all studies investigating the relationship between human capital accumulation and growth, come up with significant positive results, however (e.g. Pritchett, 2001). De la Fuente and Doménech (2006) point at the low quality of schooling and human capital data as an important factor that may explain the mitigated results in many studies.

Among young cohorts, educational attainment is higher. Yet, the fraction that does not complete upper secondary education is still about 20% on average. About 40% obtains an upper secondary degree, but no tertiary degree. More or less another 40% completes both secondary and tertiary education (OECD, Education at a Glance, Tables A1, A2.2, A3.2). Cross-country variation in these data suggests that differences in the schooling system and government policies, for example policies affecting the cost of education, may have an important influence on these numbers. But 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 tertiary level. A second important observation here is that these differences in school results feed through directly into labor market outcomes. On average in the OECD, the employment rate among people of age 25 to 64 with less than an upper secondary degree is less than 60%, the employment rate among people with a tertiary degree is higher than 80% (OECD, Employment Outlook).

In our previous work (see Heylen and Van de Kerckhove, 2010) we responded to the first and the second limitation that characterize most existing literature. 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, and economic 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. However, we disregarded differences in ability.

In this paper we maintain two contributions to the literature that we made in our earlier work<sup>2</sup>, but now extend our OLG model by allowing heterogeneous abilities. We make the assumption that within each generation three ability groups exist. These groups differ both in the degree to which they (when young) assimilate existing knowledge and inherit human capital from the middle aged generation, and in their productivity of schooling when spending time studying. One group has low ability. They inherit relatively little human capital from the middle aged generation, and will never engage in tertiary education. They will only work or have ‘leisure’. A second group has medium ability, a third group high ability. These groups inherit higher fractions of existing human capital, and do allocate time to tertiary education. Given the variation between them in the productivity of schooling, the amount of time will differ, however. The extension allows a richer and more realistic analysis of public policy effects. Labor taxes and benefits may not only differ across age groups, but also across ability groups. Moreover, it will be possible to investigate welfare effects not only by age, but also by ability group. Differences can be studied between individuals with high versus low human capital and income, both among current and future generations.

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<sup>2</sup> I.e., to study public policy effects, we again model the various linkages between labor supply and employment in different periods of life, human capital formation when young, physical capital formation, and aggregate growth. Furthermore, we again pay special attention to a careful parameterization of our model, and check its empirical validity before using it for policy simulations. Basically, we calibrate our model to the average of 13 OECD countries, and then vary fiscal policy parameters for each country. It is required that the model’s predictions for key variables in individual countries match the cross-country differences that one can observe in the data. Observable policy differences should be translated into realistic performance differences.

Our main findings are the following. First, we confirm our earlier results in Heylen and Van de Kerckhove (2010). We again identify labor taxes and (especially) ‘non-employment’ benefits as the main policy variables affecting employment. Productive government expenditures are the most effective with respect to long-run output and growth. Again we observe that output and growth may benefit also from labor tax cuts targeted at older workers, whereas the opposite holds for labor tax cuts targeted at young workers. 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 welfare losses. Third, better overall employment effects and better welfare effects for low ability groups, at a slight cost in terms of growth, are possible if one complements policies that cut labor taxes on older workers with labor tax cuts on the 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 net wage income in the economy. The best effects on employment follow if this combined tax cut is financed by overall benefit cuts.

The structure of the paper is as follows. In Section 2 we document differences in employment by age and educational attainment, education of the young, and per capita growth across 13 OECD countries since 1995. Section 3 sets out our model. In Section 4 we calibrate the model on actual data and confront its predictions with the facts described in Section 2. Our procedure is as follows. We impose common technology and preference parameters on all countries, but country-specific fiscal policy and education quality parameters. Simulating the model for each country we find that its predictions match the main facts in most countries. We conclude that the model translates observable policy differences into performance differences which are roughly in line with observations in the data. Section 5 includes the main results of a wide range of policy simulations. In this section we discuss the long-run equilibrium effects and the welfare effects per generation and ability group of fiscal policy changes. Section 6 concludes the paper.

## **2. Cross-country differences in employment, tertiary education and per capita growth**

Table 1 contains key data on employment, education and growth in 13 OECD countries in 1995-2007. One would like a reliable model to match the main cross-country differences reported here. The employment rate in hours ( $n$ ) indicates the fraction of potential hours that are actually being worked by the average person in one of three age groups:  $n_1$  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 fourth 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 ( $e$ ) is our proxy for the fraction of *effective time* spent studying by the average young person. The data combine fractions of *time as such* spent in tertiary education, and completion rates<sup>3</sup>. Taking into account completion rates is one (possible) way to control for the fact that students may spend time on a program but in the end fail. Our data for (average annual) real per capita growth concern real potential GDP per person of working age. We refer to Appendix 1 for further details on the calculation of all our data, and on the assumptions that we have to make.

**Table 1**

Employment rate in hours ( $n$ ), education rate ( $e$ ) and per capita growth in OECD countries (1995-2007)

	$n_1$ (20-34)	$n_2$ (35-49)	$n_3$ (50-64)	$n_L/n_H$	$e$	<i>Annual real per capita growth</i>
Austria	59.9	64.3	34.7	63.4	15.5	2.06
Belgium	51.1	56.8	29.3	58.1	19.5	1.77
France	48.7	60.3	38.0	67.3	19.1	1.54
Germany	49.7	55.2	34.9	61.0	16.0	1.56
Italy	50.1	61.9	33.8	62.0	9.5	1.30
Netherlands	50.8	54.6	34.2	67.4	15.2	2.20
<b>Core euro area Average</b>	<b>51.7</b>	<b>58.8</b>	<b>34.2</b>	<b>63.2</b>	<b>15.8</b>	<b>1.74</b>
Denmark	56.2	66.7	49.6	70.7	22.3	1.81
Finland	55.6	69.0	47.3	67.5	22.5	2.72
Norway	51.9	60.9	50.6	71.3	17.8	2.29
Sweden	53.6	66.1	55.4	80.8	16.4	2.18
<b>Nordic Average</b>	<b>54.3</b>	<b>65.6</b>	<b>50.7</b>	<b>72.6</b>	<b>19.7</b>	<b>2.25</b>
<b>US</b>	<b>65.6</b>	<b>74.2</b>	<b>59.6</b>	<b>66.9</b>	<b>13.8</b>	<b>1.54</b>
UK	60.8	68.4	49.4	66.7	12.9	2.13
Canada	60.9	69.5	50.4	66.9	16.1	1.68
<b>Overall average</b>	<b>55.0</b>	<b>63.7</b>	<b>43.6</b>	<b>66.9</b>	<b>16.7</b>	<b>1.91</b>

Data sources: OECD and Eurostat (see Appendix 1); data description: see main text and Appendix 1. The data for employment by age and growth concern 1995-2007, those for education 1998-2007. The data for  $n_L/n_H$  are an average for 1995, 2000 and 2006. All data are in percent.

<sup>3</sup> We calculate the fraction of *time as such* as the total number of tertiary students in full-time equivalents, divided by total population in the age group 20-34. To obtain the fraction of *effective time* we multiply by the completion rate (normalized to its cross-country average). The completion rate indicates the percentage of students who follow tertiary education, and also graduate from a tertiary program. The OECD average in 2008 was about 69%. It was much less for example in the US and Italy, much higher in Denmark and France (OECD Education at a Glance, 2010). For details, see also Appendix 1.

As is well-known, middle aged individuals work most hours, followed by the young. The older generation works the lowest number of hours. Average employment rates over all countries in these three age groups are 55.0%, 63.7% and 43.6% respectively. Furthermore, the data reveal strong cross-country differences. We observe the highest employment rates in each age group in the US. Employment rates are much lower in the core countries of the euro area. The Nordic countries take intermediate positions, although they are close to the core euro area for the younger generation. 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 67% 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.

Young people's effective participation in education is also by far the highest in the Nordic countries. These countries also show the highest potential per capita growth rates. On average, growth in the core euro area and the US was more than 0.5 percentage points lower in the period under consideration. The US and the other Anglo-Saxon countries tend to have the lowest effective participation in education among people of age 20 to 34.

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 17<sup>th</sup> percentile, the median medium ability individual at the 50<sup>th</sup> percentile and the median high ability person at the 83<sup>th</sup> percentile. In the data individuals at the 17<sup>th</sup> percentile have no upper secondary degree in most countries. Individuals at the 83<sup>th</sup> percentile have a tertiary degree.

### 3. The model

Our analytical framework consists of a computable four-period OLG-model for a small open economy. We assume perfect international mobility of physical capital but immobile labor and human capital. Seminal work in the OLG tradition has been done by Samuelson (1958) and Diamond (1965). Auerbach and Kotlikoff (1987) initiated the study of public finance shocks in a computable OLG model. Buiter and Kletzer (1993) developed an open economy version of the model with endogenous growth, putting human capital at the centre. As we have documented in Section 1, a large recent literature has used OLG models to study the effects of fiscal policy on employment, assuming exogenous growth, or on human capital and growth, ignoring the labor-leisure choice and assuming exogenous employment. New in this paper is that we explain both employment by age, and human capital and growth as endogenous variables, and that we realistically take into account differences in individuals' innate abilities.

We consider three active adult generations, the young, the middle aged and the older, and one generation of retired agents. Within each generation we assume three types of individuals with different ability  $a$  to build human capital: a group  $H$  with high ability, a group  $M$  with medium ability and a group  $L$  with low ability. These groups differ both in the degree to which they (when young) assimilate existing knowledge, i.e. inherit human capital from the middle aged generation, and in their productivity of schooling when they spend time studying. Low ability individuals inherit relatively little human capital from the middle aged generation, and will never engage in tertiary education. They will only work or have 'leisure'. Medium and high ability individuals inherit higher fractions of existing human capital, and do allocate time to tertiary education. Given the variation between them in the productivity of schooling, this amount of time will differ, however. We assume that the three ability types are of equal size, and so are the different generations. We normalize each ability group to 1, so that the size of a generation is 3, and total population is 12, and constant.

Our assumptions to model intragenerational heterogeneity are in line with recent literature. First of all, our approach is consistent with recent findings 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 assumptions also match findings that learning ability and human capital at the age of 20 are strongly positively correlated (Huggett et al., 2006, 2011). Finally, our (simplifying) assumption that the three ability types are of equal size corresponds to the approach in Guvenen et al. (2009) to model learning ability and inherited human capital as uniformly distributed in the population.

Individuals enter the model at age 20. Each period is modeled to last for 15 years. High and medium ability young people can choose either to work and generate labor income, to study and build human capital, or to devote time to 'leisure' (including other non-market activities). Low ability young individuals and all middle aged and older workers do not study anymore, they only work or have 'leisure'. Individuals retire at 65. The retirement age and decision are exogenous in our model.

Output is produced by domestic firms which act competitively and employ physical capital together with existing technology and effective labor provided by the three active generations. A final important assumption is that education generates a positive externality in the sense of Azariadis and Drazen (1990). Each young generation inherits a fraction of the average level of human capital of a middle aged generation. The higher an individual's ability, the larger the fraction he inherits. In what follows, we concentrate on the core elements of the model: the optimizing behavior of individuals, the production and inheritance of effective human capital, the behavior of domestic firms and the determination of aggregate output and growth, capital and wages.

### 3.1. Individuals

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

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

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

$$e_{2a}^t = e_{3a}^t = e_{4a}^t = n_{4a}^t = 0 \text{ and } e_{1L}^t = 0. \quad (2)$$

Superscript  $t$  indicates the period of youth, when the individual comes into the model. Subscript  $a$  refers to the 'ability type' and  $j$  refers to the  $j$ th period of life. Lifetime utility depends on consumption ( $c_{ja}$ ) and 'leisure' in each period of life. Leisure falls in hours worked ( $n_{ja}$ ) during the three active periods and - except for the low ability individuals, who do not study - in education time ( $e_{1a}$ ) when young. Since individuals only allocate time to education in their first period, we drop the subscript 1 in what follows. The intertemporal elasticity of substitution in consumption is 1, the intertemporal elasticity to substitute leisure  $1/\theta$ . Finally,  $\beta$  is the discount factor and  $\gamma$  specifies the relative value of 'leisure' versus consumption. The preference parameters  $\theta$ ,  $\beta$  and  $\gamma$  do not depend on ability type. Note, however, that  $\gamma$  may be different in each period of life. Except for the latter assumption, our specification of the instantaneous utility function is quite common in the macro literature (e.g. Benhabib and Farmer, 1994; Rogerson, 2007).

Individuals will choose consumption, labor supply and education to maximize Equation (1), subject to the constraints described in (2)-(10). Equations (3)-(5) describe the individuals' dynamic budget constraints. The LHS of these equations shows that individuals allocate their disposable income to consumption (including consumption taxes,  $\tau_c$ ), education expenditures net of government subsidies while young, and the accumulation of non-human wealth. In Equation (3),  $ec$  and  $es$  indicate full-time equivalent private education costs and education subsidies paid by the government, respectively. In each equation we denote by  $\Omega_{ja}^t$  the stock of wealth held by a type  $a$  individual who enters the model at time  $t$  at the end of his  $j$ th period of life. Equations (3) and (5) respectively indicate that individuals start and finish adult life with zero assets. During the three periods of active life, disposable income at the RHS includes after-tax labor income, non-employment benefits, interest income and lump sum transfers. In each equation,  $w_{a,k}$  stands for the real wage per unit of effective labor supplied at time  $k$  by an individual with ability  $a$ ,  $r_k$  is the exogenous (world) real interest rate at time  $k$ , and  $z_k$  is the lump sum transfer that the government pays out to all individuals at time  $k$ . Effective labor of an individual with ability  $a$  depends on hours worked ( $n_{ja}^t$ ) and effective human capital ( $h_{ja}^t$ ). Since young individuals with ability  $a$  pay a tax rate on labor income  $\tau_l$ , they earn an after-tax real wage equal to  $w_{a,t} h_{1a}^t n_{1a}^t (1 - \tau_l)$ . Note that the government has the possibility to levy different tax rates on the different age groups. To set different tax rates by ability is not possible for the government since ability is unobservable<sup>4</sup>. After-tax labor income when middle aged and older in Equation (4) is determined similarly.

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<sup>4</sup> As we demonstrate later in Section 5 however the government may tax workers differently depending on the level of their income. Setting different tax rates on different income groups may be one (imperfect) way to try to target tax policy by ability.

$$(1 + \tau_c)c_{1a}^t + (ec - es)e_a^t + \Omega_{1a}^t = w_{a,t}h_{1a}^t n_{1a}^t (1 - \tau_1) + b_1 w_{a,t} h_{1a}^t (1 - \tau_1)(1 - n_{1a}^t - e_a^t) + z_t \quad (3)$$

$$(1 + \tau_c)c_{ja}^t + \Omega_{ja}^t = w_{a,t+j-1}h_{ja}^t n_{ja}^t (1 - \tau_j) + b_j w_{a,t+j-1}h_{ja}^t (1 - \tau_j)(1 - n_{ja}^t) + (1 + r_{t+j-1})\Omega_{j-1,a}^t + z_{t+j-1}, \quad \forall j=2,3 \quad (4)$$

$$(1 + \tau_c)c_{4a}^t = (1 + r_{t+3})\Omega_{3a}^t + pp_{4a}^t + z_{t+3} \quad (5)$$

For the fraction of time that young, middle aged and older individuals are inactive, they receive a non-employment benefit from the government. The net benefit replacement rate  $b_j$  (with  $j=1,2,3$ ) is defined as a proportion of the after-tax wage of a full-time worker. Retired individuals in Equation (5) have no labor income and no non-employment benefits anymore. They consume their savings from the third period, plus interest, a public pension  $pp$  and the lump sum transfer  $z$ . Equation (6) describes this pension. We assume a public PAYG pension system in which pensions in period  $k$  are financed by contributions (labor taxes) from the active generations in that period  $k$  (see below). Individual pension benefits are related to earlier labor income. Individuals earn a net pension which is a fraction of their so-called pension base. The latter is a weighted average of net labor income in each of the three active periods of their life. The net replacement rate is  $b_4$ . The weights attached to each period are  $1/3$ . A full pension is granted if one has a full career, which is achieved when  $n_{ja}^t = 1$  for  $j = 1,2,3$ . Intuitively this requires 45 years of full time work.

$$pp_{4a}^t = b_4 \sum_{j=1}^3 \frac{1}{3} \left( w_{a,t+j-1} h_{ja}^t n_{ja}^t (1 - \tau_j) \right). \quad (6)$$

As we show in Equations (7) and (8), at the age of 20 a young worker with ability  $H$  inherits a fraction  $\pi$  of the average effective human capital of the middle aged generation. A young worker with ability  $M$  enters our model with only a fraction  $\varepsilon_M \pi$ , a young worker with ability  $L$  enters with an even lower fraction  $\varepsilon_L \pi$ . Lower ability may imply more difficulty to learn and accumulate knowledge at primary and secondary school. Lower ability individuals may as a result also be more likely to suffer from school fatigue. During their second and third period, workers supply more units of effective human capital. It is our assumption in Equation (9) that  $h_{2a}$  and therefore labor productivity, rise in education time when young ( $e_a$ ), productive government spending in percent of GDP ( $g_y$ , mainly education spending) and an overall quality of schooling parameter ( $q_a$ ). Individuals take  $g_y$  and  $q_a$  to be exogenous. Note that the human capital accumulation function itself ( $\psi_a$ ) also depends on innate ability. We specify and discuss effective human capital production and human capital inheritance in greater detail in Section 3.2. Finally, we assume in Equation (10) that human capital remains unchanged between the second and the third period. We have in mind that learning by doing in work may counteract depreciation.

$$h_{1a}^t = \varepsilon_a \pi h_2^{t-1} = \varepsilon_a \pi \frac{(h_{2H}^{t-1} + h_{2M}^{t-1} + h_{2L}^{t-1})}{3}, \forall a = H, M, L \quad (7)$$

$$0 < \pi, 0 < \varepsilon_L < \varepsilon_M < \varepsilon_H = 1 \quad (8)$$

$$h_{2a}^t = \left(1 + \psi_a(e_a^t, g_y, q_a)\right) h_{1a}^t, \quad \psi_a > 0, \psi'_a(\cdot) > 0 \quad (9)$$

$$h_{3a}^t = h_{2a}^t, \quad \forall a = H, M, L \quad (10)$$

Substituting Equations (3)-(5) for  $c_{ja}^t$  into (1), and maximizing with respect to  $\Omega_{1a}^t, \Omega_{2a}^t, \Omega_{3a}^t, n_{1a}^t, n_{2a}^t, n_{3a}^t$  and  $e_a^t$ , yields seven first order conditions for the optimal behavior of an individual with ability  $a$  entering the model at time  $t$ . Equation (11) expresses the law of motion of optimal consumption over the lifetime. Equations (12.a) and (12.b) describe the optimal labor-leisure choice in each period of active live. Individuals supply labor up to the point where the marginal utility of leisure equals the marginal utility gain from work. The latter consists of two parts. Working more hours in a particular period raises additional resources for consumption both in that period and when retired. The marginal utility gain from work rises when the marginal utility of consumption ( $1/c_{ja}^t$ ) is higher, and when an extra hour of work yields more extra consumption. Higher human capital (and its underlying determinants), lower taxes on labor, lower taxes on consumption and lower non-employment benefits contribute to the gain from work. Extra consumption during retirement rises in the pension replacement rate ( $b_4$ ).

$$\frac{c_{j+1,a}^t}{c_{ja}^t} = \beta(1 + r_{t+j}), \quad \forall j = 1, 2, 3 \text{ \& } \forall a = H, M, L \quad (11)$$

$$\frac{\gamma_1}{(1 - n_{1a}^t - e_a^t)^\theta} = \frac{w_{a,t} h_{1a}^t (1 - \tau_1)(1 - b_1)}{(1 + \tau_c) c_{1a}^t} + \frac{\beta^3 b_4 w_{a,t} h_{1a}^t (1 - \tau_1)}{3 c_{4a}^t (1 + \tau_c)}, \quad \forall a = H, M, L \quad (12.a)$$

$$\frac{\gamma_j}{(1 - n_{ja}^t)^\theta} = \frac{w_{a,t+j-1} (1 + \psi_a(e_a^t, g_y, q_a)) h_{1a}^t (1 - \tau_j)(1 - b_j)}{(1 + \tau_c) c_{ja}^t} \quad (12.b)$$

$$+ \beta^{4-j} \frac{b_4}{3} \frac{w_{a,t+j-1} (1 + \psi_a(e_a^t, g_y, q_a)) h_{1a}^t (1 - \tau_j)}{(1 + \tau_c) c_{4a}^t}, \quad \forall j = 2, 3 \text{ \& } \forall a = H, M, L$$

Equation (13) imposes for high and medium ability individuals that the marginal utility loss from investing in human capital when young equals the total discounted marginal utility gain in later periods from having more human capital. Individuals will study more the higher future versus current

after-tax real wages and the higher the marginal return of education to human capital ( $\partial\psi_a/\partial e_a$ ). Labor taxes during youth therefore encourage individuals to study, whereas labor taxes in later periods of active life and net education costs discourage them. Notice also that high benefit replacement rates in later periods ( $b_2, b_3$ ) and a high pension replacement rate ( $b_4$ ) will encourage young individuals to study. The reason is that any future benefits rise in future human capital. A final interesting result is that young people study more – all other things equal – if they expect to work harder in later periods ( $n_{2a}, n_{3a}$ ).

$$\frac{\gamma_1}{(1-n_{1a}^t-e_a^t)^\theta} - \frac{1}{c_{1a}^t} \frac{\partial c_{1a}^t}{\partial e_a^t} = \beta \frac{1}{c_{2a}^t} \frac{\partial c_{2a}^t}{\partial e_a^t} + \beta^2 \frac{1}{c_{3a}^t} \frac{\partial c_{3a}^t}{\partial e_a^t} + \beta^3 \frac{1}{c_{4a}^t} \frac{\partial c_{4a}^t}{\partial e_a^t}, \quad \forall a = H, M \quad (13)$$

$$\begin{aligned} \text{with: } \frac{\partial c_{1a}^t}{\partial e_a^t} &= \frac{-(ec-es) - b_1(1-\tau_1)w_{a,t}h_{1a}^t}{1+\tau_c}, \quad \forall a = H, M \\ \frac{\partial c_{ja}^t}{\partial e_a^t} &= \frac{\partial\psi_a(e_a^t, g_y, q_a)}{\partial e_a^t} \cdot \frac{w_{a,t+j-1}h_{1a}^t(1-\tau_j)[n_{ja}^t + b_j(1-n_{ja}^t)]}{1+\tau_c}, \quad \forall j=2,3 \text{ \& } \forall a=H,M \\ \frac{\partial c_{4a}^t}{\partial e_a^t} &= \frac{b_4}{3} \frac{\partial\psi_a(e_a^t, g_y, q_a)}{\partial e_a^t} \cdot \frac{\sum_{j=2}^3 (n_{ja}^t w_{a,t+j-1} h_{1a}^t (1-\tau_j))}{1+\tau_c}, \quad \forall a = H, M \end{aligned}$$

### 3.2. Inheritance and production of effective human capital

Equations (7) and (8) above assume that when entering the model young workers with high ability inherit a fraction  $\pi$  of the average effective human capital of the middle aged generation. The value of  $\pi$  is to be calibrated. Individuals with medium and lower ability inherit less ( $\varepsilon_L < \varepsilon_M < 1$ ). A major first element behind these different capacities to assimilate existing knowledge is obviously ‘nature’ (see also Azariadis and de la Croix, 2006). New in this paper is that we introduce the schooling system as a second determinant of the gap between the human capital of different ability groups when entering the model. A look at OECD PISA scores, for example, supports the introduction of this determinant. In Appendix 2 we report data showing that in a country like Finland the test score for science of a student at the 17<sup>th</sup> percentile is about 73% of the test score of a student at the 83<sup>th</sup> percentile. In countries like France, Italy and the US this is only about 65%. Finland therefore seems to be more successful in bringing available knowledge also to lower ability individuals. Equation (14) captures both determinants, with  $\varepsilon_{Lo}$  and  $\varepsilon_{Mo}$  reflecting nature and  $q_L/q_H$  and  $q_M/q_H$  the schooling system. Countries may differ for the latter, but they will have the same  $\varepsilon_{Lo}$  and  $\varepsilon_{Mo}$ .

$$\varepsilon_L = \varepsilon_{Lo} \cdot \left( \frac{q_L}{q_H} \right), \quad \varepsilon_M = \varepsilon_{Mo} \cdot \left( \frac{q_M}{q_H} \right) \quad (14)$$

We will use as a proxy for  $\varepsilon_{Lo}$  the average of the relative PISA science score of individuals at the 17<sup>th</sup> percentile (relative to individuals at the 83<sup>th</sup> percentile) over all 13 countries that we focus on. We will use as a proxy for  $\varepsilon_{Mo}$  the average of the relative PISA science score of individuals at the 50<sup>th</sup> percentile (relative to individuals at the 83<sup>th</sup> percentile). This procedure implies values for  $\varepsilon_{Lo}$  and  $\varepsilon_{Mo}$  of 0.673 and 0.837 respectively (see also Section 4). Basically, we assume that on average over all 13 countries, the schooling system's impact on PISA scores is neutral. What then remains is 'nature'. In individual countries, however, the influence of the schooling system need not be neutral. We will define  $q_L$  as the quality of schooling related to low ability individuals and measure it as the PISA science score of individuals at the 17<sup>th</sup> percentile in a particular country relative to the average over all 13 countries. We define  $q_M$  and  $q_H$  analogously for individuals at the 50<sup>th</sup> and the 83<sup>th</sup> percentile. For Finland for example  $q_L/q_H$  equals 1.080, for the US that is 0.972.

