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Public pension and debt policies in general equilibrium

by

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Nederlandstalige samenvatting

De beleidsmakers in de meeste OESO-landen staan voor enorme uitdagingen. Eerst en vooral worden de gezondheids- en pensioengerelateerde uitgaven verwacht sterk te stijgen door de vergrijzing. Hierdoor is de bezorgdheid omtrent de betaalbaarheid op lange termijn van het publieke pensioensysteem sterk toegenomen. Hervorming van het bestaande systeem is noodzakelijk en onvermijdelijk. De verhoogde uitgavendruk inzake pensioenen komt bovendien op een moment dat vele landen gedwongen worden hun budgettaire situatie aan te zuiveren na de recente crisis. De financiële crisis van 2007-2008 heeft namelijk tot op vandaag diepgaande gevolgen voor de economieën van vele OESO-landen en voor hun overheidsfinanciën. Ook budgettaire sanering staat vandaag dus centraal in het economisch en politieke debat. De nood aan effectieve maatregelen om de overheidsschulden te verminderen, staat gegeven de potentieel nefaste invloed van hoge schuld op toekomstige groei en welvaart buiten discussie.

In het eerste deel van dit proefschrift (hoofdstukken 2-4) focussen we op de macro-economische effecten van pensioenhervormingen. Mede onder druk van de vergrijzing en gegeven de nood aan budgettaire sanering dringen hervormingen zich op. In de wetenschappelijke literatuur is er eensgezindheid dat, om de pensioenuitdaging aan te pakken, er in de eerste plaats nood is aan (i) een hogere werkgelegenheid, vooral onder 50-plussers en (ii) een sterkere per capita economische groei (productiviteitsgroei). Vanuit deze overtuiging werden ook heel wat voorstellen geformuleerd tot hervorming van de bestaande publieke pensioensystemen. Verschillende economen hebben onderzocht hoe het pensioensysteem de individuele incentives tot werken kan beïnvloeden. Anderen tonen aan dat de aard van het pensioensysteem invloed heeft op de vorming van menselijk kapitaal via scholing en zo de economische groei kan bepalen. Ondanks tal van bijdragen, heeft de academische literatuur echter nog geen consensus bereikt over welke hervormingen het meest bijdragen tot hogere werkgelegenheid, sterkere productiviteitsgroei en welvaart. De gangbare beleidsaanbevelingen variëren sterk, gaande van hervormingen binnen het bestaande 'pay-as-you-go' repartitiesysteem tot een geleidelijke overgang naar een actuarieel neutraal kapitalisatiesysteem.

De hoofdstukken 2-4 van dit proefschrift bestuderen daarom het verband tussen enerzijds het publieke pensioensysteem en anderzijds de werkgelegenheid in drie leeftijdsgroepen, tertiaire scholing, de leeftijd waarop mensen daadwerkelijk op pensioen gaan (de effectieve pensioenleeftijd), en de economische groei. We doen dit op basis van een endogeen groeimodel met overlappende generaties. Op elk moment leven vier generaties gezinnen: drie actieve generaties (jong, middelbare leeftijd, ouder) en een gepensioneerde generatie. Jonge individuen zijn tussen 20 en 34, individuen op middelbare leeftijd tussen 35 en 49, en oudere individuen tussen 50 en 64. Gepensioneerden zijn 65+. Terwijl ouderen en individuen op middelbare leeftijd beslissen hoeveel en hoe lang ze werken, kunnen jongeren (naast werken) ook een deel van hun tijd studeren om extra menselijk kapitaal en

kennis op te bouwen. De overheid heft belastingen op arbeid, kapitaal en consumptie. Ze gebruikt deze inkomsten ter financiering van productieve uitgaven (vooral voor scholing), consumptie, transfers aan niet-werkenden (waaronder ook uitkeringen aan wie vervroegd met pensioen gaat) en reguliere pensioenen. Het pensioensysteem is van het pay-as-you-go type waarbij iemands pensioen berekend wordt als fractie (de vervangingsratio) van het verdiende eigen arbeidsinkomen over diens actieve periode. De financiering van de pensioenen gebeurt via bijdragen door alle actieven.

Ons model onderscheidt zich op verscheidene vlakken van andere studies over pensioenhervorming. Ten eerste worden alle bovenvermelde variabelen endogeen verklaard binnen het model. Op die manier nemen we alle wederzijdse relaties tussen de variabelen in rekening, wat van belang kan zijn voor de richting en omvang van beleidseffecten. Bijvoorbeeld, als de werkgelegenheid toeneemt, zal fysisch kapitaal rendabeler kunnen ingezet worden, met gunstige gevolgen voor de investeringen en de groei. Bovendien, wanneer mensen langer werken en hun (vervroegd) pensioen uitstellen, laten ze hun opgebouwd menselijk kapitaal langer renderen. Een hoger rendement voor studie bevordert scholing en zo ook de productiviteit en de groei. Omgekeerd zullen hervormingen die studeren stimuleren, mensen ook aanzetten tot langer werken om langer de vruchten van hun studie te plukken. De uiteindelijke effecten van pensioenhervormingen, zijn afhankelijk van al deze interacties.

Ten tweede bevat ons model een realistische beschrijving van de transitie van werk naar pensioen. Ook met de mogelijkheid van vervroegde uittreding uit de arbeidsmarkt houden we rekening. Deze mogelijkheid speelt namelijk een belangrijke rol in vele landen. Daarom onderscheiden we expliciet de effectieve pensioenleeftijd, die wordt gekozen door oudere werknemers, en de officiële pensioenleeftijd, die exogeen gegeven is op 65 jaar. Terwijl gunstige uitkeringen voor vervroegd pensioen werken relatief onaantrekkelijker maken, is dit niet direct het geval voor normale ouderdomspensioenen. In de literatuur wordt dit onderscheid vaak niet gemaakt.

Daarnaast houden we expliciet rekening met de link tussen individuele bijdragen en het latere pensioen. De pensioenuitkering is in ons repartitiesysteem namelijk afhankelijk van het geaccumuleerd individuele arbeidsinkomen en dus de geleverde bijdragen. Hoe meer een individu werkt, en hoe meer hij bijdraagt, hoe groter het pensioen is dat hij zal verkrijgen (al kan deze relatie in de praktijk wel verzwakt worden, bijvoorbeeld door een plafond aan de hoogte van het pensioen). Meerdere onderzoekers negeren evenwel deze link, waardoor ze wel de kost (bijdrage) van het systeem in rekening nemen, maar niet het individuele voordeel hiervan.

Ten slotte veronderstellen we in ons model een open economie. Pensioenhervormingen kunnen uitgesproken effecten hebben op de nationale besparingen. In een open economie hoeven deze gewijzigde besparingen niet noodzakelijk door te stromen in binnenlandse investeringen, ze kunnen ook in het buitenland belegd worden. Wijzigingen in binnenlandse lonen en rentevoeten zullen dan beperkter zijn dan in een gesloten economie. Dit alles heeft implicaties voor de effecten op de werkgelegenheid en de vorming van menselijk kapitaal.

De belangrijkste tekortkoming van het model zoals voorgesteld in hoofdstuk 2 is dat er geen onderscheid wordt gemaakt tussen individuen naargelang hun studiebekwaamheid. We gaan

namelijk voorbij aan het gegeven dat een nauwe band tussen het pensioen en het eigen arbeidsinkomen ook sterk ongelijkheid verhogend 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 3 het model realistischer door de individuen op te splitsen in drie specifieke bekwaamheidsgroepen. Meer bepaald onderscheiden we in elke generatie 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.

Alvorens in de hoofdstukken 2 en 3 de effecten van een aantal pensioenhervormingen te simuleren, gaan we de empirische waarde van ons model na. We doen dit voor 13 landen en gaan als volgt te werk. Eerst leggen we gelijke (via kalibratie bepaalde) technologie- en preferentieparameters op voor alle landen, maar landspecifieke kenmerken van het begrotingsbeleid en het pensioensysteem. Vervolgens vergelijken we de voorspellingen van ons theoretisch model voor elk land met de feiten. Deze feiten betreffen de geobserveerde werkgelegenheid (in uren) in drie leeftijdsgroepen (20-34, 35-49, 50-64), de deelname aan hoger onderwijs van de jongeren (20-34), de effectieve pensioenleeftijd, en de per capita economische groei sinds 1995. De set van landen die we bekijken omvat de Verenigde Staten, de kernlanden van de eurozone, het Verenigd Koninkrijk, Canada en de Scandinavische landen. In de meeste van deze landen lopen de voorspellingen van ons theoretisch model gelijk met de feiten. De verklaringskracht van ons model is ook hoog.

Vervolgens kunnen we de effecten van verschillende pensioensystemen en pensioenhervormingen (repartitiesysteem, eigen kapitalisatie, basispensioen, …) op werkgelegenheid, scholing, economische groei en ongelijkheid in kaart brengen**.** Zowel in hoofdstuk 2 als 3 vinden we de sterkste positieve effecten op de werkgelegenheid, de groei en de geaggregeerde welvaart in een repartitiestelsel wanneer het verband tussen het pensioen en de 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. Zo blijkt bovendien dat een dergelijk goed geconstrueerd repartitiestelsel beter kan presteren dan een kapitalisatiestelsel. Hoofdstuk 3 toont echter eveneens aan dat dit repartitiesysteem, wanneer het niet verder gecorrigeerd wordt, een sterke toename van de ongelijkheid impliceert, en een laag inkomen op de oude dag voor iedereen met lagere studiebekwaamheid en scholing. De meest efficiënte manier om deze ongelijkheid te verminderen, is de directe koppeling tussen het individueel arbeidsinkomen en het pensioen te handhaven, ook voor lage inkomensgroepen, maar anderzijds voor deze inkomensgroepen de vervangingsratio aanzienlijk te verhogen. De financiële haalbaarheid van deze correctie vereist wel solidariteit van de hogere inkomensgroepen.

Gebruik makend van het model ontwikkeld in vorige hoofdstukken, onderzoeken we in hoofdstuk 4 of de pensioenhervormingen die we eerder analyseerden, ook bevorderlijk kunnen zijn voor de fertiliteit in een land. Vertrekpunt voor deze vraag is de bijkomende observatie dat vele OESO-landen geconfronteerd worden met een dalende geboortegraad en bevolkingsgroei. Door de resulterende daling in de bevolking op beroepsactieve leeftijd wordt de pensioenproblematiek nog versterkt. Een grote literatuur onderzoekt de interactie tussen publieke pensioenen en fertiliteit. Algemeen is de idee dat het pensioensysteem op zich een belangrijke verklaring vormt voor de dalende geboortegraad. Een belangrijke reden is dat een pensioensysteem het belang van kinderen als verzekering op oudere leeftijd doet dalen. Vaak gehoorde hervormingen betreffen dan een drastische omschakeling naar een kapitalisatiesysteem omdat dit stabiel blijft bij demografische veranderingen of het koppelen van een deel van het pensioen aan het aantal kinderen. In hoofdstuk 4 nemen we echter het bestaande repartitiestelsel waar vele OESO-landen op steunen, als gegeven. We breiden hiervoor ons model uit met een endogene fertiliteitskeuze. We vinden dat de eenvoudige parametrische aanpassing van het bestaande systeem, zoals naar voor gebracht in voorgaande hoofdstukken, eveneens de fertiliteit kan stimuleren.

Op basis van bovenstaande resultaten kunnen enkele voorzichtige beleidsconclusies worden getrokken. Rekening houdend met de huidige vroege uittredeleeftijd en lage werkgelegenheid van ouderen lijkt het ons in landen als België aangewezen om de link te versterken tussen enerzijds het toekomstige pensioen en anderzijds het verdiende arbeidsinkomen (vooral het arbeidsinkomen in het tweede deel van de loopbaan). Onze resultaten tonen aan hoe dit kan gerealiseerd worden. Daarnaast is het eveneens belangrijk dat huidige en toekomstige generaties weten hoe hun pensioen wordt berekend en wat de specifieke kenmerken zijn van het in werking zijnde pensioensysteem. Enkel zo zullen de gedragsmechanismen die in het model worden geïntegreerd, ook in realiteit volop spelen. De overheid heeft dus een belangrijke informatieve rol te spelen.

Het tweede deel van dit proefschrift (hoofdstukken 5 en 6) focust op de tweede uitdaging voor hedendaagse economieën: de sanering van de overheidsfinanciën. We doen dit onderzoek op twee vlakken. In hoofdstuk 5 slaan we een andere methodologische weg in en gebruiken we empirische (econometrische) methodes gebaseerd op data over saneringsperiodes uit het verleden om conclusies te trekken over het succes of falen van verschillende strategieën van saneringsbeleid. In hoofdstuk 6 gaan we verder op de theoretische weg die ook in de eerdere hoofdstukken aan de basis lag.

In hoofdstuk 5 voeren we een empirisch onderzoek naar de determinanten van succesvolle schuldreductie. We bestuderen de evolutie van de publieke schuldratio gedurende 132 periodes, waarvan 40 saneringsperiodes, in 21 OESO-landen in de periode 1981-2008. Om deze periodes te definiëren gebruiken we data over de evolutie van het zogenaamd onderliggend cyclisch gezuiverd (of structureel) primair begrotingssaldo om vertekeningen uitgelokt door de conjunctuur en door éénmalige maatregelen te vermijden. Als belangrijkste nieuwe bijdrage levert dit hoofdstuk bewijs voor het belang van efficiëntie in de publieke sector als drijfkracht van succesvolle budgettaire

sanering. Eerst en vooral bevestigt ons onderzoek dat een saneringsprogramma op termijn tot sterkere dalingen in de schuldratio leidt als dit programma vooral gebaseerd is op uitgavenbeperkingen (met uitzondering van publieke investeringen). Reducties in de publieke loonmassa (zij het door het inkrimpen van de publieke tewerkstelling of het verlagen van de publieke lonen), kunnen zeer effectief zijn, maar enkel in landen met de minst efficiënte overheden. Daarnaast blijkt dat een gegeven saneringsprogramma effectiever zal zijn in het terugdringen van de schuld indien dit programma wordt uitgevoerd door een efficiëntere overheid. Bovendien blijken efficiënte overheden eveneens een beter samengesteld saneringsbeleid te voeren. Wat betreft de overige institutionele kenmerken, blijkt dat saneringsbeleid succesvoller is als dit beleid simultaan wordt uitgevoerd met productmarktderegulering en wanneer ze wordt geïmplementeerd door overheden uit het linkse politieke spectrum. Daarentegen blijkt simultane arbeidsmarktderegulering contraproductief te werken ten aanzien van de kansen op effectieve schuldafbouw. In hoofdstuk 5 gaan we dieper in op de potentiële verklaring van deze effecten.

Ook het onderzoek in hoofdstuk 6, ten slotte, draagt bij tot de discussie over de effecten van budgettaire sanering op de output en de welvaart van een land. We bestuderen deze effecten binnen een 30-periode overlappend generatie model. De basiskenmerken van dit model zijn gelijkaardig aan de modellen gebruikt in vorige hoofdstukken. Een belangrijke uitbreiding betreft de introductie van publieke tewerkstelling en productie. Terwijl de meeste theoretische macromodellen de rol van de overheid aan de uitgavenzijde reduceren tot het aankopen van goederen en het betalen van transfers, besteden wij speciale aandacht aan het modelleren van publieke tewerkstelling en productie in drie subsectoren (publieke consumptiegoederen, onderwijs, publieke infrastructuur). Gegeven de empirische discussie omtrent de rol van reducties in publieke lonen en tewerkstelling voor het succes van budgettaire sanering, zoals eerder aangehaald, is deze uitbreiding en verfijning van cruciaal belang. Dit hoofdstuk haalt aldus enkele belangrijke theoretische kanalen aan waarlangs publieke tewerkstelling een belangrijke bijdrage kan leveren aan het ontwikkelingsniveau van een land. Niet alleen bevorderen publieke goederen rechtstreeks de welvaart van een land, door investeringen in scholing, regelgeving en infrastructuur kan ook onrechtstreeks het (langetermijn) outputpotentieel van een land gestimuleerd worden.

Het is belangrijk om ook de tekortkomingen van deze laatste studie aan te duiden. Zo maken we een aantal simplifiërende veronderstellingen, die aandacht verdienen in verder onderzoek. We veronderstellen bijvoorbeeld dat de overheid geen optimaliserend gedrag vertoont; ze kiest m.a.w. geen optimale combinatie van inputfactoren om haar gewenste output zo efficiënt mogelijk te produceren. Bovendien veronderstellen we dat alle overheidssectoren gekenmerkt worden door eenzelfde productiefunctie, eenzelfde verhouding van laag- en hooggeschoolde werknemers, perfecte substitueerbaarheid tussen publieke productie en input van goederen gekocht op de markt etc. Tenslotte krijgen werknemers in de publieke sector eenzelfde loon als hun private tegenhangers, ook al is hun bijdrage in de economie verschillend. Toch is deze studie zeker waardevol, niet in het minst om de aandacht voor de modellering van publieke tewerkstelling en productie in theoretische macromodellen te vergroten.

De resultaten van deze studie kunnen in enkele punten worden samengevat. Wat betreft de effecten op het outputpotentieel, bevestigen onze simulaties het belang van sanering gebaseerd op uitgavenreductie (met uitzondering van publieke investeringen). Reducties in publieke tewerkstelling zijn te verkiezen boven belastingverhogingen op arbeid of kapitaal, maar niet boven verhogingen van de consumptiebelastingen. Wat de welvaartseffecten betreft, blijkt opnieuw dat uitgavenreductie minder nefast is dan belastingverhogingen, althans voor die generaties die de saneringsperiode volop meemaken. Voor toekomstige generaties geldt dit resultaat echter niet. Deze generaties winnen bij een budgettaire sanering nu, maar de positieve effecten blijken kleiner te zijn bij programma's die vooral gebaseerd zijn op reducties in uitgaven voor scholing, investeringen en publieke tewerkstelling dan bij programma's die gebruik maken van (om het even welke) belastingverhogingen.

Op basis van de resultaten uit hoofdstukken 5 en 6 kunnen opnieuw enkele voorzichtige beleidsconclusies worden getrokken. Eerst en vooral blijkt dat overheidsefficiëntie een belangrijke factor is om de effecten van budgettaire sanering te verklaren. Een verlaging van de publieke loonmassa is volgens onze resultaten in hoofdstuk 5 enkel effectief in landen met de minst efficiënte overheden. Een gegeven saneringsprogramma is daarnaast effectiever in het terugdringen van de schuld indien dit programma wordt uitgevoerd door een efficiëntere overheid. Tenslotte blijken efficiënte overheden eveneens een beter samengesteld saneringsbeleid te voeren. Hoofdstuk 6 leert bovendien dat het inkrimpen van de publieke tewerkstelling als deel van een saneringsprogramma misschien wel te verkiezen is boven belastingverhogingen op arbeid of kapitaal, maar niet als deze reductie resulteert in minder publieke investeringen of uitgaven voor scholing. Het is dus ook belangrijk om de economische bijdrage van het overheidspersoneel en de publieke sector in rekening te brengen.

Ons onderzoek geeft dus twee mogelijke verklaringen voor de bestaande onzekerheid in de empirische literatuur omtrent de effecten van reducties in de publieke loonmassa: enerzijds overheidsefficiëntie en anderzijds de specifieke subsector waarin deze reducties plaatsvinden. Een belangrijke taak is dus weggelegd voor verder onderzoek over de efficiëntie en productiviteit van de publieke sector, alsook over de relatie tussen publieke en private werkgelegenheid en lonen.

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CHAPTER 1

Introduction

Introduction

1. General context and motivation

The sharp increase in public debt ratios and growing concern about the sustainability of public finances since the banking crisis and the deep recession in 2008–09 have imposed the need for credible debt reduction strategies in most OECD countries. Moreover, over the next several decades, there will be significant changes in the age structure of OECD populations, which will put greater pressure on healthcare, public pensions and general government finances. These concerns have put public pension reform and fiscal consolidation high on the agenda of both policy makers and researchers. Unfortunately, debt reduction and pension reform are also among the most complicated public policy problems. As a result, there is still no consensus on either of these issues.

First, as to the debate on pension reform, there seems to be general agreement on the need for higher employment, especially among older individuals, and higher productivity growth. 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 system that most countries rely on (see for instance Diamond, 2004 and Cigno, 2010). Other papers prefer a gradual move to an actuarially neutral fully funded private system (Feldstein, 2005; Börsch-Supan and Ludwig, 2010). Often, differences in the particular specification of the model economy that is used for the analysis may explain the differences in results.

Second, a huge (and mostly empirical) literature has studied the economic effects of fiscal consolidation. Most of these studies analyze growth or output effects and try to discover the determinants of success or failure of fiscal adjustment. Most economists agree on the fact that spending-based fiscal consolidation hurts output less than tax-based consolidation, at least so in the longer run. However, much less agreement exists on (i) the possibility of expansionary output effects in the short run, (ii) the impact of fiscal adjustments on welfare and (ii) the role of institutional characteristics in shaping the outcome of a consolidation program. Furthermore, a fourth important aspect on which general consensus is missing concerns the impact and importance of cuts in public employment and the public wage bill for fiscal austerity. Some authors expect expansionary output effects, also in the short run, if the government tackles social spending and public employment or the public wage bill (Alesina and Perotti, 1996; Alesina and Ardagna, 2010). According to these authors, public wage bill cuts should therefore have a prominent role in consolidation programs. Others however are more pessimistic. Perotti (2011) expects short-run output losses after spending cuts. Heylen and Everaert (2000), Tagkalakis (2009) and Larch and Turrini (2011) do not find that fiscal consolidation is more successful when it mainly relies on government wage bill cuts. The discussion has become particularly lively in the most recent years, as shown for example by the many

contributions to the debate initiated by Corsetti (2012). Strong positions are being taken varying from 'austerity will increase confidence and encourage recovery' to 'austerity kills' (Krugman and Layard, 2012).

With this dissertation, we hope to add new insights on the road to better reform options and to make clear policy conclusions and recommendations. For this, we conduct five separate, but related studies. While chapters 2, 3 and 4 focus on the issue of pension reform, we turn our attention to fiscal consolidation policies in chapters 5 and 6.

2. Research questions, contribution and results

In **chapter 2**, we build and parameterize a four-period OLG model for an open economy to study hours of work among young, middle-aged and older workers, education of the young, the effective retirement age of older workers, and aggregate per capita growth, within one coherent framework. We explain these endogenous variables as functions of various tax rates, various kinds of government expenditures, and key characteristics of the public PAYG pension system. Old-age pensions in our model are related to earned labor income over the three periods of active life, but the link between pension benefits and earlier labor income (and contributions) may be tight or loose. The government can also decide on the weight attached to each of the three active periods in the pension assessment base. Finally, we pay particular attention to a realistic modeling of the transition from work to retirement. Workers can optimally choose their effective retirement age, and receive early retirement benefits. However, the statutory retirement age, after which old-age pensions are being paid, is exogenous. We find that our model explains the facts remarkably well for many OECD countries. We then use the model to investigate the effects of various reforms of the pension system. Studying pension reform in a model where employment by age, education and human capital, and growth are all endogenous, is the main contribution of this paper.

Our simulation results prefer an intelligent PAYG pension system above a fully funded private system. Key elements of such an intelligent system include: (1) a close link between old-age pensions, and individual labor earnings and contributions, via a high pension replacement rate, and (2) a high weight of labor income (i.e. hours worked and human capital) earned as an older worker in the pension assessment base. Pension reform in this direction encourages young individuals to study and build human capital, which promotes long-run growth. Furthermore, it encourages older individuals to work and postpone retirement. Strengthening the link between one's future old-age pension, on the one hand, and one's human capital and labor supply when older, on the other, introduces strong financial incentives which may bring about important changes in behavior. Policy reforms in this direction may also raise welfare levels of current and (especially) future generations. Furthermore, our results confirm that the partial abolishment of various early retirement regimes, through a reduction in the generosity of early retirement benefits or the introduction of more strict eligibility criteria for early retirement, substantially stimulates employment of older workers along both the intensive and extensive margin.

Our conclusion is in line with some recent literature. First, our findings support analytical results by Jaag *et al.* (2010) and Fisher and Keuschnigg (2010) among others that a *strong link between own contributions and the pension* strengthens incentives to work (see also Lindbeck and Persson, 2003 and Cigno, 2010). Flat pension regimes imply lower overall employment. Second, our findings also support the positive effects on the effective retirement age and the labor supply of older workers from *letting the pension rise in labor income and contributions paid as an older worker*, as emphasized by Sheshinski (1978), Gruber and Wise (2002), and Lindbeck and Persson (2003).

Our main innovation in **chapter 3** is to introduce heterogeneous abilities in the previous model. Welfare effects from the policy measures discussed in the previous chapter may be very different for high and low ability (wage income) individuals. This may affect policy evaluation. Therefore, we make the assumption in chapter 3 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.

Recognizing realistic differences across people in the ability to learn and to build human capital, we find that the 'intelligent' PAYG system put forward in the chapter 2 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.

Chapter 4 builds on the knowledge from the previous chapters and investigates a relatively simple issue. That is, we study whether the reform options put forward in the previous chapter also influence fertility in a positive way. Starting point for this study is the observed decline in fertility rates in many OECD countries, which raises the old-age dependency ratio and raises additional concern for the long-run viability of public pension systems. A large literature has studied the

interaction between public pensions and the fertility rate. Some authors see the pay-as-you-go pension system as one of the reasons for the decline in fertility rates (e.g. Zhang, 1995; Cigno and Rosato, 1996; Sinn, 2004 and Boldrin *et al.*, 2005). The general idea is that the introduction of a public pension system diminishes the necessity to raise children as a source of old-age income support. As such, public pensions reduce transfers within the family and hence distort demand for children. With respect to the issue of declining fertility, some economists are in favor of a switch to a fully-funded system since such a system is stable in case of demographic changes. Others advocate the idea of relating the pension benefit (partly) to the number of children raised by the pensioner (e.g. Voigtländer, 2004 and Sinn, 2005, Fenge and Meier, 2005). In this chapter, and in contrast to studies which analyze how pensions benefits can be related directly to the number of offspring (see e.g. Fenge and Meier, 2005), we take the existing PAYG pension system that most OECD countries rely on as given.

We first extend our model by giving individuals the endogenous choice of the number of offspring. We then check whether the simple parametric adjustment of this system, as proposed in chapters 2 and 3, may also enhance fertility. Our simulation results prefer an intelligent pay-as-you-go system above a fully-funded private system not only when it comes to employment and growth, but also for fertility. The higher (lower) marginal utility from work when older (young) following such a reform makes it interesting to shift work from the first period of active life to the third. Part of the available time that arises during youth is spent on education. Another part can be spent on raising offspring. Again, even when fertility is endogenous, positive effects on employment and growth are the strongest when the pay-as-you-go system 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. By contrast, shifting to a fully-funded system might even reduce fertility.

Different from the previous chapters, the studies presented in chapters 5 and 6 focus on the issue of fiscal consolidation. In **chapter 5**, we use an empirical approach to identify the drivers of the success or failure of fiscal consolidation. Analysis of the effects of fiscal consolidation has been high on the agenda of many researchers since seminal works by Giavazzi and Pagano (1990) and Alesina and Perotti (1995). Most of these researchers have tried to explain the probability of success in debt or deficit reduction (e.g. Afonso and Jalles, 2012; Alesina and Ardagna, 1998; Ardagna, 2004; Guichard et al., 2007; Larch and Turrini, 2011; McDermott and Wescott, 1996; Schaltegger and Feld, 2009; Tagkalakis, 2009). Others focus on the evolution of economic growth, private consumption, or private investment during and after consolidation periods (e.g. Alesina and Ardagna, 2012; Alesina et al., 2002; Ardagna, 2004; Giavazzi and Pagano, 1996; Hjelm, 2002; IMF, 2010a). The paper presented in chapter 5 contributes to this literature by studying directly the evolution of the ratio of public debt to GDP during and after fiscal consolidations. We embed this study in an empirical analysis of 132 fiscal episodes in 21 OECD countries in 1981–2008. Only one study has focused directly on the evolution of the debt to GDP ratio before (see Heylen and Everaert, 2000). To define these periods

we use data on the evolution of the underlying cyclically adjusted primary balance, and as such avoid biases that may be induced by one-off budgetary measures (see IMF, 2010a).

Our main contribution may be in the new evidence that we obtain on the role of public sector efficiency and a number of other institutional variables for the success of consolidation policies. The role of public sector efficiency has not yet been studied before in the context of fiscal consolidation. As to other institutions, we study the effects of labor and product market characteristics and reform, and the role of the political ideology of the government. Rising pressure on governments, especially in Europe, to reform labor and product markets, and a growing ideological divide, show the importance of the topic. However, the existing evidence in the literature on the effects of these institutions and of institutional reform during fiscal consolidation is highly ambiguous (see e.g. Alesina and Ardagna, 2012, and Tagkalakis, 2009).

Our main results from chapter 5 are the following. First, we confirm that consolidation programs imply a stronger reduction of the public debt ratio when they rely mainly on spending cuts, except public investment. Government wage bill cuts, however, only contribute to lower public debt ratios when public sector efficiency is low. Second, we find that a given consolidation program will be more effective in bringing down debt when it is adopted by a more efficient government apparatus. Third, more efficient governments adopt consolidation programs of better composition. As to other institutions, consolidation policies are more successful when they are accompanied by product market deregulation, and when left-wing governments adopt them. By contrast, simultaneous labor market deregulation may be counterproductive during consolidation periods.

In the final part of this dissertation, we propose a general equilibrium analysis to study the economic effects of fiscal consolidation. Here, we also take into account the reality of different public subsectors. More precisely, we study fiscal adjustment within a theoretical overlapping generations model with 30 generations. By explicitly modeling the behavior of all relevant actors and their interaction on different markets in the short and the long-run, a well-structured and disciplined analysis of the economic and welfare implications of fiscal consolidation becomes possible.

The main innovation in the model presented in **chapter 6** concerns our modeling of the public sector. Whereas most theoretical macro models reduce the role of the government at the expenditure side to purchasing goods and paying transfers, we pay particular attention to also modeling public employment and production. Given the empirical discussion on the role of public wage bill cuts for the success of fiscal consolidation, as illustrated in the previous chapter, this was important to do. We distinguish public employees in the production of investment goods, in education, and in the production of useful public consumption goods. As such, public sector output contributes to the construction of public capital and the accumulation of human capital, which both raise private sector output and productivity, and to the provision of direct utility. Although the modeling of a detailed public sector of production and employment is novel, there are still some important simplifications that deserve attention in future research. For instance, the government in our model does not optimally choose its inputs to efficiently produce the desired output, i.e. the input shares are exogenously pinned down. As a result, the relative share of high versus low-skilled

workers in all public sectors is identical and not optimally chosen. Moreover, the output in each sector is not chosen in an optimal way. Furthermore, the production function in all public sectors is identical and simplified. Finally, all public workers receive the same wage (per unit of effective labor), although their economic contribution is different. We stress that if the implicit assumption of an inefficient government were to generate artificial efficiency-improvements from downsizing the public sector, implementing a strong theoretic foundation for the public sector would be of prime importance. However, the results presented in this chapter tell a different story. That is, even though we have assumed an inefficient government, we do not find support that downsizing the public sector leads to unambiguous efficiency improvements, quite on the contrary. Intuitively, although the public sector does not exhibit efficient behavior, its production does result in added value for the general economy (through utility gains, more human capital accumulation or public capital). Despite the simplifications we have made in this chapter, we believe that the contribution of this study is still very significant, not at least in the way that it brings to the attention the modeling of public employment and production in theoretical macro-models.

Our analysis allows an assessment of the macroeconomic impact of reducing public employment as a means of debt reduction and thus allows assessing the claim that public employment cuts raise the effectiveness of consolidation programs. Moreover, it allows comparing these results to those adopting other consolidation instruments, such as other government expenditures or taxes on labor or consumption. The analysis is not limited to the implications for employment, private output and GDP, however. We will also study welfare effects on both current and future generations of individuals with different innate ability.

As mentioned before, the empirical consolidation literature has focused on a few key hypotheses. A *strong* one is that tax based fiscal consolidation is contractionary, whereas spending based adjustment induces expansionary output effects, also in the short-run. Expansionary effects could, according to some economists, occur when social transfers or public employment and the public wage bill are diminished. A *weaker* hypothesis is that the output effects of spending based consolidations are better (less negative) than those of tax based consolidations. Our simulations of output effects generally confirm the weaker hypothesis. Expenditure based consolidation is better than labor or capital tax based consolidation (at least when spending cuts do not concern public investment). This conclusion applies to both the short-run and the long-run. Consolidation via consumption tax increases also hurts the economy in the short-run, but is generally one of the more efficient policies in the longer run. Confirmation of the stronger hypothesis, however, is much more difficult to find. Truly expansionary output effects after spending cuts are much harder to document. Cutting public employment is not expansionary for GDP in the short and medium run. It may be expansionary for GDP in the longer run, but only if public employment is reduced in public consumption goods production.

When it comes to welfare effects, we observe much bigger differences between different age groups than between different ability types of the same age. Here we confirm Jensen and Rutherford's (2002) conclusion that intergenerational heterogeneity is the most important obstacle for fiscal tightening. Our results for welfare bring even more nuance on the possibility of

expansionary fiscal consolidation. When aggregated over all generations that are alive at the time consolidation is started, the net welfare effect of most consolidation strategies is negative. We still observe that spending based adjustments (except investment cuts) are better than tax based ones, as they imply smaller losses for the aggregate of current generations. However, things are different when we focus on the youngest and future generations. For these generations, welfare effects from consolidation are positive rather than negative. Most interestingly, these positive effects are smaller under spending based adjustments in the area of education, investment, and overall public employment, than under tax-based adjustments. Robustness tests by changing key assumptions of our model never imply changes of these conclusions, quite on the contrary.

3. Policy conclusions

Our findings from chapters 2-4 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 earnings-related replacement rate in our model. Finland introduced a system where the pension accrual rate rises with age, which corresponds to the case of a rising weight in the calculation of the pension base, as workers get older in our model (OECD 2005). There is no support in our model for policy changes that imply an extension of the pension assessment base to those years when young people may optimally be studying. Our results in chapter 3 further support this policy, except for individuals with low capacity to study at the tertiary level. An important assumption in these models is that current and future generations have perfect knowledge on the specific characteristics of the pension system. This is required to ensure that the behavioral mechanisms that are integrated in the model, will also work in reality. The government thus has an important informative role to play.

In chapter 4, we add evidence that intelligent adjustments to the current pension scheme that have been shown to have beneficial effects on employment and growth, may also serve the goal of increasing fertility. We believe this idea can be seen as complementary to proposals implying the introduction of a child-related pension benefit. As such, we adhere to the recent idea of Cigno (2010) to develop a pension system consisting of two parallel schemes: a part being Bismarckian and a part being child-related, i.e. related to having and raising children.

An important assumption throughout most chapters in this dissertation is the assumption of constant demography. Only in chapter 4 population is endogenous. It is important to stress that none of the chapters argue that the 'intelligent' pension reform that is proposed, is a panacea for the issue of ageing. The only statement we want to make based on the results put forward in this dissertation is that this reform is capable of relieving some of the pressure on the pension budget that arises due to an ageing population. The crucial element in this reasoning is that investment in education, employment at older age, per capita growth and the fertility rate all rise after the reform.

Concerning the final two chapters, we can formulate the following policy conclusions. From chapter 5 we conclude that government efficiency plays an important role in the effects of fiscal consolidation. For instance, it seems that government wage bill cuts only contribute to lower public debt ratios when public sector efficiency is low. Moreover, we also find that a given consolidation program will be more effective in bringing down debt when it is adopted by a more efficient government apparatus. Finally, more efficient governments adopt consolidation programs of better composition. From chapter 6, we conclude that general cuts in public employment are to be preferred above labor or capital tax increases, but not to consumption tax increases. We further find that public employment cuts are not helpful as a means of fiscal consolidation when they imply cuts in public investment or are concentrated in the public education sector. Overall, our study stresses the importance of taking into account the contribution of public employees for the economy.

Interestingly, our results provide two reasons for the inconsistency in the empirical literature on the effects of downsizing the public sector as a means of successful fiscal adjustment. Different levels of government efficiency, on the one hand, and the specific public sector in which cuts are imposed, on the other, may explain the ambiguous findings. Therefore, future research has an important role to shed more light on the efficiency and productivity of the public sector and on the relationship between public and private employment and wages.

References

Afonso, A. and J.T. Jalles (2012), Measuring the success of fiscal consolidations, *Applied Financial Economics*, 22:1053-1061.

Alesina, A. and S. Ardagna (1998) Tales of fiscal adjustment, *Economic Policy*, 27:489-545.

Alesina, A., and S. Ardagna (2010) Large changes in fiscal policy: Taxes versus spending, in J. R. Brown (ed.), *Tax Policy and the Economy*, 24:35-68, The University of Chicago Press.

Alesina, A. and S. Ardagna (2012) The design of fiscal adjustments, *NBER Working Paper*, N° 18423.

Alesina, A., Ardagna, S., Perotti, R. and F. Schiantarelli (2002) Fiscal policy, profits and investment, *American Economic Review*, 92:571-589.

Alesina, A. and R. Perotti (1996) Fiscal adjustments in OECD countries: composition and macroeconomic effects. *NBER Working Paper*, N° 5730.

Ardagna, S. (2004) Fiscal stabilizations: when do they work and why?, *European Economic Review*, 48:1047-1074.

Boldrin M, De Nardi M and Jones LE (2005) Fertility and social security, *NBER working paper*, N° 11146.

Börsch-Supan A.H. and A. Ludwig (2010) Old Europe ages: reforms and reform backlashes, *NBER working paper*, N°15744.

Cigno, A. (2010) How to avoid a pension crisis: a question of intelligent system design. *CESifo Economic Studies*, 56(1):21–37.

Cigno, A. and Rosati, F.C. (1996) Jointly determined saving and fertility behavior: theory, and estimates for Germany, Italy, UK and USA, *European Economic Review*, 40:1561-1589.

Corsetti, G. (2012) "Has austerity gone too far?", *Vox, Research-based policy analysis and commentary from leading economists*, 2 April.

Diamond, P. (2004) Social Security, *American Economic Review,* 94(1):1-24.

Feldstein, M.S. (2005) Rethinking social insurance, *American Economic Review,* 95(1):1–24.

Fisher, W.H. and C. Keuschnigg (2010) Pension reform and labor market incentives, *Journal of Population Economics,* 23(2):769–803.

Giavazzi, F. and G. Pagano (1996) Non-Keynesian effects of fiscal policy changes: international evidence and the Swedish experience, *Swedish Economic Policy Review*, 3(3):76-103.

Guichard, S., Kennedy, M., Wurzel, E., and C. Andre (2007) What promotes fiscal consolidation: OECD country experiences, *Economics Department Working Paper*, N° 553.

Gruber, J. and D.A. Wise (2002) Social security programs and retirement around the world: microestimation. *NBER working paper*, N° 9407.

Heylen, F. and G. Everaert (2000) Success and failure of fiscal consolidation in the OECD: a multivariate analysis. *Public Choice,* 105:103–124.

Hjelm, G. (2002) Is private consumption growth higher (lower) during periods of fiscal contractions (expansions)?, *Journal of Macroeconomics*, 24:17-39.

IMF (2010a) Will it hurt? Macroeconomic effects of fiscal consolidation, *World Economic Outlook*, October, Chapter 3.

Jaag C., Keuschnigg C. and M. Keuschnigg (2010) Pension reform, retirement, and life-cycle unemployment, *International Tax and Public Finance*, 17(5):556–585.

Jensen, S.E.H and Rutherford, T.F. (2002), Distributional effects of fiscal consolidation, *Scandinavian Journal of Economics*, 104, 471-493.

Krugman, P. and Layard, R. (2012) A Manifesto for Economic Sense.

Larch, M. and A. Turrini (2011) Received wisdom and beyond: lessons from fiscal consolidation in the EU, *National Institute Economic Review*, 217(1):R1-R18.

Lindbeck, A. and M. Persson (2003) The gains from pension reform, *Journal of Economic Literature*, 41(1):74–112.

McDermott, J. and Wescott, R. (1996) An empirical analysis of fiscal adjustments, *IMF Working Paper*, N° 96/59.

OECD (2005) Pensions at a glance: public policies across OECD countries, OECD, Paris.

Schaltegger, C. A. and L.P. Feld (2009) Are fiscal adjustments less successful in decentralized governments? *European Journal of Political Economy*, 25:115-123.

Sheshinski, E. (1978) A model of social security and retirement decisions, *Journal of Public Economics*, 10(3):337–360.

Sinn, H.-W. (2004) The pay-as-you-go pension system as fertility insurance and an enforcement device, *Journal of Public Economics*, 88(7-8):1335-1357.

Tagkalakis, A. (2009) Fiscal adjustment: do labor and product market institutions matter?, *Public Choice*, 139:389-411.

Zhang, J. (1995) Social security and endogenous growth, *Journal of Public Economics*, 58(2):185–213.

CHAPTER 2

Pension reform, employment by age and long-run growth

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

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Abstract

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

Our simulation results prefer an intelligent pay-as-you-go pension system above a fully-funded private system. When it comes to promoting employment, human capital, growth, and welfare, positive effects in a 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.

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

JEL Classification: E62, H55, J22, O41

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1. Introduction

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

To face the pension challenge, there seems to be general agreement on the need for higher employment, especially among older individuals, and higher productivity growth. Many studies have documented how the pension system may affect the incentives of individuals of different ages to work (e.g. Auerbach *et al.*, 1989; Gruber and Wise, 2002; Cremer *et al.*, 2008; Sánchez Martín, 2010; Börsch-Supan and Ludwig, 2010; Fisher and Keuschnigg, 2010; Jaag *et al.*, 2010; de la Croix *et al.*, 2010). Others have investigated the relationship between the pension system and investment in human capital formation, as a major determinant of productivity growth (e.g. Zhang, 1995; Kemnitz and Wigger, 2000; Docquier and Paddison, 2003; Zhang and Zhang, 2003; Kaganovich and Meier, 2008; Hachon, 2010; Le Garrec, 2012). Still others have demonstrated the crucial role of human capital formation to counteract the negative effects of population ageing on per capita output (e.g. Docquier and Michel, 1999; Fougère *et al.*, 2009; Ludwig *et al.*, 2011). Consensus on what pension reform would serve the goals of higher employment, productivity growth, and welfare best, has however not been reached. The results in some papers support parametric adjustments in the pay-as-you-go (PAYG) system that most countries rely on. Other papers prefer a gradual move to an actuarially neutral fully-funded private system. Often, differences in the particular specification of the model economy that is used for the analysis may explain the differences in results.

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

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

Next to the endogeneity of all key variables, our model contains a number of other features which matter for the analysis of the effects of pension reform, but which are often ignored in the literature. The most important of these is a realistic modeling of the transition from work to retirement, and the role of early retirement regimes. These regimes play an important role in many countries. We explicitly distinguish the effective (early) retirement age, which is optimally chosen, and the statutory retirement age, which is exogenous (see also Heijdra and Romp, 2009; de la Croix *et al.*, 2010). Old-age pensions in our model are paid only from the statutory retirement age onwards. A key implication is that old-age pensions do not directly raise the opportunity cost of working in our model. Early retirement benefits do. In the literature this distinction is often not made (e.g. Hu, 1979; Börsch-Supan *et al.*, 2006; Jaag *et al.*, 2010; Fisher and Keuschnigg, 2010). It may obviously affect the evaluation of old-age pension reform. As a second feature, we allow individual pension benefits in the PAYG system to depend on accumulated individual labor income and contributions, rather than on average per capita labor income. Many countries have initiated reforms that strengthen this individual contributions - benefit link. Lindbeck and Persson (2003), Zhang and Zhang (2003) and Jaag *et al.* (2010) demonstrate the importance of taking this link into account. Others however ignore it when modeling a PAYG system, which may overstate the distortion induced by this system (e.g.

[1] Fougère *et al.* (2009) and Ludwig *et al.* (2011) also develop a model with endogenous employment by age and human capital, but they have exogenous growth. Moreover, Fougère *et al.* (2009) do not study pension reform.

Börsch-Supan and Ludwig, 2010; Ludwig *et al.*, 2011)[2]. Another feature which affects our results, is the assumption of an open economy. It has been shown that pension reform may have profound effects on international capital flows (e.g. Börsch-Supan *et al.*, 2006). In an open economy, changes in national savings need not feed through into investment in the domestic economy. Factor price changes may be much weaker than presumed in closed economy models. Clearly, this may affect employment and human capital formation. As a final feature, we assume that demography and population are constant in our model. Although ageing is obviously a crucial factor behind pension reform in many countries, this assumption need not be a limitation to disentangle behavioral effects from pension reform (see also Jaag *et al.*, 2010; Fisher and Keuschnigg, 2010).

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

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

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

prefer a reform of the PAYG system along these lines above a movement to a fully-funded private system, both from the perspective of employment and growth and welfare. We show that a number of particular and realistic features of our model, which we have emphasized above, are important for this conclusion. Finally, whereas our results show that old-age pension benefits may rise in an intelligent PAYG system, early retirement benefits must be reduced.

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

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

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

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

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

intermediate positions, although they are close to the core euro area for the younger generation. The latter, however, seems to be related to education. Young people's participation in education is by far the highest in the Nordic countries. These countries also show the highest potential per capita growth rates. On average, growth in the core euro area and the US was more than 0.5 percentage points lower in the period under consideration. The US and the other Anglo-Saxon countries tend to have the lowest participation in education among people of age 20 to 34. Finally, we note that the effective retirement age also varies across countries. The retirement age is quite low in Belgium (57.9) and France (58.8). By contrast, individuals in 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)	*effective retirement age*	*e*	*annual real per capita growth*
Austria	59.9	64.3	34.7	59.5	12.5	2.06
Belgium	51.1	56.8	29.3	57.9	14.1	1.77
France	48.7	60.3	38.0	58.8	14.9	1.54
Germany	49.7	55.2	34.9	61.1	17.2	1.56
Italy	50.1	61.9	33.8	60.1	12.6	1.30
Netherlands	50.8	54.6	34.2	60.0	14.7	2.20
Core euro area average	**51.7**	**58.8**	**34.2**	**59.6**	**14.3**	**1.74**
Denmark	56.2	66.7	49.6	62.2	21.7	1.81
Finland	55.6	69.0	47.3	60.2	23.1	2.72
Norway	51.9	60.9	50.6	63.1	18.1	2.29
Sweden	53.6	66.1	55.4	63.4	17.7	2.18
Nordic average	**54.3**	**65.6**	**50.7**	**62.2**	**20.2**	**2.25**
US	**65.6**	**74.2**	**59.6**	**64.2**	**12.8**	**1.54**
UK	60.8	68.4	49.4	62.0	12.3	2.13
Canada	60.9	69.5	50.4	62.1	13.6	1.68
All country average	**55.0**	**63.7**	**43.6**	**61.1**	**15.8**	**1.91**

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

3. The model

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

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

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

3.1. Individuals

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

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

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

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

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

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

and $\ell_4^t = 1$

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

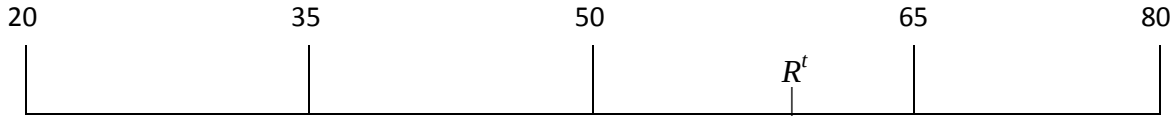
Figure 1 shows the life-cycle of an individual reaching age 20 in t. Individuals choose time devoted to work (n_j) in the three active periods and education time (e_1) when young. Since individuals only allocate time to education in their first period, we drop the subscript 1 in what follows. Time endowment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

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

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

[4] The main results in this paper are not in any way influenced by the magnitude of π, Ω or ρ.

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



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

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

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

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

$$\begin{aligned}(1+\tau_c)c_3^t + a_3^t = {} & w_{t+1} h_3^t R^t n_3^t (1-\tau_3) + b_{3a} w_{t+2} h_3^t (1-\tau_3) R^t (1 - n_3^t) \\ & + b_{3b} w_{t+2} h_3^t (1-\tau_3)(1 - R^t) + (1 + r_{t+2})a_2^t + z_{t+2})\end{aligned} \tag{7}$$

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

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

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

and:

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

with:

$$\begin{aligned} & 0 \le p_j \le 1 \\ & \textstyle\sum_{j=1}^{3} p_j = 1 \\ & x_t = 1 + \psi\left(e^t, g_y, q\right) \\ & n_3^t = R^t \tilde{n}_3^t \end{aligned} \tag{12}$$

The LHS of Equations (5)-(8) shows that individuals allocate their disposable income to consumption (including consumption taxes, τ_c) and the accumulation of non-human wealth a. We denote by a_j^t the stock of wealth that an individual who enters the model at time t holds at the end of his *j*th period of life. During the three periods of active life disposable income at the RHS includes after-tax labor income, non-employment benefits, interest income and lump sum transfers. In each equation,

w_k stands for the real wage per unit of effective labor at time k, r_k is the exogenous (world) real interest rate at time k, and z_k is the lump sum transfer that the government pays out to all individuals at time k. Effective labor of an individual depends on hours worked (n_j^t) and effective human capital (h_j^t). Since young individuals allocate a fraction n_1^t of their time to work, and pay a tax rate on labor income τ_1, they earn an after-tax real wage equal to $w_t h_1^t n_1^t (1-\tau_1)$. After-tax labor income of middle-aged and older workers in equations (6) and (7) is determined similarly. A young worker inherits his effective human capital from the middle-aged generation, as shown in Equation (9). During the second and third period, workers supply more units of effective human capital. It is our assumption in Equation (10) that *h* rises in education time when young (*e*), productive government spending in percent of GDP (g_y, mainly education) and the quality of education (*q*). We specify and discuss the effective human capital production function in Section 3.2. Individuals take g_y and *q* as exogenous. We 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.

For the fraction of time that young, middle-aged and older individuals are inactive, they receive a non-employment benefit from the government. Older workers may be eligible to two kinds of benefits: standard non-employment benefits (analogous to what young and middle-aged workers receive) as long as they are on the labor market, and early retirement benefits after having withdrawn from the labor market. All benefits are defined as a proportion of the after-tax wage of a full-time worker. The replacement rate for standard non-employment benefits is b_j with *j*=1,2,3a, for early retirement benefits it is b_{3b}.[5] After the statutory retirement age (65) individuals have no labor income and no non-employment benefits anymore. They then receive an old-age pension benefit (*pp*) and the lump sum transfer. Equation (11) describes the old-age pension. We assume a public PAYG pension system in which pensions in period *k* are financed by contributions (labor taxes) from the active generations in that period *k* (see below). Individual net pension benefits consist of two components. A first one is related to the individual's earlier net labor income. It is a fraction of his so-called pension base, i.e. a weighted average of *revalued* net labor income in each of the three active periods of life. The net replacement rate is b_{4a}. The parameters p_1, p_2 and p_3 represent the weights attached to each period. This part of the pension rises in the individual's hours of work n_j^t and his human capital h_j^t. It will be lower when the individual retires early (lower R^t). Thanks to revaluation, this part of the net pension is adjusted to increases in the overall standard of living between the time that workers build their pension entitlements and the time that they receive the pension. We assume that past earnings are revalued in line with economy-wide wage growth x and hence follow

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

practice in many OECD countries (OECD, 2005; Whiteford and Whitehouse, 2006).[6] The second component of the pension is a flat-rate or basic pension. Every retiree receives the same amount related to average net labor income in the economy at the time of retirement. This assumption assures that also basic pensions rise in line with productivity. Here, the net replacement rate is b_{4b}. Fourth generation individuals consume their pension and the lump sum transfer, as well as their accumulated wealth from the third period plus interest (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 period and when retired. The marginal utility gain from work is higher when initial consumption is lower, and when an extra hour of work yields more extra consumption. Higher human capital (and its underlying determinants), lower taxes on labor, lower taxes on consumption and lower non-employment benefits contribute to the gain from work. Extra consumption during retirement rises in the own-income-related pension replacement rate (b_{4a}), in the weight attached to the relevant period when computing the pension base (p_j), and in the revaluation parameters.

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

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

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

$$\frac{\gamma_3}{\left(\ell_3^t\right)^\theta}\frac{-\partial \ell_3^t}{\partial n_3^t} = \frac{w_{t+2}\left(1+\psi\left(e^t, g_y, q\right)\right) h_1^t (1-\tau_3)(1-b_{3a})}{c_3^t(1+\tau_c)} + \beta \frac{b_{4a} p_3 w_{t+2}\left(1+\psi\left(e^t, g_y, q\right)\right) h_1^t R^t (1-\tau_3) x_{t+2}}{c_4^t(1+\tau_c)} \tag{14.c}$$

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

Equation (15) describes the first order condition for the optimal effective retirement age. The LHS represents the utility loss from postponing retirement. Later retirement reduces enjoyed leisure

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

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

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

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

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

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

with:

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

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

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

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

It will be obvious from the above discussion that (for a given way of financing) the specific organization of pension benefits may have strong effects on behavior in earlier periods of life. Both income and substitution effects occur. The latter are particularly rich when pensions are linked to individuals' own labor income. A higher replacement rate b_{4a} raises the return to working (n) and

building human capital (e, h) in earlier periods. Changes in the particular weight attached to these earlier periods may modify these incentive effects. The return to education will rise in p_2 and p_3, but fall in p_1. The return to working in the third period will rise in p_3, etc. Policy makers may change all these parameters. We investigate the effects of policy interventions in Section 5.

3.2. Production of effective human capital

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

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

Equation (17) shows our specification for the growth rate of effective human capital. We adopt a flexible CES-specification in education time when young (e) and productive government expenditures in % of output (g_y). 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: ϕ is a

positive efficiency parameter, σ a scale parameter, v is a share parameter and κ the elasticity of substitution. These parameters will be calibrated.

$$\psi(e, g_y, q) = \phi q \left(v\, g_y^{1-\left(\frac{1}{\kappa}\right)} + (1-v) e^{1-\left(\frac{1}{\kappa}\right)} \right)^{\frac{\sigma\kappa}{\kappa-1}} \tag{17}$$

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

3.3. Domestic firms, output and factor prices

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

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

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

with: $x_{t-1} = 1 + \psi\left(e^{t-1}, g_y, q\right)$ and $n_3^{t-2} = R^{t-2} \tilde{n}_3^{t-2}$ 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 (see also Backus et al., 2008). Physical capital depreciates at rate δ_k. Capital taxes are source-based: the tax rate τ_k applies to the country in which the capital is used, regardless of who owns it. The real interest rate being given, firms will install more capital when the amount of effective labor increases or the capital tax rate falls. In that case the net return to investment in the home country rises above the world interest rate, and capital flows in. Furthermore, perfect competition implies equality between the real wage and the marginal product of effective labor (Equation 21). Higher real wages follow from an increase in physical capital per unit of effective labor. Taking into account (20), real wages per unit of effective labor will therefore fall in the world real interest rate and in domestic capital tax rates.

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

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

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

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

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

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

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

3.4. Government

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_tD_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 ΔD_{t+1}. We define D_t as outstanding public debt at beginning of period t.

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.

$$\Delta D_{t+1} = D_{t+1} - D_t = G_{yt} + G_{ct} + B_t + PP_t + Z_t + r_tD_t - T_{nt} - T_{kt} - T_{ct} \tag{23}$$

with: $G_{yt} = g_y Y_t$

$$G_{ct} = g_c Y_t$$

$$B_t = (1 - n_1^t - e^t) b_1 w_t h_1^t (1 - \tau_1) + (1 - n_2^{t-1}) b_2 w_t h_2^{t-1} (1 - \tau_2)$$
$$+ R^{t-1} (1 - \tilde{n}_3^{t-2}) b_{3a} w_t h_3^{t-2} (1 - \tau_3) + (1 - R^{t-2}) b_{3b} w_t h_3^{t-2} (1 - \tau_3)$$

$$Z_t = 4 z_t$$

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

$$T_{kt} = \tau_k [\alpha Y_t - \delta_k K_t]$$

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

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

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)[7]. In Equation (24), F_t stands for net foreign assets at the beginning of *t*. The aggregate stock of wealth A_t accumulates wealth held by individuals who entered the model in *t-1*, *t-2* and *t-3*.

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

with: $F_t = A_t - K_t - D_t$

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

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

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

[7] Domestic output and net factor income from abroad at the LHS of Equation (24) constitute national income. Since in our model there are no unilateral transfers between a country and the rest of the world, we have that $CA_t = NX_t + r_t F_t$, with NX_t representing net exports of goods and services. It is then easy to see that Equation (24) can also be written in a maybe more common way as $Y_t = C_t + I_t + G_{ct} + G_{yt} + NX_t$.

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

4.1. Preference and technology parameters

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

Table 2 Preference and technology parameters

Production parameters (output)	$\alpha = 0.285$
Effective human capital production	$\phi = 4.9,\ \sigma = 1.03,\ v = 0.125,\ \kappa = 0.375$
Preference parameters	$\beta = 0.8,\ \theta = 2,\ \gamma_1 = 0.074,\ \gamma_2 = 0.131,\ \gamma_3 = 0.176$
	$\pi = 0.5,\ \rho = 1.52,\ \Omega = 2$
World real interest rate	$r = 0.935$
Physical capital depreciation rate	$\delta_k = 0.714$

A second series of parameters have been determined by calibration: three taste for leisure parameters (γ_1, γ_2, γ_3), two parameters in the human capital production function (the efficiency parameter ϕ and the scale parameter σ), and the elasticity of substitution (ρ) in the composite leisure function in Equation (4). We have calibrated these parameters to Belgium. We choose this country since in Belgium the calculation of pension benefits fits exactly within the way we model it. Public pensions are proportional to average annual labor income earned over a period of 45 years, with equal weights to all years. There is no basic pension (OECD, 2005). In our model this comes down to

b_{4a}>0, b_{4b}=0 and p_1=p_2=p_3=1/3. The parameters γ_1, γ_2, γ_3, ϕ, σ and ρ have been determined such that with observed levels of the policy variables (tax rates, benefit replacement rates, pension replacement rate, etc.) and the observed level of schooling quality (q)[8] in Belgium, the model correctly predicts Belgium's employment rates (n_1, n_2, n_3), per capita growth rate, education rate (e) and effective retirement age (R) in 1995-2007. Underlying performance and policy data are reported in Tables 1, 3 and 4. We find that the taste for leisure rises with age (γ_1=0.074, γ_2=0.131, γ_3=0.176). Furthermore, we observe quasi constant returns in human capital production ($\sigma \approx 1$), and a stronger degree of substitutability than in the Cobb-Douglas case between the two types of leisure for older workers ($\rho = 1.52$).

We had no ex ante indication on two parameters in the human capital production function: the share parameter v and the elasticity of substitution parameter κ. We could assign sensible values to these parameters thanks to a sensitivity analysis on the results that we report in the next section. There we evaluate the capacity of our model to explain six important macro variables in 13 OECD countries. Although the influence of v and κ on the explanatory power of our model is very limited, our guideline to pin down specific values for these parameters (within a sensible range) was to minimize the deviation of our model's predictions from the true data[9]. This procedure implied v=0.125 and κ= 0.375. The result for κ reveals a higher degree of complementarity between private education time and government expenditures than in the Cobb-Douglas case. The result for v demonstrates relatively high importance for human capital formation of private education time versus productive public expenditures. Neither did we have an ex ante indication on the remaining parameters in the composite leisure function in Equation (4). We impose equal weight for both leisure types (π=0.5). The normalisation parameter Ω equals 2. The size of this parameter has no impact at all on our country predictions or simulation results.

4.2. Fiscal policy, pensions and education quality

Tables 3 and 4 describe key characteristics of fiscal policy and the pension system in 1995-2001/2004. Reported data are averages of the available annual data in that period, unless indicated otherwise. Our description of the data here is short. For some variables we provide more detail in Appendix 1. Our proxy for the tax rate on labor income concerns the total tax wedge, for which we report the marginal rate in %. The data cover personal income taxes, employee and employer social security contributions payable on wage earnings and payroll taxes. The OECD publishes these tax data for several family and income situations. Considering that workers typically earn less when they are

[8] And with the values of two parameters in the human capital production function (v, κ) that we discuss below (see also footnote 9).

[9] 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 v and κ and then calibrated the efficiency parameter ϕ and the scale parameter σ. The values for v and κ had no influence on the calibration results for γ_j and ρ. Given the obtained values for ϕ and σ, we computed the average normalized RMSE over all six variables. We then checked whether changes in v and κ, and a recalibration of σ and ϕ, could further reduce this statistic. We did this until no further reduction was possible.

young (and have lower human capital) than when they are middle-aged, we calculated our τ_1 for each country as an average of marginal tax rates for lower to middle income families. Tax rates for middle-aged and older workers were computed from OECD data for middle to higher income families.

Table 3 Fiscal policy (tax rates and government debt)

	tax rate on labor income when young (%)	tax rate on labor income when middle age and older (in %)	consumption tax rate (%)	tax rate on capital income (%)	Government debt (% of GDP)
Proxy for:	τ_1	τ_2, τ_3	τ_c	τ_k	D/Y
Austria	56.5	53.0	13.2	17.3	69.6
Belgium	66.6	67.6	13.4	27.1	111.7
France	52.4	53.3	17.1	21.7	68.9
Germany	62.5	60.0	11.1	34.4	63.1
Italy	54.7	57.1	14.7	14.9	122.1
Netherlands	52.3	51.6	12.2	24.3	68.2
Denmark	46.4	51.2	18.9	22.5	60.3
Finland	55.6	57.9	15.2	17.2	54.1
Norway	49.6	52.6	16.4	22.1	40.4
Sweden	54.5	58.1	17.9	16.1	67.2
UK	39.8	41.6	14.5	21.2	46.6
US	34.2	36.9	7.2	23.6	61.9
Canada	46.8	47.6	14.5	24.8	83.8
Average	51.7	52.9	14.3	22.1	70.6

Note: Labor tax rates are data for the total tax wedge, marginal rate (OECD, Taxing Wages). Data for 2000-04. For details on the calculation of tax rates by age group, see Appendix 1. Capital tax rates are effective marginal corporate tax rates (Institute for Fiscal Studies, their EMTR; data for 1995-2001, see also Devereux et al., 2002). Consumption tax rate: see Dhont and Heylen (2009). Data for 1995-2001. Government debt concerns general government gross financial liabilities in percent of GDP (OECD, Economic Outlook, data for 1995-2007).

As one can see in Table 3, however, differences within countries between τ_1 on the one hand and τ_2 and τ_3 on the other, are very small. Cross-country differences are much bigger. Belgium, Germany, Sweden and Finland have marginal labor tax rates above 55% or even 60%. The US and the UK have marginal labor tax rates below, or close to, 40%. Capital tax rates are effective marginal corporate tax rates reported by the Institute for Fiscal Studies (their EMTR, base case). Germany and Belgium have the highest rates. In contrast to labor (and consumption), capital is taxed relatively little in the Nordic countries. As to consumption taxes, we follow Dhont and Heylen (2009) in computing them as the ratio of government indirect tax receipts (net of subsidies paid) to total domestic demand net of indirect taxes and subsidies. Our simplifying assumption is that consumption tax rates correspond to 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_j (j = 1,2,3a). Since in our model non-employment is a structural or equilibrium phenomenon, the data that we use concern net transfers received by structurally or long-term unemployed people. They include social assistance, family benefits and housing benefits in the 60th month of benefit receipt. They also include unemployment insurance or unemployment assistance benefits if these benefits are still paid, i.e. if workers can be structurally unemployed for more than five years without losing benefit eligibility[10]. The data are expressed in percent of after-tax wages. In line with our approach to determine labor tax rates by age group, we are again guided by the same family and income cases to determine b_1, b_2 and b_{3a} (see Appendix 1). Overall, the euro area 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_{3b}.The data are again expressed in percent of after-tax final wages. To assess the generosity of early retirement we integrate the information available via b_{3a} and data for the implicit tax rate on continued work in the early retirement route as provided by Duval (2003) and Brandt *et al*. (2005). For details, see Appendix 1. We observe a very generous early retirement regime in Belgium and Finland, whereas net early retirement benefits in Anglo-Saxon countries are much lower.

Our data for productive government expenditures in Table 4 include education, active labor market expenditures, government financed R&D and public investment. Governments in the Nordic countries allocate by far the highest fractions of output to productive expenditures. Productive expenditures in percent of GDP are the lowest in the UK. The US and most core countries of the euro area take intermediate positions. Government consumption in percent of GDP is the highest also in the Nordic countries, followed at close distance by several countries of the core euro area[11]. In the US, government consumption is (much) lower.