After entering the model, young individuals may decide to study and accumulate more human capital. The specification and parameterization of the human capital production function  $\psi_a(\cdot)$  in Equation (9) is often a problem in numerical endogenous growth models. In contrast to goods production functions, there is not much empirical evidence and no consensus about the determinants of human capital growth, nor about the underlying functional form and parameter values. The literature shows a variety of functions, typically including one or two of the following inputs: individual time allocated to education, private expenditures on education by individuals themselves or by their parents, and government expenditures on education (e.g. Lucas, 1988, Glomm and Ravikumar, 1992; Docquier and Michel, 1999, Kaganovich and Zilcha, 1999; Bouzahzah *et al.*, 2002; Fougère *et al.*, 2009; Arcalean and Schiopu, 2010). In case of two inputs, the adopted functional form is very often Cobb-Douglas (e.g. Glomm and Ravikumar, 1992; Kaganovich and Zilcha, 1999; Docquier and Michel, 1999).

Our specification of the human capital production function also includes education time of young individuals and education expenditures by the government as indicators for the quantity of invested private and public resources. Compared to most of the literature, however, we differ in three respects. First, we adopt a more flexible CES functional form, allowing the elasticity of substitution to differ from 1. Second, our definition of relevant government expenditures includes more than education. It also includes active labor market expenditures, public R&D expenditures and public fixed investment. This approach goes back to our use of the broader concept of *effective* human capital<sup>5</sup>. Our third extension is - again - to take into account the quality of education and the schooling system. We recognize that better quality implies higher cognitive abilities for the same allocation of resources. Young individuals' capacity to build human capital will then rise.

All these arguments find their way in Equations (15.a) and (15.b). The former shows the growth rate of effective human capital for high and medium ability individuals as a CES specification

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<sup>5</sup> As in Dhont and Heylen (2009), effective human capital (and worker productivity) rise not only in accumulated schooling or training, but also in the productive efficiency of accumulated schooling. Education and active labor market expenditures contribute directly to more human capital being accumulated, public R&D and fixed investment expenditures will mainly raise the productive efficiency of accumulated human capital.

in education time when young ( $e_a$ ) and productive government expenditures in % of output ( $g_y$ ). In steady state both determinants are constant, which will imply constant steady state growth. We add the quality of the schooling system ( $q_a$ ) in a multiplicative way. In line with the above, we will use country-specific PISA science scores at the 83<sup>th</sup> and the 50<sup>th</sup> percentile (in deviation from their cross-country average) as proxies for  $q_H$  and  $q_M$ <sup>6</sup>. Next to  $q_a$  we introduce (constant, common) technical parameters:  $\phi_a$  is a positive efficiency parameter reflecting natural ability,  $\sigma$  a scale parameter,  $\nu$  is a share parameter and  $\kappa$  the elasticity of substitution. These parameters will be calibrated. Note in Equation (15.b) that low ability individuals supply no education time, but they also enjoy positive effects on their effective human capital and productivity from productive government expenditures. Natural ability and the quality of received schooling also play a role here.

$$\Psi_a(e_a, g_y, q_a) = \phi_a q_a \left( \nu g_y^{1-(1/\kappa)} + (1-\nu) e_a^{1-(1/\kappa)} \right)^{\sigma\kappa/(\kappa-1)}, \forall a = H, M \quad (15.a)$$

$$\Psi_L(g_y, q_L) = \phi_L q_L g_y^\sigma \quad (15.b)$$

Lack of existing empirical evidence makes an ex-ante assessment of our specification very difficult. In previous work, however, we have been able to verify that a specification like (15.a) performs better than alternative ones without quality, with a narrower definition of government expenditures, or with a different functional form (see Heylen and Van de Kerckhove, 2010; Buyse *et al.*, 2011).

### 3.3. Domestic firms, output and factor prices

Firms act competitively on output and input markets and maximize profits. All firms are identical. Total domestic output ( $Y_t$ ) is given by the production function (16). Technology exhibits constant returns to scale in aggregate physical capital ( $K_t$ ) and effective labor ( $H_t$ ), so that profits are zero in equilibrium. Equation (17) 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  $\eta_H$ ,  $\eta_M$  and  $\eta_L$  are the input shares. We will impose that  $\eta_H = 1 - \eta_L - \eta_M$ .

$$Y_t = K_t^\alpha H_t^{1-\alpha} \quad (16)$$

$$H_t = \left( \eta_H H_{H,t}^{1-(1/s)} + \eta_M H_{M,t}^{1-(1/s)} + \eta_L H_{L,t}^{1-(1/s)} \right)^{s/(s-1)} \quad (17)$$

Equation (18) specifies effective labor per ability group. Within each ability group we assume perfect substitutability of labor supplied by the different age groups.

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<sup>6</sup> Ideally, one would employ a quality indicator relating to tertiary education, but this is not (yet) available. Still, PISA scores may be very useful. They are informative about the quality that young people attain in secondary education, and with which some enter tertiary education. Quality at entrance should have a positive effect on people's capacity to learn and to raise human capital in tertiary education. Furthermore, PISA scores have been found empirically significant for growth (Hanushek and Woessmann, 2009).

$$\begin{aligned}
H_{a,t} &= n_{1a}^t h_{1a}^t + n_{2a}^{t-1} h_{2a}^{t-1} + n_{3a}^{t-2} h_{3a}^{t-2} \\
&= \left( n_{1a}^t + n_{2a}^{t-1} \frac{x_a^{t-1}}{x_{t-1}} + n_{3a}^{t-2} \frac{x_a^{t-2}}{x_{t-1} x_{t-2}} \right) h_{1a}^t, \quad \forall a = H, M, L
\end{aligned} \tag{18}$$

To derive Equation (18) we make use of Equations (9) and (10) and we define:

$$x_a^t \equiv 1 + \psi_a(e_a^t, g_y, q_a) \tag{19}$$

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

Furthermore, we exploit the result that<sup>7</sup> :  $h_{1a}^t = x_{t-1} h_{1a}^{t-1} = x_{t-1} x_{t-2} h_{1a}^{t-2}$  (20)

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

Substituting Equation (18) for  $H$ ,  $M$  and  $L$  into (17), and recognizing differences in the capacity  $\varepsilon$  to inherit human capital as indicated by Equations (7) and (8), yields Equation (21).

$$H_t = \left[ \sum_{a=H,M,L} \eta_a \varepsilon_a^{1-(1/s)} \left( n_{1a}^t + n_{2a}^{t-1} \frac{x_a^{t-1}}{x_{t-1}} + n_{3a}^{t-2} \frac{x_a^{t-2}}{x_{t-1} x_{t-2}} \right)^{1-(1/s)} \right]^{s/(s-1)} h_{1H}^t \tag{21}$$

Competitive behavior implies in Equation (22) that firms carry physical capital to the point where its after-tax marginal product equals the world real interest rate (see also Backus *et al.*, 2008). We assume no depreciation of physical capital. Capital taxes are source-based: the tax rate  $\tau_k$  applies to the country in which the capital is used, regardless of who owns it. The real interest rate being given, firms will install more capital when the amount of effective labor increases or the capital tax rate falls. In that case the net return to investment in the home country rises above the world interest rate, and capital flows in. Furthermore, perfect competition implies for each ability type equality between the real wage and the marginal product of effective labor (Equation 23). Workers of a particular ability type will earn a higher real wage when their supply is relatively scarce and when

<sup>7</sup> Starting from Equation (7), and using (9), it is easy to see that:

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

Human capital of the lower ability individuals ( $a = M, L$ ) will grow at the same rate  $\left( \frac{h_{1a}^t}{h_{1a}^{t-1}} = \frac{\varepsilon_a h_{1H}^t}{\varepsilon_a h_{1H}^{t-1}} = \frac{h_{1H}^t}{h_{1H}^{t-1}} \right)$

which explains the first part of Equation (20). Lagging this result by one period, generates the second part.

physical capital per unit of aggregate effective labor is higher. Taking into account (22), real wages per unit of effective labor will therefore fall in the world real interest rate and in domestic capital tax rates.

$$\alpha \left( \frac{H_t}{K_t} \right)^{1-\alpha} (1-\tau_k) = r_t \quad (22)$$

$$(1-\alpha) \left( \frac{K_t}{H_t} \right)^\alpha \eta_a \left( \frac{H_t}{H_{a,t}} \right)^{1/s} = w_{a,t} \quad \forall a = H, M, L \quad (23)$$

Substituting (21) for  $H_t$  and (22) for  $K_t/H_t$ , we can rewrite (16) as

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

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

$$\begin{aligned} \ln \left( \frac{Y_t}{Y_{t-1}} \right) &= \ln \left( \frac{h_{1H}^t}{h_{1H}^{t-1}} \right) = \ln(x_{t-1}) \\ &= \ln \left( \pi \cdot \frac{\left( 1 + \psi_H(e_H^{t-1}, g_y, q_H) \right) + \varepsilon_M \left( 1 + \psi_M(e_M^{t-1}, g_y, q_M) \right) + \varepsilon_L \left( 1 + \psi_L(g_y, q_L) \right)}{3} \right) \end{aligned} \quad (24)$$

In line with earlier models (e.g., Lucas, 1988; Azariadis and Drazen, 1990; Buiter and Kletzer, 1993), the long-run (per capita) growth rate is positively related to the quality of schooling ( $q$ ) and to the fraction of time that young people allocate to education ( $e$ ). It is also positively related to the share of productive government expenditures ( $g_y$ ), like in Barro (1990). Growth will rise also if young individuals incorporate a larger fraction of average human capital of the middle aged generation ( $\pi$ ,  $\varepsilon$ ). Schooling policies targeted at low and medium ability individuals may also play a role here (see Equation 14).

### 3.4. Government

The government runs a balanced budget. Productive expenditures  $G_{yt}$ , consumption  $G_{ct}$ , benefits related to non-employment  $B_t$ , old-age pension benefits  $P_t$ , education subsidies  $E_t$ , and lump sum transfers  $Z_t$  are financed by taxes on labor  $T_{nt}$ , taxes on capital  $T_{kt}$ , and taxes on consumption  $T_{ct}$ .

$$G_{yt} + G_{ct} + B_t + P_t + E_t + Z_t = T_{nt} + T_{kt} + T_{ct} \quad (25)$$

$$\begin{aligned} G_{yt} &= g_y Y_t \\ G_{ct} &= g_c Y_t \\ B_t &= B_{H,t} + B_{M,t} + B_{L,t} \\ P_t &= P_{H,t} + P_{M,t} + P_{L,t} \\ \text{with: } E_t &= (e_H^t + e_M^t) es \\ Z_t &= 12 z_t \\ T_{nt} &= T_{nH,t} + T_{nM,t} + T_{nL,t} \\ T_{kt} &= \tau_k \alpha Y_t \\ T_{ct} &= \tau_c \sum_{j=1}^4 (c_{jH}^{t+1-j} + c_{jM}^{t+1-j} + c_{jL}^{t+1-j}). \end{aligned}$$

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

$$\begin{aligned} B_{a,t} &= (1 - n_{1a}^t - e_a^t) b_1 w_{a,t} h_{1a}^t (1 - \tau_1) + \sum_{j=2}^3 (1 - n_{ja}^{t+1-j}) b_j w_{a,t} h_{ja}^{t+1-j} (1 - \tau_j) \\ P_{a,t} &= b_4 \sum_{j=1}^3 \left( \frac{1}{3} w_{a,t+j-4} h_{ja}^{t-3} n_{ja}^{t-3} (1 - \tau_j) \right) \\ T_{na,t} &= \sum_{j=1}^3 n_{ja}^{t+1-j} w_{a,t} h_{ja}^{t+1-j} \tau_j. \end{aligned}$$

Note our assumption that each ability group has size 1 and that each generation has size 3. Following Turnovsky (2000) and Dhont and Heylen (2009), we assume that the government claims given fractions  $g_y$  and  $g_c$  of output for productive expenditures and consumption. Non-employment benefits ( $B_t$ ) are an unconditional source of income support related to inactivity ('leisure') and non-market household activities. Although it may seem strange to have such transfers in a model without involuntary unemployment, one can of course analyse their employment and growth effects as a theoretical benchmark case (see also Rogerson, 2007; Dhont and Heylen, 2008, 2009). Moreover, there is also clear practical relevance. Unconditional or quasi unconditional benefits to structurally non-employed people are a fact of life in many European countries.

## 4. Parameterization and empirical relevance of the model

The economic environment described above allows us to simulate the transitory and steady state growth and employment effects of various fiscal and educational policy changes. This simulation exercise requires us first to parameterize and solve the model. In Section 4.1 we discuss our choice of preference and technology parameters. Starting from actual cross-country policy data in Section 4.2, we compare in Section 4.3 our model's predictions with the employment and growth differences that we have reported in Table 1. This comparison provides a first and simple test of our model's empirical relevance. In Section 5 we consider long-run equilibrium effects of policy changes. Section 6 discusses transitional dynamics, and welfare effects per generation and ability group. To solve the model and to perform the simulations, we choose an algorithm that preserves the non-linear nature of our model. We follow the methodology basically proposed by Boucekkine (1995) and implemented by Juillard (1996) in the program Dynare. We use Dynare 4.2.

### 4.1. Preference and technology parameters

Table 2 contains an overview of all parameters. Following among others Barro (1990), we set the rate of time preference equal to 2% per year. Considering that periods in our model consist of 15 years, this choice implies a discount factor  $\beta$  equal to 0.74. With respect to output and effective labor, we assume a share coefficient  $1-\alpha$  equal to 0.7. The elasticity of substitution  $s$  between the three ability types is set at 1.5. Both values are well in line with the literature (e.g. King and Rebelo, 1990; Caselli and Coleman, 2006). There is more controversy in the literature about the value of the intertemporal elasticity of substitution in leisure ( $1/\theta$ ). Micro studies often reveal very low elasticities. However, given our macro focus, these studies may not be the most relevant ones. Rogerson and Wallenius (2009) show that micro and macro elasticities may be unrelated. Rogerson (2007) also adopts a macro framework. He puts forward a reasonable range for  $\theta$  from 1 to 3 (Rogerson, 2007, p. 12). In line with this, we impose  $\theta$  to be equal to 2. The world real interest rate is assumed constant and equal to 3% per year, which is approximately the average real return on 10 year US government bonds in the last decade. Considering a period of 15 years, this implies that  $r = 0.558$ .

A second series of nine parameters have been determined by calibration: three taste for leisure parameters ( $\gamma_L, \gamma_M, \gamma_H$ ), the human capital inheritance parameter ( $\pi$ ), three efficiency parameters in the human capital production function ( $\phi_H, \phi_M$  and  $\phi_L$ ) and two share parameters in aggregate effective labor ( $\eta_M$  and  $\eta_L$ , where  $\eta_H$  follows as  $1-\eta_L-\eta_M$ ). The nine target values to which these parameters have been calibrated are reported at the bottom of Table 2. Five of them concern the average employment, education, and growth rates over all 13 countries in our study. The other four are the relative wages of young and middle aged workers of low and medium ability in the US. Although in practice a whole system of simultaneous equations is solved in which each target value is important for each parameter to be calibrated, it may be useful for our exposition here to bring some more structure. Certain parameters are clearly more than others linked to certain target values. The leisure parameters are basically determined such that with observed average levels of the fiscal

policy variables (tax rates, benefit replacement rates, etc.) and the observed average levels of schooling quality ( $q_a$ )<sup>8</sup> over all 13 countries, the model correctly predicts the average of these countries' employment rates by age ( $n_1, n_2, n_3$ ). We find that the taste for leisure rises with age ( $\gamma_1=0.041, \gamma_2=0.123, \gamma_3=0.274$ ). The human capital inheritance parameter is basically determined to match average per capita growth. We find an inheritance rate for the highest ability group of almost 80% ( $\pi=0.785$ ). Taking into account the values for  $\varepsilon_{M0}$  and  $\varepsilon_{L0}$  that we have discussed in Section 3.2., we obtain inheritance rates for the medium ability and the low ability groups of about 66% ( $=0.785 \times 0.837$ ) and 53% ( $=0.785 \times 0.673$ ) on average over all countries.

**Table 2** Basic parameterization and benchmark equilibrium

Technology and preference parameters				
Goods production (output)	$1-\alpha=0.7, s=1.5, \eta_H=0.47, \eta_M=0.30, \eta_L=0.23$			
Effective human capital	$\phi_H=5.17, \phi_M=5.76, \phi_L=3.26, \nu=0.25, \kappa=0.55, \sigma=0.60$			
Human capital inheritance	$\pi=0.785, \varepsilon_{M0}=0.837, \varepsilon_{L0}=0.673, \varepsilon_{M(US)}=0.827, \varepsilon_{L(US)}=0.654$			
Preference parameters	$\beta=0.74, \theta=2, \gamma_1=0.041, \gamma_2=0.123, \gamma_3=0.274$			
World real interest rate	$r=0.558$			
Fiscal policy parameters in benchmark <sup>(a, b)</sup>				
Gov. Expenditures (%)	$g_y=9.5, g_c=15.9, b_1=b_2=50.8, b_3=51.9, b_4=68.3$			
Tax rates (in %)	$\tau_k=22.1, \tau_c=14.3, \tau_1=\tau_2=\tau_3=52.5$			
Average schooling quality (benchmark)	$q_M=q_L=q_H=1$			
Target values for calibration				
Benchmark equilibrium <sup>(a)</sup>				
$n_1$	$n_2$	$n_3$	Per capita growth (annual)	$e$
55.0%	63.7 %	43.6	1.91 %	16.7 %
Relative wages US <sup>(c)</sup>				
$w_L h_{1L} / w_H h_{1H}$	$w_M h_{1M} / w_H h_{1H}$	$w_L h_{2L} / w_H h_{2H}$	$w_M h_{2M} / w_H h_{2H}$	
0.43	0.63	0.38	0.58	

Note: (a) Average for all 13 countries in Table 1; (b) For details on fiscal policy parameters and schooling quality, see the next section (Tables 3 and 4); (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 (secondary education) in the US relative to earnings of workers with a tertiary degree. For the relative wage of middle aged workers, we use the same kind of data. However, since middle age-specific data are missing, we use average values for the whole age group 25-64 as a proxy. Data for the age group 55-64 are about the same (0.38 and 0.55). Data source: OECD Education at a Glance, 2009, Table A7.1.

Calibration of the share parameters  $\eta_M$  and  $\eta_L$  is mainly driven by the values for relative wages of young workers in the US. As shown by Equation (23), these 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,

<sup>8</sup> And with the values of three parameters in the human capital production function ( $\sigma, \nu, \kappa$ ) that we discuss below (see also footnote 9).

which explains the introduction here of US relative wages rather than cross-country averages. We illustrate the key elements in our procedure to obtain values for  $\eta_L$  and  $\eta_M$  from these relative wage data in Appendix 3. The results imply  $\eta_L=0.23$ ,  $\eta_M=0.30$  and  $\eta_H=0.47$ . A similar procedure is applied to derive values for  $\phi_L$ ,  $\phi_M$  and  $\phi_L$ . These are basically determined such that the model correctly predicts relative wages of middle aged workers in the US, as well the target value for the education rate  $e$  (see also Appendix 3). We obtain  $\phi_L=3.26$ ,  $\phi_M=5.76$  and  $\phi_H=5.17$ .

Finally, we had no strong ex ante indication on three parameters in the human capital production function: the scale parameter  $\sigma$ , the share parameter  $\nu$  and the elasticity of substitution parameter  $\kappa$ . We could assign sensible values to these parameters thanks to a sensitivity analysis on the results that we report in the next section. There we evaluate the capacity of our model to explain the facts in 13 OECD countries that we reported in Table 1. Our guideline to pin down specific values for  $\sigma$ ,  $\nu$  and  $\kappa$  was to minimize the deviation of our model's predictions from the true data<sup>9</sup>. This procedure implied  $\sigma=0.60$ ,  $\nu=0.25$  and  $\kappa=0.55$ . We observe decreasing returns in human capital growth. The result for  $\kappa$  reveals a higher degree of complementarity between private education time and government expenditures than in the Cobb-Douglas case. The result for  $\nu$  demonstrates relatively high importance for human capital formation of private education time versus productive public expenditures.

#### 4.2. Fiscal policy and education quality

Tables 3 and 4 describe key characteristics of fiscal policy in 1995-2001/2004. Our proxy for the tax rate on labor income concerns the total tax wedge, for which we report the marginal rate in %. The data cover personal income taxes, employee and employer social security contributions payable on wage earnings and payroll taxes. The OECD publishes these marginal tax data for several family and income situations. Our data for  $\tau_j$  in Table 3 are the average of all these situations. 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 reported by the Institute for Fiscal Studies (their EMTR, base case). Germany and Belgium have the highest rates. In contrast to labor (and consumption), capital is taxed relatively little in the Nordic countries. As to consumption taxes, we follow Dhont and Heylen (2009) in computing them as the ratio of government indirect tax receipts (net of subsidies paid) to total domestic demand net of indirect taxes and subsidies. Our simplifying assumption is that consumption tax rates correspond to

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<sup>9</sup> From our model's predictions and the true data for 13 countries we computed for each variable ( $n_1$ ,  $n_2$ ,  $n_3$ ,  $e$ , *growth*) the root mean squared error normalized to the mean. We minimized the average normalized RMSE over all five variables. More precisely, we adopted the following iterative procedure. We chose values for  $\sigma$ ,  $\nu$  and  $\kappa$  and then calibrated the other nine parameters (although it should be mentioned that the values for  $\sigma$ ,  $\nu$  and  $\kappa$  had no influence on the calibration results for  $\gamma_j$ ). Given the obtained values for the other parameters, we computed the average normalized RMSE over all five endogenous variables. We then checked whether changes in  $\sigma$ ,  $\nu$  and  $\kappa$ , and a recalibration of the other parameters, could further reduce this statistic. We did this until no further reduction was possible.

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

**Table 3** Fiscal policy ( Tax rates)

	tax rate on labor income (in %)	consumption tax rate (%)	tax rate on capital income (%)
<b>Proxy for :</b>	$\tau_1, \tau_2, \tau_3$	$\tau_c$	$\tau_k$
Austria	54.9	13.2	17.3
Belgium	67.2	13.4	27.1
France	52.9	17.1	21.7
Germany	60.4	11.1	34.4
Italy	55.2	14.7	14.9
Netherlands	52.0	12.2	24.3
Denmark	48.6	18.9	22.5
Finland	56.2	15.2	17.2
Norway	50.8	16.4	22.1
Sweden	56.0	17.9	16.1
UK	44.9	14.5	21.2
US	37.4	7.2	23.6
Canada	46.4	14.5	24.8
<b>Overall average</b>	52.5	14.3	22.1

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 1. Capital tax rates are effective marginal corporate tax rates (Institute for Fiscal Studies, their EMTR, base case; data are for 1995-2001, see also Devereux *et al.*, 2002). Consumption tax rates are from Dhont and Heylen (2009). Data are for 1995-2001

Table 4 summarizes our data for the expenditure side of fiscal policy. A first variable is our proxy for the net non-employment benefit replacement rate  $b_j$  for young and middle aged workers. 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 60<sup>th</sup> 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<sup>10</sup>. 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  $b_j$  (see Appendix 1). Benefit replacement rates for older workers  $b_3$  are typically higher, at least in some countries due to the availability of generous

<sup>10</sup> 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](http://www.oecd.org/els/social/workincentives), Benefits and Wages, country specific files).

early retirement regimes<sup>11</sup>. Overall, the euro area and the Nordic countries pay the highest net benefits. The only exception is Italy. Transfers to structurally non-employed people are by far the lowest in the US.