Our data for the net pension replacement rates (b_{4a}, b_{4b}) concern an individual with mean earnings before retirement. The data include only (quasi-)mandatory pension programs, and are expressed as a percentage of this individual's average lifetime labor income (OECD, 2005)[12]. In the majority of countries individuals with mean earnings only receive earnings-related pensions (b_{4a}>0, b_{4b}=0). The overall average net replacement rate in these countries is around 57%, but there are strong cross-country differences. We observe the highest b_{4a} in Austria and Italy, and low rates in the US and Belgium. Differences exist also in the precise organization of the earnings-related system. Some countries have pure defined-benefit systems (e.g. Belgium, Finland, US), others have so-called

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

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

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

point systems (Germany) or notional-account systems (Italy, Sweden). Although these three systems can appear very different, OECD (2005) shows that they are all similar variants of earnings-related pension schemes. A smaller group of countries combine earnings-related and (variants of) basic pension systems. Denmark, the Netherlands and the UK have the strongest non-earnings related components[13]. As a final important remark, we emphasize that the straightforward way in which the OECD computes the pension replacement rates, in percent of an individual's average lifetime labor income, comes down to assuming in our model that the weights p_1, p_2 and p_3 are all equal to 1/3. For reasons of consistency we will therefore make this assumption for all individual countries when we derive our model's predictions. We are aware however that equal weights do not fully match practice in all countries. Some deviate from this prototype, to varying degrees. When we compare our model's predictions for these countries to the facts in the next section, we should take this into account[14]. Assuming equal weights may slightly bias our predictions.

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

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

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

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

	Non-employment benefit, young (net replacement rate, %)	Non-employment benefit, middle-aged and older (net replacement rate, %)	Early retirement benefits (net replacement rate, %)	Pension benefit (net replace-ment rate, %)	Basic pension (% of net average earnings)	Governm-ent Consump-tion (% of GDP)	Governm-ent productive expenditu-re (% of GDP)	PISA – science (divided by 1000)
Proxy for:	b_1	b_2, b_{3a}	b_{3b}	b_{4a} [(a)]	b_{4b} [(a)]	g_c	g_y	q
Austria	60.8	50.9	69.9	88.9	0	14.6	9.1	0.507
Belgium	65.1	51.7	75.1	63.1	0	16.9	8.9	0.505
France	52.3	38.3	59.9	68.8	0	18.3	11.0	0.502
Germany	65.4	59.7	68.3	71.8	0	15.3	8.6	0.502
Italy	18.5	15.3	54.9	88.8	0	14.3	8.0	0.480
Netherlands	62.5	46.6	63.9	48.8	35.3	18.4	10.3	0.525
Denmark	67.8	55.4	40.0	19.5	34.6	18.4	12.5	0.484
Finland	68.4	54.4	70.4	78.8	0	16.0	11.4	0.550
Norway	64.8	49.4	36.2	46.2	18.9	14.7	12.1	0.490
Sweden	62.8	47.8	35.2	65.9	2.3	20.0	14.0	0.507
UK	57.8	44.4	36.0	13.8	33.8	14.4	7.3	0.523
US	34.3	26.6	16.3	51.0	0	10.3	9.3	0.493
Canada	49.7	39.5	24.6	39.4	17.7	14.7	9.3	0.527
Average	56.2	44.6	49.9	57.3	11.0	15.9	10.1	0.507

Notes: A description of all variables is given in the main text. For more details, see Appendix 1. The data for net non-employment benefit replacement rates are an average for 2001 and 2004 (earlier data are not available). The data for government consumption and productive expenditures concern 1995-2001. The PISA science scores are an average for 2000, 2003 and 2006. The pension replacement rates concern 2002 (source OECD, 2005, p. 52). To split up the OECD data into our b_{4a} and b_{4b} in countries where b_{4b} >0, we have used the information in OECD (2005, part II, Country studies). We derive b_{4b} from the fraction of the total net replacement rate that goes to basic, minimum or targeted pensions (see also our footnote 13).
(a) The weights p_j to compute the pension base (with j=1, 2, 3) are in all countries assumed equal to 1/3 (see motivation in the main text).

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

Can our model match the facts that we have reported in Table 1? In this section we confront our model's predictions with the true data for 1995-2006/2007. Clearly, one should be aware of the serious limitations of such an exercise. First of all, our model is highly stylized and may (obviously) miss potential determinants of growth or employment. Second, even if we compute the true data in Table 1 as averages over a longer period, these averages need not be equal to the steady state. Countries may still be moving towards their steady state. Also, the policy variables that we report in Tables 3 and 4 may have been affected by transitory factors. Third, this exercise only concerns the last 15 years. Lack of data – especially with respect to marginal labor tax rates and non-employment transfers in the early 1990s – makes it impossible for us to execute the maybe most convincing test,

which is to relate changes in growth and employment to changes in policy within countries over longer time periods. In spite of all this, if one considers the extreme variation in the predictions of existing calibrated models investigating the effects of fiscal policy in the literature (see Stokey and Rebelo, 1995), even a minimal test of the 'goodness of fit' of our model is informative.

Our calibration implies that our model's prediction matches employment rates by age, the effective retirement age of older workers, education, and per capita growth in Belgium. A test of the model's validity is whether it can also match the data for the other countries, and the cross-country differences. Before one uses a model for policy analysis, one would like to see for example that the model does not overestimate, nor underestimate the performance differences related to observed cross-country policy differences. Our test is tough since we impose the same preference and technology parameters, reported in the upper part of Table 2, on all countries[15]. Only the fiscal policy variables, the pension replacement rates and education quality differ. Moreover, assuming perfect competition, we disregard differences in labor and product market institutions which some authors consider of crucial importance (e.g. Blanchard and Wolfers, 2000; Nickell *et al.*, 2005). Still, we find that the model matches the facts remarkably well for a large majority of countries. Basically, we here confirm earlier findings by e.g. Ohanian *et al.* (2008) and Dhont and Heylen (2008) that once one controls for fiscal policy differences, variation in taste for leisure or different market rigidities are not critical to explain cross-country variation in labor market performance.

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.

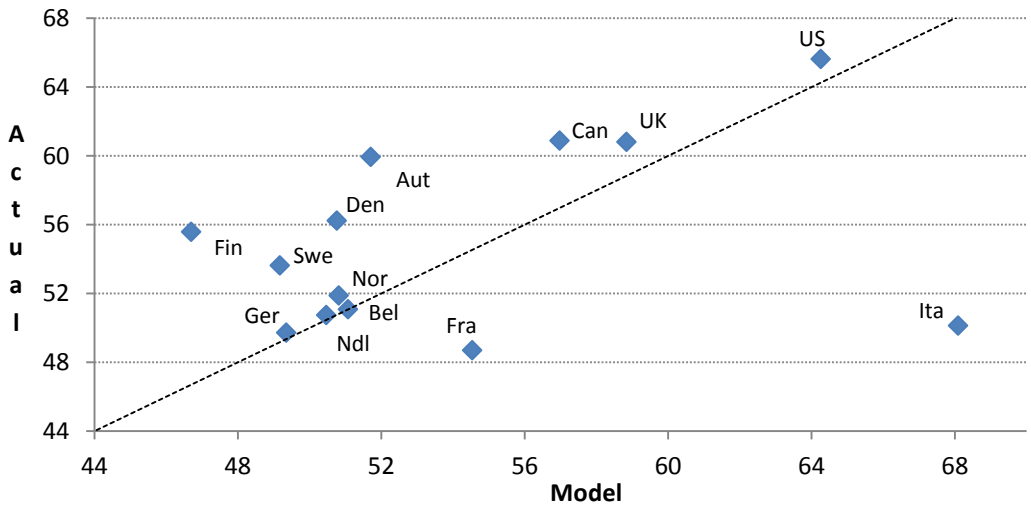
Figures 2 to 4 relate our model's predictions for three employment rates to actual observations for all countries. We add the 45°-line to assess the absolute differences between predictions and facts, as well as the coefficient of correlation between predictions and facts. Our model performs quite well. In each age group, it correctly predicts high employment rates in the US and Canada and low employment in Germany. For young workers it also correctly predicts relatively low employment in most other countries of the core euro area, and in the Nordic countries. For older workers it has relatively high employment right in the Nordic countries and the UK. Overall correlation between the model's predictions and the actual data in Figure 2 is 0.32. If we drop Italy, for which there are good reasons[16], this rises to 0.70. Correlation in Figure 3 is 0.41, in Figure 4 it is 0.76. Moreover, in each

[15] We also assume TFP to be the same in all countries. Note, however, that this assumption is not crucial. The utility function being separable and logarithmic in consumption, and goods production being Cobb-Douglas, the level of TFP does not matter for employment or growth rates. Also, differences across countries in TFP have no effect on cross-country performance differences in our model, at least if these TPF differences are constant.

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

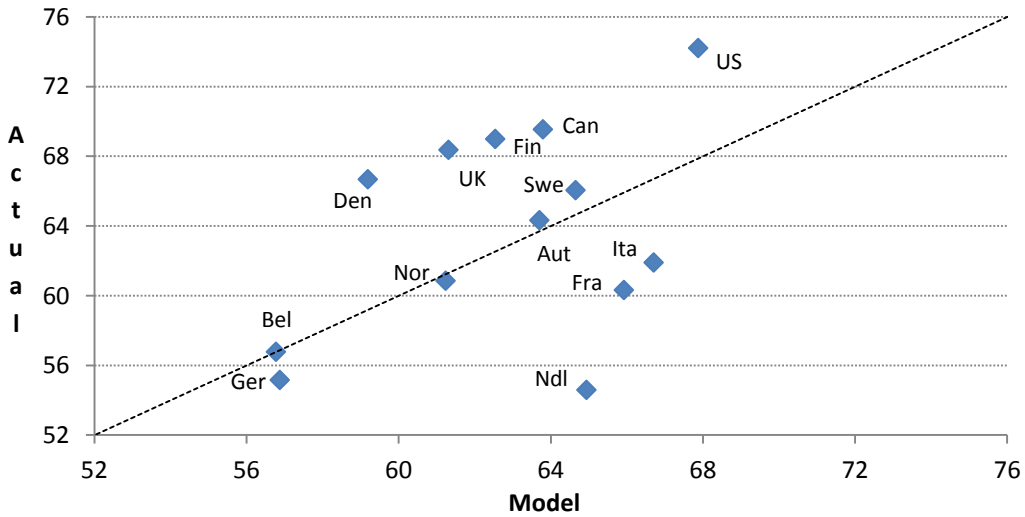
figure - again after dropping Italy from Figure 2 - the regression line (not shown) is close to the 45°-line, which suggests that our model correctly assesses the size of the employment effects of policy differences across countries. Next to Italy, there are a few other countries, where our model somewhat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

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



Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.32. Excluding Italy, correlation rises to 0.70.

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

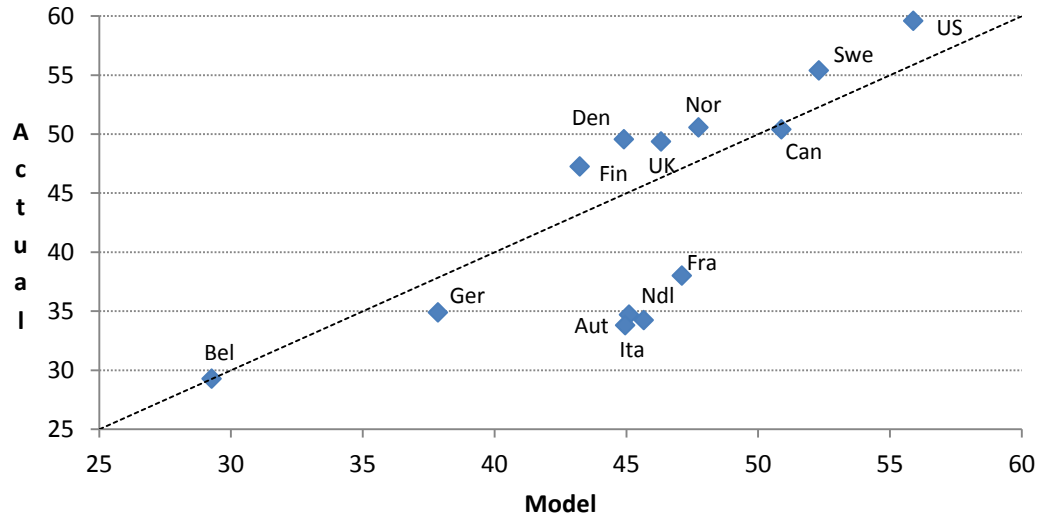


Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.41.

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%.

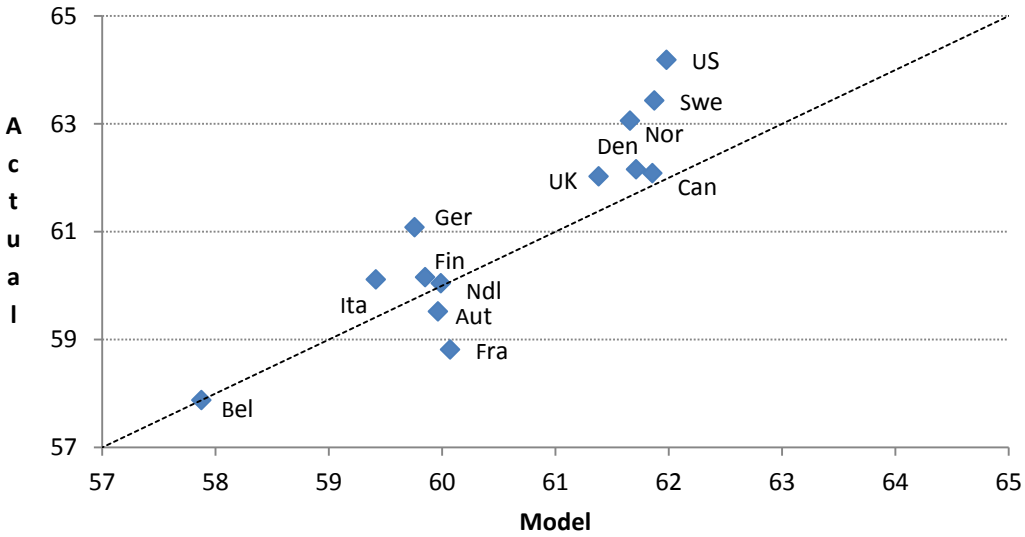
Figure 5 relates our model's predictions to the facts for the effective retirement age. The model again captures the large differences between countries. It predicts the highest retirement age in the Anglo-Saxon and Nordic countries and a much lower retirement age in core euro area countries. Correlation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

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 0.76.

Figure 5. Effective retirement age, 1995-2006

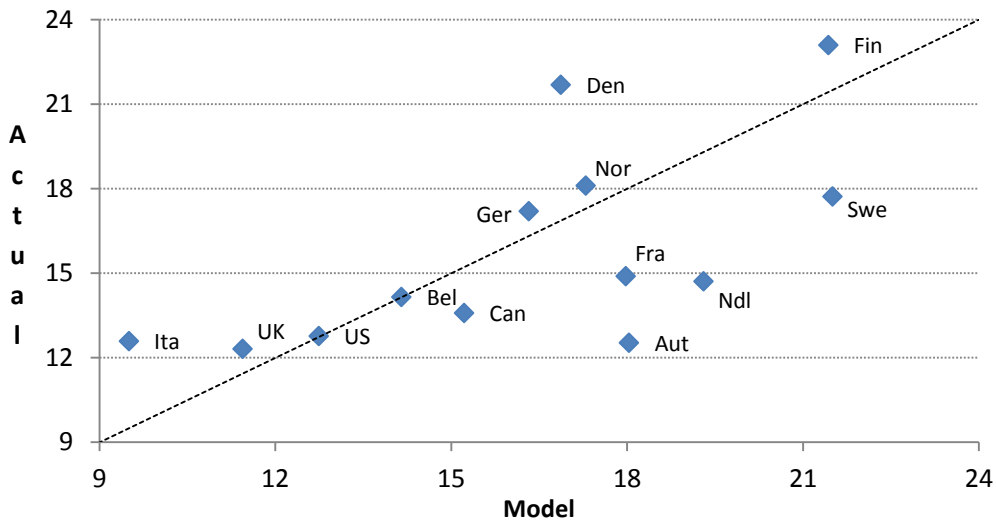


Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.91.

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, Italy and Belgium on the other. Predictions for education are quite close to the 45°-line for all individual countries except Austria, Denmark and the Netherlands. The model also has important cross-country differences right for growth. The model has difficulty

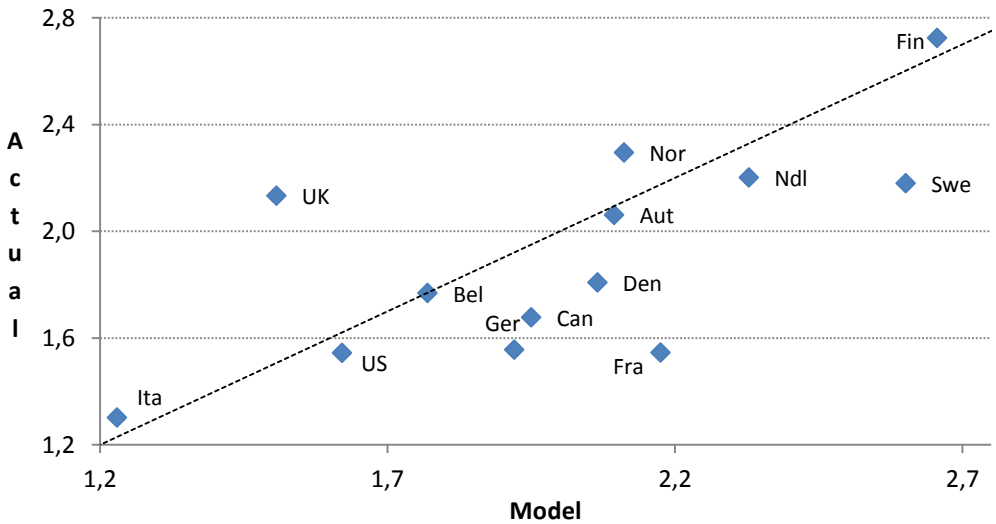
however to explain observed growth for France and the UK. Correlation between the model's predictions and the true data is 0.64 for education and 0.69 for growth. Finally, in Figure 8, we relate our model's predictions to the facts for the annual current account balance (in % of GDP). Note that we have not done any calibration on these data. Our model predicts current account balances of about the right size (between -6 and +5% of GDP). It matches cross-country differences fairly well.

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



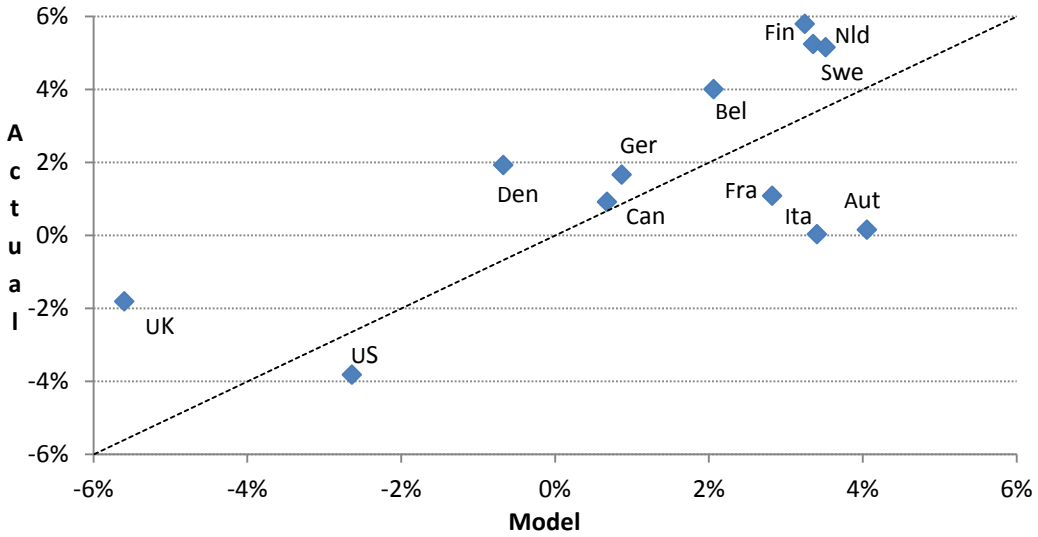
Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.64.

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



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

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



Note: The dotted line is the 45°-line. We have excluded Norway from this figure as Norway is a clear outlier in the current account data (10.7% of GDP). Correlation between actual data and the model's predictions is 0.65. When we include Norway, correlation drops to 0.42.

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 groups, aggregate employment, education of the young, the effective retirement age, and growth. In Section 5.1 we consider steady state effects, in Section 5.2 transitional dynamics and welfare effects per generation. The particular pattern of transitory effects implies that subsequent generations' welfare may be affected differently. The benchmark from which we start, and against which all policy shocks are evaluated, is the average of the six core euro area countries in our sample. Throughout all our policy simulations we assume that the government maintains a constant debt to GDP ratio in each period. To reach this goal, it adjusts lump sum transfers. The change in lump sum transfers is spread equally among all living generations.

5.1. Numerical steady state effects.

The main part of Table 5 shows the steady state effects of six changes in key features of the pension system. Changes in lump sum transfers to maintain a constant debt to GDP ratio are indicated at the bottom of the table. Policy 1 raises the earnings-related net benefit replacement rate b_{4a} from 72% in the benchmark to 77%. This policy intervention is equivalent to an ex ante increase in pension expenditures by 0.5% of GDP. The policy implies a slight increase in employment, especially among older workers. It has only minor positive effects on education and a quasi negligible impact on growth. All in all, behavioral effects are small[17]. Financial effects are somewhat stronger. A rise in the

[17] Effects are even (about 50%) smaller if labor taxes are adjusted to maintain a constant debt to GDP ratio.

replacement rate induces an increase in the pension burden and a (limited) deterioration of the government's financial balance. To keep its debt to GDP ratio constant, the government has to reduce lump sum transfers by 0.38% of output. Policies 2 and 3 alter the calculation of the pension base, such that more weight is given to the net labor income of workers when they are 'older'. These policies involve an increase in p_3, and a fall in p_1. We assume that these reforms do not hold for the current generation of retirees as they are no longer able to adapt their behavior to these new pension weights. The higher (lower) marginal utility from work when older (young) makes it interesting to shift work from the first period of active life to the third, and to postpone effective retirement. Furthermore, young individuals are encouraged to study because the lifetime 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. Interestingly, the government budget does not deteriorate. For instance, policy 3 implies an improvement in the budget balance by 1.20% of GDP[18]. All in all, simple reforms like policies 2 and 3 succeed in strongly increasing the employment rate among older workers (+4.14%-points and +7.73%-points respectively) and their effective retirement age (up to almost +1 year in policy 3). The effect on the aggregate employment rate is limited due to the significant drop in employment of the young. Fortunately, more than half of the latter is substituted into tertiary education. We observe a substantial increase in the per capita growth rate (+0.23%-points in policy 3).

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

[18] More precisely, to keep the debt to GDP ratio constant, the government can raise lump sum transfers by 1.20% of output.

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

Initial values: P_1=1/3 P_2=1/3 P_3=1/3 b_{4a}=0.72 b_{4b}=0.06	**Policy 1** b_{4a}=0.77	**Policy 2** P_1=1/6 P_2=1/3 P_3=3/6	**Policy 3** P_1=0 P_2=1/3 P_3=2/3	**Policy 4** P_1=0 P_2=1/3 P_3=2/3 b_{4a}=0.77	**Policy 5** b_{4a}=0.52 b_{4b}=0.26	**Policy 6** Fully Funded	**Policy 4b** (= policy 4, with e exoge-nous)	**Policy 6b** [(f)]	**Policy 7** Δb_{3b} =-0.281
Effect [(a)]:									
Δn_1	0.07	-2.76	-5.84	-6.14	-0.12	0.64	-2.60	3.99	0.13
Δn_2	0.23	0.15	0.41	0.69	-0.65	-0.71	-0.05	0.88	-0.61
Δn_3	0.61	4.14	7.73	8.58	-2.20	-6.78	7.48	0.32	6.43
ΔR [(c)]	0.08	0.52	0.94	1.04	-0.30	-1.07	0.93	0.17	1.86
Δe	0.08	1.48	3.09	3.37	-0.26	-0.66	0.00	-1.65	-0.52
Δn [(a, b)]	0.29	0.32	0.41	0.66	-0.92	-2.01	1.27	1.78	1.68
$\Delta N/N$ [(d)]	0.53	0.59	0.75	1.21	-1.70	-3.70	2.33	3.27	3.10
Δannual growth rate [(a)]	0.01	0.12	0.23	0.25	-0.02	-0.06	0.00	-0.14	-0.04
ΔZ ex post [(e)]	-0.38	0.79	1.20	0.82	-0.50	-3.61	0.83	1.53	2.03

Notes: (a) difference in percentage points between new steady state and benchmark, except ΔN/N and R.
(b) change in (weighted) aggregate employment rate in hours, change in percentage points.
(c) change in optimal effective retirement age in years
(d) change in volume of employment in hours, in %.
(e) change in lump sum transfer (as a fraction of output) to keep the debt to GDP ratio constant at the level of the benchmark, in %-points.
(f) policy 6b is identical to policy 6 but it keeps net non-employment benefits constant (see main text).

Policy 6 is a gradual shift from the PAYG system in the benchmark to a system with full private capital funding. This policy completely abolishes old-age pension benefits (b_{4a}, b_{4b}). For the government it implies a drastic cut in pension expenditures. We assume that this drop in expenditures feeds through into lower social security contributions for all workers such that, ex ante, the decline in total labor tax receipts in % of GDP is exactly the same as the drop in pension expenditures.[19] We observe that this transition to a private fully-funded pension scheme is not beneficial for employment. The aggregate employment rate drops by 2%-points. An important element here is that a fully-funded system breaks the direct positive link between individual labor income and the pension, which exists in the PAYG system as we have modeled it. Growth decreases (-0.06%-points) as tertiary education is

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

discouraged both by the fall in the pension replacement rate $b_{4a,}$ and by the cut in labor taxes when young. The labor tax cut when middle-aged and older cannot neutralize the negative effect. Smaller accumulation of human capital also discourages work when older. As a final result, we also observe that a shift to a fully-funded system affects the government balance negatively (as lump sum transfers decline by 3.61% of GDP). The latter is 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, this reduces the marginal product of physical capital, and causes savings to be invested abroad (see below, current account).

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

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

The role of endogenous education also qualifies the importance of labor supply effects for young workers. We also find, like Jaag *et al.* (2010), that a higher weight attached to labor income as an older worker (p_3) may reduce labor supply of the young. In our model, however, this may have positive effects due to the endogeneity of human capital and growth. The endogeneity of human capital is crucial also in the comparison of a PAYG system with a fully-funded private capital system when it comes to growth. Our results are in line with findings by Kemnitz and Wigger (2000) and

Kaganovich and Meier (2008) that a PAYG system can raise growth compared to a fully-funded scheme because it strengthens incentives to invest in education. A key element is that a PAYG system allows individuals to partially internalize the positive externalities of human capital formation. In Kemnitz and Wigger (2000), as in our approach, a PAYG system raises the return to education because of the close link between an individual's pension benefit and his/her own accumulated human capital. Kaganovich and Meier (2008) show higher growth in a flat pension system. Here, individuals will invest more in their children's education because their children's productivity determines their future pension. Policy 4b in Table 5 revisits policy 4 under the assumption of exogenous education and growth. Overall employment rises more than in policy 4, mainly thanks to a smaller shift from employment into education by young workers. Unlike the relatively limited effects here, we will see below much stronger welfare effects, especially for future generations.

Our results also go against some of the literature. Börsch-Supan and Ludwig (2010) and Ludwig *et al.* (2011) among others tend to find that economies are better able to face ageing with a fully-funded system. Furthermore, despite positive effects on employment from an intelligently designed PAYG system, many studies find the highest employment in a fully-funded system (e.g. Fisher and Keuschnigg, 2010). We learn from our simulations that the specific setup of the pension system in these papers may explain the difference. Some studies compare the fully-funded system with a flat PAYG system. Clearly, this approach is crucial for the results. If we reinforce the shift to a flat pension in our policy 5 by bringing b_{4a} to zero and by simultaneously raising b_{4b}, employment effects are indeed worse than in policy 6 (Δn in this extreme version of policy 5 would be -4 percentage points). Other studies neglect the difference between early retirement and old-age pension systems. Workers in these studies are free to choose the age at which they step from work into old-age retirement. A PAYG pension then directly raises the opportunity cost of working. Clearly, this setup is not very realistic. In most countries early retirement benefits raise the opportunity cost of work, old-age pensions don't. It is hard to quantify in our model the effects of moving from such a system (where workers optimally choose the age to go from work directly into old-age pensions) to a fully-funded system. Since such a PAYG system does not exist in most countries, it cannot establish a reliable benchmark. However, when we quantify the effects of (i) moving from our current benchmark to such a PAYG system, and (ii) moving from our current benchmark to a fully-funded system without an early retirement regime, we find that the movement to a fully-funded system yields indeed better performance and welfare. This is in line with the literature, but - again - not a realistic setup or exercise.

Policy 6b highlights a third possible reason for why one may find in the literature that moving to a fully-funded system is better than an (intelligent) PAYG system. In this policy we treat non-employment benefits differently than in policy 6. More precisely, if moving to a fully-funded system implies a cut in taxes on labor, this may also raise net non-employment benefits, when these are proportional to net wages. The gain from work versus non-employment then remains unaffected. This is what happens in policy 6. In policy 6b, by contrast, we keep net non-employment benefits unchanged, such that the labor tax cut raises the relative gain from work. This setup is much more in

line with the literature, where non-employment benefits are often disregarded. As one can see in Table 5, moving to a fully-funded system now implies a strong increase in aggregate employment. All age groups work more. It should be clear, however, that the main element here is not the shift in the pension regime, but the relative reduction in non-employment benefits. In Heylen and Van de Kerckhove (2010) we report highly similar employment effects from an absolute cut in non-employment benefits (b_j, with j=1,2,3a) for unchanged labor taxes, and a constant pension system. Moreover, the employment success of policy 6b also comes at a cost. The strong rise in the employment rate of the young runs parallel with a strong reduction in education, and the largest fall in steady state growth.

5.2. Transitional dynamics and welfare effects per generation.

We now describe the transitory adjustment path of key variables, including welfare, after the main pension reforms discussed in Table 5 (we omit Policy 1 in all figures). Figure 9 shows the evolution of aggregate output, Figure 10 the evolution of the aggregate employment rate. Policy changes are introduced in period 1. We assume that these policy changes are unanticipated and permanent. In the 'short-run' we observe small output losses after most policies, except policies 7 and 4b. The latter two policies are the only ones that succeed in raising aggregate employment in the 'short-run'. Policies 5, 6 and 6b show the worst short-run output evolution, which is again mainly driven by the evolution of employment. In the long-run, differences between policies are much more pronounced. Rather than employment, the evolution of education and human capital is now crucial. (Remember that human capital also attracts physical capital in our model). The strongest 'long-run' output effects follow from policy 4 (+20.1% after 6 periods), followed by policies 3 and 2. These are also the policies that encourage education most. Note that under the assumption of constant participation in education (policy 4b), output effects in Figure 10 are much more limited. We also observe strong output growth during periods 2, 3 and 4 under policies 6 and 6b, but this growth is not persistent [20] .

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 policy 3, a shift in the weights underlying the pension base in favor of the third period (p_3) implies a welfare gain for the current young (k=0), equal to 1.52% of benchmark consumption. The gain for the current middle-aged and

[20] The announcement of the transition to a fully-funded system, and the perspective of a gradual fall in labor taxes during periods 2, 3 and 4, as described in footnote 19, makes individuals work less when young (and work more in later periods – at lower tax rates). Young individuals therefore study more, which is good for the evolution of human capital, and output. As we report in Table 5, however, this positive education effect is not permanent (on the contrary).

retired (k = -1, -3) is slightly positive, whereas the current old slightly lose welfare (-0.59% of benchmark consumption). All future generations ($k>0$) gain. For the generation that is young in period *t+2*, for example, policy 3 implies a welfare gain of about 9% of benchmark consumption.