**Table 4 Fiscal policy (net transfer replacement rates, government consumption, productive expenditures)**

	Non-employment transfer, young and middle aged (net replacement rate, %)	Non- employment transfer, older workers (net replacement rate, %)	Pension replacement rate (net, in %)	Government consumption (% of GDP)	Government productive expenditures (% of GDP)
<b>Proxy for:</b>	$b_1, b_2$	$b_3$	$b_4$	$g_c$	$g_y$
Austria	56.3	64.0	88.9	14.6	8.8
Belgium	59.6	69.3	63.1	16.9	7.8
France	46.0	54.9	68.8	18.3	10.0
Germany	64.7	67.8	71.8	15.3	7.8
Italy	17.0	36.4	88.8	14.3	7.8
Netherlands	55.0	61.5	84.1	18.4	8.4
Denmark	61.9	52.6	54.1	18.4	10.8
Finland	56.9	67.6	78.8	16.0	10.2
Norway	55.4	48.4	65.1	14.7	11.5
Sweden	53.5	47.2	68.2	20.0	12.2
UK	51.1	45.2	47.6	14.4	6.9
US	30.5	24.4	51.0	10.3	8.8
Canada	44.6	35.6	57.1	14.7	8.8
<b>Overall average</b>	50.8	51.9	68.3	15.9	9.2

Notes: A description of all variables is given in the main text. For more details, see Appendix 1. The data for net benefit replacement rates are an average for 2001-2004 (earlier data are not available). The data for government consumption and productive expenditures concern 1995-2001. Pension replacement rates have been taken from OECD (Pensions at a Glance, 2005, p. 52). The data concern 2002

Our data for productive government expenditures ( $g_y$ ) in Table 4 include education (except study grants to households), labor market training, government financed R&D and public investment, in percent of GDP. On average, education expenditures constitute close to 60% of total  $g_y$ . Governments in the Nordic countries allocate by far the highest fractions of output to productive expenditures. Productive expenditures in percent of GDP are the lowest in the UK. The US and most core countries of the euro area take intermediate positions. Government consumption in percent of GDP is the highest also in the Nordic countries, followed at close distance by several countries of the core euro area<sup>12</sup>. In the US, government consumption is (much) lower. As a final variable in Table 4 we include the net pension replacement rate. Available data concern an individual with mean

<sup>11</sup> To assess the generosity of early retirement we rely on data for the implicit tax rate on continued work in the early retirement route (see Duval, 2003; Brandt *et al.*, 2005). For further details on the calculation of  $b_3$  we refer to Appendix 1.

<sup>12</sup> Like Dhont and Heylen (2009) we calculate our data for government consumption as total government consumption in % of GDP, diminished with the fraction of public education outlays going to wages and working-expenses. The latter are included in productive expenditures.

earnings before retirement. They include only (quasi-)mandatory public pensions, and are expressed as a percentage of this individual's average lifetime labor income, as is the case in our Equation (6). Voluntary, occupational pensions are not included. The overall average replacement rate is 68.3%, but there are strong cross-country differences.

A final set of data in Table 5 concern net education costs, and our indicator for education quality. Education costs include tuition fees, additional mandatory ancillary fees, costs of books and study material, and living costs<sup>13</sup>. Net costs can be obtained after deducting government grants. Net costs are among the highest in the US and the UK. They are among the lowest in the Netherlands, and the Nordic countries. We rely on PISA science scores to compute our proxy for the quality of schooling ( $q_a$ ) in the human capital formation functions (14, 15). We concentrate on science scores given their expected closer link to growth (Barro, 2001). Our procedure is as follows. The OECD presents for each country the mean PISA score obtained by pupils as well its standard deviation. We take the mean as representative for median ability individuals. The mean plus one standard deviation is relevant for high ability individuals, as only 16.6% will do better. The mean minus one standard deviation is relevant for low ability individuals, as only 16.6% will perform worse. We report the original OECD data in Appendix 2. The mean score is best in Finland, followed by the Netherlands, Canada and the UK. Finland also shows the lowest standard deviation, which goes along with the best test score in our sample also for low-ability individuals. As our proxy for education quality ( $q_L$ ,  $q_M$ ,  $q_H$ ) we divide each individual country score by its respective overall country average. These data are reported in Table 5. They reveal high quality across the board in Finland, the Netherlands, Canada and the UK. Quality is relatively low across the board in Italy, Denmark, Norway and the US.

Note that there is no correlation between productive government expenditures in Table 4 and the PISA scores in Table 5. Correlation with  $q_M$  for example is -0.04. There is no correlation either if we restrict productive expenditures to education only. Both variables seem to tell different stories (see also Woessmann, 2003).

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<sup>13</sup> Note that we report the data for a full-time student, in percent of per capita GDP. Given that  $e$  is the average fraction of time spent studying by the young generation, the size of which is  $\frac{1}{4}$  of total population, aggregate private education costs in percent of GDP in our model can be computed as  $(ec.e)/4$ . On average over all countries in our sample, this is about 1.1% of GDP ( $0.263 \times 0.167/4$ ). Similarly computed grants are about 0.25% of GDP on average.

**Table 5 Education (cost, subsidies, PISA science)**

	'Full-time' education cost (% GDP per capita) <sup>(a)</sup>	'Full-time' education grants (% of GDP per capita) <sup>(a)</sup>	PISA science score <sup>(b)</sup> (relative to benchmark)		
<b>Proxy for :</b>	<i>ec</i>	<i>es</i>	<i>q<sub>L</sub></i>	<i>q<sub>M</sub></i>	<i>q<sub>H</sub></i>
Austria	24.35	2.85	1.010	1.000	0.993
Belgium	18.31	0.91	0.978	0.996	1.008
France	26.12	4.92	0.973	0.990	1.002
Germany	23.54	1.14	0.975	0.990	1.000
Italy	24.24	0.94	0.931	0.947	0.957
Netherlands	23.51	13.51	1.049	1.036	1.026
Denmark	24.63	11.68	0.944	0.955	0.962
Finland	20.18	9.38	1.135	1.085	1.051
Norway	17.18	3.86	0.958	0.966	0.972
Sweden	23.57	10.37	1.002	1.000	0.998
UK	43.75	3.55	1.032	1.032	1.031
US	42.70	10.80	0.956	0.972	0.983
Canada	29.74	3.64	1.061	1.039	1.025
<b>Overall average</b>	26.29	5.97	1.000	1.000	1.000

Notes: (a) Education costs and grants have been taken from Usher and Cervenán (2005), complemented for Norway by Usher and Medow (2010). The data relate to 2003, except for Denmark and Norway (2008).

(b) Underlying data are PISA science scores at the 17<sup>th</sup>, 50<sup>th</sup> and 83<sup>th</sup> percentile in each country in 2000, 2003 and 2006. In Appendix 2 we report the average score over these three years. The data for  $q_L$ ,  $q_M$  and  $q_H$  in this table are expressed relative to the overall country average. Actual overall country average scores are 408 (17<sup>th</sup> percentile), 507 (median) and 606 (83<sup>th</sup> percentile).

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

Can our model match the facts that we have reported in Table 1? In this section we confront our model's predictions with the true data for 1995-2007. Clearly, one should be aware of the serious limitations of such an exercise. First of all, our model is highly stylized and may (obviously) miss potential determinants of growth or employment. Second, even if we compute the true data in Table 1 as averages over a longer period, these averages need not be equal to the steady state. Countries may still be moving towards their steady state. Third, this exercise only concerns the last 15 years. Due to lack of data – especially with respect to marginal labor tax rates and non-employment benefits before the mid 1990s – it is impossible for us to relate changes in growth and employment to changes in policy within countries over longer time periods. In spite of all this, if one considers the extreme variation in the predictions of existing calibrated models investigating the effects of fiscal policy in the literature (see Stokey and Rebelo, 1995), even a minimal test of the 'goodness of fit' of our model is informative. This information is important to assess the value of the simulation results that we present in the next section, and their reliability for policy analysis. In most papers in the literature a test of the external validity of the model is missing.

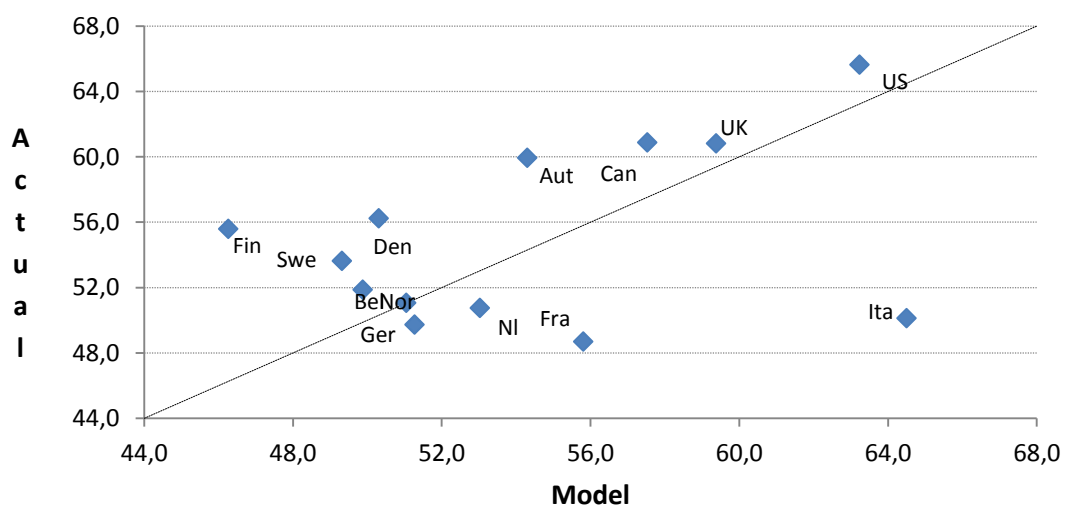
Our calibration implies that our model's prediction matches the average over all 13 countries of employment rates by age, education and per capita growth. The test of the model's validity is whether it also matches individual country data, and cross-country differences. Before one uses a model for policy 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 the fiscal policy variables, education costs and grants, the pension replacement rate and education quality differ. Moreover, assuming perfect competition, we disregard differences in labor and product market institutions which some authors consider of crucial importance (see Section 1). Still, we find that the model matches the facts remarkably well for a large majority of countries. Basically, we here confirm earlier findings by e.g. Ohanian *et al.* (2008) and Dhont and Heylen (2008) that once one controls for fiscal policy differences, variation in taste for leisure or different market rigidities are not critical to explain cross-country variation in labor market performance.

Figures 1 to 3 relate our model's predictions to actual observations for three employment rates by age (aggregated over the three ability groups). We add the 45°-line to assess the absolute differences between predictions and facts, as well as the coefficient of correlation between predictions and facts. Our model performs quite well. In each age group, it correctly predicts high employment rates in the US and Canada and low employment in Belgium and Germany. For young workers it also correctly predicts relatively low employment in most other countries of the core euro area, and in the Nordic countries. For older workers it has relatively high employment right in the Nordic countries and the UK. Overall correlation between the model's predictions and the actual data in Figure 1 is 0.36. If we drop Italy, for which there are good reasons<sup>14</sup>, this rises to 0.66. Correlation in Figure 2 is 0.51, in Figure 3 it is 0.75. Moreover, in each figure - again after dropping Italy from Figure 1 - the regression line (not shown) is close to the 45°-line, which suggests that our model correctly assesses the size of the employment effects of policy differences across countries. Next to Italy, there are a few other countries, where our model somewhat over- or underpredicts. The model's employment predictions tend to be too high for France, Italy and (except in Figure 1) the Netherlands. They tend to be too low in general for Denmark and Finland.

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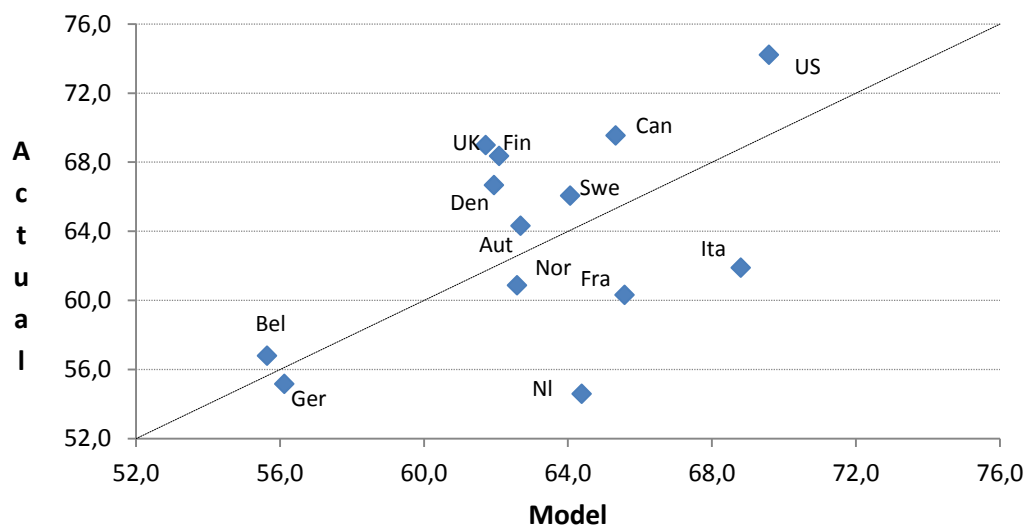
<sup>14</sup> A major element behind the deviation for this country seems to be underestimation of the fallback income position for structurally non-employed young workers. OECD data show very low replacement rates in Italy. However, as shown by Reyneri (1994), the gap between Italy and other European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

**Figure 1.** Employment rate in hours of young individuals in 13 countries, in %, 1995-2007



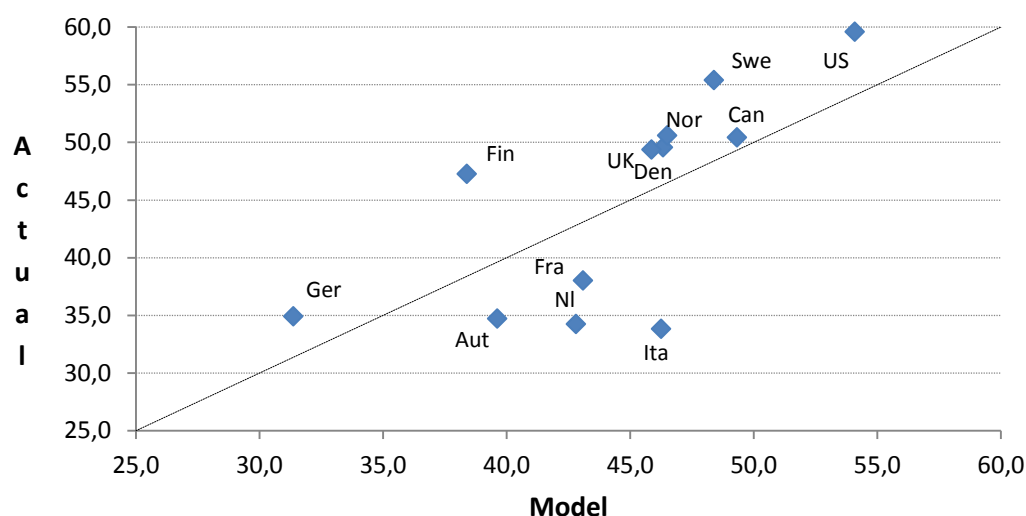
Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.36. Excluding Italy correlation rises to 0.66.

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



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

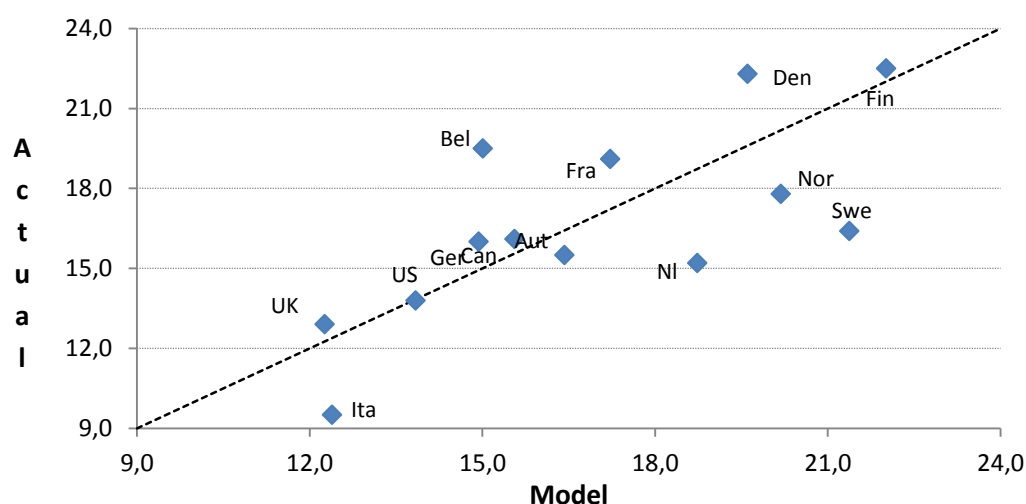
**Figure 3.** Employment rate in hours of older individuals in individual countries, in %, 1995-2007



Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.75.

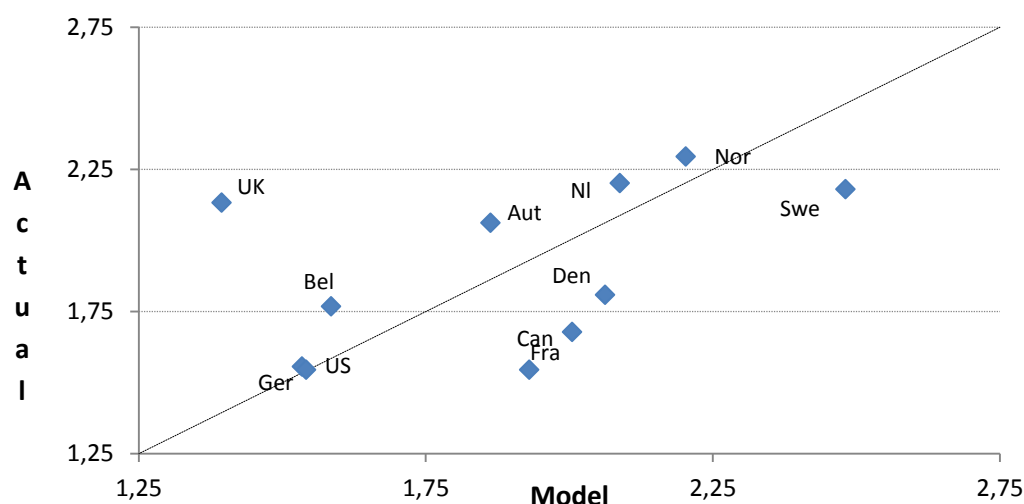
In Figures 4 and 5 we relate our model's predictions to the facts for education and growth. For education, the model correctly captures key differences between the Nordic countries on the one hand and countries like the UK and Italy on the other. Predictions for education are quite close to the 45°-line for all individual countries except Belgium, the Netherlands and Sweden. The model also has important cross-country differences right for growth. The model has more difficulty however to explain observed growth for France and especially the UK. Correlation between the model's predictions and the true data is 0.71 for education and 0.76 for growth.

**Figure 4.** Effective tertiary education rate in individual countries, in %, 1998-2007



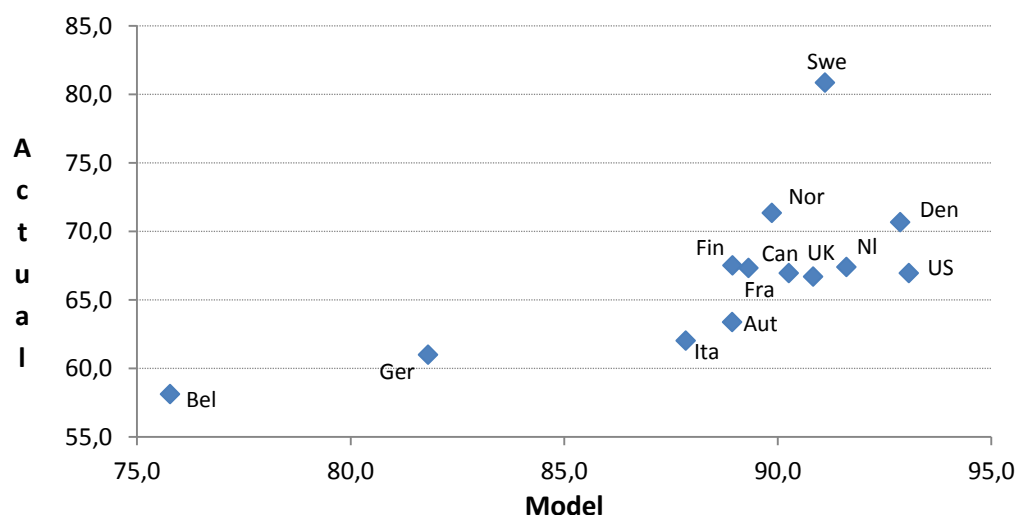
Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.71.

**Figure 5.** Annual per capita potential GDP growth in 13 countries, in %, 1995-2007



Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.76.

**Figure 6.** Relative employment of low ability individuals ( $n_L / n_H$ ) in % in 13 OECD countries (average for 1995, 2000, 2006)



Note: Correlation between actual data and the model's predictions is 0.66.

Figure 6 compares our model's predictions with the facts for the employment rate of the low ability group relative to the employment rate of high ability group (twice aggregated over the three generations). Correlation between actual data and the model's predictions is 0.66, but the model overpredicts the facts. Our model predicts the low relative employment rate of the low ability group right for countries like Belgium and Germany on the one hand, and predicts the high relative employment rate of the young ability group right for countries as Sweden and Norway on the other, but it tends to fail for the US. As to the US, our model is not the only one that misses the rather low employment rate among low-ability Americans. A large literature has tried to explain this (see The Economist, 2011 for a recent article).

## 5. 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. In the next section we focus on education policy. Our aim is to discover the (relative) effectiveness of changes in individual policy variables for the employment rate of three age groups, the employment rate of three ability groups, aggregate employment, and growth. We report steady state effects and welfare effects for current and future generations.

Starting from budget balance, we impose permanent (and unanticipated) fiscal shocks equal to 2% of initial output, i.e. output before any changes in employment or growth have taken place. We consider reductions in the tax rates and in the benefit replacement rates, and increases in government expenditures. All shocks are therefore expected to increase employment. Our benchmark from which we start, and against which all policy shocks are evaluated, is the average of 13 countries as reported at the bottom of Table 2<sup>15</sup>. Table 6 considers the effects of policy changes on steady state growth and employment, assuming that policy changes are financed by changes in lump sum transfers ( $z$ ) to maintain budget balance. In Table 7 we assume shocks to be compensated by a change in another fiscal policy variable.

Figure 7 shows the welfare effects of the policy measures described in Table 7 for the current and future generations of high and low ability individuals. Effects for the medium group are generally in between. We report on the vertical axis the welfare effect on the generation born in  $t+k$ , where  $k$  is indicated on the horizontal axis, and where  $t$  is the period when the (permanent, unanticipated) policy change is introduced. Our welfare measure is the (constant) percentage change in benchmark consumption in each period of remaining life that individuals should get to attain the same lifetime utility as after the policy shock (see also King and Rebelo, 1990). To compute this percentage change we keep employment rates at the benchmark.

In Table 8 we integrate the welfare effects induced by each policy 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 7. But now we also take into account differences in the length of remaining life. For young individuals the data in Figure 7 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 8 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 policy is announced.

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<sup>15</sup> 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, i.e. a different initial set of policy parameters and initial employment and growth (but the same preference and technology parameters). The size of effects is somewhat larger for example starting from the core euro area as benchmark.

Our main findings are as follows:

- (i) We confirm our earlier results in Heylen and Van de Kerckhove (2010) that the most effective policy to promote aggregate employment should include an overall cut in non-employment benefits, i.e. a cut for all age and ability groups (policy 3 in both Table 6 and Table 7). A key element is that this policy strongly raises the marginal utility from work versus inactivity. We observe positive responses among all age and ability groups. Young, older and lower ability individuals tend to show the strongest response. Overall labor tax cuts in policy 1 have much smaller effects, especially when financed by consumption taxes (Table 7).
- (ii) The most effective fiscal policies to promote growth include a labor tax cut on older workers and an increase in productive government expenditures (policies 2 and 4 in both tables). Both these policies raise the marginal return to education, either by making education time more productive, or by encouraging individuals to work longer during their third period. Aggregate employment effects from policy 2 are still positive, but much smaller than from policy 3, mainly because the young (of medium and high ability) restrict hours worked and study more. Rising participation in education among high and medium ability youngsters will also explain why more productive government expenditures will not be successful in raising aggregate employment. The aggregate employment rate falls in particular when additional productive expenditures are financed by a reduction of government consumption (Table 7). The same result (not shown) follows in the case of consumption tax increases.
- (iii) The bottom panel of Figure 7 reveals that the future generations of all ability groups benefit most from policies like policy 4, including higher productive expenditures (financed by a reduction of government consumption<sup>16</sup>). This holds also for the future low ability individuals, who inherit (a fraction of) the effective human capital accumulated by high and medium ability groups. For current generations, however, especially older and retired individuals, and individuals with low ability, this policy induces a welfare loss. This is confirmed in Table 8 where policy 4 induces the best net aggregate welfare effects for future generations but not for the current generations.
- (iv) Welfare differences by ability are even more explicit under policy 2. With the exception of the retired, who pay higher consumption taxes but receive no compensating gain, all high ability individuals see their welfare increase after a labor tax cut on older workers. For future high ability generations, policy 2 is the second best among the fiscal policy measures that we have simulated. Low ability individuals see much smaller welfare gains. The current generation of young (and retired) even lose significantly. Nevertheless, net aggregate welfare effects in Table 8 are positive.
- (v) Overall benefit cuts in policy 3 may be most effective to promote employment, but its long-run welfare effects are among the poorest of all fiscal policy measures. A key element is that since benefits are related to a person's human capital, they constitute part of the return to studying. Lower benefit replacement rates are therefore negative for education (see also Tables 6 and 7), and long-run output and growth. Table 8 reveals sizeable net aggregate welfare gains for policy 3.

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<sup>16</sup> Again, the same results follow from financing by means of higher consumption taxes.

**Table 6.** Fiscal shocks in the model (equal to 2% of output, ex ante) - compensated by changes in lump sum transfers (z)

Change in policy variable <sup>(a)</sup>	(1) $\Delta\tau_1=\Delta\tau_2$ $=\Delta\tau_3=-2.9$	(2) $\Delta\tau_3=-11.2$	(3) $\Delta b_1=\Delta b_2$ $=\Delta b_3=-8.3$	(4) $\Delta g_y=+2.0$	(5) $\Delta\tau_{low}=-10.2$	(6) $\Delta\tau_3=-8.5,$ $\Delta\tau_{low}=-2.5$	(7) $\Delta\tau_1=-11.2$	(8) $\Delta\tau_{low}=-19.4$
Effect <sup>(b)</sup> :								
$\Delta n_1$	0.40	-1.81	1.99	-2.35	2.51	-0.69	5.54	4.73
$\Delta n_2$	0.86	-0.02	1.65	0.86	0.46	0.10	-0.60	-0.80
$\Delta n_3$	1.34	5.62	2.35	1.34	0.72	4.51	-0.93	-1.25
$\Delta e$	0.25	1.64	-0.54	2.28	-1.15	0.90	-2.83	-1.99
$\Delta n^{(b, c)}$	0.84	1.01	1.97	-0.09	1.23	1.11	1.39	0.95
$\Delta N/N^{(d)}$	1.54	1.83	3.58	-0.16	2.24	2.02	2.53	1.73
$\Delta n_H$	0.46	0.23	2.27	-0.73	0.51	0.32	1.67	0.55
$\Delta n_M$	0.79	0.79	2.01	-0.31	1.52	1.09	1.62	1.80
$\Delta n_L$	1.28	2.00	1.62	0.77	1.66	1.91	0.88	0.50
$\Delta e_H$	0.33	2.60	-0.78	3.75	0.02	1.97	-4.69	0.00
$\Delta e_M$	0.42	2.32	-0.84	3.10	-3.47	0.77	-3.81	-5.97
$\Delta$ annual growth rate <sup>(b)</sup>	0.01	0.08	-0.03	0.35	-0.07	0.05	-0.17	-0.12
$\Delta z$ ex-post <sup>(e)</sup>	-2.54	-3.01	2.79	-1.66	-2.60	-2.86	-2.69	-2.69

Notes : (a) change in policy variable, in percentage points

(b) difference in percentage points between new steady state and benchmark, except  $\Delta N/N$

(c) change in (weighted) aggregate employment rate in hours

(d) change in volume of employment in hours, in %. Approximately,  $\Delta N/N = \Delta n/n$  with  $N$  total hours worked (and assuming potential hours constant)

(e) change in lump sum transfer (as a fraction of output) to maintain budget balance, in %-points.

(vi) In policy 5, we impose a labor tax cut on all low-wage earners. The latter include all low-ability individuals in addition to the young medium-ability individuals. Labor tax cuts on the low-wage earners have the second best effects on employment, but a negative effect on growth. Moreover, in Figure 7 they imply the strongest gap in welfare effects between ability groups. Low ability individuals win, all current and future high ability individuals lose. The political feasibility of policy 5 is therefore very unlikely, but its results may be inspiring for the development of a more balanced set of policies to the benefit all. Moreover, note in Table 8 that the net aggregate welfare effects of policy 5 are also negative.

(vii) Better overall employment effects, an improvement of the labor market position of the low ability group, and better welfare effects for this group, at a slight cost in terms of growth, are possible if one complements policies that cut labor taxes on older workers with labor tax cuts on the low wage earners (policy 6). The best effects on employment follow if this combined tax cut is

financed by overall benefit cuts (policy 6b in Table 7). Policy 6b induces also very high and positive net aggregate welfare effects.

- (viii) Additional simulations (policy 8 in Table 6) reveal that focusing tax cuts on young low wage earners alone does not bring much gain, not even for the employment rate among the low ability group. Young low ability workers would simply substitute hours worked when young for hours worked when middle aged and older. An overall positive effect on their income would even discourage their labor supply. In line with our findings in Heylen and Van de Kerckhove (2010) focusing labor tax cuts on all young workers (policy 7 in Table 6) has strong negative effects on growth. By raising the opportunity cost of studying, it pulls high and medium ability individuals out of education.

**Table 7.** Fiscal shocks in the model (equal to 2% of output) - compensated by a change in another fiscal policy variable

Change in policy variable <sup>(a)</sup>	(1) $\Delta\tau_1=\Delta\tau_2$ $=\Delta\tau_3=-2.9$	(2) $\Delta\tau_3=-11.2$	(3) $\Delta b_1=\Delta b_2$ $=\Delta b_3=-8.3$	(4) $\Delta g_y=2.0$	(5) $\Delta\tau_{low}=-10.2$	(6a) $\Delta\tau_3=-8.5$ $\Delta\tau_{low}=-2.5$	(6b) $\Delta\tau_3=-8.5$ $\Delta\tau_{low}=-2.5$
Compensating change <sup>(e)</sup>	$\Delta\tau_c=5.8$	$\Delta\tau_c=7.0$	$\Delta\tau_c=-6.2$	$\Delta g_c=-1.7$	$\Delta\tau_c=5.9$	$\Delta\tau_c=6.6$	$\Delta b_1=\Delta b_2$ $=\Delta b_3=-8.3$
Effect <sup>(b)</sup> :							
$\Delta n_1$	-0.11	-2.44	2.52	-2.70	2.03	-1.27	1.30
$\Delta n_2$	0.15	-0.90	2.43	0.37	-0.25	-0.72	1.77
$\Delta n_3$	0.23	4.39	3.55	0.58	-0.38	3.33	6.70
$\Delta e$	0.21	1.59	-0.48	2.25	-1.20	0.86	0.37
$\Delta n^{(b, c)}$	0.08	0.11	2.79	-0.61	0.49	0.27	3.04
$\Delta N/N^{(d)}$	0.15	0.19	5.07	-1.11	0.89	0.49	5.54
$\Delta n_H$	0.00	-0.31	2.78	-1.04	0.02	-0.20	2.58
$\Delta n_M$	0.04	-0.09	2.81	-0.83	0.75	0.26	3.06
$\Delta n_L$	0.21	0.72	2.77	0.03	0.69	0.74	3.49
$\Delta e_H$	0.27	2.53	-0.70	3.70	-0.04	1.90	1.17
$\Delta e_M$	0.35	2.23	-0.74	3.05	-3.55	0.69	-0.05
$\Delta$ annual growth rate <sup>(b)</sup>	0.01	0.08	-0.03	0.35	-0.07	0.05	0.02

Notes : (a) change in policy variable, in percentage points.

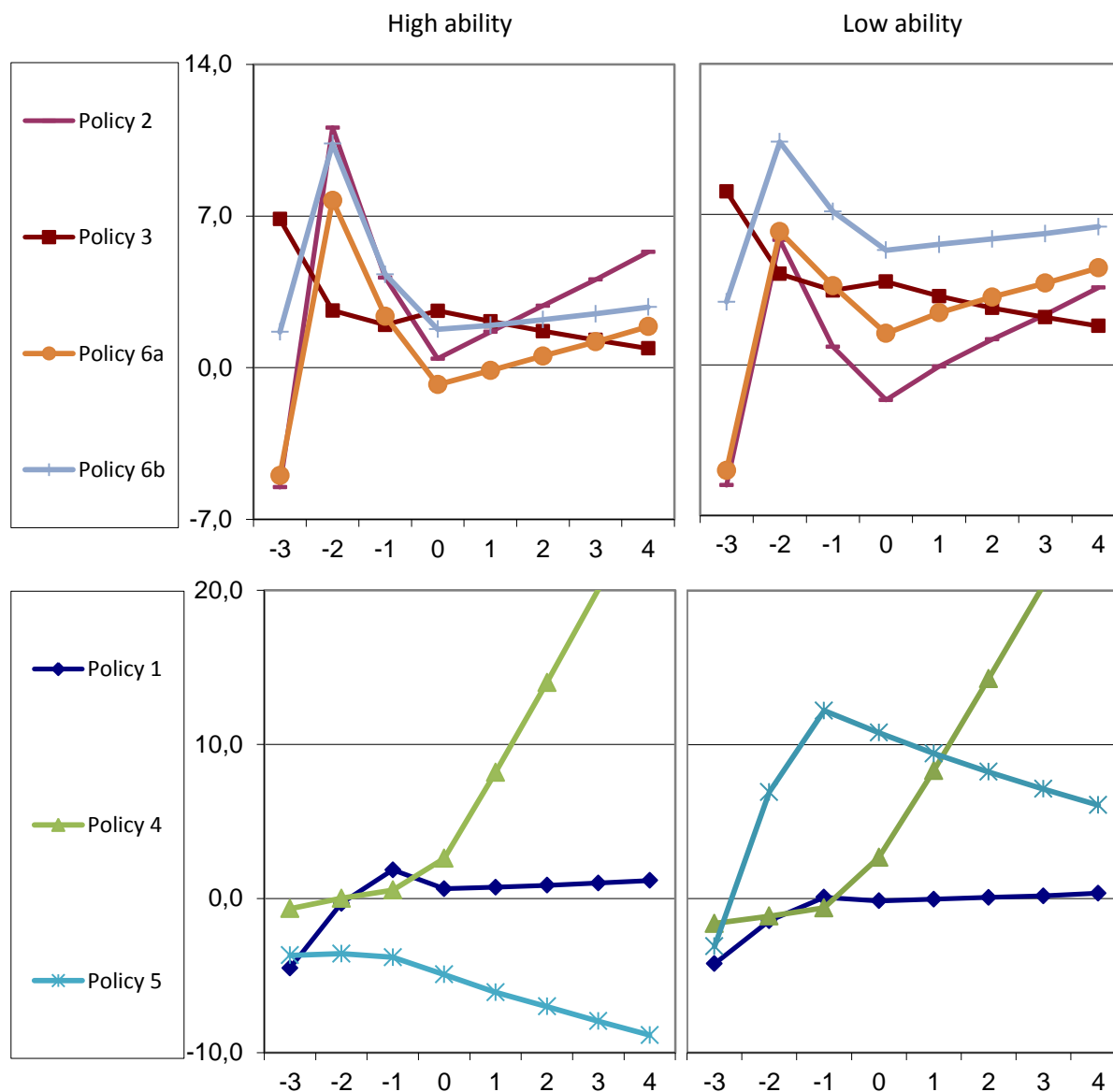
(b) difference in percentage points between new steady state and benchmark, except  $\Delta N/N$ .

(c) change in (weighted) aggregate employment rate in hours

(d) change in volume of employment in hours, in %

(e) compensating change, in percentage points

**Figure 7.** 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 8.** 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 6a	Policy 6b
All current + 4 future	0.6	4.4	4.8	16.2	-2.6	2.9	7.6
All current	0.0	1.9	2.9	0.8	-0.6	1.3	4.2

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

## 6. 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. Concern for employment and growth is not new. They have been high on the agenda of both policy makers and researchers since at least two decades.

Our main contribution in this paper is study the effects of fiscal policy on hours of work of young, middle aged and older individuals, education of the young, and aggregate growth, within one coherent framework, where all these variables are endogenous. Moreover, we realistically take into account heterogeneity in individuals' ability to build human capital. Our general equilibrium approach allows also to model important linkages between education (and growth) and labor supply during all periods of life. These linkages are generally lacking in the literature studying fiscal policy effects.

We pay particular attention to a careful calibration of our model. Before using it for policy simulations, we evaluate its empirical relevance on a group of 13 OECD countries. While we exploit cross-country differences in the composition of fiscal policies we impose the same labor and product market institutions (perfect competition), the same taste for leisure, and the same technology in all countries. We find that the predictions of our model match the main facts well for all key variables in a large majority of countries.

Our policy simulations investigate the strength of the effects of various fiscal policy shocks on steady state employment by age and ability, and growth. Our main findings are as follows. First, we confirm our earlier results in Heylen and Van de Kerckhove (2010). We again identify labor taxes and (especially) 'non-employment' benefits as the main policy variables affecting employment. Productive government expenditures are the most effective with respect to long-run output and growth. Again we observe that output and growth may benefit also from labor tax cuts targeted at older workers. 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 welfare losses. Third, better overall employment effects and better welfare effects for low ability groups, at a slight cost in terms of growth, 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 benefit cuts.

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, tax cuts on the low wage earners, and higher productive expenditures.

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## **Appendix 1: Construction of data and data sources**

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

### ***Employment rate in hours (in one of three age groups, 1995-2007)***

*Definition:* total actual hours worked by individuals in the age group / potential hours worked.

Actual hours worked = total employment in persons x average hours worked per week x average number of weeks worked per year

Potential hours = total population in the age group x 2080 (where 2080 = 52 weeks per year x 40 hours per week)

*Data sources:*

\* Total employment in the age group / total population in the age group: OECD Stat, Labour Force Statistics by Sex and Age. Data are available for many age groups, among which 20-24, 25-34, 35-44, 45-49, 50-54, 55-64. We constructed the data for our three age groups as weighted averages.

\* Average hours worked per week: OECD Stat, Labour Force Statistics, Average usual weekly hours worked on the main job. These data are available only for age groups 15-24, 25-54, 55-64. We use the OECD data for the age group 15-24 as a proxy for our age subgroup 20-24, the OECD data for the age group 25-54 as a proxy for our age (sub)groups 25-34, 35-49 and 50-54.

\* Average number of weeks worked per year: Due to lack of further detail, we use the same data for each age group. The average number of weeks worked per year has been approximated by dividing average annual hours actually worked per worker (total employment) by average usual weekly hours worked on the main job by all workers (total employment). Data source: OECD Stat, Labour Force Statistics, Hours worked.

### ***Employment rate by educational attainment***

We use data for the employment/population ratio by educational attainment for persons of age 25-64. Our ratio  $n_L/n_H$  has been computed from data for people (both sexes) with less than upper secondary education and people with tertiary education. The data in Table 1 are an average for 1995, 2000 and 2006.

*Data sources:* OECD Employment Outlook, Statistical Annex, Table D.

### ***Effective education rate of young, e (age group 20-34, 1998-2007)***

*Definition:* total effective hours studied by individuals of age 20-34 / potential hours studied

This variable is constructed as the fraction of hours spent by young people in tertiary education, multiplied by the normalized completion rate of tertiary education, as shown in the Table below.

As a proxy for the fraction of hours spent by young people in tertiary education we use the ratio of students in tertiary education in full-time units, to population of age 20-34.

Not all hours need to be effective hours, however. Students may take more years than required to complete a degree. Some students may never complete it. Countries may differ in the incidence of ineffective hours. Our approach is that the completion rate gives an indication of the overall

effectiveness of hours in tertiary education. This variable is computed as the ratio of the number of graduates from a degree in a particular year to the number of new entrants in this degree  $z$  years ago, where  $z$  is the number of years of full-time study required to complete the degree. We compute the effective time in tertiary education as the fraction of hours spent, multiplied by the completion rate normalized to the overall country average (see Table). We do not adjust by the absolute completion rate since that would imply that each successful year that a student spends in tertiary education would be classified as 'leisure' if he/she does not obtain the degree in the end.

*Data sources:*

\* Students in tertiary education in full-time units: Eurostat, Students by ISCED level, study intensity (full-time, part-time) and sex [educ\_enrl1ad], levels 5-6. Missing data for some years in some countries were obtained by interpolation from existing data.

\* Completion rate in tertiary education: OECD, Education at a Glance, 2009, Table A3.4.

	Unadjusted fraction of time in tertiary education, 1998-2007	Completion rate, 2005	Normalized completion rate	effective $e$
Austria	15.1	0.71	1.03	15.5
Belgium (Fl)	16.5	0.82	1.19	19.5
France	16.7	0.79	1.14	19.1
Germany	14.4	0.77	1.11	16.0
Italy	14.5	0.45	0.65	9.5
Netherlands	14.8	0.71	1.03	15.2
Denmark	18.2	0.85	1.23	22.3
Finland	21.6	0.72	1.04	22.5
Norway	18.9	0.65	0.94	17.8
Sweden	16.4	0.69	1.00	16.4
US	20.3	0.47	0.68	13.8
UK	13.9	0.64	0.93	12.9
Canada	15.5	0.72	1.04	16.1
Overall average	16.7	0.69	1.00	16.7

***Annual real potential per capita GDP growth rate (aggregate, 1995-2007)***

*Definition:* Annual growth rate of real potential GDP per person of working age

*Data sources:*

\* real potential GDP: OECD Statistical Compendium, Economic Outlook, supply block, series GDPVTR.

\* population at working age: OECD Statistical Compendium, Economic Outlook, labour markets, series POPT.

**Tax rate on labor income ( $\tau_j$  for  $j=1,2,3$ )**

*Definition:* Total tax wedge, marginal tax rate in % of gross wage earnings. The data cover personal income taxes, employee and employer social security contributions payable on wage earnings and payroll taxes.

*Data source:* OECD, Statistical Compendium, Financial and Fiscal Affairs, Taxing Wages, Comparative tax rates and benefits (new definition).

The OECD publishes 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.

**Net benefit replacement rates when young and middle aged ( $b_1, b_2$ )**

*Definition:* The data concern net transfers received by long-term unemployed people and include social assistance, family benefits and housing benefits in the 60<sup>th</sup> month of benefit receipt. They also include unemployment insurance or unemployment assistance benefits if these benefits are still paid, i.e. if workers can be structurally unemployed for more than five years without losing benefit eligibility. The data are expressed in % of after-tax wages. The OECD provides net replacement rates for six family situations and three earnings levels. Our data in Table 4 are the averages of these 18 cases. Data for 2001-04.

*Data source:* OECD, Tax-Benefit Models, [www.oecd.org/els/social/workincentives](http://www.oecd.org/els/social/workincentives)

*Data adjustment:* Original OECD data for Norway include the so-called “waiting benefit” (ventestønad), which a person could get after running out of unemployment benefits. Given the conditional nature of these “waiting benefits”, they do not match our definition of benefits paid to structurally non-employed individuals. We have therefore deducted them from the OECD data, which led to a reduction of net replacement rates by about 19 percentage points. For example, recipients should demonstrate high regional mobility and willingness to take a job anywhere in Norway. The “waiting benefit” was terminated in 2008. We thank Tatiana Gordine at the OECD for clarifying this issue with us.

**Net benefit replacement rates ( $b_3$ )**

To calculate our proxy for  $b_3$  we have taken into account 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 early retirement benefit replacement rate  $r_3$ .

If we look at the data, we observe that  $r_3$  is higher than the net unemployment benefit replacement rate  $b_2$  in some countries (e.g. Belgium, France, Netherlands,...) but not in others (Denmark, Norway, Sweden, US). It is unlikely that older workers will choose the early retirement option in the latter group of countries. They may however strongly prefer this option in the former group. The implication of these arguments is that we will assume  $b_3 = b_2$  in countries where  $r_3 < b_2$ . By contrast, in countries where  $r_3 > b_2$ , it seems more adequate to model  $b_3$  as a weighted average of  $r_3$  and  $b_2$ . The weight of each component would obviously depend on eligibility criteria in the early retirement system. Due to lack of specific data on this, however, we had to make a very rough assumption. Underlying the data in Table 4 is the assumption that  $b_3 = 0.75b_2 + 0.25r_3$ . Clearly, our results in the main text do not depend in any serious way on this assumption.

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

## Appendix 2: OECD PISA science scores (average for 2000, 2003, 2006)

	Median	Standard deviation	High	Low
Austria	507	95	602	412
Belgium	505	106	611	399
France	502	105	607	397
Germany	502	104	606	398
Italy	480	100	580	380
Netherlands <sup>(a)</sup>	525	97	622	428
Denmark	484	99	583	385
Finland	550	87	637	463
Norway	490	99	589	391
Sweden	507	98	605	409
UK <sup>(b)</sup>	523	102	625	421
US	493	103	596	390
Canada	527	94	621	433
<b>Overall average</b>	507	99	606	408

Notes: The median science score and the standard deviation in this table are based on OECD data for 2000, 2003 and 2006. High and low are computed as the median plus or minus one standard deviation. Given the close to normal distribution of individual PISA scores, they are proxies for individuals at the 83<sup>th</sup> and the 17<sup>th</sup> percentile.

(a) Data are missing for 2000, (b) data are missing for 2003.

Data source: [www.pisa.oecd.org/](http://www.pisa.oecd.org/)

### Appendix 3: Detail on calibration procedure to determine $\eta_a$ and $\phi_a$ (with $a=L, M$ )

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

$$\frac{w_{L,t} h_{1L}^t}{w_{H,t} h_{1H}^t} = \frac{w_{L,t} \varepsilon_{L(US)} h_{1H}^t}{w_{H,t} h_{1H}^t} = \frac{w_{L,t}}{w_{H,t}} \cdot \varepsilon_{L(US)} = 0.43.$$

We also know from Equation (23) that  $\frac{w_{L,t}}{w_{H,t}} = \frac{\eta_L}{\eta_H} \left( \frac{H_{H,t}}{H_{L,t}} \right)^{1/s}$  which implies for the US:

$$\frac{\eta_L}{\eta_H} \left( \frac{H_{H,t}}{H_{L,t}} \right)^{1/s} = \frac{0.43}{\varepsilon_{L(US)}} = \frac{0.43}{0.654} = 0.66.$$

Similarly, it is easy to obtain for the medium ability group:

$$\frac{\eta_M}{\eta_H} \left( \frac{H_{H,t}}{H_{M,t}} \right)^{1/s} = \frac{0.63}{\varepsilon_{M(US)}} = \frac{0.63}{0.827} = 0.76.$$

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

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

$$\begin{aligned} \frac{w_{L,t} h_{2L}^{t-1}}{w_{H,t} h_{2H}^{t-1}} &= \frac{w_{L,t} x_L^{t-1} \varepsilon_{L(US)} h_{1H}^{t-1}}{w_{H,t} x_H^{t-1} h_{1H}^{t-1}} = \frac{w_{L,t} x_L^{t-1}}{w_{H,t} x_H^{t-1}} 0.654 = 0.38 \\ \frac{w_{M,t} h_{2M}^{t-1}}{w_{H,t} h_{2H}^{t-1}} &= \frac{w_{M,t} x_M^{t-1} \varepsilon_{M(US)} h_{1H}^{t-1}}{w_{H,t} x_H^{t-1} h_{1H}^{t-1}} = \frac{w_{M,t} x_M^{t-1}}{w_{H,t} x_H^{t-1}} 0.827 = 0.58 \end{aligned}$$

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

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## **CHAPTER 4**

### **Pension reform in an OLG model with heterogeneous abilities**

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# Pension reform in an OLG model with heterogeneous abilities

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## Abstract

We study the effects of pension reform in a four-period OLG model for an open economy where hours worked by three active generations, education of the young, the retirement decision of older workers, and aggregate growth, are all endogenous. Within each generation we distinguish individuals with high, medium or low ability to build human capital. This extension allows to investigate also the effects of pension reform on the income and welfare levels of different ability groups. Particular attention goes to the income at old-age and the welfare level of low-ability individuals.