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

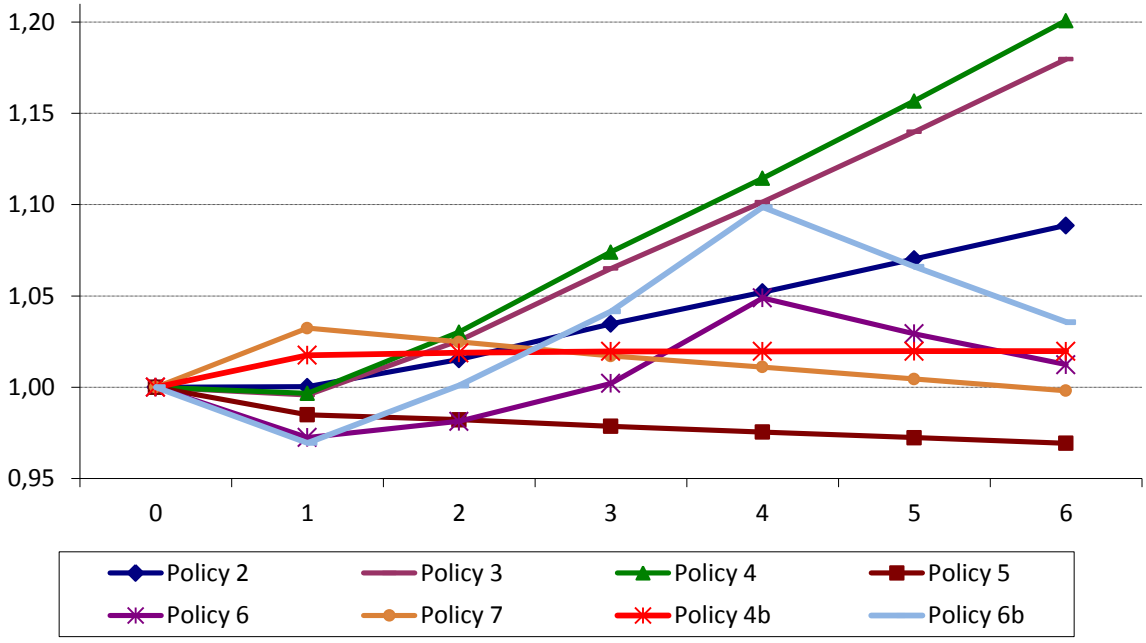
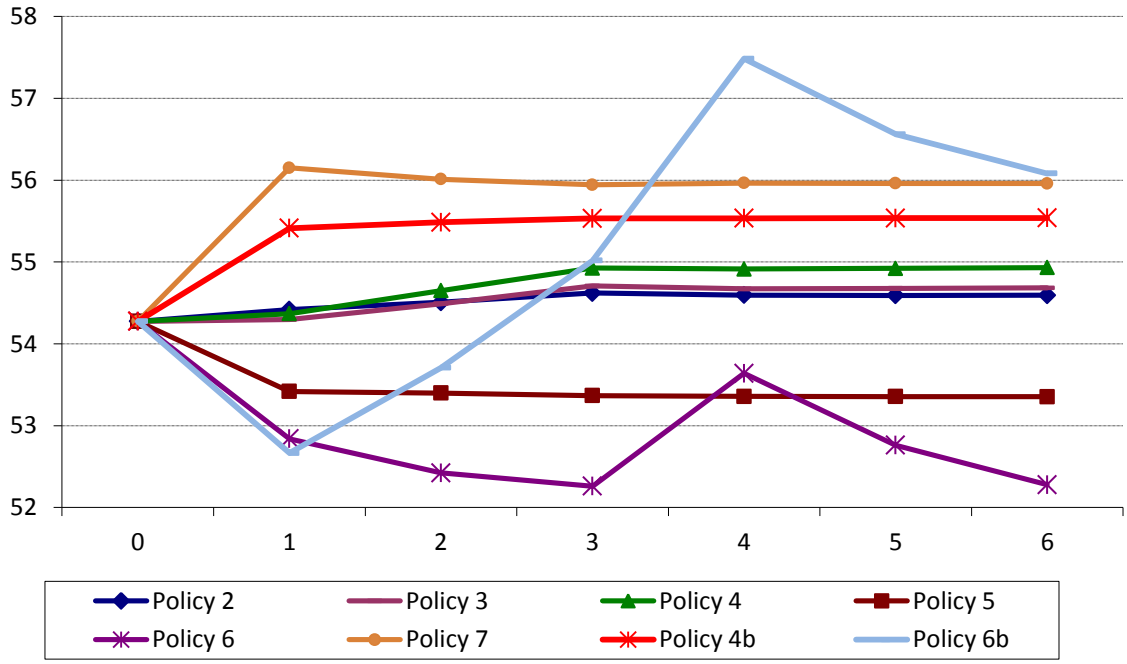
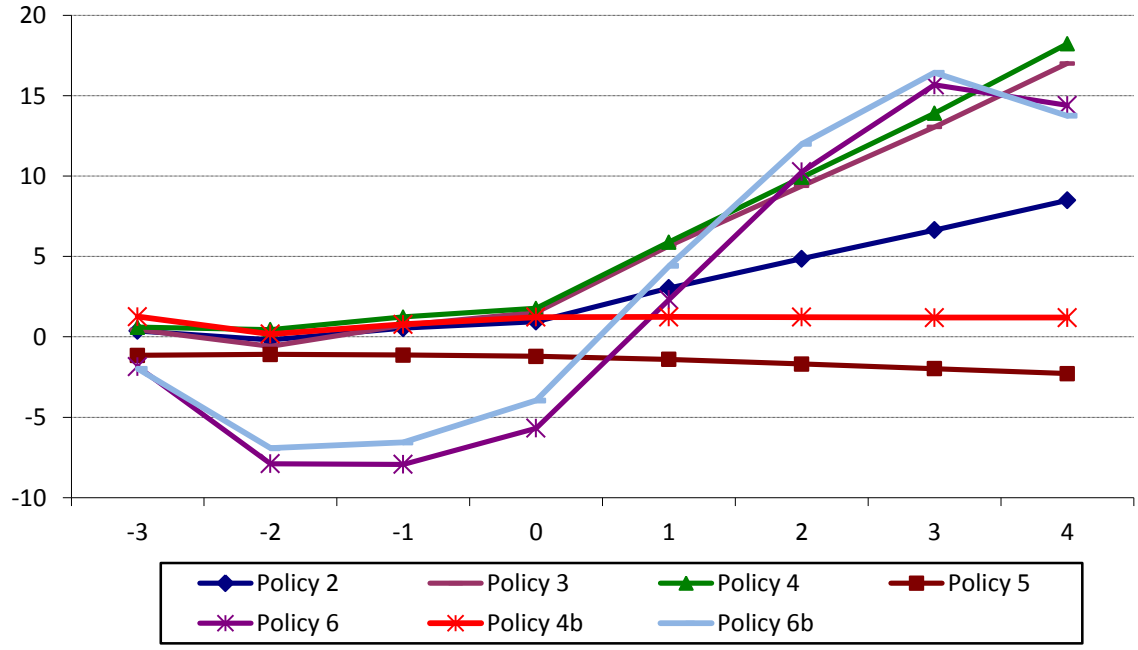


Figure 10. Aggregate employment rate in % after permanent policy shocks introduced in period 1 (benchmark period=0)



Our most interesting findings concern the overall welfare gain for current and (especially) future generations following the adoption of policy 4. An increase in the pension replacement rate, combined with a higher weight p_3 in the computation of the pension base, does not only have significant beneficial effects on employment and growth, but also on welfare. This reform results in the largest welfare gains when compared to our other policy measures. A comparison of welfare effects from policies 4 and 4b reveals, however, the crucial role of policy 4's strong positive effects on growth. This observation is important: neglecting possible effects of pension reform on human capital and growth may yield very different conclusions about welfare. The important role of endogenous human capital has recently been shown also by Ludwig *et al.* (2011). Finally, we observe the considerable overall welfare losses for current generations following the adoption of policy 6. The cost imposed on the transition generations is a well-known problem in policy proposals that consider to substitute a fully-funded private system for a PAYG model. Welfare effects on future generations are much more positive, however. A different treatment of non-employment benefits in policy 6b does not affect these conclusions. Finally, we observe consistently negative welfare effects on all generations from moving to basic pensions in policy 5.

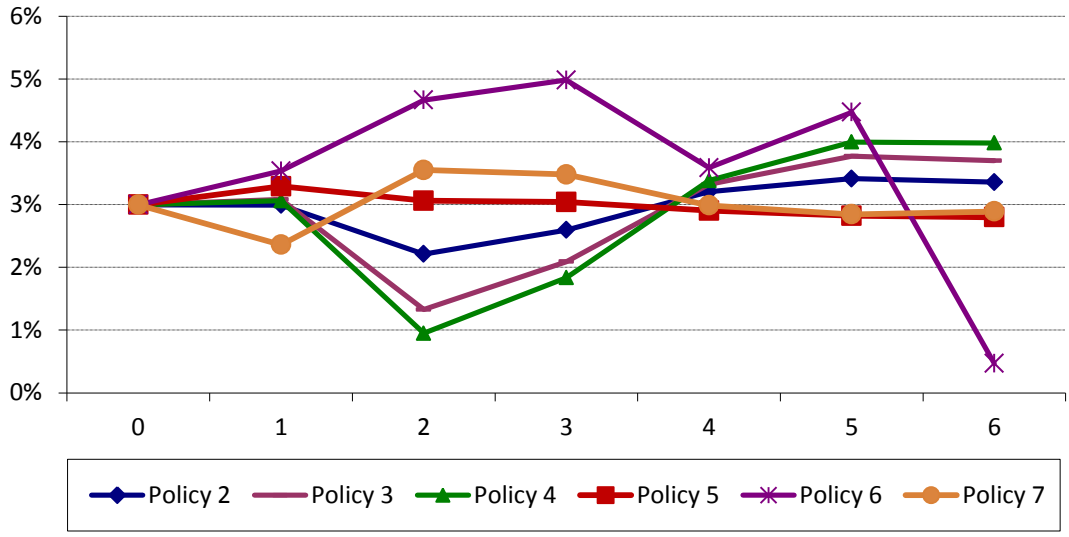
Figure 11. Welfare effects for current and future generations after pension reform



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

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

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



6. Conclusion

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

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

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

Our simulation results prefer an intelligent PAYG pension system above a fully-funded private system. Key elements of an intelligent PAYG system include: (i) a close link between old-age pensions, and individual labor earnings and contributions, via a high pension replacement rate, (ii) a high weight of

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

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

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

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References

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

Altig, D.A., Auerbach, A., Kotlikoff, L., Smetters, K. and Walliser, J. (2001) Simulating fundamental tax reform in the United States. *American Economic Review* 91, 574–595.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Hu, S.C. (1979) Social security, the supply of labor and capital accumulation, *American Economic Review*, 69(3), 274-283.

Jaag, C., Keuschnigg, C. and Keuschnigg, M. (2010) Pension reform, retirement, and life-cycle unemployment, *International Tax and Public Finance,* 17, 556-585.

Juillard, M. (1996) Dynare: A program for the resolution and simulation of dynamic models with forward variables through the use of a relaxation algorithm. *Working Paper*, N° 9602, CEPREMAP.

Kaganovich, M. and Meier, V. (2008) Social security systems, human capital, and growth in a small open economy, *CESifo Working Paper*, N° 2488.

Kaganovich, M. and Zilcha, I. (1999) Education, social security and growth, *Journal of Public Economics*, 71, 289-309.

Kemnitz, A. and Wigger, B.U. (2000) Growth and social security: the role of human capital, *European Journal of Political Economy*, 16, 673-683.

King, R.G. and Rebelo, S. (1990) Public policy and economic growth: developing neoclassical implications, *Journal of Political Economy*, 98, S126-150.

Le Garrec, G. (2012) Social security, income inequality and growth, *Journal of Pension Economics and Finance*, 11, 53-70.

Lindbeck, A. and M. Persson (2003) The gains from pension reform, *Journal of Economic Literature*, 41, 74-112.

Ludwig A., Schelkle T. and Vogel E. (2011) Demographic change, human capital and welfare, *Review of Economic Dynamics*, forthcoming.

Lucas, R.E. (1988) On the mechanics of economic development, *Journal of Monetary Economics*, 22, 3-42.

Nickell, S., Nunziata, L., and Ochel, W. (2005) Unemployment in the OECD since the 1960s. What do we know?, *Economic Journal*, 115, 1-27.

OECD (2005) *Pensions at a Glance: Public policies across OECD countries*, OECD, Paris.

Ohanian, L., Raffo, A., and Rogerson, R. (2008) Long-term changes in labor supply and taxes: Evidence from OECD countries, 1956-2004, *Journal of Monetary Economics*, 55, 1353-1362.

Reyneri, E. (1994) Italy: A long wait in the shelter of the family and of safeguards from the State in: O. Benoit-Guilbot and D. Gaillie (eds.), *Long-term Unemployment*, London, Pinter, 97-110.

Rogerson, R. (2007) Taxation and market work: Is Scandinavia an outlier?, *NBER Working Paper*, N° 12890.

Rogerson, R. and Wallenius, J. (2009) Micro and macro elasticities in a life cycle model with taxes, *Journal of Economic Theory*, 144, 2277-2292.

Salomäki, A. (2003) Remain in or withdraw from the labour market? A comparative study on incentives, *European Economy Economic Papers*, N° 193.

Samuelson, P.A. (1958) An Exact Consumption-Loan Model of Interest, With or Without the Social Contrivance of Money, *Journal of Political Economy*, 66, 467-482.

Sánchez Martín, A. (2010) Endogenous Retirement and Public Pension System Reform in Spain, *Economic Modelling*, 27, 336-349.

Sheshinski, E. (1978) A Model of Social Security and Retirement Decisions, *Journal of Public Economics*, 10, 337-360.

Stokey, N.L. and Rebelo, S. (1995) Growth effects of flat-rate taxes, *Journal of Political Economy*, 103, 519-550.

Turnovsky, S.J. (2000) Fiscal policy, elastic labor supply, and endogenous growth, *Journal of Monetary Economics*, 45, 185-210.

Whiteford, P. and Whitehouse, E. (2006) Pension Challenges and Pension Reforms in OECD Countries, *Oxford Review of Economic Policy*, 22(1), 78-94.

Whitehouse, E., D'Addio, A., Chomik, R. And Reilly, A. (2009) Two decades of pension reform: What has been achieved and what remains to be done, *The Geneva Papers*, 34, 515-535.

Woessman, L. (2003) Schooling resources, educational institutions and student performance: the international evidence, *Oxford Bulletin of Economics and Statistics*, 65, 117-170.

Zhang, J. (1995) Social security and endogenous growth, *Journal of Public Economics*, 58, 185-213.

Zhang, J. and Zhang, J. (2003) Long-run effects of unfunded social security with earnings-dependent benefits, *Journal of Economic Dynamics and Control*, 28, 617-641.

Appendix: Construction of data and data sources

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

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

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

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

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

Data sources:

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

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

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

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

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

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

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

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

pop total population of age 20-34

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

Data sources:

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

* Part-time students in age groups 20-24, 25-29, 30-34: OECD Stat, Education and Training, Students enrolled by age (all levels of education, all educational programmes). We subtracted the data for full-time students from those for 'full-time and part-time students'.
Data are available in 1995-2006. However, for many countries (quite) some years are missing. Period averages are computed on the basis of all available annual data.

Average effective retirement age *(1995-2006)*
Definition: Average age of all persons (being 40 or older) withdrawing from the labor force in a given period.
Data sources:
* OECD, Ageing and Employment Policies – Statistics on average effective age of retirement

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

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

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_1, b_2, b_{3a})*

Definition: The data concern net transfers received by long-term unemployed people and include social assistance, family benefits and housing benefits in the 60th month of benefit receipt. They also include unemployment insurance or unemployment assistance benefits if these benefits are still paid, i.e. if workers can be structurally unemployed for more than five years without losing benefit eligibility. The data are expressed in % of after-tax wages. The OECD provides net replacement rates for six family situations and three earnings levels. In line with our assumptions for labor tax rates (see above), we computed b_1 as the average of the net benefit replacement rates for 'families' with earnings levels corresponding to 67% and 100% of the average worker's wage (AW). We computed b_2 as the average of the net benefit replacement rates for 'families' with earnings levels corresponding to 100% and 167% of the average worker's wage. The reported data are averages for 2001 and 2004. We assume b_{3a} to be equal to b_2.

Data source: OECD, Tax-Benefit Models, www.oecd.org/els/social/workincentives

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

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

To calculate our proxy for b_{3b} we have focused on the possibility for older workers in some countries to leave the labor market along fairly generous early retirement routes. Duval (2003) and Brandt *et al.* (2005) provide data for the so-called implicit tax rate on continued work for five more years in the early retirement route at age 55 and age 60. The idea is as follows. If an individual stops working (instead of continuing for five more years), he receives a benefit (early retirement, disability…) and no longer pays contributions for his future pension. A potential disadvantage is that he may receive a lower pension later, since he contributed less during active life. Duval (2003) calculated the difference between the present value of the gains and the costs of early retirement, in percent of gross earnings before retirement. We use his data as a proxy for the gross benefit replacement rate for older workers in the early retirement route. To compute the net benefit replacement rate, we assume the same tax rate on early retirement benefits as on unemployment benefits. We call this net benefit replacement rate r_3. However, these implicit tax rates are only very rough estimates of the real incentive to retire embedded in early retirement schemes and are subject to important caveats (Duval, 2003). *"First, the focus on a single "early retirement route" leaves aside the participation effects of a number of other social transfer programs that may actually be used as early retirement devices. Second, the actual strictness of eligibility criteria for these programs is imperfectly reflected in the calculations. For instance, even in those countries for which it has been assumed that*

retirement on account of disability is not […] *an available option, due to the official strictness of eligibility criteria, the share of disability benefit status in non employment actually grew significantly during the second half of the 1990s (e.g. Sweden, United States).”* (Duval, 2003, p. 15). In sum, the available implicit tax rates take into account neither the strictness of eligibility criteria nor the presence of alternative social transfer programs that may de facto be used as early retirement devices. Our assumption will be that a realistic replacement rate for the early retirement route (b_{3b}) will be a weighted average of r_3 and b_{3a}, where we take the latter as a proxy for the replacement rate in alternative social transfer programs. If $r_3 > b_{3a}$, older workers will aim for the official early retirement route, but they may not all meet eligibility criteria and have to fall back on alternative programs. If $r_3 < b_{3a}$, workers will aim for the alternative, but again they may not be eligible. We propose that $b_{3b} = \xi b_{3a} + (1-\xi)r_3$. Underlying the data in Table 4 is the assumption that $\xi=0.5$. Correlation between b_{3b} and r_3 is 0.95. Cross-country differences roughly remain intact. Clearly, our results in the main text do not depend in any serious way on this assumption for ξ.

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

CHAPTER 3

Pension reform in an OLG model with heterogeneous abilities

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; Fenge *et al.*, 2008; 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.*, 2010). Others have investigated the relationship between the pension system and investment in human capital formation, as a major determinant of productivity growth (e.g. Zhang, 1995; Kemnitz and Wigger, 2000; Zhang and Zhang, 2003; Kaganovich and Meier, 2008; Cremer *et al.*, 2011; 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.*, 2013).

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.* (2013) and Ludwig *et al.* (2012) are exceptions[1]. 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) and Cremer *et al.* (2011) 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

[1] Ludwig *et al.* (2012) develop a model with endogenous employment by age and human capital, but they have exogenous growth. Buyse *et al.* (2013) also have endogenous growth.

reveal that in 2008 about 30% 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.* (2013). 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.* (2013). 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

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

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

Data sources: OECD (see Appendix A); data description: see main text and Appendix A. 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.

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 A for details on the calculation of our data, and on the assumptions that we have to make.

As is well-known, middle aged individuals work most hours, followed by the young. The older generation works the lowest number of hours. Average employment rates across countries in these three age groups are 55.0%, 63.7% and 43.6% respectively. Furthermore, the data reveal strong cross-country differences. We observe the highest employment rates in each age group in the US. Employment rates are much lower in the core countries of the euro area. 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[2]. Individuals enter the model at age 20. Each period is modeled to last for 15 years. High and medium ability young people can choose either to work and generate labor income, to study and build human capital, or to devote time to 'leisure' (including other non-market activities). Low ability young individuals and all middle aged and older workers do not study anymore, they only work or have 'leisure'. The statutory old-age retirement age in our model is 65. Individuals may however optimally choose to leave the labor force sooner in a regime of early retirement.

Output is produced by domestic firms which act competitively and employ physical capital together with existing technology and effective labor provided by the three active generations. A final important assumption is that education generates a positive externality in the sense of Azariadis and 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:

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

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

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

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

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

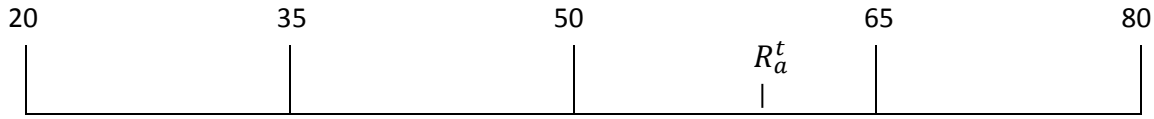
$$\ell_{4a}^t = 1 \text{ and } e_{1L}^t = 0.$$

Superscript t indicates the period of youth, when the individual comes into the model. Subscript j refers to the jth period of life and a refers to the 'ability type'. Lifetime utility depends on consumption (c_{ja}^t) and enjoyed leisure (ℓ_{ja}^t) in each period of life. The intertemporal elasticity of

[2] Assuming demography and population to be constant may seem strange given that ageing is a crucial factor behind pension reform in many countries. Note however that this assumption is not uncommon (see also Jaag *et al.*, 2010; Fisher and Keuschnigg, 2010; Buyse *et al.*, 2013). Moreover, and most importantly, it need not be a limitation to disentangle behavioral effects from different routes of pension reform.

substitution in consumption is 1, the intertemporal elasticity to substitute leisure $\frac{1}{\theta}$. Finally, β is the discount factor and γ specifies the relative value of leisure versus consumption. The preference parameters γ_1 , $\gamma_2$and γ_3 do not depend on ability type. Note, however, that γ_j may be different in each period of life. Except for the latter assumption, our specification of the instantaneous utility function is quite common in the macro literature (e.g. Benhabib and Farmer, 1994; Rogerson, 2007).

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



Period	*t*	*t+1*	*t+2*	*t+3*
Work	n_{1a}^t	n_{2a}^t	$n_{3a}^t = R_a^t \tilde{n}_{3a}^t$	*0*
Study	e_{1a}^t	*0*	*0*	*0*
leisure time	$1 - n_{1a}^t - e_{1a}^t$	$1 - n_{2a}^t$	$R_a^t(1 - \tilde{n}_{3a}^t) + (1 - R_a^t)$	*1*

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

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: $n_{3a}^t = R_a^t . \tilde{n}_{3a}^t$. 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.*, 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.[3] Equation (4) expresses that individuals prefer to have a balanced combination of both rather than an 'extreme' amount of one of them (and very little of the other). In this equation ζ is the constant elasticity of substitution, μ is a usual share parameter and Γ is added as a normalization constant such that the magnitude of ℓ_{3a}^t corresponds to the magnitude of total leisure time $(1 - n_{3a}^t)$. The latter assumption allows to interpret γ_3 as the relative value of leisure versus consumption in the third period, comparable to γ_1 and γ_2. The main results in this paper are not in any way influenced by the magnitude of μ, Γ or ζ.

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

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

$$\begin{aligned}(1+\tau_c)c_{2a}^t + \Omega_{2a}^t = {} & w_{a,t+1}h_{2a}^t n_{2a}^t(1-\tau_w) + bw_{a,t+1}h_{2a}^t(1-\tau_w)(1-n_{2a}^t) \\ & +(1+r_{t+1})\Omega_{1a}^t + z_{t+1}\end{aligned} \tag{6}$$

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

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

For the fraction of time that young, middle aged and older individuals are inactive, they receive a non-employment benefit from the government. Older workers may be eligible to two kinds of

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

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}[4].

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 ρ_{wa}. The parameters p_1, p_2 and p_3 represent the weights attached to each period. This part of the pension rises in the individual's hours of work n_{ja}^t and his human 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).[5] The second component of the pension is a flat-rate or basic pension. Every retiree receives the same amount related to average net labor income in the economy at the time of retirement. This assumption assures that also basic pensions rise in line with productivity. Here, the net replacement rate is ρ_{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.

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

With: $0 \leq p_j \leq 1$

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

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

[4] 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.

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

Note that we allow ability-specific pension replacement rates ρ_{wa} and ρ_{fa}. This specification is in line with the data in many countries, 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 π of the average effective human capital of the middle aged generation. A young worker with ability M enters our model with only a fraction $\varepsilon_M \pi$, a young worker with ability L enters with an even lower fraction $\varepsilon_L \pi$. Lower ability may imply more difficulty to learn and accumulate knowledge at primary and secondary school (Azariadis and de la Croix, 2002 and Cremer *et al.*, 2011). 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 labor 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 (ψ_a) also depends on innate ability. We specify and discuss effective human capital production and human capital inheritance in greater detail in Section 3.2. Finally, we assume in Equation (13) that human capital remains unchanged between the second and the third period. We have in mind that learning by doing in work may counteract depreciation.

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

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

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

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

Substituting Equations (2)-(4) for ℓ_{ja}^t and (5)-(8) for c_{ja}^t into (1), and maximizing with respect to $\Omega_{1a}^t, \Omega_{2a}^t, \Omega_{3a}^t, n_{1a}^t, n_{2a}^t, \tilde{n}_{3a}^t, R_a^t$ and e_{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 (ρ_{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 ρ_{wa}. To the extent that higher replacement rates raise individuals' consumption possibilities (c_{ja}^t), they also cause adverse income effects on labor supply. Basic pensions (ρ_{fa}) do not directly occur in Equations (15), but they do affect employment via this income effect.

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

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

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

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

Equation (16) describes the first order condition for the optimal effective retirement age. The LHS represents the utility loss from postponing retirement. Later retirement reduces enjoyed leisure as early retiree, but raises enjoyed leisure in between periods of work for given work time $\tilde{n}_{3a}^t$. The RHS shows the marginal utility gain from postponing retirement. This marginal gain follows from consuming the extra labor income (vis-à-vis the early retirement benefit) in the third period, and the higher future old-age pension after 65. The latter effect rises in ρ_{wa} and p_3.

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

Finally, Equation (17) imposes for high and medium ability individuals that the marginal utility loss from investing in human capital when young equals the total discounted marginal utility gain in later periods from having more human capital. Individuals will study more the higher future versus current after-tax real wages and the higher the marginal return of education to human capital $\left(\frac{\partial \psi_a}{\partial e_{1a}^t}\right)$. 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 (ρ_{wa}), combined with high weights p_2 and p_3, will encourage young individuals to study. The reason is that any future benefits and the future pension rise in future labor income, and therefore human capital. A final interesting result is that young people study more – all other things equal – if they expect to work harder in later periods (n_{2a}^t, $n_{3a}^t = R_a^t.\tilde{n}_{3a}^t$).

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

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

It will be obvious from the above discussion that (for a given way of financing) the specific organization of pension benefits may have strong effects on behavior in earlier periods of life. Both income and substitution effects occur. The latter are particularly rich when pensions are linked to individuals' own labor income. A higher replacement rate ρ_{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 ϑ_H of the average effective human capital of the middle aged generation. The value of ϑ_H is to be calibrated. Individuals with medium and lower ability inherit less ($\varepsilon_L < \varepsilon_M < 1$). OECD PISA scores leave no doubt. On average over the 13 countries that we focus on in this paper, the test scores for science of students at the 17th and the 50th percentiles are 67.3% and 83.7% respectively of the test score of students at the 83th percentile. We take these numbers as proxies for ε_L and ε_M (see also Section 4). After entering the model, young individuals may decide to study and accumulate more human capital. The specification and parameterization of the human capital production function $\psi_a(.)$ in Equation (12) is often a problem in numerical endogenous growth models. In contrast to goods production functions, there is not much empirical evidence and no consensus

about the determinants of human capital growth, nor about the underlying functional form and parameter values. The literature shows a variety of functions, typically including one or two of the following inputs: individual time allocated to education, private expenditures on education by individuals themselves or by their parents, and government expenditures on education (e.g. Lucas, 1988, Glomm and Ravikumar, 1992; Docquier and Michel, 1999, Kaganovich and Zilcha, 1999; Bouzahzah *et al.*, 2002; 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[6]. Our third extension is to take into account the quality of education and the schooling system. We recognize that better quality implies higher cognitive skills for the same allocation of resources. Young individuals' capacity to build human capital will then rise.

All these arguments find their way in Equations (18.a) and (18.b). The former shows the *growth* rate of effective human capital for high and medium ability individuals as a CES specification in education time when young (e_{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.[7] Next to q we introduce (constant common) technical parameters: ϕ_a is a positive efficiency parameter reflecting natural ability, σ a scale parameter, υ a share parameter and κ the elasticity of substitution. These parameters will be calibrated. Note in Equation (18.b) that low ability individuals supply no education time, but they also enjoy positive effects on their effective human capital from productive government expenditures. The quality of the schooling system q also plays a role here.

[6] 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.

[7] 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).

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

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

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.*, 2013).

3.3. Domestic firms, output and factor prices

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

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

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

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

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

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

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

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

Furthermore, we exploit the result that[8] :

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

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

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

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

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

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

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

$$Y_t = \left(\frac{K_t}{H_t}\right)^{\alpha} H_t$$

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

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

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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.

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

In line with earlier models (e.g., Lucas, 1988; Azariadis and Drazen, 1990; Buiter and Kletzer, 1993), the long-run (per capita) growth rate is positively related to the quality of schooling (q) and to the fraction of time that young people allocate to education (e_{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 (π, ε_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_tD_t are financed by taxes on labor T_{nt}, taxes on capital T_{kt}, and taxes on consumption T_{ct} and/or by new debt ΔD_{t+1}. We define D_t as outstanding public debt at the beginning of period t.

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

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

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

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

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.*

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

with: $F_t = A_t - K_t - D_t$

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

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

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.

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 [(a)]

n_1	n_2	n_3	R	$per\ capita\ annual\ growth$	e
51.1%	56.8%	29.3%	57.9	1.77%	14.2%

Relative wages US [(b)]

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

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.

4.1. Preference and technology parameters

Table 2 contains an overview of all parameters. We set the rate of time preference equal to 1.5% per year. Considering that periods in our model consist of 15 years, this choice implies a discount factor β equal to 0.8. In the production function we assume a capital share coefficient α equal to 0.285. 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 θ from 1 to 3 (Rogerson, 2007, p. 12). In line with this, we impose θ to be equal to 2. The world real interest rate is assumed constant and equal to 4.5% per year. Considering a period of 15 years, this implies that r = 0.935. Finally, we set the physical capital depreciation rate to 8% per year, which implies δ_k=0.714. These values are also within the range of existing studies (see e.g. Heijdra and Romp, 2009).

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 (π), three efficiency parameters in the human capital production function (ϕ_H, ϕ_M and ϕ_L), the elasticity of substitution (ζ) in the composite leisure function in Equation (4) and two share parameters in aggregate effective labor (η_M and η_L, where η_H follows as $1 - \eta_L - \eta_M$). The ten target values to which these parameters have been calibrated are reported at the bottom of Table 2. Six of them concern the employment rates, the effective retirement age, education, and growth for Belgium in our study. We choose this country since in Belgium the calculation of pension benefits fits exactly within the way we model it. Public pensions are proportional to average annual labor income earned over a period of 45 years, with equal weights to all years. In our model this comes down to $\rho_w > 0, \rho_f = 0$ and $p_1 = p_2 = p_3 = \frac{1}{3}$[9]. The other four target values are the relative wages of young and middle aged workers of low and medium ability in the US. Although in practice a whole system of simultaneous equations is solved in which each target value is important for each parameter to be calibrated, it may be useful for our exposition here to bring some more structure. Certain parameters are clearly more than others linked to certain target values. The leisure parameters, including the elasticity of substitution in the composite leisure function (4), are basically determined such that with observed average levels of the policy variables (tax rates, non-employment benefit replacement rates, pension replacement rates, etc.) and the observed level of schooling quality (q)[10] 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 ε_M and ε_L, we obtain inheritance rates for the medium ability and the low ability groups of about 71% (=0.85x0.837) and 57% (=0.85x0.673). As we have explained in the beginning of Section 3.2., we rely on PISA science scores to obtain ε_M and ε_L.

[9] 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).

[10] And with the values of three parameters in the human capital production function $(\sigma, \upsilon, \kappa)$ that we discuss below (see also footnote 11).