Our simulation results prefer an intelligent pay-as-you-go pension system above a fully-funded private system. When it comes to promoting employment, human capital, growth, and aggregate welfare, positive effects in a pay-as-you-go system are the strongest when it includes a tight link between individual labor income (and contributions) and the pension, and when it attaches a high weight to labor income earned as an older worker to compute the pension assessment base. Such a regime does, however, imply welfare losses for the current low-ability generations, and rising inequality in welfare. Complementing or replacing this ‘intelligent’ pay-as-you-go system by basic and/or minimum pension components is negative for aggregate welfare, employment and growth. Better is to maintain the tight link between individual labor income and the pension also for low-ability individuals, but to strongly raise their replacement rate.

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

**JEL Classification:** E62; H55; J22; J24

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## 1. Introduction

Concern for the long-run financial viability of public pension systems has put pension reform high on the agenda of policy makers and researchers. The past two decades have seen a wave of reforms in many countries (Whitehouse *et al.*, 2009). At the same time the literature on pension economics has grown rapidly (see e.g. Lindbeck and Persson, 2003; Barr, 2006; and many recent papers that we refer to below). To face the pension challenge, there seems to be general agreement on the need for higher employment, especially among older individuals, and higher productivity growth. Many studies have documented how the pension system may affect the incentives of individuals of different ages to work (e.g. Sheshinski, 1978; Auerbach *et al.*, 1989; Gruber and Wise, 2002; Börsch-Supan and Ludwig, 2010; Sommacal, 2006; Fisher and Keuschnigg, 2010; Jaag *et al.*, 2010; de la Croix *et al.*, 2013). Others have investigated the relationship between the pension system and investment in human capital formation, as a major determinant of productivity growth (e.g. Zhang, 1995; Kemnitz and Wigger, 2000; Zhang and Zhang, 2003; Kaganovich and Meier, 2008; Le Garrec, 2012). Still others have demonstrated the crucial role of human capital formation to counteract the negative effects of population ageing on per capita output (e.g. Docquier and Michel, 1999; Ludwig *et al.*, 2012). Consensus on what pension reform would serve the goals of higher employment, productivity growth, and welfare best, has however not been reached. The results in some papers support parametric adjustments in the pay-as-you-go (PAYG) system that most countries rely on. Other papers prefer a gradual move to an actuarially neutral fully-funded private system. Often, differences in the particular specification of the model economy that is used for the analysis may explain the differences in results (Buyse *et al.*, 2011).

The above mentioned literature has strongly improved our understanding of the effects of pension systems on employment, education and growth. Still, it is limited in some respects. First of all, about all existing studies either investigate incentives to work in a model with exogenous human capital and growth, or investigate human capital and growth while ignoring the labor-leisure choice and the endogeneity of labor supply. Buyse *et al.* (2011) and Ludwig *et al.* (2012) are exceptions<sup>1</sup>. These two studies also clearly demonstrate the importance of modelling the many mutual relationships between key variables. For example, if policy can make people postpone retirement and work longer, the return to investment in education will rise, and so may human capital and growth. Conversely, policies that promote education will also encourage people to work longer since they will then get a higher return from their investment. Also, if pension reform discourages employment of the young, it may still be positive if this contributes to education and growth. For a proper assessment of the effects of pension reform it is important to take such interactions into account.

Second, with the exception of Sommacal (2006) who distinguishes exogenous fractions of skilled and unskilled workers, the above mentioned literature disregards differences in abilities and capacity of people to learn. Models with education and growth typically assume that everyone is able to study and succeed in education. Reality is different, however. Data reveal that in 2008 about 30%

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<sup>1</sup> Ludwig *et al.* (2012) develop a model with endogenous employment by age and human capital, but they have exogenous growth. Buyse *et al.* (2011) also have endogenous growth.

of the 25-64 year old population on average 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 therefore remained below 30%. Among young cohorts, educational attainment is higher. Yet, the fraction that does not complete upper secondary education is still about 20% on average. About 40% obtains an upper secondary degree, but no tertiary degree. More or less another 40% completes both secondary and tertiary education (OECD, Education at a Glance, Tables A1, A2.2, A3.2). The simple fact that innate ability as for example reflected by IQ varies across people, implies that one can never expect everyone to succeed at the secondary, let alone the tertiary level.

In this paper we study pension reform in a general equilibrium four-period OLG model where hours of work of young, middle aged and older individuals, education and human capital formation of the young, the retirement decision of the older generation, and aggregate per capita growth are all endogenous. We build on our earlier work in Buyse *et al.* (2011). The model includes a public PAYG old-age pension system which pays out pensions to a fourth generation of retired. The statutory retirement age in the model is 65 and exogenous. Old-age pensions are paid from this age onwards. Individuals, however, may optimally choose a lower effective (early) retirement age. They then receive early retirement benefits. Our main innovation in this paper is to introduce heterogeneous abilities. We make the assumption that within each generation three ability groups exist. These groups differ both in the degree to which they (when young) assimilate existing knowledge, i.e. inherit human capital from the middle aged generation, and in their productivity of schooling when they spend time studying. One group has low ability. They inherit relatively little human capital from the middle aged generation, and will never engage in tertiary education. They will only work or have 'leisure'. A second group has medium ability, a third group high ability. These groups inherit higher fractions of existing human capital, and do allocate time to tertiary education. Given the variation between them in the productivity of schooling, this amount of time will differ, however.

Our aim is then to investigate the effects of various parametric adjustments in the old-age PAYG pension system on the employment rate of young, middle aged and older workers, education, growth and welfare. These parametric adjustments include changes in benefit levels, changes in the link between benefits and individual contributions, and changes in the weights of the three active periods in the computation of the old-age pension assessment base, i.e. earned labor income used to calculate pension benefits. We also consider the effects of moving to full private capital funding. An advantage of realistically introducing heterogeneous abilities, and therefore an important contribution of this paper, is that we will be able to study differential effects of pension reform on the income and welfare levels of individuals with different abilities and human capital. Particular attention goes to the income at old-age and the welfare level of the low-ability individuals. The link to a major issue as old-age poverty (see e.g. Kidd and Whitehouse, 2009) is obvious.

Our results prefer an 'intelligent' PAYG system above a fully-funded private system. When it comes to promoting employment, human capital, growth, and aggregate welfare, we find positive effects in a PAYG system to be the strongest when it includes a tight link between individual labor income (and contributions) and the pension, and when it attaches a high weight to labor income earned as an

older worker to compute the pension assessment base. Pension reform in this direction encourages young individuals to study and build human capital, which promotes long-run growth. Furthermore, it encourages older workers to postpone retirement. Strengthening the link between one's future old-age pension, on the one hand, and one's human capital and labor supply when older, on the other, introduces strong financial incentives which may bring about important changes in behavior. In this sense, our results fully confirm those of Buyse *et al.* (2011). However, our paper also sharply clarifies the limitations of neglecting heterogeneity in people's ability. We find that the above described 'intelligent' PAYG system implies welfare losses for the current low-ability generations who cannot study and who earn low wages. Aggregate welfare inequality rises strongly. Complementing or replacing this system by basic and/or minimum pension components promotes welfare of the current and (maybe some) future low-ability generations, but it is negative for aggregate welfare, employment and growth. Labor supply and employment among low-ability individuals in particular fall sharply. Better is to maintain the tight link between individual labor income and the pension also for low-ability individuals, but to significantly raise their replacement rate.

The structure of this paper is as follows. In Section 2 we document differences in employment by age, education of the young, the effective retirement age, and per capita growth across 13 OECD countries since 1995. Section 3 sets out our model. Next to the pension system, we introduce a role for education quality as well as a rich fiscal policy block. The government in the model sets tax rates on labor, capital and consumption. It allocates its revenue to productive expenditures (mainly for education), consumption, 'non-employment' benefits (including early retirement benefits), old-age pensions, and interest payments on outstanding debt. In Section 4 we calibrate the model on actual data and confront its predictions with the facts described in Section 2. Section 5 includes the results of a range of model simulations. We investigate the steady state employment, education and growth effects of various reforms of the pension system. We also study welfare effects per generation and per ability group. Section 6 concludes the paper.

## **2. Cross-country differences in employment, tertiary education and per capita growth**

Table 1 contains key data on employment, education and growth in 13 OECD countries in 1995-2007. One would like a reliable model to match the main cross-country differences reported here. The employment rate in hours ( $n$ ) indicates the fraction of potential hours that are actually being worked by the average person in one of three age groups (20-34, 35-49, 50-64). Comparable data for hours worked by ability type (skill level) are not available. Potential hours are 2080 per person per year (52 weeks times 40 hours per week). The observed employment rate rises if more people in an age group have a job, and if the employed work more hours. The employment rate in the age group of 50 to 64 is also affected by the average age at which older workers withdraw from the labor force. We include the effective retirement age in the Table. In most countries, this age is well below the official age to receive old-age pensions (65 in most countries, 60 in France and Italy). The education rate ( $e$ ) is our proxy for the fraction of time spent studying by the average person of age 20-34. It has been calculated as the total number of students in full-time equivalents, divided by total population in this

age group. Our data for (average annual) real per capita growth concern real potential GDP per person of working age. We refer to Appendix 1 for details on the calculation of our data, and on the assumptions that we have to make.

**Table 1**

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

	<i>n</i> <sub>1</sub> (20-34)	<i>n</i> <sub>2</sub> (35-49)	<i>n</i> <sub>3</sub> (50-64)	Effective retirement age	<i>e</i>	Annual real per capita growth
Austria	59.9	64.3	34.7	59.5	12.5	2.06
Belgium	51.1	56.8	29.3	57.9	14.1	1.77
France	48.7	60.3	38.0	58.8	14.9	1.54
Germany	49.7	55.2	34.9	61.1	17.2	1.56
Italy	50.1	61.9	33.8	60.1	12.6	1.30
Netherlands	50.8	54.6	34.2	60.0	14.7	2.20
<b>Core euro area average</b>	<b>51.7</b>	<b>58.8</b>	<b>34.2</b>	<b>59.6</b>	<b>14.3</b>	<b>1.74</b>
Denmark	56.2	66.7	49.6	62.2	21.7	1.81
Finland	55.6	69.0	47.3	60.2	23.1	2.72
Norway	51.9	60.9	50.6	63.1	18.1	2.29
Sweden	53.6	66.1	55.4	63.4	17.7	2.18
<b>Nordic Average</b>	<b>54.3</b>	<b>65.6</b>	<b>50.7</b>	<b>62.2</b>	<b>20.2</b>	<b>2.25</b>
<b>US</b>	<b>65.6</b>	<b>74.2</b>	<b>59.6</b>	<b>64.2</b>	<b>12.8</b>	<b>1.54</b>
UK	60.8	68.4	49.4	62.0	12.3	2.13
Canada	60.9	69.5	50.4	62.1	13.6	1.68
<b>All country Average</b>	<b>55.0</b>	<b>63.7</b>	<b>43.6</b>	<b>61.1</b>	<b>15.8</b>	<b>1.91</b>

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

As is well-known, middle aged individuals work most hours, followed by the young. The older generation works the lowest number of hours. Average employment rates 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. The Nordic countries take intermediate positions, although they are close to the core euro area for the younger generation. The latter, however, seems to be related to education. Young people's effective participation in education is also by far the highest in the Nordic countries. These countries also show the highest potential per capita growth rates. On average, growth in the core euro area and the US was more than 0.5 percentage points lower in the period under consideration. The US and the other Anglo-Saxon countries tend to have the lowest participation in education among people of age 20 to 34. Finally, we note that the effective retirement age also varies across countries. The retirement age is quite low in Belgium (57.9) and France (58.8). By contrast, individuals in Nordic or Anglo-Saxon

countries participate longer. Unsurprisingly, correlation between the effective retirement age and the employment rate among older workers ( $n_3$ ) is very high (0.89).

### 3. The model

Our analytical framework consists of a computable four-period OLG-model for a small open economy. We assume perfect international mobility of physical capital but immobile labor and human capital. Seminal work in the OLG tradition has been done by Samuelson (1958) and Diamond (1965). Auerbach and Kotlikoff (1987) initiated the study of public finance shocks in a computable OLG model. Buiter and Kletzer (1993) developed an open economy version of the model with endogenous growth, putting human capital at the centre. As we have documented in Section 1, a large literature has used OLG models to study the behavioral effects of the pension system either on employment assuming exogenous growth, or on human capital and growth ignoring the labor-leisure choice and assuming exogenous employment. New in this paper is that we explain both employment by age, and human capital and growth as jointly endogenous variables *and* that we realistically take into account differences in individuals' innate abilities.

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

Output is produced by domestic firms which act competitively and employ physical capital together with existing technology and effective labor provided by the three active generations. A final important assumption is that education generates a positive externality in the sense of Azariadis and Drazen (1990). Each young generation inherits a fraction of the average level of human capital of a middle aged generation. The higher an individual's ability, the larger the fraction he inherits. In what follows, we concentrate on the core elements of the model: the optimizing behavior of individuals, the production and inheritance of effective human capital, the behavior of domestic firms and the determination of aggregate output and growth, capital and wages.

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

### 3.1. Individuals

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

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

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

$$\ell_{1a}^t = 1 - n_{1a}^t - e_{1a}^t \quad (2)$$

$$\ell_{2a}^t = 1 - n_{2a}^t \quad (3)$$

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

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

Superscript  $t$  indicates the period of youth, when the individual comes into the model. Subscript  $j$  refers to the  $j$ th period of life and  $a$  refers to the ‘ability type’. Lifetime utility depends on consumption ( $c_{ja}^t$ ) and enjoyed leisure ( $\ell_{ja}^t$ ) in each period of life. The intertemporal elasticity of substitution in consumption is 1, the intertemporal elasticity to substitute leisure  $\frac{1}{\theta}$ . Finally,  $\beta$  is the discount factor and  $\gamma$  specifies the relative value of leisure versus consumption. The preference parameters  $\theta, \beta$  and  $\gamma$  do not depend on ability type. Note, however, that  $\gamma$  may be different in each period of life. Except for the latter assumption, our specification of the instantaneous utility function is quite common in the macro literature (e.g. Benhabib and Farmer, 1994; Rogerson, 2007).

Equations (2)-(4) describe the individual’s enjoyed leisure in each of the four periods of his life. For a proper understanding we summarize his life-cycle in Figure 1. Time endowment in each period is normalized to 1. Next to leisure, individuals devote time to work ( $n_{ja}^t$ ) in their three active periods and to education ( $e_{1a}^t$ ) when young. In the first period of active life, leisure therefore falls in labor supply and in education time. Only the low ability individuals do not study ( $e_{1L}^t = 0$ ). In the second and third period leisure falls in labor supply only. A key element in the individuals’ optimal choice of leisure time in the third period of life (50-65) is 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 then time in early retirement. We use  $n_{3a}^t$  to denote the fraction of time devoted to work between 50 and 65, and  $\tilde{n}_{3a}^t$  as the fraction of time devoted to work before early retirement, but after 50. As labor market exit is irreversible and post-retirement employment is not allowed in our model, the relationship between use  $n_{3a}^t$  and  $\tilde{n}_{3a}^t$  is as follows:  $n_{3a}^t = R_a^t \cdot \tilde{n}_{3a}^t$ . In the third period, leisure time thus 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 (see also Buyse *et al.*, 2011). We assume imperfect substitutability between the two leisure types. The idea here is that leisure time after and between

periods of work is not the same as leisure time in periods when individuals are not economically active anymore<sup>3</sup>. 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  $\zeta$  is the constant elasticity of substitution,  $\mu$  is a usual share parameter and  $\Gamma$  is added as a normalization constant such that the magnitude of  $\ell_{3a}^t$  corresponds to the magnitude of total leisure time ( $1 - n_{3a}^t$ ). The latter assumption allows to interpret  $\gamma_3$  as the relative value of leisure versus consumption in the third period, comparable to  $\gamma_1$  and  $\gamma_2$ . The main results in this paper are not in any way influenced by the magnitude of  $\mu$ ,  $\Gamma$  or  $\zeta$ .

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

	20	35	50	$R_a^t$	65	80
	<div style="border-top: 1px solid black; border-bottom: 1px solid black; height: 20px; position: relative;"> <div style="position: absolute; left: 0; top: -5px; width: 100%; border-left: 1px solid black; border-right: 1px solid black;"></div> <div style="position: absolute; left: 10%; top: -5px; width: 10%; border-left: 1px solid black; border-right: 1px solid black;"></div> <div style="position: absolute; left: 25%; top: -5px; width: 10%; border-left: 1px solid black; border-right: 1px solid black;"></div> <div style="position: absolute; left: 40%; top: -5px; width: 10%; border-left: 1px solid black; border-right: 1px solid black;"></div> <div style="position: absolute; left: 55%; top: -5px; width: 10%; border-left: 1px solid black; border-right: 1px solid black;"></div> <div style="position: absolute; left: 70%; top: -5px; width: 10%; border-left: 1px solid black; border-right: 1px solid black;"></div> <div style="position: absolute; left: 85%; top: -5px; width: 10%; border-left: 1px solid black; border-right: 1px solid black;"></div> </div>					
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:  $e_{1L}^t = 0$ .

Individuals will choose consumption, labor supply and education to maximize Equation (1), subject to Equations (2)-(4) and the constraints described in (5)-(13). Equations (5)-(8) describe the individuals’ dynamic budget constraints. The LHS of these equations shows that individuals allocate their disposable income to consumption (including consumption taxes,  $\tau_c$ ) and the accumulation of non-human wealth. In each equation we denote by  $\Omega_{ja}^t$  the stock of wealth held by a type  $a$  individual who enters the model at time  $t$  at the end of his  $j$ th period of life. Equations (5) and (8) respectively indicate that individuals start and finish adult life with zero assets. During the three periods of active life, disposable income at the RHS includes after-tax labor income, non-employment benefits, interest income and lump sum transfers. In each equation,  $w_{a,k}$  stands for the real wage per unit of effective labor supplied at time  $k$  by an individual with ability  $a$ ,  $r_k$  is the exogenous (world) real interest rate at time  $k$ , and  $z_k$  is the lump sum transfer that the government pays out to all individuals at time  $k$ . Effective labor of an individual with ability  $a$  depends on hours worked ( $n_{ja}^t$ ) and effective human capital ( $h_{ja}^t$ ). Given the tax rate on labor income  $\tau_w$ , young individuals earn an after-tax real wage equal to  $w_{a,t} h_{1a}^t n_{1a}^t (1 - \tau_w)$ . After-tax labor income when middle aged and older in Equations (6) and (7) are determined similarly.

<sup>3</sup> The former may be particularly valuable from the perspective of relaxation and time to spend on personal activities of short duration. The latter may be valuable to enjoy activities which take more time and ask for longer term commitment (e.g. long journeys, non-market activity as a volunteer).

$$(1 + \tau_c)c_{1a}^t + \Omega_{1a}^t = w_{a,t}h_{1a}^tn_{1a}^t(1 - \tau_w) + bw_{a,t}h_{1a}^t(1 - \tau_w)(1 - n_{1a}^t - e_{1a}^t) + z_t \quad (5)$$

$$(1 + \tau_c)c_{2a}^t + \Omega_{2a}^t = w_{a,t+1}h_{2a}^tn_{2a}^t(1 - \tau_w) + bw_{a,t+1}h_{2a}^t(1 - \tau_w)(1 - n_{2a}^t) + (1 + r_{t+1})\Omega_{1a}^t + z_{t+1} \quad (6)$$

$$(1 + \tau_c)c_{3a}^t + \Omega_{3a}^t = w_{a,t+2}h_{3a}^t\tilde{n}_{3a}^tR_a^t(1 - \tau_w) + bw_{a,t+2}h_{3a}^t(1 - \tau_w)R_a^t(1 - \tilde{n}_{3a}^t) + b_{er}w_{a,t+2}h_{3a}^t(1 - \tau_w)(1 - R_a^t) + (1 + r_{t+2})\Omega_{2a}^t + z_{t+2} \quad (7)$$

$$(1 + \tau_c)c_{4a}^t = (1 + r_{t+3})\Omega_{3a}^t + pp_a^t + z_{t+3} \quad (8)$$

For the fraction of time that young, middle aged and older individuals are inactive, they receive a non-employment benefit from the government. Older workers may be eligible to two kinds of benefits: standard non-employment benefits (analogous to what young and middle aged workers receive) as long as they are on the labor market, and early retirement benefits after having withdrawn from the labor market. All benefits are defined as a proportion of the after-tax wage of a full-time worker. The net replacement rate for standard non-employment benefits is  $b$ , for early retirement benefits it is  $b_{er}$ <sup>4</sup>.

After the statutory retirement age (65) individuals have no labor income and no non-employment benefits anymore. They then receive an old-age pension benefit ( $pp_a^t$ ) and the lump sum transfer. Equation (9) describes the old-age pension. We assume a public PAYG pension system in which pensions in period  $k$  are financed by contributions (labor taxes) from the active generations in that period  $k$  (see below). Individual net pension benefits consist of two components. A first one is related to the individual's earlier net labor income. It is a fraction of his so-called pension base, i.e. a weighted average of *revalued* net labor income in each of the three active periods of life. The net replacement rate is  $\rho_{wa}$ . 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 capital  $h_{ja}^t$ . It will be lower when the individual retires early (lower  $R_a^t$ ). Thanks to revaluation, this part of the net pension is adjusted to increases in the overall standard of living between the time that workers build their pension entitlements and the time that they receive the pension. We assume that past earnings are revalued in line with economy-wide wage growth  $x$  and hence follow practice in many OECD countries (OECD, 2005; Whiteford and Whitehouse, 2006).<sup>5</sup> The second component of the

<sup>4</sup> Our approach to model early retirement benefits as a function of a worker's last labor income, similar to standard non-employment benefits, reflects regulation and/or common practice in many countries. In some countries (e.g. Belgium, the Netherlands) workers can enter the early retirement regime only from employment, with their benefits being linked to the last wage. In other countries (e.g. Denmark) there is only access from unemployment, with the early retirement benefit being linked to the unemployment benefit. As to common practice, Duval (2003) confirms that in many countries, unemployment-related or disability benefits can be used *de facto* to bridge the time between the effective retirement age and old-age pension eligibility. Again there is a link between benefits and former wages.

<sup>5</sup> We explain economy-wide wage growth in Section 3.3. Individuals take it as exogenous.

pension is a flat-rate or basic pension. Every retiree receives the same amount related to average net labor income in the economy at the time of retirement. This assumption assures that also basic pensions rise in line with productivity. Here, the net replacement rate is  $\rho_{fa}$ . Fourth generation individuals consume their pension and the lump sum transfer, as well as their accumulated wealth from the third period plus interest (Equation 8). They leave no debts, nor bequests.

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

With:  $0 \leq p_j \leq 1$

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

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

Note that we allow ability-specific pension replacement rates  $\rho_{wa}$  and  $\rho_{fa}$ . This specification is in line with the data in many countries, which show that the importance of own-income related versus flat components may be very different depending on people's earned income, and therefore ability (see Section 4.2. and Table 5 below). For other policy variables like labor tax rates such differences are much smaller (Heylen and Van de Kerckhove, 2010). The introduction of ability-specific pension replacement rates also allows a richer policy analysis.

Equations (10) and (11) describe the intergenerational transfer of human capital. At the age of 20 a young worker with ability  $H$  inherits a fraction  $\pi$  of the average effective human capital of the middle aged generation. A young worker with ability  $M$  enters our model with only a fraction  $\varepsilon_M \pi$ , a young worker with ability  $L$  enters with an even lower fraction  $\varepsilon_L \pi$ . Lower ability may imply more difficulty to learn and accumulate knowledge at primary and secondary school (Azariadis and de la Croix, 2006). During their second and third period, workers supply more units of effective human capital. It is our assumption in Equation (12) that  $h_{2a}^t$ , and therefore labour productivity, rise in education time when young ( $e_{1a}^t$ ), productive government spending in percent of GDP ( $g_y$ , mainly education spending) and an overall quality of schooling parameter ( $q$ ). Individuals take  $g_y$  and  $q$  to be exogenous. Note that the human capital accumulation function itself ( $\psi_a$ ) also depends on innate ability. We specify and discuss effective human capital production and human capital inheritance in greater detail in Section 3.2. Finally, we assume in Equation (13) that human capital remains unchanged between the second and the third period. We have in mind that learning by doing in work may counteract depreciation.