Calibration of the share parameters η_M and η_L is mainly driven by the values for relative wages of young workers in the US. As shown by Equation (26), these share parameters are important determinants of the relative productivity of 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, which explains the introduction here of US relative wages rather than those in Belgium (or in any other European country). We illustrate the key elements in our procedure to obtain values for η_L and η_M from these relative wage data in Appendix B. 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 ϕ_L, ϕ_M and ϕ_H. These are basically determined such that the model correctly predicts relative wages of middle aged workers in the US, as well the target value for the education rate e (see also Appendix B). 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 σ, the share parameter v and the elasticity of substitution parameter κ. We could assign sensible values to these parameters thanks to a sensitivity analysis on the results that we report in the next section. There we evaluate the capacity of our model to explain the facts in 13 OECD countries that we reported in Table 1. Our guideline to pin down specific values for σ, v and κ was to minimize the deviation of our model's predictions from the true data[11]. This procedure implied $\sigma = 0.60, v = 0.125$ and $\kappa = 0.375$. We observe decreasing returns in human capital growth. The result for κ reveals a higher degree of complementarity between private education time and government expenditures than in the Cobb-Douglas case. The result for v demonstrates relatively high importance for human capital formation of private education time versus productive public expenditures. Neither did we have an ex ante indication on the remaining parameters in the composite leisure function in Equation (4). We impose equal weight for both leisure types (μ=0.5). The normalisation parameter Γ equals 2. The size of this parameter has no impact at all on our country predictions or simulation results.

4.2. Fiscal policy, pensions and education quality

Tables 3 and 4 describe key characteristics of fiscal policy in 1995-2001/2004. Our proxy for the tax rate on labor income concerns the total tax wedge, for which we report the marginal rate in %. The data cover personal income taxes, employee and employer social security contributions payable on wage earnings and payroll taxes. The OECD publishes these marginal tax data for eight family and

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

income situations. Our data for τ_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 3 Fiscal policy: Tax rates and government debt

	tax rate on labor income (in %)	consumption tax rate (%)	tax rate on capital income (%)	Public debt (% of GDP)
Proxy for:	τ_w	τ_c	τ_k	D/Y
Austria	54.9	13.2	17.3	69.6
Belgium	67.2	13.4	27.1	111.7
France	52.9	17.1	21.7	68.9
Germany	60.4	11.1	34.4	63.1
Italy	55.2	14.7	14.9	122.1
Netherlands	52.0	12.2	24.3	68.2
Denmark	48.6	18.9	22.5	60.3
Finland	56.2	15.2	17.2	54.1
Norway	50.8	16.4	22.1	40.4
Sweden	56.0	17.9	16.1	67.2
UK	44.9	14.5	21.2	46.6
US	37.4	7.2	23.6	61.9
Canada	46.4	14.5	24.8	83.8
Overall average	52.5	14.3	22.1	70.6

Notes: Labor tax rates are data for the total tax wedge, marginal rate (OECD, Taxing Wages). Data are for 2000-2004. Earlier data are not available. For details, see Appendix A. Capital tax rates are effective marginal corporate tax rates (Institute for Fiscal Studies, their EMTR, base case; data are for 1995-2001, see also Devereux *et al*., 2002). Consumption tax rates are from Dhont and Heylen (2009). Data are for 1995-2001.

Table 4 summarizes our data for the expenditure side of fiscal policy. A first variable is our proxy for the net non-employment benefit replacement rate b. Since in our model non-employment is a structural or equilibrium phenomenon, the data that we use concern net transfers received by structurally or long-term unemployed people. They include social assistance, family benefits and housing benefits in the 60th month of benefit receipt. They also include unemployment insurance or

unemployment assistance benefits if these benefits are still paid, i.e. if workers can be structurally unemployed for more than five years without losing benefit eligibility[12]. The data are expressed in percent of after-tax wages. In line with our approach to determine labor tax rates, we again compute the average of data reported by the OECD for a wide range of family and income cases to determine *b* (see Appendix A). Overall, the euro area countries and the Nordic countries pay the highest net benefits on average. Transfers to structurally non-employed people are by far the lowest in the US. A related variable is our proxy for the net early retirement benefit replacement rate b_{er}. The data are again expressed in percent of after-tax final wages. To assess the generosity of early retirement we integrate the information available via *b* and data for the implicit tax rate on continued work in the early retirement route as provided by Duval (2003) and Brandt *et al.* (2005). For details, see Appendix A. We observe a very generous early retirement regime in Belgium and Finland, whereas net early retirement benefits in Anglo-Saxon countries are much lower.

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)
Proxy for:	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
Overall average	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 A. 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.

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

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[13]. In the US, government consumption is (much) lower.

Table 5 contains our data for the net pension replacement rates $\rho_{wa}$and ρ_{fa}. The data have been taken or computed from OECD (2005). They include only (quasi-)mandatory pension programs[14]. In line with our specification in Equation (9), ρ_{wa} is expressed as a percentage of an individual's average lifetime net labor income, while ρ_{fa} is expressed as a percentage of average economy-wide net labor 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 A 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 (ρ_{wM}>85%), Belgium and the US the lowest (ρ_{wM}< 65%)[15]. Five countries also pay basic pensions to individuals with mean or higher earnings: the Netherlands, Denmark, Norway, the UK and Canada. For individuals with low earnings, the situation is somewhat the opposite. Their pension includes a significant basic (or similar) component in most countries. Unsurprisingly, the Netherlands, Denmark and the UK pay the highest 'basic' amounts[16].

[13] 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.

[14] 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 ρ_{wa}. Voluntary, occupational pensions are not included in our data.

[15] 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.

[16] As we explain in Appendix A, it should be mentioned that our proxy for ρ_{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 ρ_{fa} is that they are not (or even inversely) linked to earnings.

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[17]. 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

	Net earnings-related pension replacement rate (% average earned net labor income)			Net basic pension replacement rate (% economy-wide average net labor income)			PISA science score (divided by 1000)
Proxy for:	Low	Medium	High	Low	Medium	High	
	ρ_{wL}	ρ_{wM}	ρ_{wH}	ρ_{fL}	ρ_{fM}	ρ_{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
Overall average	**49.9**	**54.8**	**51.0**	**19.3**	**13.0**	**12.6**	**0.507**

Notes: Pension replacement rates have been taken or computed from OECD (2005, p. 52 and part II). The data concern 2002.
For more details, see Appendix A. 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, 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

[17] 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.

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

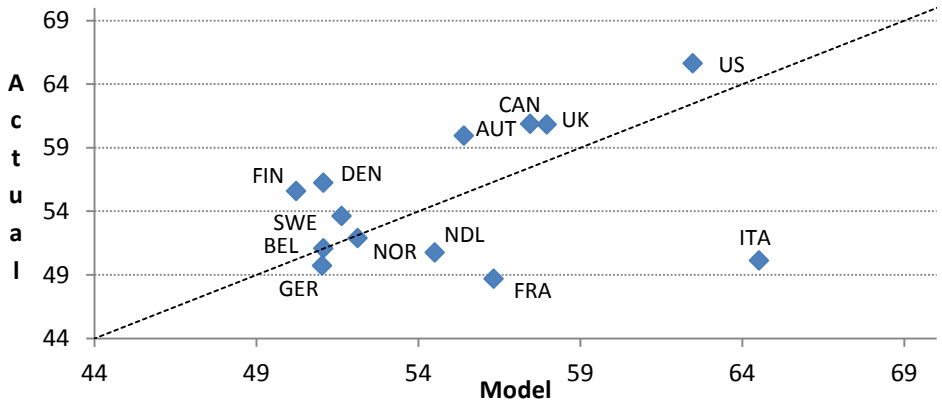
Can our model match the facts that we have reported in Table 1? In this section we confront our model's predictions with the true data for 1995-2007. Clearly, one should be aware of the serious limitations of such an exercise. First of all, our model is highly stylized and may (obviously) miss potential 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[18], 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



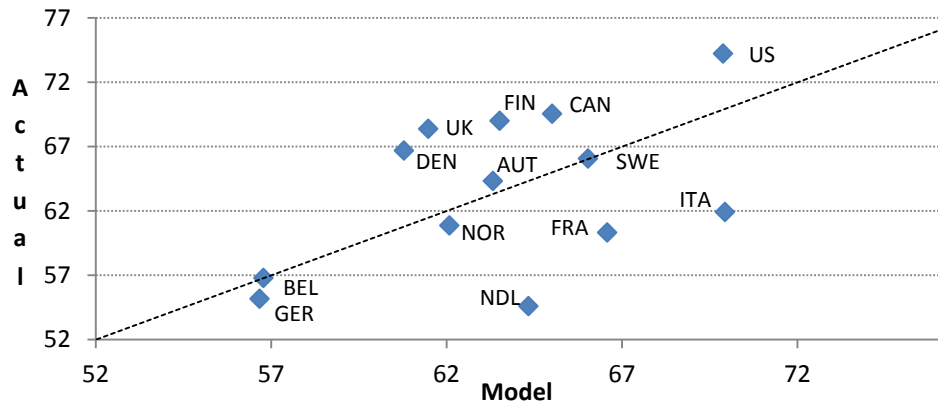
Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.35. Excluding Italy correlation rises to 0.69.

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

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

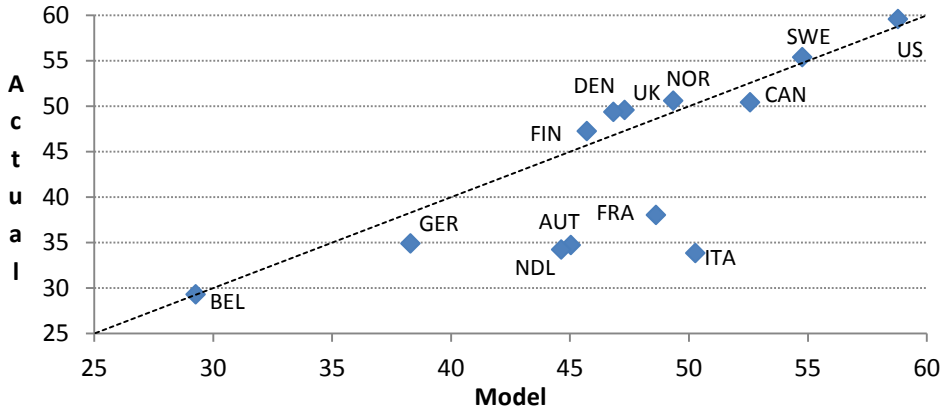
countries except Germany and (especially) Denmark and Finland. The model does not match the high participation in education in the latter two countries. Finally, our model has important cross-country differences right for growth. The model has some difficulty however to explain observed growth for the UK and Canada. Correlation between the model's predictions and the true data is 0.76 for education and 0.69 for growth.

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



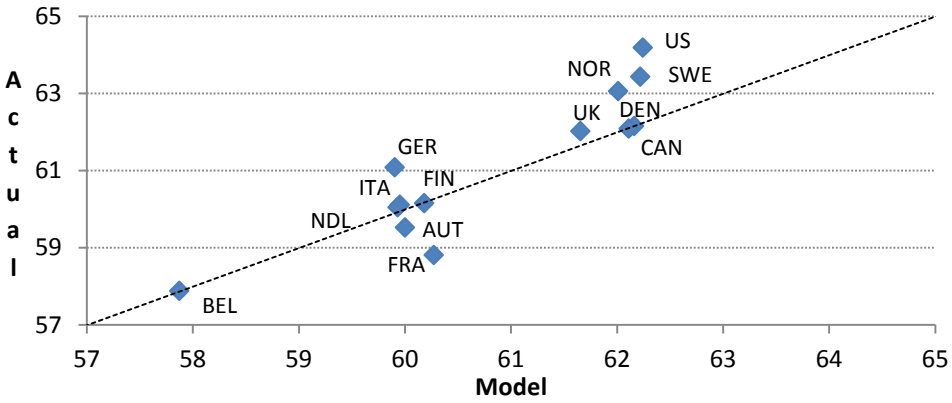
Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.48.

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



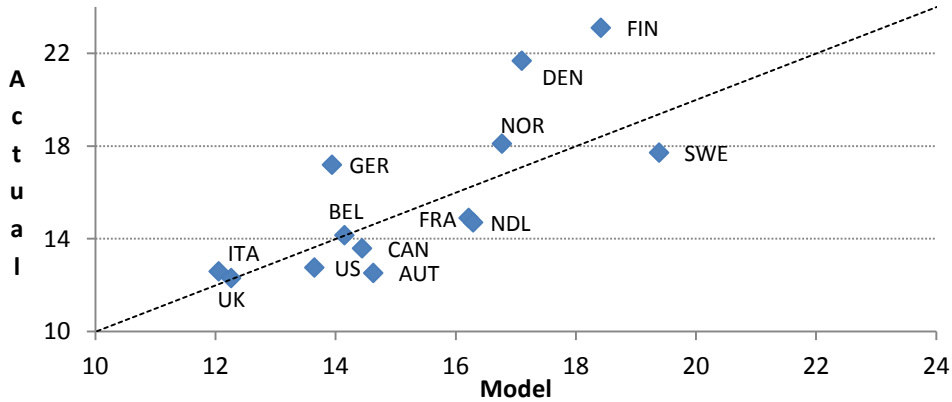
Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.76.

Figure 5. Effective retirement age, 1995-2006



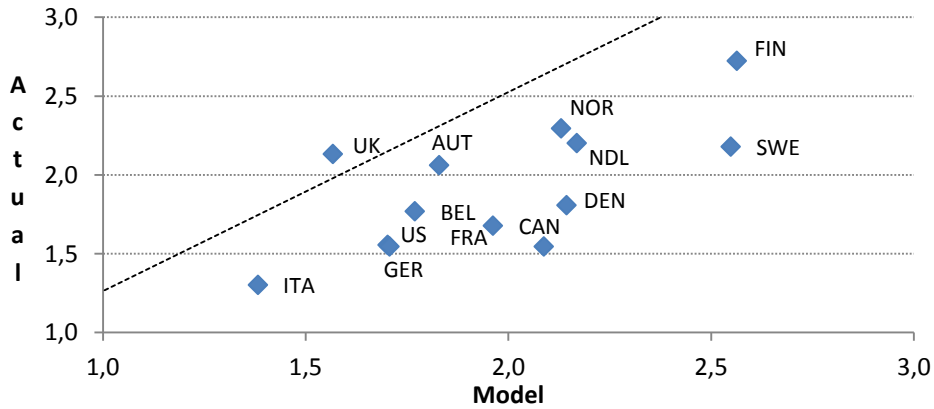
Note: The dotted line is the 45°-line. Correlation between actual data and the model's predictions is 0.91.

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[19].

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% (ρ_{wL}) and 71% (ρ_{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% (ρ_{fH}) and 15% (ρ_{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[20]. 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

[19] 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 ρ_{fa} applies) changes.

[20] 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 Buyse *et al.* (2013). 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 (Δn_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).

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 ρ_{wa}=0 ρ_{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 ρ_{wL}=0.85	Policy 6 p_{1MH}=0 p_{2MH}=1/3 p_{3MH}=2/3 ρ_{wL}=0.85	Policy 7 Fully Funded
Effect [(a)]:							
Δn_1	-3.41	-0.51	-1.06	-3.33	-3.56	-2.84	0.04
Δn_3	0.12	-1.00	-3.02	-0.92	0.36	0.29	-1.47
Δn_3	7.02	-3.48	-10.4	1.15	8.24	5.99	-7.80
ΔR [(c)]	0.85	-0.47	-1.41	0.09	1.00	0.80	-1.15
Δe	1.37	0.00	-0.46	1.37	1.37	1.41	-0.36
Δn [(a. b)]	0.92	-1.55	-4.50	-1.14	1.31	0.88	-2.79
$\Delta N/N$ [(d)]	1.66	-2.81	-8.14	-2.06	2.37	1.62	-5.05
Δn_H	0.60	0.01	-3.88	0.61	0.59	0.60	-2.84
Δn_M	0.72	0.01	-4.66	0.73	0.72	0.72	-2.98
Δn_L	1.43	-4.68	-4.96	-4.75	2.61	1.10	-2.55
Δ annual growth rate[(b)]	0.08	0.00	-0.03	0.08	0.08	0.08	-0.02
$\Delta\tau_c$ [(e)]	-1.19	1.66	5.07	1.15	-0.38	0.13	7.50

Notes: Initial values: ρ_{wL}=59.4, ρ_{wM}=70.6, ρ_{wH}=66.1, ρ_{fL}=14.6, ρ_{fM}=7.0, ρ_{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.

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.

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[21].

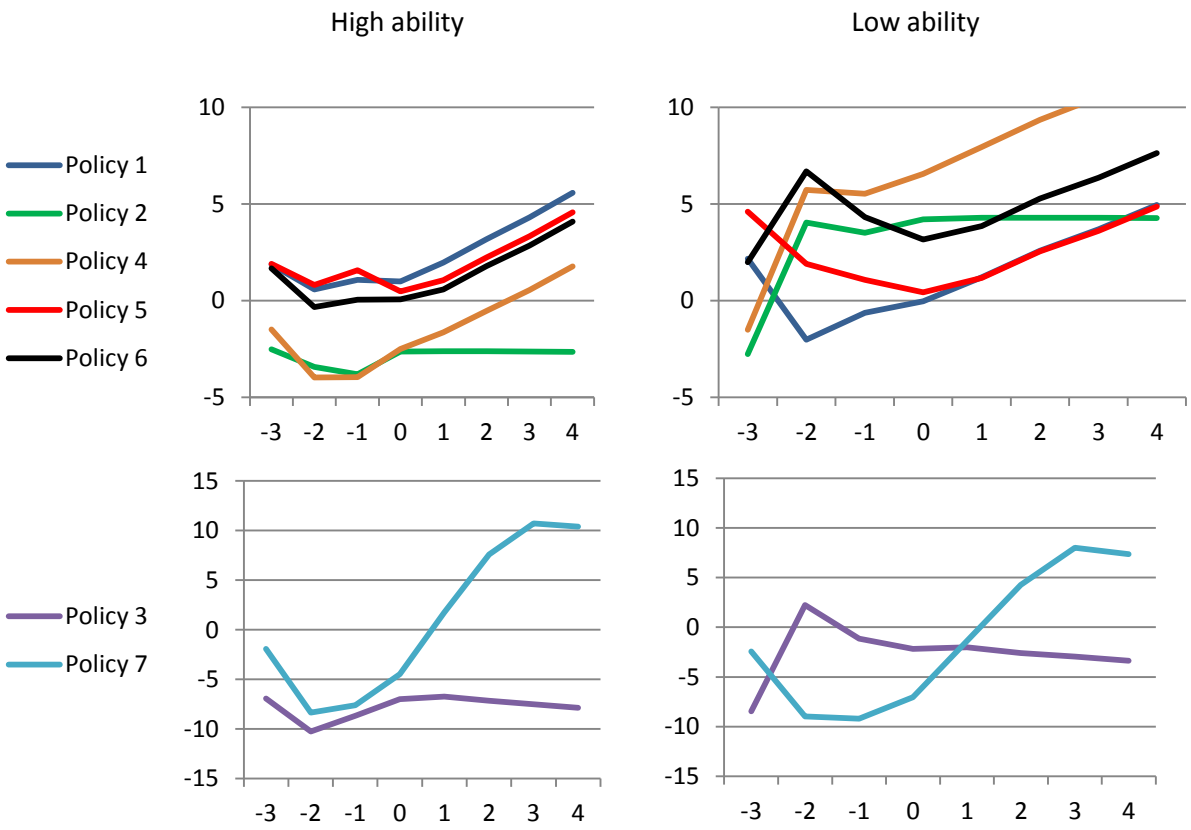
Policy 3 imposes a shift from own-earnings related pensions to 'basic' pensions on all individuals. Every retiree gets a basic pension equal to 75% of average net labor income per worker in the economy. In our model ρ_w goes to zero for all ability groups, ρ_f becomes 0.75. This policy basically goes 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

[21] As a narrow alternative to policy 2, we also investigated the introduction of a minimum pension combined with an abolishment of all basic pensions. All effects were very similar. Only the required increase in the consumption tax rate was smaller, since the government could save money from ρ_{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.

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.

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 (Δn=1.31) or on the employment rate of low-ability individuals (Δn_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, τ_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.

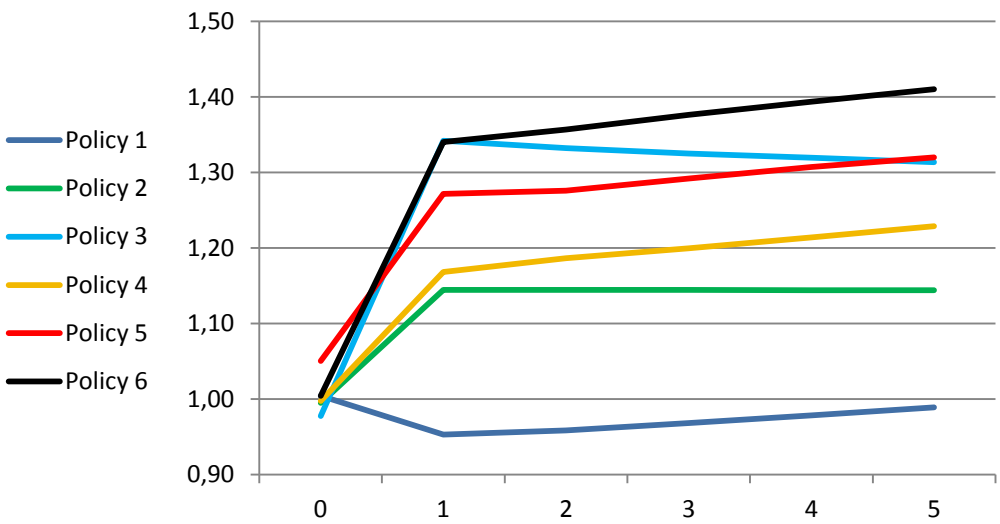
Table 7. Net welfare effect after compensating welfare transfers (expressed as % of initial GDP)

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 (ρ_{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 (ρ_{wa}, ρ_{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.[22] We observe in Table 6 that this transition to a private fully-funded pension scheme is not beneficial for employment. The new steady state shows lower hours worked among all ability groups and all age groups. The fall in employment is the strongest among older workers. The aggregate employment rate 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[23]. This result is well-known in the literature. Although the future gains in Figure 8 are relatively strong when compared to those from e.g. policy 6, it should also be recognized that in the more distant future ($k>5$) a fully-funded system will bring less gains. A key element is that it lacks the incentives to promote human capital formation and growth inherent in policies 1, 5 and 6.

The possibility that a fully-funded pension system has lower growth than a PAYG model has been shown before by Kemnitz and Wigger (2000), Zhang and Zhang (2003), and 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.* (2013). A major element is that the existing literature generally compares a fully-funded system with a specific

[22] In particular, the gradual decline in ρ_{wa} and ρ_{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, ρ_{wa} and ρ_{fa} are zero. At each moment, overall labor tax rates are reduced to ex ante compensate for the decline in pension expenditures.

[23] The explanation for the welfare loss of current generations in our model is as follows. The announcement of the transition to a fully-funded system, and the perspective of a gradual fall in labor taxes during periods 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. Conclusion

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 ρ_w in our model (and a low ρ_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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References

Altig, D.A., Auerbach, A., Kotlikoff, L., Smetters, K. and Walliser, J., 2001, Simulating fundamental tax reform in the United States, American Economic Review 91, 574–595.

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

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

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

Azariadis, C. and de la Croix, D., 2002, Growth or equality? Losers and gainers from financial reform, CORE Discussion Paper, N° 2002/058.

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

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

Barro, R.J., 2001, Human capital and growth, American Economic Review, 91, 12-17.

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

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

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

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

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

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

Buyse, T., Heylen, F. and Van de Kerckhove, R., 2013, Pension reform, employment by age, and long-run growth, Journal of Population Economics, 62(2), 769-809.

Caselli, F. and Coleman, W.J., 2006, The world technology frontier, American Economic Review, 96, 499-522.

Cremer, H., Gahvari, F. and Pestieau, P., 2011, Fertility, human capital accumulation, and the pension system, Journal of Public Economics, 95(11-12), 1272-1279.

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

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

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

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

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

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

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

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

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

Fenge, R., de Ménil, G., and Pestieau, P. (eds.), 2008, Pension Strategies in Europe and the United States, The MIT Press.

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

Fiorito R. and Zanella, G., 2012, The anatomy of aggregate labor supply elasticity, Review of Economic Dynamics, 15, 171-187.

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

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

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

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

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

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

Jaag, C., Keuschnigg, C. and Keuschnigg, M., 2010, Pension reform, retirement, and life-cycle unemployment, International Tax and Public Finance, 17, 556-585.

Juillard, M., 1996, Dynare: A program for the resolution and simulation of dynamic models with forward variables through the use of a relaxation algorithm. Working Paper, N° 9602, CEPREMAP.

Kaganovich, M. and Meier, V., 2008, Social security systems, human capital, and growth in a small open economy, CESifo Working Paper, N° 2488.

Kaganovich, M. and Zilcha, I., 1999, Education, social security and growth, Journal of Public Economics, 71, 289-309.

Kemnitz, A. and Wigger, B.U., 2000, Growth and social security: the role of human capital, European Journal of Political Economy, 16, 673-683.

Kidd, S. and Whitehouse, E., 2009, Pensions and old-age poverty, in Holzmann, R., Robalino, D.A and Takayama, N., Closing the coverage gap: the role of social pensions and other retirement income transfers, World Bank, Chapter 3.

King, R.G. and Rebelo, S., 1990, Public policy and economic growth: developing neoclassical implications, Journal of Political Economy, 98, S126-150.

Le Garrec, G., 2012, Social security, income inequality and growth, Journal of Pension Economics and Finance, 11, 53-70.

Lindbeck, A. and M. Persson, 2003, The gains from pension reform, Journal of Economic Literature, 41, 74-112.

Ludwig A., Schelkle T. and Vogel E., 2012, Demographic change, human capital and welfare, Review of Economic Dynamics, 15, 94-107.

Lucas, R.E., 1988, On the mechanics of economic development, Journal of Monetary Economics, 22, 3-42.

Nickell, S., Nunziata, L., and Ochel, W., 2005, Unemployment in the OECD since the 1960s. What do we know?, Economic Journal, 115, 1-27.

OECD, 2005, Pensions at a Glance: Public policies across OECD countries, OECD, Paris.

Ohanian, L., Raffo, A., and Rogerson, R, 2008, Long-term changes in labor supply and taxes: Evidence from OECD countries, 1956-2004, Journal of Monetary Economics, 55, 1353-1362.

Reyneri, E., 1994, Italy: A long wait in the shelter of the family and of safeguards from the State in: O. Benoit-Guilbot and D. Gaillie (eds.), Long-term Unemployment, London, Pinter, 97-110.

Rogerson, R, 2007, Taxation and market work: Is Scandinavia an outlier?, NBER Working Paper, N° 12890.

Rogerson, R. and Wallenius, J., 2009, Micro and macro elasticities in a life cycle model with taxes, Journal of Economic Theory, 144, 2277-2292.

Samuelson, P.A., 1958, An exact consumption-loan model of interest, with or without the social contrivance of money, Journal of Political Economy, 66, 467-482.

Sheshinski, E., 1978, A model of social security and retirement decisions, Journal of Public Economics, 10, 337-360.

Sommacal, A., 2006, Pension systems and intragenerational redistribution when labor supply is endogenous, Oxford Economic Papers, 58, 379-406.

Stokey, N.L. and Rebelo, S., 1995, Growth effects of flat-rate taxes, Journal of Political Economy, 103, 519-550.

Turnovsky, S.J., 2000, Fiscal policy, elastic labor supply, and endogenous growth, Journal of Monetary Economics, 45, 185-210.

Whiteford, P. and Whitehouse, E., 2006, Pension Challenges and Pension Reforms in OECD Countries, Oxford Review of Economic Policy, 22(1), 78-94.

Whitehouse, E., D'Addio, A., Chomik, R. and Reilly, A., 2009, Two decades of pension reform: What has been achieved and what remains to be done, The Geneva Papers, 34, 515-535.

Woessman, L., 2003, Schooling resources, educational institutions and student performance: the international evidence, Oxford Bulletin of Economics and Statistics, 65, 117-170.

Zhang, J., 1995, Social security and endogenous growth, Journal of Public Economics, 58, 185-213.

Zhang, J. and Zhang, J., 2003, Long-run effects of unfunded social security with earnings-dependent benefits, Journal of Economic Dynamics and Control, 28, 617-641.

Appendix A: Construction of data and data sources

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

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

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

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

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

Data sources:

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

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

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

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

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

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

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

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

pop total population of age 20-34

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

Data sources:

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

* Part-time students in age groups 20-24, 25-29, 30-34: OECD Stat, Education and Training, Students enrolled by age (all levels of education, all educational programmes). We subtracted the data for full-time students from those for 'full-time and part-time students'.
Data are available in 1995-2006. However, for many countries (quite) some years are missing. Period averages are computed on the basis of all available annual data.

Average effective retirement age *(1995-2006)*
Definition: Average age of all persons (being 40 or older) withdrawing from the labor force in a given period.
Data source: OECD, Ageing and Employment Policies – Statistics on average effective age of retirement.

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

Tax rate on labor income *(τ_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 60th month of benefit receipt. They also include unemployment insurance or unemployment assistance benefits if these benefits are still paid,

i.e. if workers can be structurally unemployed for more than five years without losing benefit eligibility. The data are expressed in % of after-tax wages. The OECD provides net replacement rates for six family situations and three earnings levels. 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

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 ξ=0.5. Correlation between b_{er} and r_{er} lies around 0.92. Cross-country differences roughly remain intact. Our results in the main text do not depend in any serious way on this assumption for ξ.

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

Net pension replacement rates *(*ρ_{wa} and ρ_{fa} for *a=L,M,H*)

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

Since in our model ρ_{fa} is a percentage of the average net wage in the economy (Equation 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 ρ_{fa}. This ratio can be derived from the 'pension modelling' tables in the individual country studies, at various multiples of average earnings.

Appendix B: Detail on calibration procedure to determine η_a and ϕ_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 ϕ_L, ϕ_M and ϕ_H), it is easy to see that we have three remaining equations in three unknowns (η_H, η_M, η_L) that can be solved.

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

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

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

CHAPTER 4

Pensions and fertility: a simple proposal for reform

Pensions and fertility: a simple proposal for reform

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Abstract

In this paper, we evaluate the effects of a parametric adjustment to an earnings-related PAYG pension system. We show that a simple but 'intelligent' reform, in which the calculation of the pension base is changed, may result not only in more employment and growth, but also in an increase in fertility. Such an 'intelligent' pension design would maintain the strong link between own labor income and the earned pension, while putting more weight on the labor income earned as an older worker in the calculation of the pension base. The higher (lower) marginal utility from work when older (young) following this reform makes it interesting to shift work from the first period of active life to the later. Part of the available time that arises during youth is spent on education. Another part can be spent on raising offspring. By contrast, a shift to a fully-funded system might even reduce fertility.

The goal of this paper is to indicate that 'intelligent' adjustments to the pension scheme that have been shown to have beneficial effects on employment and growth, may also serve the goal of increasing fertility. We believe this idea can be seen as complementary to proposals implying the introduction of a child-related pension benefit. As such, we adhere to the recent idea of Cigno (2010) to develop a pension system consisting of two parallel schemes: a part being Bismarckian and a part being child-related, i.e. related to having and raising children. The results in this paper give insight on how to construct the former part.

Keywords: demographic change, retirement, pension reform, overlapping generations

JEL Classification: E62, H55, J13, J22

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1. Introduction: research question and related literature

Public pension systems face increasing pressure in many OECD countries given the overall rise in life expectancy and decline in fertility rates. In order to face the pension challenge in an ageing society, many economists agree on the need for higher employment, especially among older individuals, and higher productivity growth. While a lot of research has been performed on this issue, a consensus on best pension reform has not yet been reached.[1] Some studies are in favor of parametric adjustments in the pay-as-you-go (PAYG) system that many countries rely on, while others prefer a move to a fully-funded private system.

Given the importance of the demographic evolution for the sustainability of a pension system, a large literature has studied the interaction between public pensions and the fertility rate. Some authors see the public pay-as-you-go pension system as one of the reasons for the decline in fertility rates (e.g. Zhang, 1995; Cigno and Rosato, 1996; Sinn, 2004 and Boldrin *et al.*, 2005). The general idea is that the introduction of a public pension system diminishes the necessity to raise children as a source of old-age income support. As such, public pensions reduce transfers within the family and hence distort demand for children.
With respect to the issue of declining fertility, several pension reform proposals have already been put forward. In order to revert the decline in population growth, some economists are in favor of a switch to a fully-funded system since such a system is stable in case of demographic change. Others advocate the idea of relating the pension benefit received at the time of retirement (partly) to the number of children raised by the pensioner (e.g. Voigtländer, 2004 and Sinn, 2005). Such a children-pay-as-you-go (CPAYG) system directly raises the return to having children. Moreover, it does not suffer from problems related to ageing as individuals who do not have children are forced to save for their own old-age income. One possible caveat, however, would arise if quality (i.e. investments in a child's education) is substituted by quantity (Becker, 1960).[2]

In this paper, and in contrast to studies that analyze how pensions benefits can be related directly to the number of offspring (see e.g. Fenge and Meier, 2005), we take the existing PAYG pension system that most OECD countries rely on as given. We propose a fertility-increasing reform that does not require the introduction of a CPAYG. We propose one specific parametric adjustment policy, which is also shown to be beneficial for economic growth and employment of older workers. More specifically, we are in favor of a pension system that maintains the strong link between own labor income and the earned pension, while putting a high weight on the labor income earned as an older worker in the calculation of the pension assessment base. Pension reform in this direction not only encourages young individuals to study and build human capital and encourages older individuals to

[1] Many studies document how the pension system may affect the incentives of individuals of different ages to work (e.g. Auerbach *et al.*, 1989; Fisher and Keuschnigg, 2010; de la Croix *et al.*, 2010). Others investigate the relationship between the pension system and human capital investment (e.g. Zhang and Zhang, 2003).

[2] It should be mentioned that, as a remedy to low fertility, many countries have resorted to other policy instruments such as child subsidies, parental leave schemes and public provision of day-care centres.

work and postpone retirement. It may also bring about behavioral effects that induce individuals to bear more children and may hence increase total fertility. To show these effects, we extend the general equilibrium four-period OLG model of Buyse *et al.* (2013) to allow for an endogenous fertility choice. The model explains hours of work of young, middle-aged and older individuals, education and human capital formation of the young, fertility, retirement of the older generation and aggregate growth (per capita). It includes a public PAYG old-age pension system. The statutory retirement age is 65 and exogenous. To keep the model as streamlined as possible, we abstract from concerns as longevity and the inability of certain individuals to bear children. The remainder of this paper is organized as follows. Section 2 describes the model and calibration. In Section 3 we show the results of simple pension reform proposals. Section 4 concludes.

2. The model

We use the computable overlapping-generations model for a small open economy of Buyse *et al.* (2013) as our starting point. We maintain most of the assumptions in their model such as perfect international mobility of physical capital and immobile labor. We will not develop the complete model here – we refer to the original paper of Buyse *et al.* – but instead focus on the novelties that are relevant to this paper such as the decision about the number of offspring and the old-age social security system. For completeness, however, all equations of the model are reported in Appendix A. As to notation, a superscript *t* indicates the period an individual enters the model while a subscript *t* refers to the historical time period.

Demographics

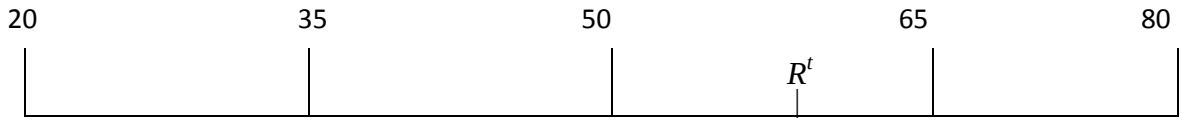
A certain generation *t,* which enters the model at the age of 20, consists of N_t individuals. Within each generation agents are assumed homogeneous. d_1^t and d_2^t denote the number of children raised by generation *t,* born either during the young or middle-aged period of adulthood. Both the total number of offspring and the time to have children are hence decision variables for the household. Population grows according to the following equation $N_{t+1} = d_1^t N_t + d_2^t N_{t-1}$. Each period is modeled to last for 15 years in real life. There is no uncertainty concerning mortality: all individuals die at the age of 80.

Individuals

The model consists of three active adult generations, the young, the middle-aged and the older, and one generation of retired agents. Figure 1 shows the life-cycle time profile of an individual reaching age 20 in *t*. Young people, i.e. between the age of 20 and 35, can choose either to work and generate labor income (*n*), to study and build human capital (*e*) or to devote time to raising children ($s_1 d$), where s_1 is a time cost per child (see further). The remaining time is spent on 'leisure' (including other non-market activities). Time endowment is normalized to 1 in each period. Middle-aged workers may also raise children but do not study. Older workers do not bear children and do not study; they only work, have 'leisure' and continue raising their children born the period before. Note

that the period of childhood (i.e. the period before the age of 20 when children live with their parents) is not modeled explicitly.

Figure 1. Life-cycle of an individual of generation t[3]



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^t	0	0	0
Raising children	$s_1 d_1^t$	$s_2 d_1^t + s_1 d_2^t$	$s_2 d_2^t$	0
'Leisure' time	$1 - n_1^t - e_1^t - s_1 d_1^t$	$1 - n_2^t - s_2 d_1^t - s_1 d_2^t$	$R^t(1 - \tilde{n}_3^t) + (1 - R^t) - s_2 d_2^t$	1

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. The determination of early retirement is part of the individuals' optimal choice of 'leisure' time in the third period of life (50-65). Individuals choose *R,* which relates to the optimal effective retirement age and which is defined as the fraction of time between age 50 and 65 that the individual participates in the labor market; *(1-R)* is then time in early retirement. We use n_3 to denote the fraction of time devoted to work between 50 and 65, and $\tilde{n}_3$ as the fraction of time devoted to work before early retirement, but after 50. As labor market exit is irreversible and post-retirement employment is not allowed in our model, the relationship between n_3 and $\tilde{n}_3$ is as follows: $n_3 = R.\tilde{n}_3$. Finally, note that retired agents leave no debts, nor bequests.

$$U_t = \sum_{j=1}^{4} \beta^{j-1} \left[\ln c_j^t + \gamma_j \frac{{l_j^t}^{1-\theta}}{1-\theta} \right] + \gamma_{d1} \ln d_1^t + \gamma_{d2} \ln d_2^t \tag{1}$$

Equation (1) shows the intertemporal utility function that an individual reaching age 20 in t maximizes. Lifetime utility depends on consumption (c_j) and enjoyed 'leisure' (l_j) in each period of life. Superscript t indicates the period of youth, when the individual comes into the model. Furthermore, β 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, γ_j specifies the relative value of leisure versus consumption. Note that γ may be different in each period of life.

[3] A superscript *t* indicates the period of youth of an individual. Subscripts 1, 2, 3 and 4 refer respectively to the period in which the individual is young, middle-age, old or retired.

A final part of Equation (1) is related to the utility of having children. As mentioned above, individuals decide upon the number of offspring they bear in their first (d_1^t) or second (d_2^t) period of life. When choosing this number of children, individuals take into account both the benefits and costs from raising them. As to the benefits, we assume that individual utility depends directly on the number of children. This assumption of weak altruism is mainstream in the literature (e.g. Eckstein and Wolpin, 1985; Galor and Weil, 1996; Eckstein *et al*., 1988; Fanti and Gori, 2012 and Cipriani, 2013). It implies that children are considered as a pure consumption good and not as an investment good, i.e. children yield utility to their parents only in the period in which they are born.[4] For simplicity, we assume a logarithmic specification: $u(d_i^t) = \gamma_{di} \ln(d_i^t)$ for $i = 1, 2$.[5]
Raising children is also costly. There are two types of costs which prevail both in the first (subscript 1) and second (subscript 2) period after a child is born. First, parents spend some exogenous amount s_1 (resp. s_2) of their available time on child rearing (see also Figure 1). If raising an additional child thus implies taking less leisure, this has a direct negative effect on utility. If on the other hand, it means less labor supply, it has an indirect financial effect due to lower labor income.[6] Second, there is also a direct financial cost to bring up offspring. We think of food costs, living expenditures, college tuition... We define the latter as a fraction of the after-tax wage income (see also Cipriani, 2013). We assume these fractions to be ω_1 resp. ω_2.

As mentioned before, we will not describe in detail all equations of the model in the main text. However, we do mention the first order condition for the decision on the number of children in Equations (2a) and (2b) below.

$$\frac{\gamma_{d1}}{d_1^t} = \gamma_1 \frac{s_1}{\left(1-n_1^t-e^t-s_1 d_1^t\right)^\theta} + \beta\gamma_2 \frac{s_2}{\left(1-n_2^t-s_2 d_1^t-s_1 d_2^t\right)^\theta} + \frac{\omega_1 n_1^t w_t h_1^t (1-\tau_w)}{c_1^t(1+\tau_c)} + \beta \frac{\omega_2 n_2^t w_{t+1} h_2^t (1-\tau_w)}{c_2^t(1+\tau_c)} \tag{2a}$$

$$\frac{\gamma_{d2}}{d_2^t} = \beta\gamma_2 \frac{s_1}{\left(1-n_2^t-s_2 d_1^t-s_1 d_2^t\right)^\theta} + \beta^2\gamma_3 \frac{s_2}{\left(l_3^t\right)^\theta} + \beta \frac{\omega_1 n_2^t w_{t+1} h_2^t (1-\tau_w)}{c_2^t(1+\tau_c)} + \beta^2 \frac{\omega_2 n_3^t w_{t+2} h_3^t (1-\tau_w)}{c_3^t(1+\tau_c)} \tag{2b}$$

The above first order conditions state that individuals choose the number of children d_i^t to equalize the costs and benefits of raising an additional child. The left-hand side of Equations (2a) and (2b)

[4] Many studies exist in which children are considered as investment goods. Bental (1989) and Sinn (2004) consider a transfer from children to elderly parents. However, given the fact that may developed countries have social security systems and old-age pension systems, the motive for having children as an investment good is not that prevelant anymore.

[5] Note that the utility-value of offspring can be different depending on their timing of birth. In our model, for instance, the fact that γ_{d2} might be smaller than γ_{d1} could capture the fact that the higher the mother's age when pregnant, the higher the possibility of difficulties during the period of pregnancy, premature birth or congenital handicap of the child.

[6] We do not model a time cost of bearing children in the third period after the child is born. We believe this is a realistic assumption. It would of course be possible to introduce such a cost s_3. In that case, as long as children require more care and attention, in terms of time costs, when parents are younger than age 50 the results in this paper will hold.

describe the direct utility gain from bearing an additional child given our assumption of children as consumption goods. The right-hand side shows the marginal utility loss. This loss consists of two components. All things equal, more children reduce the available leisure time in the first two periods of parenthood, as shown by the first two terms on the right-hand side. These terms thus capture the time cost of having children. The final two components in Equation (2) capture the financial cost of having children. That is, bearing an additional child implies that a higher fraction of income is spent on children (according to fraction $\omega_{1,2}$). Again, given the set-up of the model, these effects occur both in the first and second period of parenthood. The resulting fall in after tax-consumption leads to a drop in utility.

Another important feature of the model is the social security system. Our set-up is as follows. First, between the moment of withdrawal from the labor market (time R^t) and the age of 65, individuals receive an early retirement benefit. This benefit is defined as a proportion of the after-tax wage of a full-time worker. Second, after the statutory retirement age, individuals receive an old-age pension benefit. 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*. Individual net pension benefits consist of two components. These are shown in Equation (3) below. A first component 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 ρ_w. The parameters p_1, p_2 and p_3 represent the weights attached to each period. In our calibration (see further), it is assumed that these three parameters are equal to 1/3. This part of the pension rises in the individual's hours of work n_j^t and his human capital h_j^t. It will be lower when the individual retires early (lower R^t). Thanks to revaluation, this part of the net pension is adjusted to increases in the overall standard of living between the time that workers build their pension entitlements and the time that they receive the pension. We assume that past earnings are revalued in line with economy-wide wage growth *x* and hence follow practice in many OECD countries (OECD, 2005; Whiteford and Whitehouse, 2006). The second component of the pension is a flat-rate or basic pension. Every retiree receives the same amount related to average net labor income in the economy at the time of retirement. This assumption assures that also basic pensions rise in line with productivity. Here, the net replacement rate is ρ_f.

$$pp_4^t = \rho_w \sum_{j=1}^{3}\left(p_j w_{t+j-1} h_j^t n_j^t (1-\tau_j) \prod_{i=j}^{3} x_{t+i-1}\right) + \rho_f \frac{1}{3}\sum_{j=1}^{3}\left(w_{t+3} h_j^{t+4-j} n_j^{t+4-j}(1-\tau_j)\right) \quad (3)$$

with: $0 \leq p_j \leq 1$

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

$n_3^t = R^t \tilde{n}_3^t$

Firms

Domestic firms act competitively on both input and output markets. They use physical capital together with existing technology and effective labor provided by the three active generations as

inputs in the production process. All firms are identical and total domestic output is given by a standard Cobb-Douglas production function with constant returns to scale. Firm maximization leads to two well-known equations. First the wage per efficiency unit of labor equals the marginal productivity of one additional unit of effective labor. Second, the real interest rate equals the after-tax marginal productivity of capital, corrected for capital depreciation. These first order conditions are also reported in the Appendix.

Human capital

Human capital has a crucial role in the model. We assume that the average level of human capital of a middle-aged generation is inherited by the next young generation. This mechanism, which is the source of per capita growth in the model, generates a positive externality from education in the sense of Azariadis and Drazen (1990). A young individual may subsequently augment its stock of human capital through time investment in education. The private return to schooling depends not only on the initial stock of human capital but also on the quality of the education system (q) and the amount of government expenditures on education (g_y). We assume a CES-specification for the human capital accumulation function. We show the empirical relevance of such a specification in Buyse *et al.* (2012, 2013).

Government

The model includes an extensive fiscal block. The government raises taxes on individuals' consumption (τ_c) and labor income (τ_w) and on firms' capital (τ_k). The expenditures consist of productive expenditures (G_y), which raise the return to education, consumption goods (G_c), which are wasteful, 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 on outstanding debt ($r_t D_t$). Note that we disregard alternative government expenditures in the model such as expenditures for child benefits, subsidies care, public expenditures for schools… A comparative analysis of different policies to raise fertility (either through pension reform or child care) is not the purpose of this paper. Fenge and Meier (2009) for instance, compare the effects of family allowances and fertility-related pensions.

Calibration

We calibrate our model to Belgian data on employment, education rates and growth rates. We choose this country since in Belgium the calculation of pension benefits fits exactly within the way we model it. Belgian public pensions are proportional to average annual labour income earned over a period of 45 years, with equal weights to all years. There is no basic pension (OECD, 2005). As to the pension equation in our model, i.e. equation (2) above, this comes down to ρ_w>0, ρ_f=0 and p_1=p_2=p_3=1/3. We believe that the assumption to calibrate our model to Belgium does not restrict us in any way to generalize the results to other OECD countries. In Buyse et al. (2013), where the authors also calibrate on Belgium, the model is first validated empirically for a group of 13 OECD countries. Before using the parameterized theoretical model for policy simulations, the authors thus

test whether the model's predictions are within reliable bands. More specifically, the authors impose common technology and preference parameters on all countries, but country-specific fiscal policy and pension system parameters. Simulating the model for each country they find that its predictions match the main facts in most countries. These facts concern observed hours of work in three age groups (20-34, 35-49, 50-64), education of the young (20-34), the effective retirement age, and per capita growth since 1995.

We basically follow the same calibration strategy as in the above paper. We mention the resulting parameter values in Appendix B. As to the novel parameters in this model, i.e. on the costs and utility of children, our assumptions are as follows. The average total fertility rate (TFR) for Belgium in the period 2003-2012 was about 1.8. Given that we do not consider men and women in our model, but a representative individual, we want to target a TFR of 0.9 (=1.8/2) in the calibration. Data for Belgium further reveal that about 85% of the offspring are born before the age of 35. We calibrate the relative utility value of children (γ_{d1} and γ_{d2}) versus consumption to match these figures.[7] We further assume a time cost of 10% of available time per child in the first period after the child is born and 5% in the second period (i.e. s_1=0.1 and s_2=0.05). This assumption is in line with for instance Casarico and Sommacal (2012), who assume a time cost of raising children of about 6% in the adult period (which in their model lasts for 25 years). In our simulations, we will neglect the financial cost of raising offspring and set $\omega_1 = \omega_2 = 0$. Note that for the main results in this paper, the presence of financial costs in in fact superfluous in our model. We come back to this in the next section.

3. Simulation results

The objective of this paper is to exploit the above model in order to analyze the impact of pension policy on fertility, employment, education and growth. Before we proceed, it is important to note that any impact of these policies on the government budget is neutralized by a change in lump-sum transfers. In other words, we assume that lump sum transfers are endogenously changed to maintain a constant debt to GDP ratio.[8] Table 1 shows the results of our simulations. We show the steady-state effects on labor supply of young, middle-aged and older workers, the retirement decision of older workers, the education decision of the young, per capita growth, TFR and population growth. The required change in lump-sum transfers to maintain a constant debt ratio is indicated at the bottom of the table.

In the first and second column of Table 1, we adopt the preferred policies put forward in Buyse *et al.* (2013). More specifically, in Policy 1, we alter the calculation of the pension base, such that more weight is given to the net labor income of workers when they are 'older'. In Equation (3) above, this policy involves an increase in p_3, and a fall in p_1. We assume that this reform does not hold for the

[7] This implies that we set d_1 and d_2 to a value of respectively 0.765 and 0.135 in the calibration.

[8] Alternatively, simulations in which the consumption tax is used as endogenous instrument are available on request. The general results obtained in this paper do not change.

current generation of retirees, as they are no longer able to adapt their behavior to these new pension weights.

Table 1. Steady-state effects of pension reform – Effects for Belgium

Initial values: p_1=1/3 p_2=1/3 p_3=1/3 ρ_w =0.631 ρ_f =0	**Policy 1** p_1=0 p_2=1/3 p_3=2/3	**Policy 2** p_1=0 p_2=1/3 p_3=2/3 ρ_w=0.70	**Policy 3** ρ_w=0 ρ_f=0 $\Delta\tau_j < 0$	**Policy 4** ρ_w=0 ρ_f=0 $\Delta\tau_j < 0$ $\Delta[b_j(1-\tau_j)] = 0$
Effect [(a)]:				
Δn_1	-6.46	-6.88	0.54	4.17
Δn_2	-1.22	-0.81	-1.05	1.72
Δn_3	7.69	8.94	-13.67	-0.50
ΔR [(b)]	1.36	1.59	-2.28	0.28
Δe	2.02	2.33	-0.24	-1.34
TFR	2.1	2.1	1.8	1.6
Δd annual [(c)]	0.88	0.88	0.03	-0.67
Δ annual per capita growth [(a)]	0.16	0.18	-0.02	-0.11
ΔZ ex post [(d)]	2.83	2.64	-5.24	3.40

Notes: The benchmark values are as follows: n_1=51.1, n_2=56.8, n_3=29.3, R=57.9, e=14.1, d=0.91, TFR=1.8.
(a) difference in percentage points between new steady state and benchmark, except R.
(b) change in optimal effective retirement age in years.
(c) change in annual population growth rate, in % points.
(d) change in lump sum transfer (as a fraction of output) to keep the debt-to-GDP ratio constant at the level of the benchmark, in percentage points.

An important effect from Policy 1 is the rise in the fertility rate. We observe an increase of 0.88 percentage points in the annual population growth rate after this reform. For Belgium, this would imply a rise in the population growth rate from about -0.60% to 0.28% per year. The mechanism driving this increase is a substitution effect. 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. Part of the available time that arises during youth is spent on education. Young individuals are encouraged to study 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. Another part of the available time is spent on raising children. As such, the positive effect on fertility is indirect as the drop in work hours at the period of youth allows for more time to be spent on raising children. Note that we also observe a small drop in the mean age at birth (not presented). As bearing offspring after the age of 35 also leads to more time costs during the third active period (that is, after the age of 50), the proposed pension reform in fact discourages having children at later ages. Overall, however, the net effect on the total fertility rate is strongly positive. Finally, note that as long as children require more care and attention, in terms of time costs, when

parents are younger than age 50 (which is a realistic assumption) our results will hold. Moreover, our results prevail even when would have included a direct financial cost (i.e. $\omega_1, \omega_2 > 0$) of raising children in the simulation exercises.

The increase in fertility reduces the financial pressure on the pension system and the overall government budget. The drop, although small, in the mean age at birth is also positive from the point of view of pension funding. Note that the impact on the government budget is not negative at all: lump-sum transfers are allowed to rise due to this reform, as shown in the final row in Table 1.

Given the rise in lump-sum transfers to maintain a constant debt-to-GDP ratio, it becomes possible to even slightly increase the generosity of the pension system by augmenting ρ_w, the income-related pension replacement rate. We do this in Policy 2 where we let the earnings-related replacement increase from the initial 0.631 to 0.70. The rise in the pension replacement rate strengthens the link between earned labor income and work (especially at older ages) on the one hand and the pension benefit on the other. Further increases in employment, education rates and growth can be observed. Fertility and population growth are constant. Interestingly, when one would include a financial cost in the simulations, this pension policy, which leads to a rise in household consumption, would reduce the relative cost of having children and fertility would increase even more.

The second part of Table 1 (Policies 3 and 4) shows the effects of a gradual shift from the PAYG system in the benchmark to a system with full private capital funding. These policies completely abolish old-age pension benefits (ρ_w, ρ_f). For the government, this reform would imply a drastic cut in pension expenditures. We therefore 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.[9] Policy 4 adds an additional feature to this reform. It acknowledges that, when the move to a fully-funded system implies a cut in taxes on labor, this will in our model also raise net non-employment benefits, as these are proportional to net wages. The gain from work versus non-employment then remains unaffected. Therefore, we keep the net non-employment benefit replacement rate unchanged in Policy 4, such that the labor tax cut raises the relative gain from work.[10] In a way, this feature biases upwards the impact on employment. However, this setup is much more in line with the existing literature, where non-employment benefits are often disregarded (see our discussion in Buyse et al., 2013).

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

[10] Mathematically, this implies constant $b_j(1 - \tau_j)$.

An important effect of shifting to a fully-funded system is that the direct positive link between individual labor income and the pension system, which exists in the PAYG system as we have modeled it, is broken. Interestingly, as one can see in Table 1, the effect on employment depends on the assumption we make with respect to the net replacement rate of non-employment benefits. In Policy 3, where we only lower labor taxes to compensate for the decline in pension benefits, the effect on employment is clearly negative. (See the significant drop in employment of older workers). In Policy 4, when we keep the net benefit rates constant, the effect becomes positive due to the mechanism explained above. Whatever set-up is chosen, however, both policies imply the same negative impact on schooling. Growth decreases (up to -0.10%-points in Policy 4) as tertiary education is discouraged by the fall in the pension replacement rate ρ_w. Finally, both policies indicate either a zero or negative impact on the total fertility rate and population growth rate. Although the reduction in hours worked due to the drop in the pension generosity in Policy 3 leads to more available time to raise children, the drop in labor taxes (partly) offsets this effect. In case we would have included a financial cost in the simulations, defined as a fraction of net labor income, the depressing effect of a shift to a fully-funded system on the fertility and population growth rate is even larger. In this case, labor tax cuts increase the net income of individuals, and thereby raise the cost of children. Moreover, the drop in public pensions increases private savings (see next paragraph) and decreases households' consumption. This drop in consumption raises the marginal utility of additional consumption and again indirectly increases the costs from bearing children.

We further note that our simulations confirm an additional feature of moving to a fully-funded system as observed in Buyse *et al.* (2013). Although this reform encourages national savings (see e.g. Feldstein, 1974 and 2005), this need not imply an increase in domestic physical capital formation, and capital taxes, in an open economy. If effective labor supply and employment fall, this reduces the marginal product of physical capital, and causes savings to be invested abroad. This result is not shown but available on request.

4. Conclusion

In this paper, we evaluate the effects of a parametric adjustment to an earnings-related PAYG pension system. We show that a simple but intelligent reform in which the calculation of the pension base is changed, may result not only in more employment and growth, but also in an increase in fertility. Such an intelligent pension design would maintain the strong link between own income and the earned pension, while putting more weight on the labor income earned as an older worker in the calculation of the pension base. By contrast, a shift to a fully-funded system can even reduce fertility.

Note that our proposal above is not in any way an assault on the possible introduction of a child-related pension pillar or other policy instruments as remedies to low fertility. We acknowledge the possible positive impact of such instruments. However, we do show that when one takes the existing earnings-related pension scheme as given, and wants to maintain it, there exist other possibilities of reform such that fertility is stimulated. The main mechanism that drives our result goes as follows. Given that bearing children is costly and that this cost occurs mainly in the beginning

of adulthood, a reform in which the pension benefit depends more on hours worked and earned labor income in the later periods of active life, reduces the relative cost of bearing children. As a positive side effect, it may also stimulate individuals to study longer, as already shown by previous research (Buyse *et al.,* 2013). Note further that we have not allowed for an exogenous increase in longevity in the model, as to reflect the issue of ageing. Therefore, it is important to stress that we do not argue that the 'proposed' pension reform is a panacea for the issue of ageing. The only statement we want to make based on the results put forward in this paper is that our proposed pension reform is capable of relieving some of the pressure on the pension budget that arises due to an ageing population. The crucial element in this reasoning is that investment in education, employment at older age, per capita growth and the fertility rate all rise after the introduction of the pension reform.

More generally, our results can be aligned with a recent proposal by Cigno (2010). He proposes a two-scheme pension system: "*a part being Bismarckian in which individuals qualify for a pension by working and paying contributions, and an unconventional one allowing them to qualify for a pension by having children, and investing time and money in their upbringing*." We believe that future research should focus on how these two pillars can be optimally combined and constructed. That is, how can parametric adjustments of the current pension system, combined with the introduction of a child-related pension, be constructed in such a way that benefits employment, growth and welfare best? The results in this paper give insight on how to construct the former part.

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References

Auerbach AJ, Kotlikoff LJ, Hagemann RP, Nicoletti G (1989) The economic dynamics of an ageing population: the case of four OECD countries. OECD Economics Department Working Papers, No. 62

Azariadis C, Drazen A (1990) Threshold externalities in economic development. Quarterly Journal of *Economics* 105(2):501-526

Becker G (1960) An economic analysis of fertility, in: Coale AJ (ed.) Demographic and Economic *Change in Developing Counties*, Princeton University Press, Princeton (NJ).

Bental B (1989) The old age security hypothesis and optimal population growth, Journal of Population Economics, 1(4):285-301.

Boldrin M, De Nardi M and Jones LE (2005) Fertility and social security, NBER working paper, No. 11146.

Buyse T, Heylen F and Van de Kerckhove R (2012) Pension reform in an OLG model with heterogeneous abilities, FEB Working Papers, No. 12/810.

Buyse T, Heylen F and Van de Kerckhove R (2013) Pension reform, employment by age and long-run growth, Journal of Population Economics, 62(2):769-809.

Casarico A and Sommacal A (2012) Labor Income Taxation, Human Capital, and Growth: the Role of Childcare, The Scancinavian Journal of Economics, 114(4):1182-1207.

Cigno A (1993) Intergenerational transfers without altruism. Family, market and state, European Journal of Political Economy, 9:505-518.

Cigno A and Rosati FC (1996) Jointly determined saving and fertility behavior: theory, and estimates for Germany, Italy, UK and USA, European Economic Review, 40:1561-1589.

Cigno A (2010) How to avoid a pension crisis: a question of intelligent system design. CESifo Economic Studies 56(1):21-37.

Cipriani GP (2013) Population ageing and PAYG pensions in the OLG model, IZA Discussion Papers, No. 7144.

de la Croix D, Pierrard O, Sneessens HR (2010) Aging and pensions in general equilibrium: labor market imperfections matter. IZA Discussion Papers, No. 5276

Eckstein Z and Wolpin KI (1985) Endogenous fertility and optimal population size, Journal of Public Economics, 27(1):93-106.

Eckstein Z, Stern S and Wolpin KI (1988) Fertility choice, land, and the Malthusian hypothesis, International Economic Review, 29(2):353-361.

Fanti L and Gori L (2012) A Note on Child Policy and Fertility in an Overlapping Generations Small Open Economy: When the Labour Market institutions Matter, International Journal of Population Research, Volume 2012.

Feldstein MS (1974) Social security, induced retirement, and aggregate capital accumulation. Journal of Political Economy 82(5):905-926.

Feldstein MS (2005) Rethinking social insurance. American Economic Review 95(1):1-24

Fenge R and Meier V (2005) Pensions and fertility incentives, Canadian Journal of Economics/Revue canadienne d'économique, 38(1):28-48.

Fenge R and Meier V (2009) Are family allowances and fertility-related pensions perfect substitutes?, International Tax and Public Finance, 16:137-163.

Fisher WH, Keuschnigg C (2010) Pension reform and labor market incentives. Journal of Population Economics 23(2):769-803

Galor O and Weil DN (1996) The gender gap, fertility, and growth, American Economic Review, 86(3):374-387.

OECD (2005) Pensions at a glance: public policies across OECD countries. OECD, Paris

Sinn H-W (2004) The pay-as-you-go pension system as fertility insurance and an enforcement device, Journal of Public Economics, 88(7-8):1335-1357.

Sinn H-W (2005) Europe's Demographic Deficit A Plea For A Child Pension System, *De Economist*, 153(1):1-45.

Voigtländer M (2004) A perfect marriage: child-related pensions and public education, Otto-Wolff-Institut Discussion Paper, No. 2/2004.

Whiteford PB, Whitehouse E (2006) Pension challenges and pension reforms in OECD countries. Oxford Review of Economic Policy 22(1):78-94.

Zhang J (1995) Social security and endogenous growth. Journal of Public Economics 58(2):185-213

Zhang J, Zhang J (2003) Long-run effects of unfunded social security with earnings-dependent benefits. Journal of Economic Dynamics and Control 28(3):617-641.