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

$$0 < \pi, \quad 0 < \varepsilon_L < \varepsilon_M < \varepsilon_H = 1 \quad (11)$$

$$h_{2a}^t = \left(1 + \psi_a(e_{1a}^t, g_y, q)\right) h_{1a}^t, \quad \psi_a > 0, \psi'_a > 0 \quad (12)$$

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

Substituting Equations (2)-(4) for  $\ell_{ja}^t$  and (5)-(8) for  $c_{ja}^t$  into (1), and maximizing with respect to  $\Omega_{1a}^t, \Omega_{2a}^t, \Omega_{3a}^t, n_{1a}^t, n_{2a}^t, \tilde{n}_{3a}^t, R_a^t$  and  $e_{1a}^t$ , 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. Extra consumption during retirement rises in the own-income- related pension replacement rate ( $\rho_{wa}$ ), in the weight attached to the relevant period when computing the pension base ( $p_j$ ), and in the revaluation parameters. Equations (15.a)-(15.c) highlight positive substitution effects from the pension replacement rate  $\rho_{wa}$ . 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 ( $\rho_{fa}$ ) do not directly occur in Equations (15), but they do affect employment via this income effect.

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

$$\frac{\gamma_1}{(\ell_{1a}^t)^\theta} \frac{-\partial \ell_{1a}^t}{\partial n_{1a}^t} = \frac{w_{a,t} h_{1a}^t (1-\tau_w)(1-b)}{c_{1a}^t (1+\tau_c)} + \beta^3 \frac{\rho_{wa} p_1 w_{a,t} h_{1a}^t (1-\tau_w) x_t x_{t+1} x_{t+2}}{c_{4a}^t (1+\tau_c)} \quad (15.a)$$

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

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

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. The latter effect rises in  $\rho_{wa}$  and  $p_3$ .

$$\begin{aligned} \frac{\gamma_3}{(\ell_{3a}^t)^\theta} \frac{-\partial \ell_{3a}^t}{\partial R_a^t} &= \frac{w_{a,t+2}(1+\psi_a(e_{1a}^t, g_y, q))h_{1a}^t(1-\tau_w)(\tilde{n}_{3a}^t + b(1-\tilde{n}_{3a}^t) - b_{er})}{c_{3a}^t(1+\tau_c)} \\ &+ \beta \frac{\rho_{wa} p_3 w_{a,t+2}(1+\psi_a(e_{1a}^t, g_y, q))h_{1a}^t \tilde{n}_{3a}^t (1-\tau_w)x_{t+2}}{c_{4a}^t(1+\tau_c)} \end{aligned} \quad (16)$$

Finally, Equation (17) imposes for high and medium ability individuals that the marginal utility loss from investing in human capital when young equals the total discounted marginal utility gain in later periods from having more human capital. Individuals will study more the higher future versus current after-tax real wages and the higher the marginal return of education to human capital  $\left(\frac{\partial \psi_a}{\partial e_{1a}^t}\right)$ . 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 ( $\rho_{wa}$ ), 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 ( $n_{2a}^t$ ,  $n_{3a}^t = R_a^t \cdot \tilde{n}_{3a}^t$ ).

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

$$\begin{aligned} \text{with: } \frac{\partial c_{1a}^t}{\partial e_{1a}^t} &= - \frac{b w_{a,t} h_{1a}^t (1-\tau_w)}{1+\tau_c} \\ \frac{\partial c_{2a}^t}{\partial e_{1a}^t} &= \frac{\partial \psi_a(e_{1a}^t, g_y, q)}{\partial e_{1a}^t} \frac{w_{a,t+1} h_{1a}^t (1-\tau_w) [n_{2a}^t + b(1-n_{2a}^t)]}{1+\tau_c} \\ \frac{\partial c_{3a}^t}{\partial e_{1a}^t} &= \frac{\partial \psi_a(e_{1a}^t, g_y, q)}{\partial e_{1a}^t} \frac{w_{a,t+2} h_{1a}^t (1-\tau_w) [R_a^t (\tilde{n}_{3a}^t (1-b) + b - b_{er}) + b_{er}]}{1+\tau_c} \\ \frac{\partial c_{4a}^t}{\partial e_{1a}^t} &= \rho_{wa} \frac{\partial \psi_a(e_{1a}^t, g_y, q)}{\partial e_{1a}^t} \frac{\sum_{j=2}^3 (p_j n_{ja}^t w_{a,t+j-1} h_{1a}^t (1-\tau_w) \prod_{i=j}^3 x_{t+i-1})}{1+\tau_c} \end{aligned}$$

It will be obvious from the above discussion that (for a given way of financing) the specific organization of pension benefits may have strong effects on behavior in earlier periods of life. Both income and substitution effects occur. The latter are particularly rich when pensions are linked to individuals' own labor income. A higher replacement rate  $\rho_{wa}$  raises the return to working ( $n$ , for all ability groups) and to building human capital ( $e, h$ , for high and medium-ability individuals) in earlier periods. Changes in the particular weight attached to these earlier periods may modify these incentive effects. The return to education will rise in  $p_2$  and  $p_3$ , but fall in  $p_1$ . The return to working in

the third period will rise in  $p_3$ , etc. Policy makers may change all these parameters. We investigate the effects of policy interventions in Section 5.

### 3.2. Inheritance and production of effective human capital

Equations (10) and (11) above assume that when entering the model young workers with high ability inherit a fraction  $\pi$  of the average effective human capital of the middle aged generation. The value of  $\pi$  is to be calibrated. Individuals with medium and lower ability inherit less ( $\varepsilon_L < \varepsilon_M < 1$ ). OECD PISA scores leave no doubt. On average over the 13 countries that we focus on in this paper, the test scores for science of students at the 17<sup>th</sup> and the 50<sup>th</sup> percentiles are 67.3% and 83.7% respectively of the test score of students at the 83<sup>th</sup> percentile. We take these numbers as proxies for  $\varepsilon_L$  and  $\varepsilon_M$  (see also Section 4). After entering the model, young individuals may decide to study and accumulate more human capital. The specification and parameterization of the human capital production function  $\psi_a(\cdot)$  in Equation (12) is often a problem in numerical endogenous growth models. In contrast to goods production functions, there is not much empirical evidence and no consensus about the determinants of human capital growth, nor about the underlying functional form and parameter values. The literature shows a variety of functions, typically including one or two of the following inputs: individual time allocated to education, private expenditures on education by individuals themselves or by their parents, and government expenditures on education (e.g. Lucas, 1988, Glomm and Ravikumar, 1992; Docquier and Michel, 1999, Kaganovich and Zilcha, 1999; Bouzahzah *et al.*, 2002; Ludwig *et al.*, 2012). In case of two inputs, the adopted functional form is very often Cobb-Douglas (e.g. Glomm and Ravikumar, 1992; Kaganovich and Zilcha, 1999; Docquier and Michel, 1999).

Our specification of the human capital production function also includes education time of young individuals and education expenditures by the government as indicators for the quantity of invested private and public resources. Compared to most of the literature, however, we differ in three respects. First, we adopt a more flexible CES functional form, allowing the elasticity of substitution to differ from 1. Second, our definition of relevant government expenditures includes more than education. It also includes active labor market expenditures, public R&D expenditures and public fixed investment. This approach goes back to our use of the broader concept of *effective* human capital<sup>6</sup>. Our third extension is to take into account the quality of education and the schooling system. We recognize that better quality implies higher cognitive abilities for the same allocation of resources. Young individuals' capacity to build human capital will then rise.

All these arguments find their way in Equations (18.a) and (18.b). The former shows the *growth* rate of effective human capital for high and medium ability individuals as a CES specification in education

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<sup>6</sup> As in Dhont and Heylen (2009), effective human capital (and worker productivity) rise not only in accumulated schooling or training, but also in the productive efficiency of accumulated schooling. Education and active labor market expenditures contribute directly to more human capital being accumulated, public R&D and fixed investment expenditures will mainly raise the productive efficiency of accumulated human capital.

time when young ( $e_{1a}^t$ ) and productive government expenditures in % of output ( $g_y$ ). In steady state both determinants are constant, which will imply constant steady state growth. We add the quality of the schooling system ( $q$ ) in a multiplicative way. We will use country-specific PISA science scores as a proxy for  $q$ .<sup>7</sup> Next to  $q$  we introduce (constant common) technical parameters:  $\phi_a$  is a positive efficiency parameter reflecting natural ability,  $\sigma$  a scale parameter,  $v$  a share parameter and  $\kappa$  the elasticity of substitution. These parameters will be calibrated. Note in Equation (18.b) that low ability individuals supply no education time, but they also enjoy positive effects on their effective human capital from productive government expenditures. The quality of the schooling system  $q$  also plays a role here.

$$\psi_a(e_{1a}, g_y, q) = \phi_a q \left( v g_y^{1-\frac{1}{\kappa}} + (1-v) e_{1a}^{1-\frac{1}{\kappa}} \right)^{\frac{\sigma \kappa}{\kappa-1}} \quad \forall a = H, M \quad (18.a)$$

$$\psi_L(g_y, q) = \phi_L q g_y^\sigma \quad (18.b)$$

Lack of existing empirical evidence makes an ex-ante assessment of our specification very difficult. In previous work, however, we have been able to verify that a specification like (18.a) performs better than alternative ones without quality, with a narrower definition of government expenditures, or with a different functional form (see Heylen and Van de Kerckhove, 2010; Buyse *et al.*, 2011).

### 3.3. Domestic firms, output and factor prices

Firms act competitively on output and input markets and maximize profits. All firms are identical. Total domestic output ( $Y_t$ ) is given by the production function (19). Technology exhibits constant returns to scale in aggregate physical capital ( $K_t$ ) and effective labor ( $H_t$ ), so that profits are zero in equilibrium. Equation (20) defines total effective labor as a CES aggregate of effective labor supplied by the three ability groups. In this equation  $s$  is the elasticity of substitution between the different ability types of labor and  $\eta_H, \eta_M$  and  $\eta_L$  are the input shares. We will impose that  $\eta_H = 1 - \eta_M - \eta_L$ .

$$Y_t = K_t^\alpha H_t^{1-\alpha} \quad (19)$$

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

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

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<sup>7</sup> Ideally, one would employ a quality indicator relating to tertiary education, but this is not (yet) available. Still, PISA scores may be very useful. They are informative about the quality that young people attain in secondary education, and with which some enter tertiary education. Quality at entrance should have a positive effect on people's capacity to learn and to raise human capital in tertiary education. Furthermore, PISA scores have been found empirically significant for growth (Hanushek and Woessmann, 2009).

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

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

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

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

Furthermore, we exploit the result that<sup>8</sup>:

$$h_{1a}^t = x_{t-1} h_{1a}^{t-1} = x_{t-1} x_{t-2} h_{1a}^{t-2}, \tag{23}$$

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

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

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

Competitive behavior implies in Equation (25) that firms carry physical capital to the point where its after-tax marginal product net of depreciation equals the world real interest rate. Physical capital depreciates at rate  $\delta_k$ . Capital taxes are source-based: the tax rate  $\tau_k$  applies to the country in which the capital is used, regardless of who owns it. The real interest rate being given, firms will install more capital when the amount of effective labor increases or the capital tax rate falls. In that case the net return to investment in the home country rises above the world interest rate, and capital flows in. Furthermore, perfect competition implies for each ability type equality between the real wage and the marginal product of effective labor (Equation 26). Workers of a particular ability type will earn a higher real wage when their supply is relatively scarce and when physical capital per unit of aggregate effective labor is higher. Taking into account (25), real wages per unit of effective labor will therefore fall in the world real interest rate and in domestic capital tax rates.

<sup>8</sup> Starting from Equation (10), and using (11), (12) and (22), it is easy to see that:

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

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

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

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

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

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

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

$$\begin{aligned} \ln \left( \frac{Y_t}{Y_{t-1}} \right) &= \ln \left( \frac{h_{1H}^t}{h_{1H}^{t-1}} \right) = \ln(x_{t-1}) \\ &= \ln \left( \pi \frac{(1+\psi_H(e_{1H}^{t-1}, g_y, q)) + \varepsilon_M(1+\psi_M(e_{1M}^{t-1}, g_y, q)) + \varepsilon_L(1+\psi_L(g_y, q))}{3} \right) \end{aligned} \quad (27)$$

In line with earlier models (e.g., Lucas, 1988; Azariadis and Drazen, 1990; Buiter and Kletzer, 1993), the long-run (per capita) growth rate is positively related to the quality of schooling ( $q$ ) and to the fraction of time that young people allocate to education ( $e_{1a}$ ). It is also positively related to the share of productive government expenditures ( $g_y$ ), like in Barro (1990). Growth will rise also if young individuals incorporate a larger fraction of average human capital of the middle aged generation ( $\pi, \varepsilon_a$ ).

### 3.4. Government

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

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

with:  $G_{yt} = g_y Y_t$

$$G_{ct} = g_c Y_t$$

$$B_t = B_{H,t} + B_{M,t} + B_{L,t}$$

$$PP_t = PP_{H,t} + PP_{M,t} + PP_{L,t}$$

$$Z_t = 12Z_t$$

$$\begin{aligned}
T_{nt} &= T_{nH,t} + T_{nM,t} + T_{nL,t} \\
T_{kt} &= \tau_k(\alpha Y_t - \delta_k K_t) \\
T_{ct} &= \tau_c \sum_{j=1}^4 (c_{jH}^{t+1-j} + c_{jM}^{t+1-j} + c_{jL}^{t+1-j})
\end{aligned}$$

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

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

Note our assumption that each ability group has size 1 and that each generation has size 3. Following Turnovsky (2000) and Dhont and Heylen (2009), we assume that the government claims given fractions  $g_y$  and  $g_c$  of output for productive expenditures and consumption. Non-employment benefits ( $B_t$ ) are an unconditional source of income support related to inactivity (leisure) and non-market household activities. Although it may seem strange to have such transfers in a model without involuntary unemployment, one can of course analyse their employment and growth effects as a theoretical benchmark case (see also Rogerson, 2007; Dhont and Heylen, 2008, 2009). Moreover, there is also clear practical relevance. Unconditional or quasi unconditional benefits to structurally non-employed people are a fact of life in many European countries. Note also our assumption that the pension system is fully integrated into government accounts. We do not impose a specific financing of the PAYG pension plan, the government can use resources from the general budget to finance pensions. Finally, as we have mentioned before, the government pays the same lump sum transfer  $z_t$  to all individuals living at time  $t$ .

### 3.5. Aggregate equilibrium and the current account

Optimal behavior by firms and households, and government spending for productive and consumption purposes, underlie aggregate domestic demand for consumption and investment goods in the economy. Our assumption that the economy is open implies that aggregate domestic demand may differ from supply and income, which generates international capital flows and imbalance on the current account. Equation (29) describes aggregate equilibrium as it can be derived from Equations (5)-(8), defined for all generations living at time  $t$ , Equations (19)-(21), (25)-(26) and (28). The LHS of (29) represents national income. It is the sum of domestic output  $Y_t$  and net factor income from abroad  $r_t F_t$ , with  $F_t$  being net foreign assets at the beginning of  $t$ . The aggregate stock of wealth  $A_t$  accumulates wealth held by individuals who entered the model in  $t-1$ ,  $t-2$  and  $t-3$ . At the RHS of (29)  $CA_t$  stands for the current account in period  $t$ .

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

with:  $F_t = A_t - K_t - D_t$   
 $CA_t = F_{t+1} - F_t = \Delta A_{t+1} - \Delta K_{t+1} - \Delta D_{t+1}$   
 $I_t = \Delta K_{t+1} + \delta_k K_t$

#### 4. Parameterization and empirical relevance of the model

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

##### 4.1. Preference and technology parameters

Table 2 contains an overview of all parameters. We set the rate of time preference equal to 1.5% per year. Considering that periods in our model consist of 15 years, this choice implies a discount factor  $\beta$  equal to 0.8. In the production function we assume a capital share coefficient  $\alpha$  equal to 0.285. 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 and the capital share are well within the range of values imposed in the literature (e.g. Docquier and Michel, 1999; Altig *et al.*, 2001; Heijdra and Romp, 2009). So is the value for  $s$ . The empirical labor literature consistently documents values between 1 and 2 (see Caselli and Coleman, 2006). There is more controversy about the value of the intertemporal elasticity of substitution in leisure ( $\frac{1}{\theta}$ ). Micro studies often reveal very low elasticities. However, given our macro focus, these studies may not be the most relevant ones (Rogerson and Wallenius, 2009; Fiorito and Zanella, 2012). Rogerson (2007) also adopts a macro framework. He puts forward a reasonable range for  $\theta$  from 1 to 3 (Rogerson, 2007, p. 12). In line with this, we impose  $\theta$  to be equal to 2. The world real interest rate is assumed constant and equal to 4.5% per year. Considering a period of 15 years, this implies that  $r = 0.935$ . Finally, we set the physical capital depreciation rate to 8% per year, which implies  $\delta_k = 0.714$ . These values are also within the range of existing studies (see e.g. Heijdra and Romp, 2009).

**Table 2** Basic parameterization and benchmark equilibrium

Technology and preference parameters					
Goods production (output)	$\alpha = 0.285, s = 1.5, \eta_H = 0.47, \eta_M = 0.30, \eta_L = 0.23$				
Effective human capital	$\phi_H = 5.34, \phi_M = 4.66, \phi_L = 2.83, v = 0.125, \kappa = 0.375, \sigma = 0.6$				
Human capital inheritance	$\pi = 0.85, \varepsilon_M = 0.837, \varepsilon_L = 0.673$				
Preference parameters	$\beta = 0.80, \theta = 2, \gamma_1 = 0.070, \gamma_2 = 0.126, \gamma_3 = 0.170$ $\mu = 0.5, \zeta = 1.54, \Gamma = 2$				
World real interest rate	$r = 0.935$				
Capital depreciation rate	$\delta_k = 0.714$				
Target values for calibration					
Employment, growth and education <sup>(a)</sup>					
$n_1$	$n_2$	$n_3$	$R$	<i>per capita annual growth</i>	$e$
51.1%	56.8%	29.3%	57.9	1.77%	14.2%
Relative wages US <sup>(b)</sup>					
$w_L h_{1L}/w_H h_{1H}$	$w_M h_{1M}/w_H h_{1H}$		$w_L h_{2L}/w_H h_{2H}$	$w_M h_{2M}/w_H h_{2H}$	
0.43	0.63		0.38	0.58	

Notes: (a) Values for Belgium, see Table 1;

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

A second series of ten parameters have been determined by calibration: three taste for leisure parameters ( $\gamma_1, \gamma_2, \gamma_3$ ), the human capital inheritance parameter ( $\pi$ ), three efficiency parameters in the human capital production function ( $\phi_H, \phi_M$  and  $\phi_L$ ), the elasticity of substitution ( $\zeta$ ) in the composite leisure function in Equation (4) and two share parameters in aggregate effective labor ( $\eta_M$  and  $\eta_L$ , where  $\eta_H$  follows as  $1 - \eta_L - \eta_M$ ). The ten target values to which these parameters have been calibrated are reported at the bottom of Table 2. Six of them concern the employment rates, the effective retirement age, education, and growth for Belgium in our study. We choose this country since in Belgium the calculation of pension benefits fits exactly within the way we model it. Public pensions are proportional to average annual labor income earned over a period of 45 years, with equal weights to all years. In our model this comes down to  $\rho_w > 0, \rho_f = 0$  and  $p_1 = p_2 = p_3 = \frac{1}{3}$ <sup>9</sup>. The other four target values are the relative wages of young and middle aged workers of low and medium ability in the US. Although in practice a whole system of simultaneous equations is solved in which each target value is important for each parameter to be calibrated, it may be useful for our exposition here to bring some more structure. Certain parameters are clearly more than others linked to certain target values. The leisure parameters, including the elasticity of substitution in the

<sup>9</sup> Only individuals with labor income below about 75% of the mean receive an additional social assistance benefit. We include this as 'basic pension' for the low ability individuals ( $\rho_{fL} > 0$ , see Table 5, and our discussion there).

composite leisure function (4), are basically determined such that with observed average levels of the policy variables (tax rates, non-employment benefit replacement rates, pension replacement rates, etc.) and the observed level of schooling quality ( $q$ )<sup>10</sup> in Belgium, the model correctly predicts Belgium's employment rates by age ( $n_1, n_2, n_3$ ) and effective early retirement age ( $R$ ). We find that the taste for leisure rises with age ( $\gamma_1 = 0.070, \gamma_2 = 0.126, \gamma_3 = 0.170$ ) 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 human capital inheritance parameter is basically determined to match average per capita growth. We find an inheritance rate for the highest ability group of 85% ( $\pi = 0.85$ ). Taking into account the values for  $\varepsilon_M$  and  $\varepsilon_L$ , we obtain inheritance rates for the medium ability and the low ability groups of about 71% ( $=0.85 \times 0.837$ ) and 57% ( $=0.85 \times 0.673$ ). As we have explained in the beginning of Section 3.2., we rely on PISA science scores to obtain  $\varepsilon_M$  and  $\varepsilon_L$ .

Calibration of the share parameters  $\eta_M$  and  $\eta_L$  is mainly driven by the values for relative wages of young workers in the US. As shown by Equation (26), these share parameters are important determinants of the relative productivity of labour. Actual wages are informative if a close link can be assumed between wages and productivity. This condition is much more likely fulfilled in the US, which explains the introduction here of US relative wages rather than those in Belgium (or in any other European country). We illustrate the key elements in our procedure to obtain values for  $\eta_L$  and  $\eta_M$  from these relative wage data in Appendix 2. The results imply  $\eta_L = 0.23, \eta_M = 0.30$  and  $\eta_H = 0.47$ . A similar procedure is applied to derive values for  $\phi_L, \phi_M$  and  $\phi_H$ . These are basically determined such that the model correctly predicts relative wages of middle aged workers in the US, as well the target value for the education rate  $e$  (see also Appendix 2). We obtain  $\phi_L = 2.83, \phi_M = 4.66$  and  $\phi_H = 5.34$ .

Finally, we had no strong ex ante indication on three parameters in the human capital production function: the scale parameter  $\sigma$ , the share parameter  $\nu$  and the elasticity of substitution parameter  $\kappa$ . We could assign sensible values to these parameters thanks to a sensitivity analysis on the results that we report in the next section. There we evaluate the capacity of our model to explain the facts in 13 OECD countries that we reported in Table 1. Our guideline to pin down specific values for  $\sigma, \nu$  and  $\kappa$  was to minimize the deviation of our model's predictions from the true data<sup>11</sup>. This procedure implied  $\sigma = 0.60, \nu = 0.125$  and  $\kappa = 0.375$ . We observe decreasing returns in human capital growth. The result for  $\kappa$  reveals a higher degree of complementarity between private education time and government expenditures than in the Cobb-Douglas case. The result for  $\nu$

<sup>10</sup> And with the values of three parameters in the human capital production function ( $\sigma, \nu, \kappa$ ) that we discuss below (see also footnote 11).

<sup>11</sup> From our model's predictions and the true data for 13 countries we computed for each variable ( $n_1, n_2, n_3, R, e, growth$ ) the root mean squared error normalized to the mean. We minimized the average normalized RMSE over all six variables. More precisely, we adopted the following iterative procedure. We chose values for  $\sigma, \nu$  and  $\kappa$  and then calibrated the other ten parameters (although it should be mentioned that the values for  $\sigma, \nu$  and  $\kappa$  hardly affected the calibration results for  $\gamma_j$ ). Given the obtained values for the other parameters, we computed the average normalized RMSE over all six endogenous variables. We then checked whether changes in  $\sigma, \nu$  and  $\kappa$ , and a recalibration of the other parameters, could further reduce this statistic. We did this until no further reduction was possible.

demonstrates relatively high importance for human capital formation of private education time versus productive public expenditures. Neither did we have an ex ante indication on the remaining parameters in the composite leisure function in Equation (4). We impose equal weight for both leisure types ( $\mu=0.5$ ). The normalisation parameter  $\Gamma$  equals 2. The size of this parameter has no impact at all on our country predictions or simulation results.