Appendix A: Model equations

Demographics

$$N_{t+1} = d_1^t N_t + d_2^t N_{t-1} \qquad \text{(Population growth)}$$

Individuals

$$U_t = \sum_{j=1}^{4} \beta^{j-1} \left[\ln c_j^t + \gamma_j \frac{l_j^{t\,1-\theta}}{1-\theta} \right] + \gamma_{d1} \ln d_1^t + \beta\, \gamma_{d2} \ln d_2^t \qquad \text{(Utility function)}$$

$$l_1^t = 1 - n_1^t - e^t - s_1 d_1^t$$

$$l_2^t = 1 - n_2^t - e^t - s_2 d_1^t - s_1 d_2^t$$

$$l_3^t = \Gamma \left[\frac{1}{\Gamma} \left(R^t (1 - \tilde{n}_3^t) \right)^{1-\frac{1}{\rho}} + \frac{1}{\Gamma} (1 - R^t)^{1-\frac{1}{\rho}} \right]^{\frac{\rho}{\rho-1}} - s_2 d_2^t \qquad \text{(Time constraints)}$$

$$l_4^t = 1$$

$d_1^t < \frac{1}{s_1}$ and $d_2^t s_1 + d_1^t s_2 < 1$ and $d_2^t s_2 < 1$

$$(1+\tau_c) c_1^t + a_1^t = w_t h_1^t n_1^t (1-\tau_w)(1-\omega_1 d_1^t) + b_1 w_t h_1^t (1-\tau_w)(1 - n_1^t - e^t) + z_t$$

$$(1+\tau_c) c_2^t + a_2^t = w_{t+1} h_2^t n_2^t (1-\tau_w)(1-\omega_2 d_1^t - \omega_1 d_2^t) + b w_{t+1} h_2^t (1-\tau_w)(1-n_2^t) + (1+r_{t+1}) a_1^t + z_{t+1}$$

$$(1+\tau_c) c_3^t + a_3^t = (1-\omega_2 d_2^t) w_{t+2} h_3^t R^t \tilde{n}_3^t (1-\tau_w) + b w_{t+2} h_3^t (1-\tau_w) R^t (1-\tilde{n}_3^t) + b_{er} w_{t+2} h_3^t (1-\tau_w)(1-R^t) + (1+r_{t+2}) a_2^t + z_{t+2}$$

$$(1+\tau_c) c_4^t = (1+r_{t+3}) a_3^t + pp_4^t + z_{t+3} \qquad \text{(Budget constraints)}$$

$$pp_4^t = \rho_w \sum_{j=1}^{3} \left(p_j w_{t+j-1} h_j^t n_j^t (1-\tau_w) \prod_{i=j}^{3} x_{t+i-1} \right) + \rho_f \frac{1}{3} \sum_{j=1}^{3} \left(w_{t+3} h_j^{t+4-j} n_j^{t+4-j} (1-\tau_w) \right) \qquad \text{(Old-age pension benefit)}$$

Firms

$Y_t = K_t^{\alpha} H_t^{1-\alpha}$ (Production function)

$\left[\alpha \left(\frac{H_t}{K_t}\right)^{1-\alpha} - \delta_k\right](1-\tau_k) = r_t$ (FOC w.r.t. K_t)

$(1-\alpha)\left(\frac{K_t}{H_t}\right)^{\alpha} = w_t$ (FOC w.r.t. $\mathrm{H_t}$)

$H_t = n_1^t h_1^t N_t + n_2^{t-1} h_2^{t-1} N_{t-1} + n_3^{t-2} h_3^{t-2} N_{t-2}$ (Effective labor)

$n_3^t = R^t \tilde{n}_3^t$

Human capital

$h_1^t = h_2^{t-1}$ (Human capital externality)

$h_3^t = h_2^t = \left(1 + \Psi\left(e^t, g_y, q\right)\right) h_1^t = x_t h_1^t$ (Evolution of human capital)

$$\Psi\left(e, g_y, q\right) = \phi q \left(v g_y^{1-\left(\frac{1}{k}\right)} + (1-v) e^{1-\left(\frac{1}{\kappa}\right)}\right)^{\sigma\kappa/(\kappa-1)}$$

(Human capital accumulation function)

Government

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

(Government budget constraint)

with:

$G_{yt} = g_y Y_t$ (Productive expenditures)

$G_{ct} = g_c Y_t$ (Government consumption expenditures)

$$B_t = (1 - n_1^t - e^t) b w_t h_1^t (1-\tau_w) N_t + (1 - n_2^{t-1}) b w_t h_2^{t-1} (1-\tau_w) N_{t-1} + R^{t-2}(1-\tilde{n}_3^t) b w_t h_3^{t-2} (1-\tau_w) N_{t-2} + (1 - R^{t-2}) b_{er} w_t h_3^{t-2} (1-\tau_w) N_{t-2}$$

(Non-employment benefits)

$Z_t = z_t (N_t + N_{t-1} + N_{t-2} + N_{t-3})$ (Lump-sum transfers)

$T_{nt} = \sum_{j=1}^{3} n_j^{t+1-j} w_t h_j^{t+1-j} \tau_j N_{t+1-j}$ (Labor taxes)

$T_{kt} = \tau_k [\alpha Y_t - \delta_k K_t]$ (Capital taxes)

$T_{ct} = \tau_c \sum_{j=1}^{4} c_j^{t+1-j} N_{t+1-j}$ (Consumption taxes)

$$PP_4^t = \rho_f \sum_{j=1}^{3} \left(p_j w_{t+j-4} h_4^{t-3} n_j^{t-3} \left(1-\tau_{jw}\right) \prod_{i=j}^{3} x_{t+i-4}\right) + \rho_w \frac{1}{3} \sum_{j=1}^{3} \left(w_t h_j^{t+1-j} n_j^{t+1-j} (1-\tau_w)\right)$$

(Pension expenditures)

Definition of parameters not described in the main text

α	Elasticity of output w.r.t. physical capital
β	Individual discount factor
$1/\theta$	Intertemporal elasticity to substitute leisure
γ_j	Relative preference for leisure at age 'j'
γ_d	Relative preference for children
ρ	Elasticity of substitution in enjoyed leisure in the third period of life
$1/\Gamma$	Share parameter in enjoyed leisure in the third period of life
r	Exogenous world real interest rate
ϕ	Efficiency parameter in human capital production
σ	Scale parameter in human capital production
v	Share parameter
κ	Elasticity of substitution between education time and productive government expenditures
δ_k	Depreciation rate of physical capital

Appendix B: Calibration of main parameters

Production parameters (output)	$\alpha = 0.285$
Effective human capital production	$\phi = 4.2, \sigma = 0.96, v = 0.125, \kappa = 0.375$
Preference parameters	$\beta = 0.8, \theta = 2, \gamma_1 = 0.052, \gamma_2 = 0.093, \gamma_3 = 0.162$ $\gamma_{d1} = 0.062, \gamma_{d2} = 0.008\ \rho = 1.63, \Gamma = 2$
World real interest rate	$r = 0.935$
Physical capital depreciation rate	$\delta_k = 0.714$
Child costs	$\omega_1 = 0, \omega_2 = 0, s_1 = 0.10\ , s_2 = 0.05$

Fiscal policy data used for calibration

Capital tax rate (%)	$\tau_k = 27.1$
Labor tax rate (%)	$\tau_w = 67.2$
Consumption tax rate (%)	$\tau_c = 13.4$
Government debt (% of GDP)	$D_t/Y_t = 111.7$
Non-employment benefit replacement rates (%)	$b = 59.6$
Early-retirement benefit replacement rate (%)	$b_{er} = 79.0$
Pension benefit (net replacement rate, %)	$\rho_w = 63.1$
Basic pension (% of net average earnings)	$\rho_f = 0$
Government consumption (% of GDP)	$g_c = 16.9$
Government productive expenditures (% of GDP)	$g_y = 8.9$
PISA-science (divided by 1000)	$q = 5.05$

Note: for more information on the construction and sources of these data, we refer to Buyse et al. (2013).

CHAPTER 5

Government efficiency, institutions and the effects of fiscal consolidation on public debt

Government efficiency, institutions, and the effects of fiscal consolidation on public debt

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Abstract

We study the evolution of the ratio of public debt to GDP during 132 fiscal episodes in 21 OECD countries in 1981-2008. Our main focus is on debt dynamics during 40 consolidation periods. To define these periods we use data on the evolution of the underlying cyclically adjusted primary balance, and as such avoid biases that may be induced by one-off budgetary measures. The paper brings new evidence on the role of public sector efficiency for the success of fiscal consolidation. First, we confirm that consolidation programmes imply a stronger reduction of the public debt ratio when they rely mainly on spending cuts, except public investment. Government wage bill cuts, however, only contribute to lower public debt ratios when public sector efficiency is low. Second, we find that a given consolidation programme will be more effective in bringing down debt when it is adopted by a more efficient government apparatus. Third, more efficient governments adopt consolidation programmes of better composition. As to other institutions, consolidation policies are more successful when they are accompanied by product market deregulation, and when they are adopted by left-wing governments. By contrast, simultaneous labour market deregulation may be counterproductive during consolidation periods.

JEL codes: E62, H62, H63

Keywords: public debt, fiscal consolidation, fiscal policy composition, labour and product market institutions and reform, government efficiency

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1. Introduction

The sharp increase in public debt ratios and growing concern about the sustainability of public finances since the recession in 2008-09 have imposed the need for a significant fiscal adjustment and credible debt reduction strategies in most OECD countries.

Many countries have gained experience with fiscal consolidation programmes in the past two or three decades. Analysis of the effects of fiscal consolidation has also been high on the agenda of many researchers since seminal work by Giavazzi and Pagano (1990) and Alesina and Perotti (1995). Most of these researchers have tried to explain the probability of success in debt or deficit reduction (e.g. McDermott and Wescott, 1996; Alesina and Ardagna, 1998; Ardagna, 2004; Guichard *et al.*, 2007; Schaltegger and Feld, 2009; Tagkalakis, 2009; Larch and Turrini, 2011; Afonso and Jalles, 2012). Others focus on the evolution of economic growth, private consumption, or private investment during and after consolidation periods (e.g. Giavazzi and Pagano, 1996; Hjelm, 2002; Alesina *et al.*, 2002; Ardagna, 2004; IMF, 2010a; Alesina and Ardagna, 2012).

This paper contributes to the literature by studying directly the evolution of the ratio of public debt to GDP during and after fiscal consolidations. We embed this study in an empirical analysis of 132 fiscal episodes in 21 OECD countries in 1981-2008. To the best of our knowledge, only one study has investigated the dynamics of the public debt ratio during consolidation periods before (see Heylen and Everaert, 2000). Given that ultimately it is the evolution of public debt that matters most in a consolidation context, this scarcity of available studies is surprising. A particular advantage of our approach is that it allows to empirically exploit the whole variation in outcomes after consolidation programmes. In our view, changes in the public debt to GDP ratio by for example -10, -1, +5 or +25 percentage points are very different outcomes, which are worth being explained, rather than being restricted to either 'success' cases or 'failures'. Compared to Heylen and Everaert (2000) we make progress along several lines. First, we include more recent fiscal episodes. Second, we also test more recent hypotheses on the success or failure of fiscal consolidation. We take Alesina and Perotti's well-known composition hypothesis as our starting point, and also control for the influence of the international macroeconomic environment and of any preceding devaluation. More recent hypotheses concern the influence of labour and product market institutions and institutional reform, and the ideological orientation of the government. As we document in this paper, the literature has not come up with unambiguous answers concerning the effects of these institutions. Moreover, they have hardly been studied simultaneously. Most importantly, we put forward a new hypothesis emphasizing the role of public sector efficiency. We show that the level of public sector efficiency matters for the effects of any given consolidation programme, as well as for the characteristics of the programmes (size, composition) that governments adopt. We study all hypotheses simultaneously within one common framework, and with one dataset. Third, when defining fiscal episodes, we take the IMF (2010a) criticism seriously and focus on the evolution of *underlying* cyclically adjusted primary budget balances. The influence of one-off measures is excluded when we select fiscal episodes and test composition effects. Finally, our analysis allows to distinguish short-run effects of

fiscal adjustment policies on the debt to GDP ratio, i.e. effects during the adjustment period, from more persistent longer run effects.

The structure of this paper is as follows. In Section 2 we define 132 fiscal episodes in 21 OECD countries since 1981. Among these, 40 are classified as consolidation episodes, 29 as expansions. The others are 'neutral' periods. In Section 3 we review some of the existing hypotheses on the determinants of the success or failure of fiscal consolidation, in particular those where institutions are important, and we refer to the results of related empirical studies. In addition, we launch a new hypothesis on the role of public sector efficiency. In Section 4 we derive our empirical specification for the evolution of the ratio of public debt to GDP, and discuss our estimation methodology. Section 5 contains the results of our empirical work. We conclude our paper and summarize our main results in Section 6.

2. Fiscal episodes in the OECD, 1981-2008

The fiscal consolidation literature commonly determines consolidation and expansion periods using a criterion based on swings in the cyclically adjusted primary balance in percent of GDP (further *CAPB*). In a recent study, IMF (2010a) criticizes this method. Although the *CAPB* corrects for interest expenditures and business cycle fluctuations, it may sometimes give wrong signals about actual policy changes. Periods in which no specific consolidation measures were taken, were sometimes classified by researchers as consolidations. Also, periods with a deteriorating *CAPB* despite severe consolidation measures were sometimes not selected (IMF, 2010a). An important element is the influence of one-off budgetary measures. When one-off measures are taken, they may typically imply a temporary improvement of the reported *CAPB*, followed by a subsequent deterioration when their effect disappears. From the reported *CAPB*, one might erroneously conclude that a fiscal consolidation year was followed by an expansion year, whereas in reality there was no deliberate policy at all. A second problem is that traditional cyclical adjustment methods may sometimes suffer from measurement errors. They may for example fail to remove swings in tax revenue that are associated with (cyclically affected) asset price movements.

Instead of the *CAPB* as a selection variable for consolidation and expansion periods, we use the underlying cyclically adjusted primary balance in percent of potential GDP (*CAPBu*). The latter corrects the *CAPB* for one-off transactions and budgetary measures. *CAPBu* data are published by the OECD. Annual data are available since 1980. On the basis of these data, we then distinguish three kinds of fiscal episodes. Each episode is a period of flexible duration in which the *CAPBu* consistently moves in the same direction. Following Heylen and Everaert (2000), a consolidation period is a period of at least two consecutive years when the *CAPBu* improves by at least 2 percentage points. Besides the requirement that the *CAPBu* improves in each single year of the consolidation period, there should be an improvement by at least 0.25 percentage points in the first year of the consolidation period and at least 0.10 percentage points in the final year. With the latter conditions, we hope to exclude years of mere stabilization. Similarly, we define an expansion period as a period of at least two consecutive years when the *CAPBu* deteriorated by at least 2 percentage points. Periods that do

not fit our definition of expansion nor consolidation, are labeled 'neutral'. Applying these criteria to 21 OECD countries in 1981-2008 yields 40 consolidations, 29 expansions and 63 neutral periods. Table 1 shows the different consolidation and expansion periods and their changes in the *CAPBu*. We also display the associated change in the gross government debt to GDP ratio (*GD*) up to two years after the end of the period. We list all neutral periods in a companion working paper (see Heylen *et al*., 2011, their Table 1).

The definition of fiscal episodes is not uniform in the literature. Heylen and Everaert (2000), Guichard *et al*. (2007) and recently Alesina and Ardagna (2012) also define episodes of flexible duration. Most others, however, specify periods of a fixed number of one or two, and sometimes three, years during which the change of the *CAPB* exceeds a chosen number (e.g. Alesina and Perotti, 1995; Alesina and Ardagna, 1998; von Hagen *et al.*, 2002; Tavares, 2004; Larch and Turrini, 2011). An important advantage of our flexible duration approach is that it allows to study homogeneous episodes as well-defined cases. Each episode ends with a change in policy. Among the 40 consolidation episodes that we define, 37 are followed by 'neutral' policy. Clearly, this facilitates consistent estimation of policy effects. If one defines episodes as periods of for example one or two years, the next episode may be of a different kind, but it may also be of the same kind. It may then be more difficult to study longer run debt dynamics.

Furthermore, it is not common to use the *CAPBu* as a selection criterion to define fiscal episodes. To check if this variable is indeed more reliable than the *CAPB*, we have compared our selection of periods with the ones found by the IMF. The IMF (2010a) uses a narrative action-based approach to select fiscal adjustments. The authors emphasize five striking years which the commonly used *CAPB*-method incorrectly classifies as consolidations. Moreover, they point out five effective years of consolidation which are not classified as such. Nine of these ten years relate to 1981-2008[54]. We report the details from our comparison in Heylen *et al.* (2011). We conclude that with the exception of only one case (Finland 1992), the change in the *CAPBu* gives the same signal as the IMF narrative approach. The data that one obtains to evaluate policy using Δ*CAPBu* are in general much closer to the action-based indicator from the IMF than the data obtained when considering Δ*CAPB*.

[54] Incorrectly classified as severe consolidations according to the *CAPB*-method are Belgium 1984, Germany 1996, Japan 1999, Finland 2000 and Japan 2006. Incorrectly not classified as consolidations are Ireland 1982, Finland 1992, Finland 1993 and Italy 1993.

Table 1. Fiscal consolidation and expansion periods in the OECD: 1981-2008

Consolidation periods				**Expansion periods**			
Country	Period (t_s - t_f)	*ΔCAPBu*	*ΔGD*	**Country**	Period (t_s - t_f)	*ΔCAPBu*	*ΔGD*
Austria	1984-1985	2.32	13.5	**Austria**	1993-1995	-2.40	9.2
	1996-1997	3.88	1.4		1998-2000	-2.04	6.3
Belgium	1982-1987	9.47	35.1	**Belgium**	2002-2005	-2.19	-24.0
	1993-1994	2.77	-3.3	**Canada**	1982-1985	-2.65	24.5
	1996-1998	2.41	-21.7		2001-2003	-3.55	-10.5
Canada	1986-1988	3.71	8.3	**Denmark**	1989-1995	-3.94	7.5
	1993-1997	7.23	1.1	**Finland**	1982-1983	-3.30	4.4
Denmark	1983-1986	10.5	2.2		1985-1987	-3.51	-0.8
	1996-1999	2.45	-23.4		1990-1992	-6.41	44.3
	2003-2005	4.18	-24.1		2001-2004	-4.29	-6.9
Finland	1993-1996	4.40	16.6	**Hungary**	1997-1998	-2.55	-16.5
	1998-2000	6.46	-15.2		2001-2002	-5.04	4.2
France	1994-1999	3.63	13.2		2005-2006	-2.62	13.3
Germany	2003-2007	2.96	14.4	**Ireland**	2000-2002	-5.23	-18.9
Ireland	1982-1984	5.95	37.3	**Italy**	2000-2003	-4.37	-6.5
	1986-1989	6.25	-6.1	**Japan**	1992-1996	-5.68	50.0
	1992-1994	2.59	-21.0	**Netherlands**	1989-1990	-3.16	4.8
	2003-2004	2.05	-7.3		2001-2002	-3.04	-1.7
Italy	1982-1983	4.37	-2.3	**New Zealand**	1996-1999	-2.80	-18.3
	1990-1993	6.18	27.0	**Norway**	1987-1992	-7.68	-3.5
	1995-1997	3.19	5.5		2001-2003	-6.17	14.9
	2006-2007	2.27	7.8	**Portugal**	1989-1991	-2.72	0.6
Japan	1981-1985	3.72	29.7	**Spain**	1988-1991	-2.50	16.8
	2005-2008	3.01	32.9	**Sweden**	1990-1993	-6.92	30.6
Netherlands	1981-1983	3.11	28.9		2001-2003	-4.68	-4.4
	2004-2005	2.59	-9.9	**UK**	1990-1993	-5.42	15.6
New Zealand	1992-1994	3.86	-15.3		2001-2004	-5.55	0.9
Norway	1994-1995	5.40	-8.7	**USA**	1982-1986	-2.69	20.2
	2004-2007	6.39	-0.7		2001-2003	-5.95	6.9
Portugal	1982-1984	7.37	19.5				
	2006-2007	2.73	14.4				
Spain	1992-1997	5.25	19.8				
Sweden	1981-1984	4.12	22.8				
	1986-1987	3.09	-20.0				
	1996-2000	8.20	-20.8				
	2004-2005	2.26	-12.0				
UK	1981-1982	2.72	1.8				
	1994-1999	6.97	-8.3				
USA	1987-1989	2.00	9.0				
	1993-1998	4.59	-15.8				
Average		4.42	3.16	**Average**		-4.11	5.61

Note: *ΔCAPBu*: change in the underlying cyclically adjusted primary government balance in percent of potential GDP (change in percentage points between t_{s-1} and t_f); *ΔGD*: change in the gross public debt ratio in percent of GDP (change in percentage points between t_{s-1} and t_{f+2}). We indicate by t_s the first year of the consolidation period and by t_f the last year. Next to the 19 countries in this table, our dataset also includes Poland (1997-2008) and the Czech Republic (2000-2008). These two countries only yield 'neutral' fiscal episodes (see Heylen *et al.*, 2011).

Data sources: OECD (2010a) and European Commission, AMECO. See Appendix 2 for details.

The left part of Table 1 confirms a well-known fact. Even if during consolidation severe fiscal measures are taken, this does not guarantee a reduction of the public debt ratio. In about half of the 40 consolidation periods the debt ratio rises. Correlation between *ΔCAPBu* and *ΔGD* during all consolidation periods is surprisingly positive (0.14). Among the worst periods we find Ireland, 1982-84, Belgium, 1982-87 and Japan, 2005-08, with increases in the debt ratio of more than 30 percentage points. Table 1, however, also reveals many successful consolidation episodes, with debt ratio reductions by more than 20 percentage points (e.g. Denmark, 1996-99, 2003-05; Ireland, 1992-94 and Sweden, 1996-2000). Heylen and Everaert (2000) observed the same striking differences and pointed to economic growth during the consolidation period as much more important for the evolution of the public debt ratio than the size of the consolidation programme. We confirm their finding in our working paper. Correlation between the change of the output gap and *ΔGD* during the 40 consolidation periods in Table 1 is -0.47 (see Heylen *et al.*, 2011, Figure 1). Only in three consolidation periods we observe a falling public debt ratio in times of weak growth (Belgium, 1993-94; Ireland, 1992-94; Italy, 1982-83).

3. Consolidation, growth and the public debt ratio

The previous section has shown the absence of a clear relationship between the size of consolidation efforts and the change of the public debt ratio. It also indicated economic growth as crucial for the success of consolidation. These findings have inspired a huge amount of research into the determinants of the success or failure of fiscal consolidation programmes. Building on earlier work by Feldstein (1982) and Barro (1989), seminal contributions have been made by Giavazzi and Pagano (1990, 1996) and Alesina and Perotti (1995, 1996). Alesina and Perotti (1996), Alesina and Ardagna (1998) and Heylen and Everaert (2000) present early surveys of the literature. For recent discussions, we refer to IMF (2010a) and Larch and Turrini (2011).

The thread throughout this literature may be summarized as follows. Basically, tight fiscal policy programmes may have negative (Keynesian) effects on demand and economic growth, at least in the short run. As a result of these growth effects, consolidation efforts may have only a limited impact on the debt to GDP ratio, or no impact at all. Debt may be reduced, but so may GDP (see also IMF, 2010a, OECD, 2010b). Several authors, however, have argued that if the characteristics of the consolidation programme and the context within which it takes place are good, fiscal adjustment may also bring about favourable effects. Favourable expectation and/or credibility effects for example may raise private consumption and investment. If labour costs fall, competitiveness and net exports may improve. The net effect on growth may then even be positive. In this paper we take the well-known composition hypothesis as our starting point, and also control for the influence of the international macroeconomic environment and of any preceding devaluation. Our focus is on the influence of labour and product market institutions and institutional reform, and on the ideological orientation of the government. The literature has not come up with unambiguous answers concerning the effects of these institutions. As our main contribution, we also introduce a new hypothesis on the role of public sector efficiency when discussing composition.

3.1. Composition and the role of public sector efficiency

The importance of the composition of consolidation programmes has been emphasized in particular by Alesina and Perotti (1995, 1996). In their view, programmes that rely mainly on government consumption cuts (especially cuts in the wage bill) and social transfer cuts have a high probability of success, i.e. a high probability of safeguarding economic growth and reducing the debt ratio. Programmes that rely mainly on tax rises and government investment cuts, on the other hand, are expected to fail. Various explanations relating to both the demand side and the supply side of the economy may justify this hypothesis (see e.g. Alesina and Perotti, 1996; Alesina and Ardagna, 1998; IMF, 2010a). Empirically, it has received support from a lot of authors, e.g. McDermott and Wescott (1996), Perotti (1996), Alesina and Ardagna (1998, 2012), von Hagen *et al.* (2002), and Schaltegger and Feld (2009). Heylen and Everaert (2000) confirm the favourable effects from transfer cuts, and from *not* cutting public investment, but they do not find that fiscal consolidation is more successful when it mainly relies on public wage bill cuts. Tagkalakis (2009) and Larch and Turrini (2011) confirm the contribution to successful consolidation of social spending cuts via a reduction of the generosity of the unemployment benefit system, but they find no prominent role for government wage bill cuts in successful consolidation either.

Taking the ambiguity in the literature on the effects of government wage bill cuts as a starting point, we advance in this paper a new hypothesis emphasizing the role of public sector efficiency. It says that wage bill cuts may contribute to debt reduction if public sector efficiency is low, but that it will not contribute when public sector efficiency is high. In the latter case, downsizing the public sector may have negative effects on overall productivity and growth. Such negative effects may undermine competitiveness, and reduce asset prices and private agents' permanent income. Investment and consumption will then fall. Angelopoulos *et al.* (2008) provide evidence on growth that may support our hypothesis. They find that the relationship between the size of the public sector and economic growth depends critically on public sector efficiency. At low efficiency, a growing public sector reduces growth. At high efficiency they find the opposite. Furthermore, it will be our hypothesis that efficient public authorities are more successful in setting up and implementing consolidation programmes. There are two elements in this hypothesis. A first one is that the same consolidation programme will be more effective in bringing down the public debt ratio when it is adopted by a more efficient government apparatus. Private agents may then see the programme as more credible, and believe it to be more durable. A second element is that more efficient governments adopt better consolidation programmes when it comes to size and composition. Efficiency in collecting tax revenue may be one element to explain this. Also, tax compliance and acceptance of expenditure cuts may be higher when citizens have stronger appreciation for, and more confidence in governments that are more efficient.

3.2. Labour and product market institutions

The literature reveals various ways in which labour and product market institutions may matter for the outcome of fiscal consolidation. Both the existing level of institutions and possible changes in the context of labour or product market reform, may be important. However, the sign of the influence of these institutions is theoretically often ambiguous. Tagkalakis (2009) discusses most channels. He also illuminates the possible trade-offs that policy makers may face between reforming labour and/or product markets and initiating fiscal consolidation.

One of the reasons for tax based consolidations to fail is that they induce higher wage claims and labour costs. Theory suggests that this adverse effect will mainly occur in economies with powerful, but uncoordinated unions and uncoordinated wage setting. It will not occur in highly competitive labour markets, where unions may be too weak to claim higher wages, or in economies with strong but coordinated unions and coordinated wage bargaining (Calmfors and Driffill, 1988). In the case of coordination, unions internalize the negative aggregate effects from asking higher wages. They know that if they raise wage claims, wages will rise in large parts of the economy. This will create additional unemployment and new fiscal problems, such that in the end union members pay anyway. It is therefore better to accept the loss of purchasing power from the beginning. Ardagna (2004) finds evidence supporting this hypothesis. Along the same line of arguments, encompassing unions may also better see the long-run advantages of fiscal consolidation, and convince workers to accept the efforts needed. Tagkalakis (2009), however, also points to counter arguments. Strong and coordinated unions may undermine the success of fiscal consolidation when they use their power to organize opposition, or to push the composition of consolidation into the wrong direction. They may for example block off transfer cuts or cuts in the public wage bill. They may even cause higher expenditures, for example to compensate any losers of consolidation policies. Tagkalakis' evidence tends to support these counter arguments. He finds that weaker unions/weaker degrees of coordination raise the likelihood of successful consolidation. In their recent study Alesina and Ardagna (2012) cannot confirm either view on the influence of unions.

Similar ambiguity exists on the effects of (changes in) employment protection legislation and product market regulation. On the one hand, deregulated goods and labour markets may imply higher employment, higher firm entry, and higher productivity and growth. In deregulated markets, interest groups are typically also less powerful, implying less opposition to efficient fiscal consolidation. It would then follow that flexible markets and/or complementary deregulation and structural reform raise the chances for successful consolidation. On the other hand, deregulation and reform may also imply short-run disruptions, more firings, more need to compensate losers, and a loss of political negotiation capital for the government (Tagkalakis, 2009). Flexible markets and/or structural reform may then undermine the success of fiscal consolidation. The existing empirical evidence is mixed. When it comes to product market deregulation, Tagkalakis (2009) finds that it does not raise the likelihood of successful fiscal consolidation, Larch and Turrini (2011) and Alesina and Ardagna (2012) find that it does. For the labour market, Tagkalakis (2009) and Larch and Turrini (2011) agree in finding no positive contribution from a reduction of employment protection

legislation. Alesina and Ardagna (2012), by contrast, claim that labour market deregulation improves the outcome of fiscal consolidation. Their evidence is not strong however.

3.3. Political institutions: ideology

A large literature has studied the effects of political institutions. Some studies investigate effects on the likelihood that a fiscal adjustment programme is started, others concentrate on the chances that this programme is successful or fails (see e.g. Mierau *et al*., 2007, for a survey). Frequently studied institutions are the ideological orientation of the government and the degree of government fragmentation. Our attention in this paper goes out to the influence of ideology. For research on fragmentation, see e.g. Volkerink and de Haan (2001), Perotti and Kontopoulos (2002) and de Haan *et al.* (2012). Moreover, we focus on the outcome of consolidation efforts. Mierau *et al.* (2007) show that the decision to start a fiscal adjustment, is primarily driven by economic factors and hardly affected by political variables.

As to ideology, political parties from the left are traditionally associated with bigger government, higher (social) expenditures, and higher taxes, but not necessarily more unbalanced budgets. These preferences may explain why in periods of consolidation, governments from the left may find it more difficult to cut transfers and the public wage bill, and why they may prefer revenue based strategies and tax increases (Tavares, 2004). Given the importance of the precise composition of fiscal consolidation, the hypothesis may follow that left-wing policy makers have lower probabilities to bring down public debt rates if necessary. Right-wing governments would prefer spending cuts to reduce debts and deficits, which would raise their chances for successful consolidation. Alesina and Perotti (1995) tested this hypothesis, but could not find support for it. Ardagna (2004) even shows the opposite. According to her results, left-wing governments are more likely to implement fiscal stabilizations associated with a persistent reduction of the debt to GDP ratio. One possible explanation is that left-wing governments face less resistance to reform than right-wing ones. Unions for example may be more willing to offer their support to left-wing governments and allow them to cut government spending and/or increase tax rates.

4. Dynamics of the public debt ratio: empirical specification and method

In this section we first derive the basic specification underlying our empirical analysis. Next we discuss a number of extensions and our estimation methodology. We also give insight in our data.

4.1. Basic econometric specification

Our starting point is Equation (1), the well-known formula for the dynamics of the government debt ratio. In this equation, GD_t is the ratio of nominal gross government debt to nominal GDP at the end of year t, PB_t is the nominal primary balance in percent of nominal GDP in t, $r_{n,t}$ the nominal interest rate on outstanding government debt, $g_{n,t}$ the growth rate of nominal GDP, and SF_t the stock-flow

adjustment in percent of GDP. The latter captures the effect on the public debt ratio from the accumulation of financial assets for example, and remaining statistical adjustments.

$$\Delta GD_t = -PB_t + \frac{(r_{n,t}-g_{n,t})}{1+g_{n,t}} GD_{t-1} + SF_t \quad (1)$$

Equation (2) follows from (1) after splitting up the primary balance in three components. We have already defined $CAPBu_t$ as the underlying cyclically adjusted component. Furthermore, $CCPB_t$ is the cyclical component in percent of GDP, and $ONEOFF_t$ captures the effect on the primary balance of one-off budgetary measures. It is defined as net revenue. Y_t^*/Y_t is potential to actual nominal GDP.

$$\Delta GD_t = -CAPBu_t \frac{Y_t^*}{Y_t} - CCPB_t + \frac{(r_{n,t}-g_{n,t})}{(1+g_{n,t})} GD_{t-1} - ONEOFF_t \frac{Y_t^*}{Y_t} + SF_t \quad (2)$$

with: $PB_t = CAPBu_t \frac{Y_t^*}{Y_t} + CCPB_t + ONEOFF_t \frac{Y_t^*}{Y_t}$

Equation (2) shows the major influence of real economic growth as a driver of the change in the debt ratio, which we highlighted at the end of Section 2. This influence runs via two channels. First, for given inflation, higher real growth reduces the burden of inherited debt, $\left((r_{n,t} - g_{n,t})/(1 + g_{n,t})\right)GD_{t-1}$. Second, by raising tax receipts and reducing unemployment benefit expenditures, higher growth raises the cyclical component of the primary balance, *CCPB*. Both channels contribute to debt reduction ($\Delta GD<0$). The other main determinants of the change of the public debt ratio are the underlying cyclically adjusted primary balance ($CAPBu_t$) and the interest rate ($r_{n,t}$). Fiscal policy makers control the former. The latter will depend also on actions from monetary policy makers. Finally, Equations (1) and (2) show the influence of the historical fiscal situation as reflected by GD_{t-1}.

Starting from Equation (2), we impose three major rearrangements to derive the basic econometric specification that we estimate in Section 5. First, in our regressions, we will not include the cyclical component of the primary balance (*CCPB*), nor the domestic interest and growth rates (g_n, r_n). It is clear from the literature that the evolution of these variables is highly endogenous. They are affected by the precise characteristics of discretionary policy and by the context within which policy is executed. By not controlling for *CCPB*, g_n and r_n in the regressions, we allow the exogenous fiscal policy variables and context variables to pick up the endogenous effects that they bring about. Fiscal policy variables that we include are the *CAPBu* and *ONEOFF*. These policy variables are cyclically adjusted and expressed in percent of potential GDP. They typically result from decisions taken before the year *t*. As context variables we include international nominal growth and interest rates (*GROWTH*, *INTEREST*), and we control for the possible influence of a *preceding* devaluation (*DEVAL*) on domestic growth and interest rates. Later we also introduce other variables, like institutions, to test other hypotheses that we formulated in Section 3. A final element in Equation (2) concerns the effects on the gross public debt ratio from stock-flow adjustments. It will be harder to account for these. Most of them are small and will show up in the error term. An important exception, however, concerns stock-flow adjustments due to deliberate government support to the banking sector (capital injections) during financial crises (see IMF, 2010b, p. 14). To capture these we introduce

CRISIS dummies related to the recent financial crisis and to the banking crisis in Finland and Sweden in the early 1990s. Taking these arguments into account generates the following straight-forward empirical specification for the change in the government debt ratio in country *i* and year *t*.

$$\Delta GD_t = \alpha_i + \beta_1 CAPBu_{i,t} + \beta_3 BURDEN_{i,t} + \beta_4 ONEOFF_{i,t} + \beta_5 DEVAL_{i,t} + \beta_6 CRISIS_{i,t} + v_{i,t} \quad \text{(3a)}$$

with: $BURDEN_{i,t} = \frac{(INTEREST_t - GROWTH_t)}{1+GROWTH_t} GD_{i,t-1}$

$\beta_1, \beta_4, \beta_5 < 0$ and $\beta_3, \beta_6 > 0$.

In this equation β_1 captures the effect on the change of the debt ratio from the level of the government's (underlying cyclically adjusted primary) surplus. Our expectation from Equation (2) would be that β_1 is close to -1. It may differ from this value, however, when it picks up the above mentioned endogenous responses of domestic interest and growth rates (for given international interest and growth) to changes in the government's basic fiscal position. $BURDEN_{i,t}$ is a new variable. It captures the automatic 'snowball' component of debt dynamics, as well as the effect from (exogenous) international nominal growth and interest rates on their domestic counterparts. Finally, α_i is a country-specific fixed effect, and $\upsilon_{i,t}$ is the country and year specific error term. The fixed effect may for example capture the influence of variables that explain structurally higher or lower potential growth or interest rates in individual countries during the period under consideration[55].