#### 4.2. Fiscal policy, pensions and education quality

Tables 3 and 4 describe key characteristics of fiscal policy in 1995-2001/2004. Our proxy for the tax rate on labor income concerns the total tax wedge, for which we report the marginal rate in %. The data cover personal income taxes, employee and employer social security contributions payable on wage earnings and payroll taxes. The OECD publishes these marginal tax data for eight family and income situations. Our data for  $\tau_w$  in Table 3 are the average of all these situations. 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 simplifying 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 60<sup>th</sup> 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<sup>12</sup>. 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 1). 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

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<sup>12</sup> 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](http://www.oecd.org/els/social/workincentives), Benefits and Wages, country specific files).

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

**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 :	$\tau_w$	$\tau_c$	$\tau_k$	$D/Y$
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
<b>Overall average</b>	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 1. Capital tax rates are effective marginal corporate tax rates (Institute for Fiscal Studies, their EMTR, base case; data are for 1995-2001, see also Devereux *et al.*, 2002). Consumption tax rates are from Dhont and Heylen (2009). Data are for 1995-2001.

Our data for productive government expenditures ( $g_y$ ) in Table 4 include education, active labor market expenditures, government financed R&D and public investment, in percent of GDP. On average, education expenditures constitute close to 60% of total  $g_y$ . Governments in the Nordic countries allocate by far the highest fractions of output to productive expenditures. Productive expenditures in percent of GDP are the lowest in the UK. The US and most core countries of the euro area take intermediate positions. Government consumption in percent of GDP is the highest also in the Nordic countries, followed at close distance by several countries of the core euro area<sup>13</sup>. In the US, government consumption is (much) lower.

<sup>13</sup> Like Dhont and Heylen (2009) we calculate our data for government consumption as total government consumption in % of GDP, diminished with the fraction of public education outlays going to wages and working-expenses. We include the latter in productive expenditures.

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

	Non-employment benefit (net replacement rate, %)	Early retirement benefits (net replacement rate, %)	government consumption (% of GDP)	government productive expenditures (% of GDP)
<b>Proxy for :</b>	$b$	$b_{er}$	$g_c$	$g_y$
Austria	56.3	71.6	14.6	9.1
Belgium	59.6	79.0	16.9	8.9
France	46.0	63.8	18.3	11.0
Germany	64.7	70.8	15.3	8.6
Italy	17.0	55.7	14.3	8.0
Netherlands	55.0	68.1	18.4	10.3
Denmark	61.9	43.2	18.4	12.5
Finland	61.3	73.8	16.0	11.4
Norway	56.9	39.9	14.7	12.1
Sweden	55.4	39.0	20.0	14.0
UK	51.1	39.4	14.4	7.3
US	30.5	18.3	10.3	9.3
Canada	44.4	27.0	14.7	9.3
<b>Overall average</b>	52.2	53.8	15.9	10.1

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

Table 5 contains our data for the net pension replacement rates  $\rho_{wa}$  and  $\rho_{fa}$ . The data have been taken or computed from OECD (2005). They include only (quasi-)mandatory pension programs<sup>14</sup>. In line with our specification in Equation (9),  $\rho_{wa}$  is expressed as a percentage of an individual's average lifetime net labor income, while  $\rho_{fa}$  is expressed as a percentage of average economy-wide net labor income at the time of retirement. We consider individuals at 50 percent of mean earnings as representative for the low ability group, individuals with mean earnings as representative for the medium ability group, and individuals at twice the mean earnings as representative for the high ability group. Appendix 1 gives more details on the construction of the data. In the majority of countries individuals with mean or higher earnings only receive earnings-related pensions ( $\rho_{wa} > 0, \rho_{fa} = 0$  for  $a = M, H$ ). Among these countries, Austria and Italy pay the highest net replacement rates ( $\rho_{wM} > 85\%$ ), Belgium and the US the lowest ( $\rho_{wM} < 65\%$ )<sup>15</sup>. 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

<sup>14</sup> In most countries mandatory programs are public. For Denmark, the Netherlands and Sweden the data also include benefits from mandatory private systems. These benefits are earnings-related and included under  $\rho_{wa}$ . Voluntary, occupational pensions are not included in our data.

<sup>15</sup> Next to the pension level, differences exist also in the precise organization of the earnings-related system. Some countries have pure defined-benefit systems (e.g. Belgium, Finland, US), others have so-called point systems (Germany) or notional-account systems (Italy, Sweden). Although these three systems can appear very different, OECD (2005) shows that they are all similar variants of earnings-related pension schemes.

pension includes a significant basic (or similar) component in most countries. Unsurprisingly, the Netherlands, Denmark and the UK pay the highest ‘basic’ amounts<sup>16</sup>.

We emphasize that the straightforward way in which the OECD computes the pension replacement rates, in percent of an individual’s average lifetime labor income, comes down to assuming in our model that the weights  $p_1, p_2$  and  $p_3$  are all equal to 1/3. For reasons of consistency we will therefore make this assumption for all individual countries when we derive our model’s predictions. We are aware, however, that equal weights do not fully match practice in all countries. Some deviate from this prototype, to varying degrees<sup>17</sup>. When we compare our model’s predictions for these countries to the facts in the next section, we should take this into account. Assuming equal weights may slightly bias our predictions.

**Table 5** Net pension replacement rates and PISA education score

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

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

A final variable in Table 5 is our indicator for education quality ( $q$ ) in the human capital production function (12, 18). For each country we use PISA science scores. We concentrate on test results for science given their expected closer link to growth (Barro, 2001). The mean score is best in Finland, followed by the Netherlands, Canada and the UK. Education quality is relatively low in Italy,

<sup>16</sup> As we explain in Appendix 1, it should be mentioned that our proxy for  $\rho_{fa}$  also includes targeted and minimum pensions. Basic pensions pay the same amount to every retiree. Targeted plans pay a higher benefit to poorer pensioners and reduced benefits to better-off ones. Minimum pensions are similar to targeted plans. Their main aim is to prevent pensions from falling below a certain level (OECD, 2005, p. 22-23). Our main motivation to merge these three categories in our proxy for  $\rho_{fa}$  is that they are not (or even inversely) linked to earnings.

<sup>17</sup> 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.

Denmark, Norway and the US. Note that there is no correlation between productive government expenditures in Table 4 and the PISA scores in Table 5. The coefficient of correlation is -0.04. There is no correlation either if we restrict productive expenditures to education only. Both variables seem to tell different stories (see also Woessmann, 2003).

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

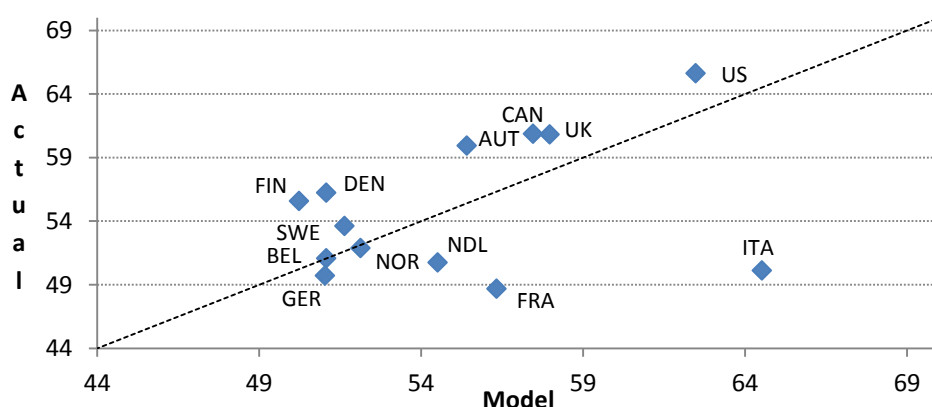
Can our model match the facts that we have reported in Table 1? In this section we confront our model's predictions with the true data for 1995-2007. Clearly, one should be aware of the serious limitations of such an exercise. First of all, our model is highly stylized and may (obviously) miss potential determinants of growth or employment. Second, even if we compute the true data in Table 1 as averages over a longer period, these averages need not be equal to the steady state. Countries may still be moving towards their steady state. Third, this exercise only concerns the last 15 years. Due to lack of data – especially with respect to marginal labor tax rates and non-employment benefits before the mid 1990s – it is impossible for us to relate changes in growth and employment to changes in policy within countries over longer time periods. In spite of all this, if one considers the extreme variation in the predictions of existing calibrated models investigating the effects of fiscal policy in the literature (see Stokey and Rebelo, 1995), even a minimal test of the 'goodness of fit' of our model is informative. This information is important to assess the value of the 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, education, and per capita growth in Belgium. The test of the model's validity is whether it can also match the data for the other countries, and cross-country differences. Before one uses a model for policy analysis, one would like to see for example that the model does not overestimate, nor underestimate the performance differences related to observed cross-country policy differences. Our test is tough since we impose the same preference and technology parameters, reported in the upper part of Table 2, on all countries. Only fiscal policy variables, the pension replacement rate, and education quality differ. Moreover, assuming perfect competition, we disregard differences in labor and product market institutions which some authors consider of crucial importance (e.g. Nickell *et al.*, 2005). Still, we find that the model matches the facts remarkably well for a large majority of countries. Basically, we here confirm earlier findings by e.g. Ohanian *et al.* (2008) and Dhont and Heylen (2008) that once one controls for fiscal policy differences, variation in taste for leisure or different market rigidities are not critical to explain cross-country variation in labor market performance.

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

Figures 2 to 4 relate our model's predictions to actual observations for three employment rates by age (aggregated over the three ability groups). We add the 45°-line to assess the absolute differences between predictions and facts, as well as the coefficient of correlation between predictions and facts. Our model performs quite well. In each age group, it correctly predicts high employment rates in the US and Canada and low employment in Germany. For young workers it also correctly predicts relatively low employment in most other countries of the core euro area, and in the Nordic countries. For older workers it has relatively high employment right in the Nordic countries and the UK. Overall correlation between the model's predictions and the actual data in Figure 2 is 0.35. If we drop Italy, for which there are good reasons<sup>18</sup>, this rises to 0.69. Correlation in Figure 3 is 0.48, in Figure 4 it is 0.76. Moreover, in each figure - again after dropping Italy from Figure 2 - the regression line (not shown) is close to the 45°-line, which suggests that our model correctly assesses the size of the employment effects of policy differences across countries. Next to Italy, there are a few other countries, where our model somewhat over- or underpredicts. The model's employment predictions tend to be too high for France and the Netherlands. They are too low in Figures 2 and 3 for Denmark and Finland.

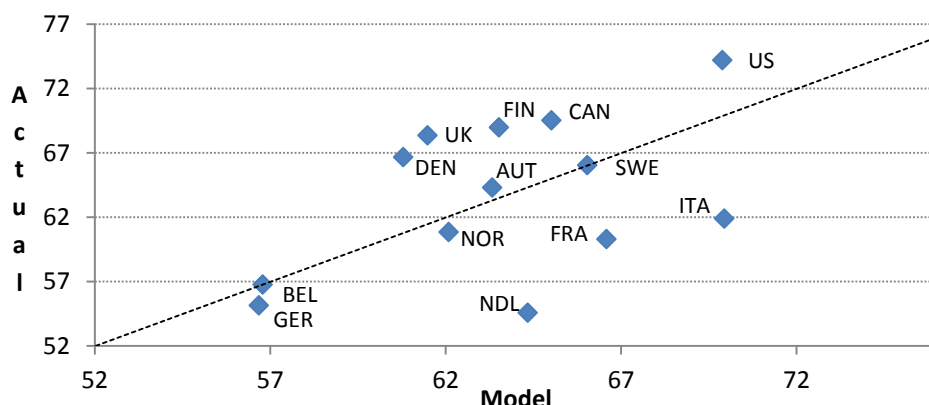
**Figure 2.** Employment rate in hours of young individuals in 13 countries, in %, 1995-2007



Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.35. Excluding Italy correlation rises to 0.69.

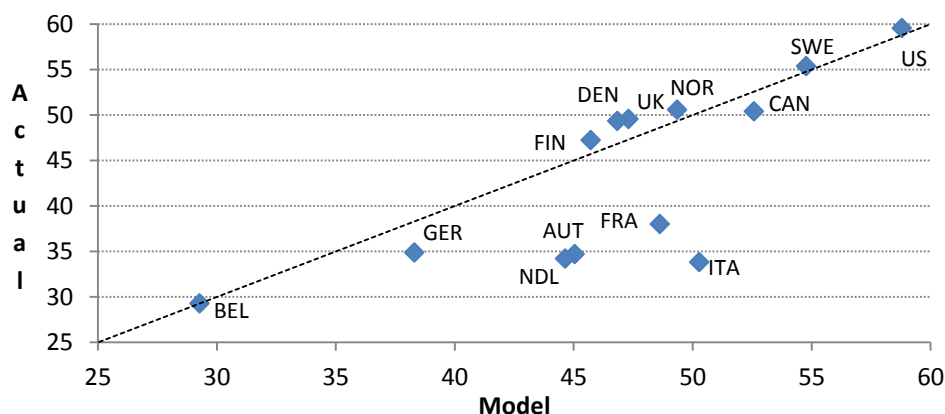
<sup>18</sup> A major element behind the deviation for this country seems to be underestimation of the fallback income position for structurally non-employed young workers. OECD data show very low replacement rates in Italy. However, as shown by Reyneri (1994), the gap between Italy and other European countries is much smaller than it seems when family support as an alternative to unemployment benefits is taken into account. Fernández Córdón (2001) shows that in Italy young people live much longer with their parents than in other countries.

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



Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.48.

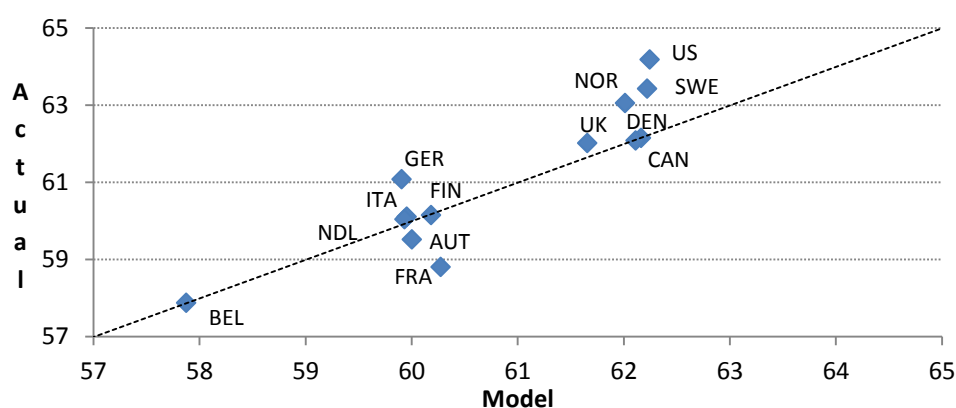
**Figure 4.** Employment rate in hours of older individuals in individual countries, in %, 1995-2007



Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.76.

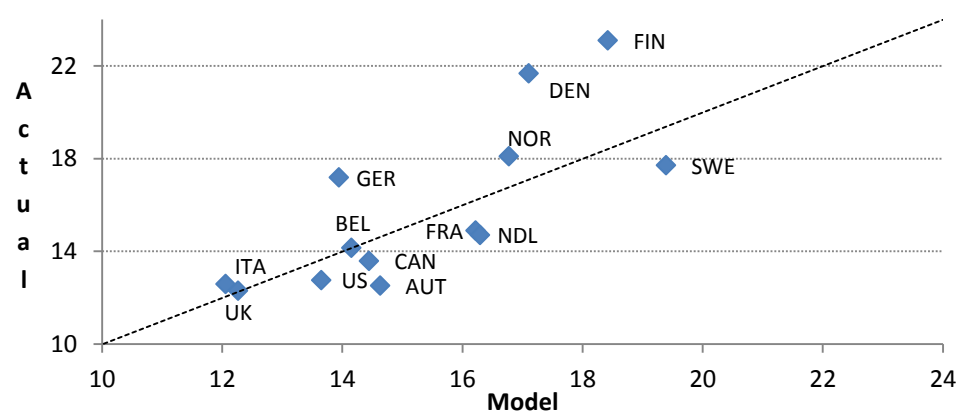
Figure 5 relates our model's predictions to the facts for the effective retirement age. The model again captures the large differences between countries. It predicts the highest retirement age in the Anglo-Saxon and Nordic countries and a much lower retirement age in core euro area countries. Correlation between actual data and the model's predictions is 0.91. In Figures 6 and 7 we relate our model's predictions to the facts for education and growth. For education, the model correctly captures key differences between the Nordic countries on the one hand and countries like the UK and Italy on the other. Predictions for education are quite close to the 45°-line for all individual countries except Germany and (especially) Denmark and Finland. The model does not match the high participation in education in the latter two countries. Finally, our model has important cross-country differences right for growth. The model has some difficulty however to explain observed growth for the UK and Canada. Correlation between the model's predictions and the true data is 0.76 for education and 0.69 for growth.

**Figure 5. Effective retirement age, 1995-2006**



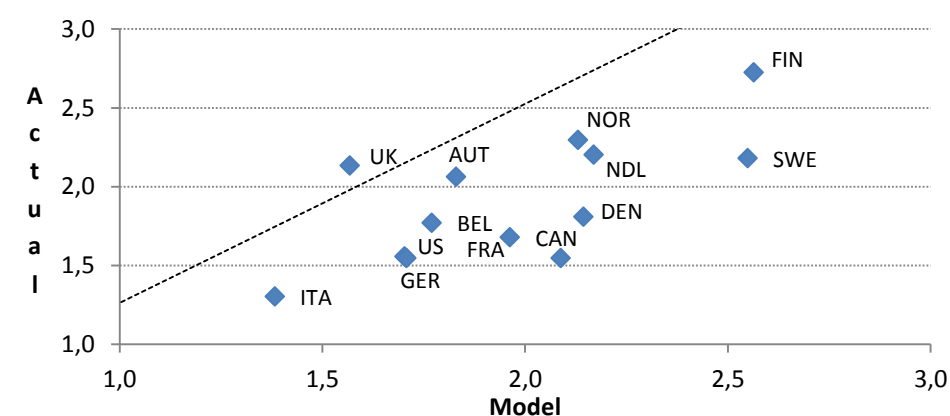
Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.91.

**Figure 6. Tertiary education rate in individual countries, in %, 1995-2006**



Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.76.

**Figure 7. Annual per capita potential GDP growth in 13 countries, in %, 1995-2007**



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

## 5. Public pension reform

Having established the empirical relevance of our model, we now simulate a series of policy shocks. Our aim is to discover the (relative) effectiveness of various reforms of the pension system for the employment rate of three age and three ability groups, aggregate employment, education of the young, growth, and income at old-age (especially for the low-ability group). We report steady state effects, and welfare effects per generation and per ability group. We also show the pension level of low-ability retirees. Throughout all our policy simulations we assume that the government maintains a constant debt to GDP ratio in each period. To reach this goal, it adjusts the consumption tax rate. Alternative simulations where the government adjusts lump sum transfers yield the same conclusions as the ones we report below. For a proper understanding of timing, it will be our assumption that the economy is in steady state at time  $t=-1$ . Reform is announced at time  $t=0$  and implemented with a delay of 1 period, i.e. at time  $t=1$ . Hence, reforms apply to everyone except the generation of retirees at  $t=0$ , since they are no longer able to adapt their behavior<sup>19</sup>.

Table 6 shows the steady state effects of seven (permanent) reforms in key features of the pension system. The benchmark from which we start, and against which all policy shocks are evaluated, is the average of the six core euro area countries in our sample. The parameters describing the benchmark pension system are indicated in the upper left corner of the table and in a first note below the table. Individual earnings-related replacement rates vary in the benchmark between 59% ( $\rho_{wL}$ ) and 71% ( $\rho_{wM}$ ). They are applied to a pension base where each active period has equal weight ( $p_{ja}=1/3$ ). Basic pensions take values between 6% ( $\rho_{fH}$ ) and 15% ( $\rho_{fL}$ ) of aggregate average net labor income. No particular minimum level is imposed to the pension ( $MP=0$ ). The percentage point change in the consumption tax rate to maintain a constant debt to GDP ratio is indicated at the bottom of the table.

Figure 8 shows the welfare effects of these policy changes for high and for low-ability individuals of current and future generations. The results for medium-ability individuals are in general quite close to those for the high-ability group. We report on the vertical axis the welfare effect on individuals of the generation born  $k$  periods after the announcement 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 announcement. The data at  $k=-3$  concern the retirees in that period<sup>20</sup>. 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 1% of

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<sup>19</sup> Current retirees will therefore not experience a change in their pension replacement rate(s), nor in the rules behind the computation of their pension assessment base. Their disposable income can change, however, when the government adjusts consumption taxes to keep the ratio of public debt to GDP constant, or when the aggregate average net wage (to which the basic pension replacement rate  $\rho_{fa}$  applies) changes.

<sup>20</sup> Consistent with footnote 19, these retirees are only indirectly affected by the policy change.

benchmark consumption. It implies a welfare loss for the current older low-ability individuals ( $k=-2$ ) equal to 2% 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 are 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 announced.

Given its importance for welfare at old-age, and the risk of old-age poverty, we focus in Figure 9 on the evolution of the pension level of low-ability retirees in the periods after a policy reform. Reported data at time  $t=0$  concern the pension level of those who are retired at the moment of announcement of the new policy and who are only indirectly affected by it. Data at  $t=3$  concern the pension level of those who are young at the time of announcement. All data are expressed relative to the benchmark.

The starting point of our discussion is policy 1, which introduces for all individuals an increase in  $p_3$ , and a fall in  $p_1$ , along the lines preferred by Buysse *et al.* (2011). To compute the pension base, the weight of labor income earned as an older worker rises to  $2/3$ , the weight of labor income earned when young falls to 0. Our results confirm the important positive effects of such a reform for aggregate employment and growth. The higher (lower) marginal utility from work when older (young) makes it interesting to shift work from the first period of active life to the third, and to postpone effective retirement ( $n_3$  and  $R$  rise,  $n_1$  falls). The positive effect that we observe on  $R$  and  $n_3$  is fully in line with earlier arguments by Sheshinski (1978) and Gruber and Wise (2002), among others. Jaag *et al.* (2010) also predict a shift from  $n_1$  to  $n_3$  when  $p_1$  falls and  $p_3$  rises. Unlike in Jaag *et al.*, however, the role of endogenous education in our model strongly qualifies the fall in young workers' labor supply. As is clear in Table 6, young individuals are encouraged to study ( $e$  increases) because the lifetime rate of return to building human capital rises. This follows first from the reduction of the opportunity cost of studying when young, second from the perspective of working longer, and third from the greater importance of effective human capital when old in the pension calculation. Extra schooling contributes to steady-state growth and reinforces incentives to work at older age. We observe an increase in the annual growth rate by 0.08 %-points. Note also that the employment rate rises in each ability group ( $n_H, n_M, n_L$ ), but most so among low-ability individuals ( $\Delta n_L=1.43$ ). These individuals can only respond to the new policy by working longer, they cannot study and enjoy higher human capital. Interestingly, the government budget does not deteriorate. It

becomes possible to cut the consumption tax rate while keeping the ratio of public debt to GDP constant (see bottom of Table 6).

A quick comparison with the other policies in Table 6, to be discussed immediately, reveals that most of them are less effective than policy 1 when it comes to promoting (aggregate) employment and growth. Table 7 also reveals significant net aggregate welfare gains. The main disadvantage of policy 1, however, is the welfare loss that it imposes on the current older and middle aged generations of low-ability individuals (Figure 8, upper panel, RHS). These individuals work more, but can hardly consume more. Even if policy 1 offers a convincing solution to the overall challenge of employment and growth in today's economies, and even if it may contribute to safeguard the welfare state in the future, it may also worsen conditions for a significant part of the lower ability individuals. Moreover, it may offer no solution to the problem of old-age poverty faced by many. Figure 9 shows an important fall relative to the benchmark in the pension level of many generations of low-ability individuals to come. These observations make it politically difficult to impose such a policy.

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

Initial values: $p_{1a}=1/3$ $p_{2a}=1/3$ $p_{3a}=1/3$ $MP=0$	Policy 1 $p_{1a}=0$ $p_{2a}=1/3$ $p_{3a}=2/3$	Policy 2 $MP=0.6$	Policy 3 $\rho_{wa}=0$ $\rho_{fa}=0.75$	Policy 4 $p_{1a}=0$ $p_{2a}=1/3$ $p_{3a}=2/3$ $MP=0.6$	Policy 5 $p_{1a}=0$ $p_{2a}=1/3$ $p_{3a}=2/3$ $\rho_{wL}=0.85$	Policy 6 $p_{1MH}=0$ $p_{2MH}=1/3$ $p_{3MH}=2/3$ $\rho_{wL}=0.85$	Policy 7 Fully Funded
Effect <sup>(a)</sup> :							
$\Delta n_1$	-3.41	-0.51	-1.06	-3.33	-3.56	-2.84	0.04
$\Delta n_3$	0.12	-1.00	-3.02	-0.92	0.36	0.29	-1.47
$\Delta n_3$	7.02	-3.48	-10.4	1.15	8.24	5.99	-7.80
$\Delta R$ <sup>(c)</sup>	0.85	-0.47	-1.41	0.09	1.00	0.80	-1.15
$\Delta e$	1.37	0.00	-0.46	1.37	1.37	1.41	-0.36
$\Delta n$ <sup>(a, b)</sup>	0.92	-1.55	-4.50	-1.14	1.31	0.88	-2.79
$\Delta N/N$ <sup>(d)</sup>	1.66	-2.81	-8.14	-2.06	2.37	1.62	-5.05
$\Delta n_H$	0.60	0.01	-3.88	0.61	0.59	0.60	-2.84
$\Delta n_M$	0.72	0.01	-4.66	0.73	0.72	0.72	-2.98
$\Delta n_L$	1.43	-4.68	-4.96	-4.75	2.61	1.10	-2.55
$\Delta$ annual growth rate <sup>(b)</sup>	0.08	0.00	-0.03	0.08	0.08	0.08	-0.02
$\Delta \tau_c$ <sup>(e)</sup>	-1.19	1.66	5.07	1.15	-0.38	0.13	7.50

Notes: Initial values:  $\rho_{wL}=59.4$ ,  $\rho_{wM}=70.6$ ,  $\rho_{wH}=66.1$ ,  $\rho_{fL}=14.6$ ,  $\rho_{fM}=7.0$ ,  $\rho_{fH}=6.0$ .

(a) difference in percentage points between new steady state and benchmark. except  $\Delta N/N$  and  $R$ .

(b) change in (weighted) aggregate employment rate in hours, change in percentage points.

(c) change in optimal effective retirement age in years

(d) change in volume of employment in hours, in percent.

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

Policies 2 and 3 focus on the problem of low pensions for low-ability individuals. Policy 2 maintains all benchmark replacement rates, but also introduces a minimum pension. Individuals are sure of a pension equal to at least 60% of average net labor income per worker in the economy. In practice the latter implies a strong increase in the pension level for the low-ability group (see also Figure 9), but no ex-ante change for the other two groups. Their optimal behavior given all policy variables implies a pension that is above 60% of the average net wage from the beginning. We remind that none of the policy reforms that we discuss apply to the retired at the moment of the announcement of the reform, so they are not eligible to the minimum pension. As shown by Figure 8, all low-ability individuals except the retired ( $k=-3$ ) experience welfare increases up to about 4% under policy 2. For the welfare of all other individuals, however, these policies have very negative effects. A key element is the drastic drop in the employment rate among low-ability individuals. The perspective of a minimum pension introduces a strong disincentive for them to work (see also Sommacal, 2006). The implied fall in aggregate employment and its negative effects on the government's budget, force the latter to raise consumption tax rates for all. Furthermore, medium and higher ability individuals can also expect a fall in their wage per unit of effective labor due to the reduction of low-ability labor supply<sup>21</sup>.

Policy 3 imposes a shift from own-earnings related pensions to 'basic' pensions on all individuals. Every retiree gets a basic pension equal to 75% of average net labor income per worker in the economy. In our model  $\rho_w$  goes to zero for all ability groups,  $\rho_f$  becomes 0.75. This policy basically goes one step further than policy 2. It breaks the relationship between the pension and an individual's human capital and labor supply also for the high and medium-ability groups. The fall in the return to studying and to working also for these groups is at the basis of an overall and strong fall in employment, education time and growth. Figure 8 reveals negative welfare effects almost across the board, especially for higher ability individuals and all future generations. Only current older low-ability individuals gain. They benefit most from higher pensions. Due to lower growth, this gain will not persist for the future low-ability generations however. As a result, policy 3 shows among the worst net aggregate welfare effects in Table 7.

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

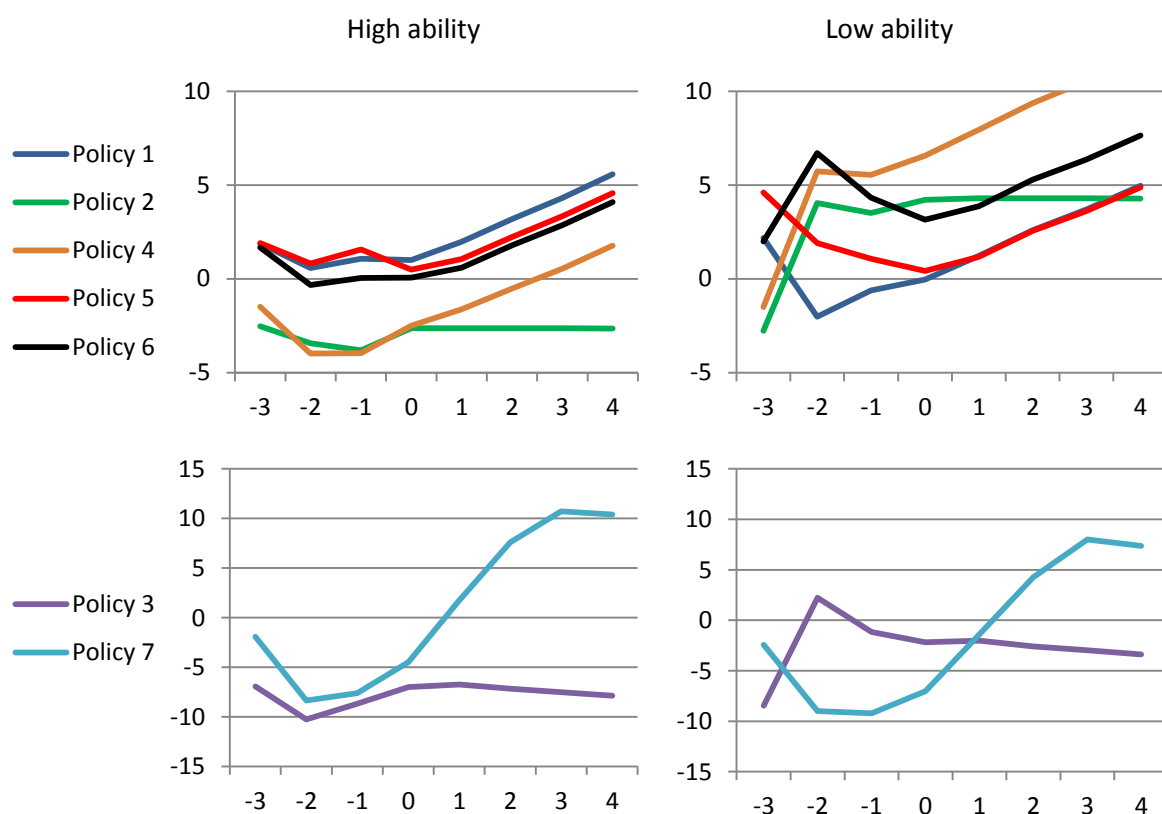
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<sup>21</sup> As a narrow alternative to policy 2, we also investigated the introduction of a minimum pension combined with an abolishment of all basic pensions. All effects were very similar. Only the required increase in the consumption tax rate was smaller, since the government could save money from  $\rho_{fa}$  going to 0.

losses on the current generations of high and medium-ability individuals, which drastically reduces its chances politically. Net aggregate effects in Table 7 are still negative.

Policy 5 tackles the problem of low income at old-age for the low-ability group by significantly raising their individual earnings-related pension replacement rate to 85% ( $\Delta\rho_{wL} = 25.6\%$ -points). This policy combines the efficiency gains from policy 1 with strong incentives for the low-ability group to work more and longer. In contrast to the disincentives induced by basic or minimum pensions, policy 5 raises the return to work since it yields more future pension. Among all the policies that we discuss in Table 6, not one has more favorable effects on aggregate employment ( $\Delta n=1.31$ ) or on the employment rate of low-ability individuals ( $\Delta n_L=2.61$ ). Higher pensions can as a result be paid without the need for the government to raise consumption taxes. Given the strong rise in output and employment,  $\tau_c$  can even be reduced. Compared to policy 1, welfare effects for the low-ability group are better, without hurting the medium and high-ability groups. Policy 5 induces the best net aggregate welfare effects in Table 7.

**Figure 8.** Welfare effects for individuals belonging to current and future generations after pension reform



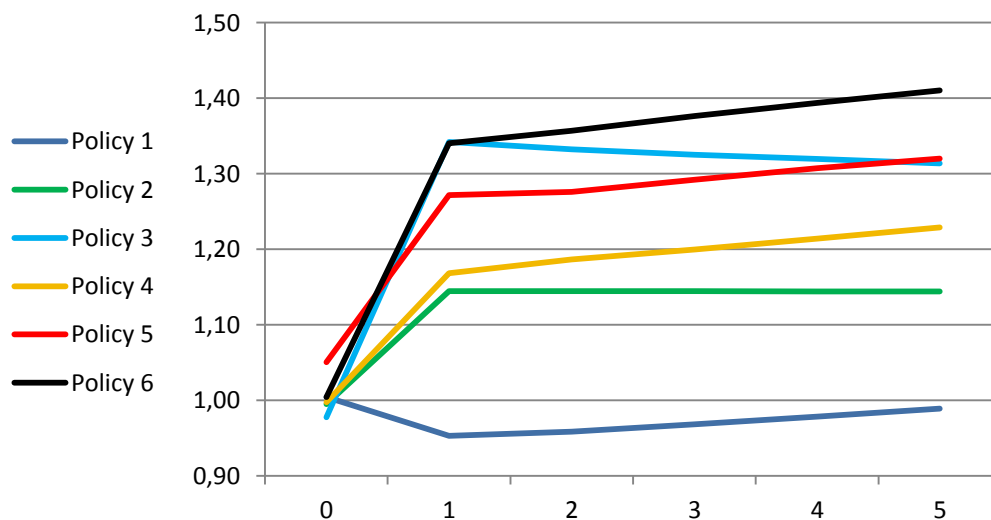
Note: The vertical axis indicates the welfare effect for individuals belonging to the generation born  $k$  periods after the announcement of permanent pension reform. The horizontal axis indicates  $k$ . Negative numbers for  $k$  point at generations born before the reform.

**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 7
All current + 4 future	1.8	-1.6	-6.1	-0.2	1.9	1.8	-2.8
All current	0.6	-1.3	-4.2	-0.8	1.0	0.9	-4.5

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

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

**Figure 9.** Pension level (relative to benchmark) of low-ability retirees at time  $t$  (where  $t=0$  is when the policy reform is announced and  $t=1$  is when it is implemented)

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

Policy 7 is a gradual shift from the PAYG system in the benchmark to a system with full private capital funding. This policy completely abolishes old-age pension benefits ( $\rho_{wa}, \rho_{fa}$ ). For the government it

implies a drastic cut in pension expenditures. We assume that this drop in expenditures feeds through into lower social security contributions for all workers such that, ex ante, the decline in total labor tax receipts in % of GDP is exactly the same as the drop in pension expenditures.<sup>22</sup> We observe in Table 6 that this transition to a private fully-funded pension scheme is not beneficial for employment. The new steady state shows lower hours worked among all ability groups and all age groups. The fall in employment is the strongest among older workers. The aggregate employment rate  $n$  drops by about 2.8%-points. An important element here is that a fully-funded system breaks the direct positive link between individual labor income and the pension, which exists in the PAYG system as we have modeled it. Steady state time allocated to education also falls, slightly. So does growth (-0.02%-points). Furthermore, we observe that a shift to a fully-funded system affects the government balance negatively (as the consumption tax rate has to be increased by more than 7 percentage points). The latter is mainly due to the decline in the tax base as hours of work decrease. Another element is that, although we also find that moving to a system with private capital funding encourages national savings (see e.g. Feldstein, 1974, 2005), this need not imply an increase in domestic physical capital formation, and capital taxes. If effective labor supply and employment fall, so will the marginal product of physical capital, which causes savings to be invested abroad. Figure 8 reveals a strong intertemporal trade-off in the welfare effects from moving to a fully-funded system. Future generations gain, but current, transitional generations experience large welfare losses<sup>23</sup>. This result is well-known in the literature. Although the future gains in Figure 8 are relatively strong when compared to those from e.g. policy 6, it should also be recognized that in the more distant future ( $k > 5$ ) a fully-funded system will bring less gains. A key element is that it lacks the incentives to promote human capital formation and growth inherent in policies 1, 5 and 6.

The possibility that a fully-funded pension system has lower growth than a PAYG model has been shown before by Kemnitz and Wigger (2000), Zhang and Zhang (2003), and Kaganovich and Meier (2008). The endogeneity of education and human capital is crucial for that result also in their models. The inferior employment effects from a shift to a fully-funded system may, however, be surprising from the perspective of recent work by e.g. Börsch-Supan and Ludwig (2010), Ludwig *et al.* (2012) and Fisher and Keuschnigg (2010). For a discussion of this issue we refer to Buyse *et al.* (2011). A major element is that the existing literature generally compares a fully-funded system with a specific

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<sup>22</sup> In particular, the gradual decline in  $\rho_{wa}$  and  $\rho_{fa}$  is announced at time  $t=0$  and implemented as follows. Pension benefits are not reduced for retirees at the moment of policy announcement ( $t=0$ ), since retirees are not able to react to a pension reduction. In  $t=1$  and  $t=2$  the replacement rates are respectively reduced to 2/3 and 1/3 of their initial rates. From  $t=3$  onwards,  $\rho_{wa}$  and  $\rho_{fa}$  are zero. At each moment, overall labor tax rates are reduced to ex ante compensate for the decline in pension expenditures.

<sup>23</sup> The explanation for the welfare loss of current generations in our model is as follows. The announcement of the transition to a fully-funded system, and the perspective of a gradual fall in labor taxes during periods 1, 2 and 3, as described in footnote 22, makes individuals shift hours worked to the future. During transition the young will study more, but total effective labor falls. Since this reduces the marginal productivity of physical capital, it will also discourage investment. Capital flows out. The economy experiences a strong drop in aggregate output (and tax revenue), which will force the government to raise consumption taxes. In later periods the economy enjoys the benefits from having accumulated more human capital during transition, but increased education efforts are not permanent (on the contrary).

PAYG system which is less ‘intelligent’ than in our policies 5 or 6. Either one assumes for example a ‘flat’ PAYG system where individuals’ pensions do not depend on their own human capital and labor earnings (as in our policy 3), or one models the public old-age pension system as an immediate alternative to work, neglecting the reality of early retirement systems.

## 6. Conclusions

We study the effects of pension reform in a four-period OLG model for an open economy where hours worked by three active generations, education of the young, the retirement decision of older workers, and aggregate growth, are all endogenous. Within each generation we distinguish individuals with high, medium or low ability to build human capital, which allows to investigate also the effects of pension reform on the income and welfare levels of different ability groups. Our specification of pension benefits allows for both own-earnings related and flat-rate or basic components. The weight of each component may differ for individuals with different abilities. Next to the pension system, we introduce a role for education quality as well as a rich fiscal policy block. The government sets tax rates on labor, capital and consumption. It allocates its revenue to productive expenditures (mainly for education), consumption, non-employment benefits (including early retirement benefits) and pensions.

We check the validity of our model and our calibration by simulating the model for 13 OECD countries and comparing its results with the true data. Imposing common technology and preference parameters but country-specific policy parameters, we find that the predictions of our model match the main facts remarkably well.

Simulating various models of pension reform, we find that an ‘intelligent’ PAYG system may have positive effects on both employment, the effective retirement age, education, aggregate growth and welfare. These positive effects are the strongest when the PAYG system includes a tight link between individual labor income (and contributions) and the pension, and when it attaches a high weight to labor income earned as an older worker to compute the pension assessment base. Such a system stimulates individuals’ labor supply when they are middle aged and older, and education when they are young. Positive effects on human capital formation promote future productivity and earnings capacity, also for future generations. An ‘intelligent’ PAYG system may perform (much) better than a system with a strong basic pension component, or a system with full private funding.

Recognizing realistic differences across people in ability to learn and to build human capital, however, we find that this ‘intelligent’ PAYG system implies significant welfare losses for current generations of low-ability individuals, who cannot study and who work at low wages. We therefore study various alternatives to maintain the aggregate efficiency gains of an ‘intelligent’ PAYG system, while at the same time contributing to higher income at old-age and welfare for all individuals. Most promising is to maintain the tight link between individual labor income and the pension also for low-ability individuals, but to strongly raise their replacement rate. Such a system performs much better

economically, and may expect to receive much more support politically, than basic or minimum pension components to promote the income of low-ability individuals. A tight link between individual labor income and the pension, combined with a high replacement rate, is a very effective way to promote labor supply. Basic and minimum pension models by contrast have strong negative effects on labor supply of low-ability individuals. A second welfare increasing adjustment would be to maintain equal weights in the pension assessment base for low-ability individuals. Since these individuals cannot study at the tertiary level, it is not optimal to give a lower weight to the labor income they earn when young.

Our findings tend to support recent pension reforms in countries like Sweden and Finland. Sweden moved from a quite non-actuarial PAYG system to a quasi-actuarial system with individual notional accounts (Lindbeck and Persson, 2003; OECD, 2005). These accounts establish a close relationship between working hours, labor earnings and contributions on the one hand, and future pensions on the other, as in the case of a high replacement rate  $\rho_w$  in our model (and a low  $\rho_f$ ). Finland introduced a system where the pension accrual rate rises with age, which corresponds to the case of a rising  $p_j$  as workers get older in our model (OECD, 2005). Our results support this policy, except for individuals with low capacity to study at the tertiary level.

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## Appendix 1: Construction of data and data sources

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

### ***Employment rate in hours (in one of three age groups, 1995-2007)***

*Definition:* total actual hours worked by individuals in the age group / potential hours worked.

Actual hours worked = total employment in persons x average hours worked per week x average number of weeks worked per year.

Potential hours = total population in the age group x 2080 (where 2080 = 52 weeks per year x 40 hours per week)

*Data sources:*

\* Total employment and total population in the age group: OECD Stat, Labour Force Statistics by Sex and Age. Data are available for many age groups, among which 20-24, 25-34, 35-44, 45-49, 50-54, 55-64. We constructed the data for our three age groups as weighted averages.

\* Average hours worked per week: OECD Stat, Labour Force Statistics, Average usual weekly hours worked on the main job. These data are available only for age groups 15-24, 25-54, 55-64. We use the OECD data for the age group 15-24 as a proxy for our age subgroup 20-24, the OECD data for the age group 25-54 as a proxy for our age (sub)groups 25-34, 35-49 and 50-54.

\* Average number of weeks worked per year: Due to lack of further detail, we use the same data for each age group. The average number of weeks worked per year has been approximated by dividing average annual hours actually worked per worker (total employment) by average usual weekly hours worked on the main job by all workers (total employment). Data source: OECD Stat, Labour Force Statistics, Hours worked.

### ***Education rate of the young (age group 20-34, 1995-2006)***

*Definition:* total hours studied by individuals of age 20-34 / potential hours studied

As a proxy we have computed the ratio:  $(fts_{20-34} + 0.5pts_{20-24} + 0.25pts_{25-34}) / pop_{20-34}$

with: *fts* the number of full-time students in the age group 20-34

*pts* the number of part-time students in the age groups 20-24 and 25-34.

*pop* total population of age 20-34

Full-time students are assumed to spend all their time studying. For part-time students of age 20-24 we make the assumption (for all countries) that they spend 50% of their time studying, part-time students of age 25-34 are assumed to spend 25% of their time studying. Due to the limited number of part-time students, these specific weights matter very little.

*Data sources:*

\* Full-time students in age groups 20-24, 25-29, 30-34: OECD Stat, Education and Training, Students enrolled by age (all levels of education, all educational programmes, full-time)

\* Part-time students in age groups 20-24, 25-29, 30-34: OECD Stat, Education and Training, Students enrolled by age (all levels of education, all educational programmes). We subtracted the data for full-time students from those for 'full-time and part-time students'.

Data are available in 1995-2006. However, for many countries (quite) some years are missing. Period averages are computed on the basis of all available annual data.

***Average effective retirement age (1995-2006)***

*Definition:* Average age of all persons (being 40 or older) withdrawing from the labor force in a given period.

*Data source:* OECD, Ageing and Employment Policies – Statistics on average effective age of retirement.

***Annual real potential per capita GDP growth rate (aggregate, 1995-2007)***

*Definition:* Annual growth rate of real potential GDP per person of working age

*Data sources:*

\* real potential GDP: OECD Statistical Compendium, Economic Outlook, supply block, series GDPVTR.

\* population at working age: OECD Statistical Compendium, Economic Outlook, labour markets, series POPT.

***Tax rate on labor income ( $\tau_w$ )***

*Definition:* Total tax wedge, marginal tax rate in % of gross wage earnings. The data cover personal income taxes, employee and employer social security contributions payable on wage earnings and payroll taxes.

*Data source:* OECD, Statistical Compendium, Financial and Fiscal Affairs, Taxing Wages, Comparative tax rates and benefits (new definition).

The OECD publishes 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 rates when young and middle aged (b)***

*Definition:* The data concern net transfers received by long-term unemployed people and include social assistance, family benefits and housing benefits in the 60<sup>th</sup> month of benefit receipt. They also include unemployment insurance or unemployment assistance benefits if these benefits are still paid, i.e. if workers can be structurally unemployed for more than five years without losing benefit

eligibility. The data are expressed in % of after-tax wages. The OECD provides net replacement rates for six family situations and three earnings levels. Our data in Table 4 are the averages of these 18 cases. Data for 2001-04.

*Data source:* OECD, Tax-Benefit Models, [www.oecd.org/els/social/workincentives](http://www.oecd.org/els/social/workincentives)

*Data adjustment:* Original OECD data for Norway include the so-called “waiting benefit” (ventestønad), which a person could get after running out of unemployment benefits. Given the conditional nature of these “waiting benefits”, they do not match our definition of benefits paid to structurally non-employed individuals. We have therefore deducted them from the OECD data, which led to a reduction of net replacement rates by about 19 percentage points. For example, recipients should demonstrate high regional mobility and willingness to take a job anywhere in Norway. The “waiting benefit” was terminated in 2008. We thank Tatiana Gordine at the OECD for clarifying this issue with us.

### **Early retirement replacement rates ( $b_{er}$ )**

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 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  $\xi=0.5$ . 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  $\xi$ .

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

**Net pension replacement rates** ( $\rho_{wa}$  and  $\rho_{fa}$  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  $\rho_{wa}$  includes all earnings-related pensions and mandatory occupational pensions when they depend on wages or hours worked. Our proxy for  $\rho_{fa}$  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  $\rho_{fa}$  is a percentage of the average net wage in the economy (Equation 9), whereas the above described OECD data are in percent of an individual's net wage, we multiply the OECD data with the ratio of the replacement in percent of average earnings to the replacement rate in percent of individual earnings to obtain our  $\rho_{fa}$ . This ratio can be derived from the 'pension modelling' tables in the individual country studies, at various multiples of average earnings.

**Appendix 2:** Detail on calibration procedure to determine  $\eta_a$  and  $\phi_a$  (with  $a = L, M, H$ )

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 (26) 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:

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

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

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 and  $x_L, x_M$  and  $x_H$ , which themselves depend on  $\phi_L, \phi_M$  and  $\phi_H$ ), it is easy to see that we have three remaining equations in three unknowns ( $\eta_H, \eta_M, \eta_L$ ) that can be solved.

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

$$\begin{aligned} \frac{w_{L,t}h_{2L}^{t-1}}{w_{H,t}h_{2H}^{t-1}} &= \frac{w_{L,t}x_L^{t-1}\varepsilon_L h_{1H}^{t-1}}{w_{H,t}x_H^{t-1}h_{1H}^{t-1}} = \frac{w_{L,t}x_L^{t-1}}{w_{H,t}x_H^{t-1}} 0.673 = 0.38. \\ \frac{w_{M,t}h_{2M}^{t-1}}{w_{H,t}h_{2H}^{t-1}} &= \frac{w_{M,t}x_M^{t-1}\varepsilon_M h_{1H}^{t-1}}{w_{H,t}x_H^{t-1}h_{1H}^{t-1}} = \frac{w_{M,t}x_M^{t-1}}{w_{H,t}x_H^{t-1}} 0.837 = 0.58. \end{aligned}$$

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