As our second rearrangement we introduce richer dynamics. Equation (3b) allows for different short-run and equilibrium (or longer run) effects from discretionary policy changes on the change of the debt ratio.

$$\Delta GD_{i,t} = \alpha_i + \beta_1 CAPBu_{i,t-1} + \beta_2 \Delta CAPBu_{i,t} + \beta_3 BURDEN_{i,t} + \beta_4 ONEOFF_{i,t}$$
$$+\beta_5 DEVAL_{i,t} + \beta_6 CRISIS_{i,t} + v_{i,t} \quad \text{(3b)}$$

Fiscal consolidation efforts for example bring about a *temporary* $\Delta CAPBu > 0$ which may imply a *permanent* increase of the level of *CAPBu* and permanently better debt dynamics (more favourable ΔGD) in the subsequent periods. The coefficient β_1 measures this permanent (longer run) effect, whereas β_2 captures the temporary effect during the consolidation period. If short-run and equilibrium effects are the same, it would follow that $\beta_2 = \beta_1$, and we return to Equation (3a). The Keynesian view however would be that due to negative (positive) effects from fiscal consolidation policies (expansion policies) on domestic growth, β_2 would be smaller in absolute value. Non-keynesian effects, however, may raise β_2. According to the hypotheses reported in the previous sections, the composition of underlying tax and/or expenditure changes may play a key role here. As

[55] Note that we include no time dummies in Equation (3a). International growth and interest rates and the crisis dummies in the regression pick up the main time effects common to all countries.

a final remark on dynamics, note that even temporary effects on the change in the debt ratio (*ΔGD*) give rise to permanent effects on the level of *GD*.

Our third rearrangement is to move from the annual specification in (3b) to a multi-annual one in Equation (4). This rearrangement reflects the focus in this paper on the evolution of the public debt ratio during well-defined multi-annual fiscal episodes. Equation (4) follows from summing Equation (3b) over all years that are part of the same episode. In Appendix 1 we illustrate the derivation of Equation (4) for the case where a fiscal episode includes two years.

$$\Delta GD_{i,T} = \alpha_i DURATION_{i,T} + \beta_1 AvgCAPBu_{i,T}.DURATION_{i,T} + \beta_2 \Delta CAPBu_{i,T}$$
$$+\beta_3 BURDEN_{i,T}.DURATION_{i,T} + \beta_4 ONEOFF_{i,T} + \beta_5 DEVAL_{i,T} + \beta_6 CRISIS_{i,T} + v_{i,T} \qquad (4)$$

In this equation, $\Delta GD_{i,T}$ is the change in the ratio of public debt to GDP in country *i* during episode *T*, $AvgCAPBu_{i,T}$ is the average annual underlying cyclically adjusted primary balance in % of potential GDP during this episode, $DURATION_{i,T}$ indicates the length of the episode in years, and $\Delta CAPBu_{i,T}$ is the change in *CAPBu* during the episode[56]. $ONEOFF_{i,T}$ is the sum of all annual one-off measures over the fiscal episode *T*, $DEVAL_{i,T}$ indicates the size of a devaluation in the year before the episode, and $CRISIS_{i,T}$ again captures the effect of stock-flow adjustments during banking crisis in *T*. The analogy with Equation (3b) is clear. Whereas β_1 captures the permanent effects on debt dynamics from changing a country's basic financial position reflected by $AvgCAPBu_{i,T}$, β_2 measures the more temporary effect from deliberate policy actions ($\Delta CAPBu_{i,T}$). The data for $\Delta GD_{i,T}$ and $\Delta CAPBu_{i,T}$ are reported in Table 1. Remember that we calculate $\Delta GD_{i,T}$ over a period including two years after the end of the fiscal episode. Since many of the exogenous determinants of the evolution of the debt ratio operate via all kinds of effects on private agents' behaviour and growth (e.g. credibility effects, expectation effects), it may take some time for these effects to materialize. As a final variable in Equation (4), we computed $BURDEN_{i,T}$ from average international interest and growth rates during the episode *T* and from the level of a country's government debt ratio in the year before the start of the episode *T*. The latter we indicate as *GDINIT*. Algebraically,

$$BURDEN_{i,T} = \left(Avg \left(\frac{INTEREST_t - GROWTH_t}{1 + GROWTH_t} \right)_T \right).GDINIT_{i,T}$$

4.2. Extensions: composition, non-linearity, institutions

In our empirical analysis we extend Equation (4) in three ways. The first one allows to test for composition effects. It has been shown in many studies that the way in which governments change

[56] $\Delta GD_{i,T}$ is computed as the change in GD_i between t_{s-1} and t_{f+2}, where t_s is the first year of the episode and t_f the last one. $\Delta CAPBu_{i,T}$ is the total change in $CAPBu_i$ between t_{s-1} and t_f. Finally, $AvgCAPBu_{i,T}$ is an annual average computed over all years from t_{s-1} to t_{f-1}.

their *CAPBu* may matter for the effects of fiscal policy (see Section 3.1). We introduce this idea in our Equation (4) by substituting one of the following two decompositions for $\Delta CAPBu_{i,T}$:

$$\Delta CAPBu_{i,T} = \Delta INCu_{i,T} - \Delta NIEXPu_{i,T} + \Delta OTHERu_{i,T} \tag{5}$$

$$\Delta CAPBu_{i,T} = \Delta TAXB_{i,T} + \Delta TAXT_{i,T} - \Delta WAGE_{i,T} - \Delta NONWAGE_{i,T} - \Delta SOCEXP_{i,T} - \Delta SUBS_{i,T} - \Delta INV_{i,T} + \Delta OTHERu2_{i,T} \tag{6}$$

The same decompositions can be made for the level of $AvgCAPBu_{i,T}$. In (5) we make use of a rather general decomposition of $\Delta CAPBu$. This decomposition distinguishes changes in underlying current government revenues ($\Delta INCu$) and changes in underlying non-interest expenditures ($\Delta NIEXPu$). A very small rest category of changes in underlying 'other' net revenue closes the equation. One can think of net capital transfers received by the government. The median of the absolute value of $\Delta OTHERu$ over all countries and years in our dataset is less than 0.1% of GDP. Equation (6) is a much more detailed decomposition of $\Delta CAPBu$. At the revenue side, we distinguish changes in cyclically adjusted direct taxes on business (*TAXB*), and changes in the sum of cyclically adjusted direct taxes on households, indirect taxes, and social security contributions paid by workers and firms (*TAXT*)[57]. At the expenditure side, we decompose changes in non-interest expenditures into changes in government wage consumption (*WAGE*), government non-wage consumption (*NONWAGE*), social security benefits paid (*SOCEXP*), subsidies (*SUBS*) and investment in physical capital (*INV*). Again, a component $\Delta OTHERu2$ closes the equation. This component is larger than $\Delta OTHERu$. It includes changes in net capital transfers, property income, and other current expenditures (e.g. transfers outside social security). In Table 2 below we report all variables that will occur in our regressions, with their definition. All fiscal policy data are provided by the OECD, or computed from OECD data. They are adjusted for the cycle and for one-offs, and always expressed in percent of potential GDP.

By introducing Equations (5) and (6) for $\Delta CAPBu$ into Equation (4), and by consequently assigning separate coefficients β_{2j} to each component, we fully take into account the government budget identity in our estimations. Kneller *et al.* (1999) have demonstrated the importance of appropriately dealing with this identity in order to obtain unbiased estimates and a correct interpretation of the effects of changes in each revenue or expenditure component. Our approach implies that each of the estimated individual coefficients β_{2j} measures the effect of a change in the *CAPBu* on the government debt ratio if this change is brought about by one particular expenditure or revenue component, controlling for (keeping constant) all other components. The composition hypothesis claims that the coefficients β_{2j} may differ strongly. Even if each unit change in a revenue or expenditure variable brings about the same change in the *CAPBu*, its effect on the debt ratio may vary. Changes in different components of the government budget may affect the behaviour of

[57] In an earlier version of this paper we included each of the three subcomponents of *TAXT* separately. Empirically, however, we could never observe significant differences between their estimated coefficients. This conclusion also holds for the results that we present later in this paper (Table 4). We therefore decided to merge them.

households, firms, investors, etc. differently. Effects on growth may be different, and so may be effects on (the change of) the debt ratio.

A second extension of Equation (4) allows for different coefficients on the fiscal policy variables according to the episode to which they belong: years of neutral policy, consolidation or expansion. One reason for doing this is possible asymmetry in the response of households or firms to fiscal contraction versus expansion. For example, if forward-looking households face borrowing constraints, they may cut consumption more after a tax increase than raise consumption after a tax cut. Pozzi *et al.* (2004) report evidence supporting this hypothesis. The response in real demand and output to fiscal shocks would then be stronger during consolidation. The fall in the ratio of public debt to GDP during consolidation would then be smaller than its rise during expansion. Another factor which may have similar consequences is asymmetry in price or wage flexibility. If prices are more rigid downwards, real output effects during consolidation could again be stronger.

A third series of extensions of Equation (4) concerns the introduction of institutions and institutional reform as additional explanatory variables to test the other hypotheses that we advanced in Section 3. Table 2 defines also these additional variables.

4.3. Estimation method

In regression equations like Equation (3b), which use annual data, and where only cyclically adjusted policy variables, predetermined variables, and exogenous foreign variables show up as regressors, the least squares estimation methodology would seem a most reasonable choice. An unexpected domestic growth slowdown for example which would raise the debt to GDP ratio and show up in the error term is not expected to affect these regressors. We know from the literature, however, that the validity of this choice may be challenged. A first reason is imperfect cyclical adjustment of fiscal variables. IMF (2010a, p. 4) demonstrates how traditional methods may for example fail to remove swings in tax revenue that are associated with asset price or commodity price movements. If the latter coincide with the cycle, the traditionally computed *CAPB* may be positively correlated with growth shocks. A second reason is that fiscal policy makers may react to shocks in the public debt ratio (Blanchard and Perotti, 2002). Although Beetsma *et al.* (2008) test this assumption for public spending in the European Union, and find no reaction within the year, this does not exclude that there is a reaction in a multi-annual setting like ours in Equation (4). Even if governments cannot respond within the same year, it may be possible in periods lasting longer. For example, consolidating governments that are hit by an adverse shock to the debt ratio may adjust their earlier plans. They may change tax codes or spending rules to raise their *CAPBu*, or take *ONEOFF* policy measures, in order to reach the goals for the debt ratio that they may have set. The use of the *CAPBu* may make us somewhat less vulnerable to the first problem. Given also the second problem, however, the possibility of correlation between the error term and some of our explanatory variables cannot be excluded ex-ante. If serious, this would impose the use of IV methods. Considering this possibility, it was very important for us to test the endogeneity of $\Delta CAPBu_{i,T}$, $AvgCAPBu_{i,T}$ and $ONEOFF_{i,T}$. We used the Wu-Hausman test as described in Davidson and MacKinnon (1993, p. 237-

242). Since the reliability of this test depends crucially on having strong instruments for the potentially endogenous variables, we first define these instruments and demonstrate their strength.

Table 2. Description of variables

Policy variables	
GD	Gross public debt in % of GDP.
GDINIT	Gross public debt in % of GDP in the year before the start of a fiscal episode.
GDINIT2	Gross public debt in % of GDP two years before the start of a fiscal episode
CAPBu	Underlying cyclically adjusted primary balance, in % of potential GDP.
CAPBuINIT	Underlying cyclically adjusted primary balance in the year before the start of a fiscal episode.
CAPBuINIT2	Underlying cyclically adjusted primary balance two years before the start of a fiscal episode.
ONEOFF	One-off budgetary measures (net revenue), in % of potential GDP.
INCu	Underlying current receipts, in % of potential GDP.
NIEXPu	Underlying non-interest expenditures, in % of potential GDP.
TAXB	Cyclically adjusted direct taxes on business, in % of potential GDP (corporate tax).
TAXT	Sum of cyclically adjusted direct taxes on households, indirect taxes on production and imports, and social security contributions, in % of potential GDP.
WAGE	Government final wage consumption expenditures, in % of potential GDP.
NONWAGE	Government final non-wage consumption expenditures, in % of potential GDP.
INV	Government fixed capital formation, in % of potential GDP.
SUBS	Subsidies, in % of potential GDP.
SOCEXP	Social security benefits paid by general government, in % of potential GDP.
OTHERu(u2)	Underlying other net revenue, in % of potential GDP.
DURATION	Number of years of the fiscal episode.
DEVAL	Official nominal devaluation in % in the year before the start of a fiscal episode
International macro-context	
INTEREST	'International' nominal short term interest rate, in % [(a)]
GROWTH	'International' nominal GDP growth rate, in % [(a)]
BURDEN	See main text.
CRISIS08	Dummy variable taking the value 1 in all fiscal episodes including the years 2006, 2007 or 2008 ($\Delta GD_{i,T}$ computed for these episodes includes 2008).
CRISIS91sf	Dummy variable taking the value 1 in fiscal episodes in Sweden and Finland covering 1991-92.
Institutions	
EPL	Overall strictness of employment protection. Scale from 0 (least) to 6 (most restrictive).
UNION	Trade union density, in %.
COOR	Index from 1 to 5 rising in the degree of wage bargaining coordination.
PMR	Index for product market regulation. Varies from 0 (least) to 6 (most regulated).
LEFT	Dummy variable taking the value 1 if the government is left-wing and 0 otherwise.
PSEAdm	Index of government efficiency in administration. Varies in the data from about 0.5 (least efficient) to about 5 (most efficient).
PSEAvg	Index of overall government efficiency in administration, education, infrastructure and stabilization. Varies in the data from about 0.7 to about 4.

Notes: For a detailed description of all variables, and our data sources, see Appendix 2.

(a) For all European countries except the UK, *INTEREST* and *GROWTH* are the (weighted) average short-term nominal interest rate and the average nominal GDP growth rate among 21 European OECD countries. For Canada we use interest and growth data from the US. For the US we use average data for Canada, Europe, and Japan. Finally, for Japan, New Zealand and the UK, we take the average of the data for Europe and the US.

For $AvgCAPBu_{i,T}.DURATION_{i,T}$ and $\Delta CAPBu_{i,T}$ in Equation (4) we define instruments that reflect the fiscal situation before the start of the episode. A first instrument that we use for both these potentially endogenous variables is the *CAPBu* one year before the start of the episode. We call this variable *CAPBuINIT*. As a second instrument for $AvgCAPBu_{i,T}.DURATION_{i,T}$ we specify the *CAPBu* two years before the start of the episode (*CAPBuINIT2*). For $\Delta CAPBu_{i,T}$ we define the public debt ratio two years before the start of the episode (*GDINIT2*) as our second instrument. The explanatory power of these variables for fiscal policy in later years has been shown before in the literature. Mierau *et al.* (2007) and Tagkalakis (2009) for example show a highly significant effect from a weak fiscal position on the likelihood of future fiscal adjustment in a panel of OECD countries. Moreover, since *CAPBuINIT* and *CAPBuINIT2* will have been decided by policy makers at least one or two years before the episode *T*, they are predetermined with respect to Equation (4). Also *GDINIT2* is a predetermined variable. This makes them valid instruments provided that there is no autocorrelation in the error term υ[58]. As instruments for $ONEOFF_{i,T}$ we define three dummy variables. A first dummy is also predetermined. It is 1 if the beginning of a fiscal episode is preceded by a change of the government and the government's ideological orientation. Typically, these are occasions where political parties from either left or right take power after years of opposition. It can be expected that they come with a coherent new vision and programme. Moreover, such governments are more likely to enjoy the political capital and window of opportunity brought by change (Haggard and Webb, 1994; Mierau *et al*., 2007). It is our hypothesis that they rely less on one-off revenues. The remaining two dummies capture specific policy actions in two countries which are unrelated to shocks in domestic growth and the debt ratio. Such well-observable cases are particularly helpful to identify the effects of one-off measures on the public debt ratio. The first of these dummies is 1 for Finland in 1995 when the government had to compensate farmers for falling agricultural prices after joining the European Union (OECD, 1995). The second dummy is 1 for Japan in 1998 when the government made a one-time capital transfer to the Japan National Railway (IMF, 2010a, p. 27). As a final remark, we mention that the six instruments that we define do not themselves belong in Equation (4). Tests show that they do not matter for the change in the debt ratio beyond their influence on $\Delta CAPBu_{i,T}$, $AvgCAPBu_{i,T}$ and $ONEOFF_{i,T}$.

To assess the instruments' explanatory power in our sample of fiscal episodes we first ran simple regressions of $\Delta CAPBu_{i,T}$ and $AvgCAPBu_{i,T}.DURATION_{i,T}$ on a constant and their two instruments and of $ONEOFF_{i,T}$ on a constant and its three instruments. We obtained R^2 statistics of 0.38, 0.65 and 0.26 respectively. All instruments have the expected sign and are significant at the 2% level in these regressions. Then, for each of the three potentially endogenous variables, we executed Wald tests on the significance of their instruments in the so-called first stage regression, i.e. a regression of the potentially endogenous variable on all exogenous variables in Equation (4) and on all six instruments. These Wald tests yield F-statistics far above Staiger and Stock's (1997) rule of

[58] A direct test of autocorrelation is not possible in our setup since this delivers no series of residuals at annual frequency. The evidence that we obtain from overidentifying restrictions tests, however, is consistent with the hypothesis that this condition is satisfied (see footnote 6).

thumb value of 10. More precisely, we obtain values of 19.9, 31.5 and 82.8 in the first stage regressions for $\Delta CAPBu_{i,T}$, $AvgCAPBu_{i,T}.DURATION_{i,T}$ and $ONEOFF_{i,T}$ respectively.

Having defined instruments with good explanatory power finally allowed us to reliably execute the Wu-Hausman test. Augmenting our basic specification (Equation 4) with the three residual series from the first stage regressions for $\Delta CAPBu_{i,T}$, $AvgCAPBu_{i,T}.DURATION_{i,T}$ and $ONEOFF_{i,T}$ and re-estimating with the least squares method, resulted in highly insignificant coefficients for these residual series. A Wald test could not reject their joint insignificance (*p*-value 0.58). We can as a result not reject the null that our regressors in Equation (4) are exogenous and least squares estimates are consistent[59]. Given also its efficiency, we use this method. Details on all above mentioned tests are available upon request.

5. Empirical analysis

In this section we present the results of an empirical analysis of the evolution of the public debt to GDP ratio in 132 fiscal episodes in 21 OECD countries in 1981-2010. Section 5.1. concentrates on the effects of fiscal policies as obtained from estimating Equation (4) or extended versions of this equation. Extensions allow for different effects from the various subcomponents of the cyclically adjusted primary balance according to Equations (5) or (6), and for different effects from fiscal variables in consolidation, expansion or neutral episodes. In our discussion we will mainly focus on effects during consolidation. In Section 5.2. we investigate the role of institutions and institutional change. To assess the statistical significance of our estimates we report White heteroscedasticity-consistent standard errors. The reason is that we focus on multiple fiscal episodes in each country, which implies that error terms are bound to be dependent over observations[60].

5.1. Basic results

Column (1) in Table 3 contains the results from estimating Equation (4). All variables have the expected sign. With the exception of *ONEOFF,* they are all highly significant. The coefficients on $\Delta CAPBu$ and *BURDEN* are not significantly different from 1 in absolute value. For *BURDEN* this is in line with expectations that one would derive from Equation (2), even if now international growth and interest rates are involved. Note that the strong significance of *BURDEN* in our regressions confirms

[59] With more instruments than potentially endogenous variables, 2SLS estimation allows a test of overidentifying restrictions. Estimating for example Eq. (4) by 2SLS, using our set of six instruments, yields a *p*-value of 0.24 for this test. The null hypothesis that we defined valid instruments for the Wu-Hausman test cannot be rejected.

[60] Ideally, one applies standard errors that are clustered on the country level. In practice, however, this is not advisable in our setup with 21 countries. As described by Angrist and Pischke (2009, p. 310-320), when the number of clusters is small (less than 42), clustering biases estimated standard errors downward. Moreover, the Bell and McCaffrey adjustment to reduce this bias proves unfeasible technically in our case. Angrist and Pischke (their footnote 17, p. 320) mention this problem when regressors are dummy variables that are 1 for one of the clusters and 0 otherwise. Our crisis dummy *CRISIS91sf* comes very close to this example.

the importance of international growth and interest rates for each country's debt evolution, most so for high debt countries. For ∆*CAPBu* the outcome is as expected if over the fiscal episode the effect of discretionary policy on output and growth is about neutral. The inherited fiscal balance as reflected by the level of *AvgCAPBu*, however, obtains a coefficient which is clearly larger than 1 in absolute value. In line with arguments raised in Section 4.1., having a better fiscal position seems to matter for *∆GD* not only by the mere fact of having to borrow less, as in the first term of Equation (2). It may also bring about favourable endogenous domestic interest and/or growth rate effects, affecting the 'snowball' mechanism. Moreover, the fact that *∆GD* has been computed over a period up to two years after the fiscal episode may enlarge the induced cumulative effects on interest payments. For *ONEOFF*, by contrast, we find no significant effect. One may imagine that negative credibility or expectation effects on private sector behaviour and/or financial markets explain (part of) this result. As to the other explanatory variables, our results confirm that a preceding devaluation may contribute significantly to a reduction of the public debt ratio. Finally, the *CRISIS* dummies capture direct stock-flow adjustments of more than 10 percentage points on the debt to GDP ratio in all countries during the 2008 financial crisis, and even more than 20 percentage points in Sweden and Finland during their banking crisis in the early 1990s.

Table 3. Estimation results – 1

	ΔGD			
Explanatory variables	(1)	se	(2)	se
Constant	3.23	2.15	2.34	2.04
AvgCAPBu*DURATION	-1.42***	0.16	-1.42***	0.16
BURDEN*DURATION	1.11***	0.22	1.16***	0.22
ΔCAPBu	-1.06***	0.30	-	
ONEOFF	-1.12	0.88	-1.25	0.88
CRISIS08	10.8***	2.22	11.2***	2.19
CRISIS91sf	25.4***	6.08	19.8***	6.49
DEVAL	-2.28***	0.41	-2.68***	0.46
Consolidation				
ΔCAPBu	-		-0.38	0.43
Expansion				
ΔCAPBu	-		-2.41***	0.47
Neutral				
ΔCAPBu	-		0.51	1.23
R-squared	0.77		0.79	
Adjusted R-squared	0.71		0.73	
Country fixed effects (times DURATION)	yes		yes	
Number of obs. (countries)	132(21)		132(21)	

Notes: 'se' indicates White heteroscedasticity-consistent standard errors;
*** (**) (*) indicates statistical significance at the 1% (5%) (10%) level. For a definition of all variables, see Table 2. *AvgCAPBu* indicates the average level of *CAPBu* during the fiscal episode (see our discussion of Equation 4, footnote 3).

In column (2) we allow the coefficient on ∆*CAPBu* to differ during fiscal consolidation episodes, expansion episodes and neutral periods. Differences are remarkable. Effects of discretionary action

on the debt ratio are much smaller during consolidation than in expansion. Our regression results do not provide a sharp explanation for this finding, but it clearly seems that domestic output (and therefore the denominator in the debt ratio) responds much more to policy in consolidation than in expansion, for example due to asymmetry in private sector behaviour. In line with the evidence of Pozzi *et al.* (2004) that we referred to at the end of Section 4.2., households may cut consumption after tax increases, but not raise it after tax cuts. Also, they may not raise consumption after public expenditure cuts, but reduce it after public expenditure increases. These asymmetries notwithstanding, it is clear that permanent consolidation efforts imply a better future *CAPBu* level. The effect of consolidation efforts may be small and insignificant during the consolidation episode (as revealed by the coefficient on Δ*CAPBu*). By permanently improving (future) *AvgCAPBu*, however, they will permanently facilitate debt reduction. The other estimation results in column (2) are hardly affected by allowing for different coefficients on Δ*CAPBu*.

Note that we also allowed different coefficients on *AvgCAPBu.DURATION* in the three regimes, but this did not yield anything significant. The *p*-value on a Wald test that all three coefficients are the same, is 0.79. Throughout all regressions that we report in this paper, it is a robust result that there are no significant differences in the estimated coefficients on fiscal 'level' variables (β_1). Neither do we observe significantly different effects on *BURDEN.DURATION* in consolidation, expansion or neutral periods.

Table 4 allows for different effects from the various (cyclically adjusted) revenue and expenditure components behind the government balance. Column (3) introduces the basic decomposition of Δ*CAPBu* in changes in underlying non-interest expenditures Δ*NIEXPu* and current receipts Δ*INCu*. At the top of the table we decompose *AvgCAPBu.DURATION* accordingly, and as such allow for possibly different permanent effects of taxes and expenditures on debt dynamics, i.e. effects on Δ*GD* which persist even after the end of a consolidation or expansion episode. Our main results for the consolidation episodes are the following. First, fiscal adjustment efforts have only limited effects on the government debt ratio during the episode itself, which confirms our findings in Table 3. Column (3) reveals a negative coefficient on Δ*INCu* during consolidation. The most likely effect from raising taxes on the public debt to GDP ratio during the consolidation period is therefore negative. However, this effect is small and not significantly different from zero. Things are even worse at the expenditure side, where the estimated coefficient on Δ*NIEXPu* is even less significant. It also obtains an unexpected negative sign. As a group, expenditure cuts seem ineffective in bringing down the debt ratio, at least during the consolidation period. Stronger impact effects on output, as one typically finds in multiplier studies (e.g. Blanchard and Perotti, 2002), may explain the lower effectiveness at the expenditure side. Another explanation may be that *NIEXPu* pools various expenditure components, with possibly opposite effects on the debt ratio (e.g. public investment versus social transfers). Although these observations may raise doubt about the composition hypothesis, it would be too fast to draw this negative conclusion. Maybe more important, and in line with the composition hypothesis, are our results in the upper part of column (3). When we also decompose the level of *AvgCAPBu*, we observe significant positive effects from *AvgNIEXPu* and significant

negative effects from *AvgINCu* with the former being much larger in absolute value. Permanent improvements of the *CAPBu* will have stronger favourable effects on future debt dynamics if these permanent improvements are realized by means of expenditure cuts rather than tax increases. Although, as such, this finding confirms the composition hypothesis that consolidation policies are more effective when they operate at the expenditure side, it can clearly not be concluded that tax policies are ineffective.

Columns (4)-(6) investigate the composition hypothesis in greater detail. These columns introduce for each policy regime the decomposition of *ΔCAPBu* that we put forward in Equation (6). The level of *AvgCAPBu* at the top of the table, however, is still decomposed in its two major categories *INCu* and *NIEXPu* (and *OTHERu*) as in column (3). A Wald test cannot reject the null hypothesis that at this level all expenditure subcategories have the same coefficient and all income subcategories have the same coefficient. The upper part of columns (4)-(6) confirms that permanent improvements of the *CAPBu*, realized either by expenditure cuts or by tax increases, do have favourable effects on future debt dynamics, but the effects from permanent expenditure cuts are stronger. During the consolidation period, however, it is more difficult to observe strong effects, at least at first inspection. Straightforward estimation in column (4) yields mainly insignificant coefficients, often with an unexpected sign. At the revenue side, the only significant and robust result is the favourable (negative) effect on the public debt ratio from raising direct taxes on business (*ΔTAXB*). Although this result goes against the composition hypothesis, Alesina and Perotti (1995) also observed it. So did Heylen and Everaert (2000). At the expenditure side during consolidation periods, the only significant result in column (4) is the negative coefficient on *ΔWAGE.* Again, this is surprising from the perspective of the composition hypothesis. However, as we documented in Section 3.1., similar results for *ΔWAGE* were found earlier by Heylen and Everaert (2000) and Tagkalakis (2009). The estimated negative effect on *ΔINV* during consolidation is much more in line with the composition hypothesis. In column (4) this effect is still insignificant, however. Just like in Table 3, these policy effects are again larger than those during consolidations. As to the other variables in column (3), we observe some changes of limited importance compared to our findings in Table 3. The main difference is that now *ONEOFF* becomes statistically significant, whereas the early 1990s crisis dummy in Sweden and Finland (*CRISIS91sf*) loses significance. Both crisis dummies become smaller. In expansionary episodes all policy effects have the expected sign, and are highly significant.

Table 4. Estimation results – 2 – composition

	ΔGD							
Explanatory variables	(3)	se	(4)	se	(5)	se	(6) [(b)]	se
Constant	3.37°	2.1	2.27	2.5	4.57°	3.0	5.36°	3.2
AvgINCu*DURATION	-1.18***	0.2	-0.97***	0.2	-0.90***	0.3	-	0.3
AvgNIEXPu*DURATION	1.46***	0.2	1.12***	0.2	1.09***	0.3	1.21**	0.3
AvgOTHERu*DURATION	-0.68	0.6	-0.44	0.6	-0.37	0.9	0.26	1.3
BURDEN*DURATION	1.30***	0.3	1.10***	0.2	1.12***	0.4	1.08**	0.5
ONEOFF	-2.48***	0.9	-2.31***	0.9	-2.03**	1.0	-2.32*	1.3
CRISIS08	8.50***	2.4	12.7***	2.5	17.3***	3.2	15.0**	4.3
CRISIS91sf	3.15	6.1	14.0*	7.7	9.53	7.3	16.7**	7.5
DEVAL	-2.03***	0.7	-1.62***	0.6	-2.30	2.0	-0.33	2.1
Consolidation								
ΔINCu	-0.51	0.8	-		-		-	
ΔTAXB	-		-7.87***	2.2	-4.54**	2.0	-4.40	3.1
ΔTAXT	-		-0.28	1.2	1.31	1.5	1.09	1.7
ΔNIEXPu	-0.20	0.6	-		-		-	
ΔSOCEXP	-		1.88	2.1	0.20	2.0	0.49	2.6
ΔSUBS	-		1.86	3.6	7.86***	2.8	11.0**	3.5
ΔINV	-		-3.90	2.9	-8.09***	2.5	-	3.7
ΔWAGE	-		-4.28*	2.4	6.56°	4.3	13.2**	6.6
ΔNONWAGE	-		-2.68	3.0	-25.3***	7.1	-29.2**	13.5
ΔOTHERu2	-		4.91**	2.3	6.07***	2.3	6.14**	2.9
ΔOTHERu	-11.1***	2.8	-		-		-	
PSEAdm*DURATON	-		-		-3.15**	1.3	-	1.4
PSEAdm*DURATION*ΔWAGE	-		-		-2.17***	0.6	-	0.9
PSEAdm*DURATION*ΔNONWAGE	-		-		4.16***	1.0	4.91**	2.1
Expansion								
ΔINCu	-2.39***	0.8	-		-		-	
ΔTAXB	-		-5.55**	2.4	-5.47**	2.3	-4.84*	2.8
ΔTAXT	-		0.85	1.4	-0.23	1.3	-0.06	1.5
ΔNIEXPu	3.08***	0.6	-		-		-	
ΔSOCEXP	-		3.46**	1.7	3.73**	1.7	2.43	1.9
ΔSUBS	-		11.9*	6.2	16.1***	4.6	15.6**	5.3
ΔINV	-		2.09	3.3	-2.0	3.6	-3.80	4.3
ΔWAGE	-		2.95	2.3	7.84*	4.1	7.19*	4.2
ΔNONWAGE	-		2.87	2.7	-5.75*	3.2	0.69	6.8
ΔOTHERu2	-		-1.77	3.2	-0.52	3.3	1.46	3.7
ΔOTHERu	-14.8***	5.0	-		-		-	
PSEAdm*DURATON	-		-		-2.06°	1.4	-2.40°	1.6
PSEAdm*DURATION*ΔWAGE	-		-		-0.29	1.0	-0.31	1.0
PSEAdm*DURATION*ΔNONWAGE	-		-		1.66***	0.6	-0.28	1.6
Neutral [(a)]								
Adjusted R-squared	0.76		0.79		0.84		0.79	
Country fixed effects (times DURATION)	yes		yes		yes		yes	
Number of obs. (countries)	132(21)		132(21)		118(19)		107(17)	

Notes: 'se' indicates heteroscedasticity-consistent (White) standard errors; *** (**) (*)(°) indicates statistical significance at the 1% (5%) (10%)(15%) level. For a definition of all variables, see Table 2.

(a) The results for the neutral periods are available upon request. Coefficients are generally insignificant.

(b) The sample here excludes all observations where WAGE<9.2% on average during the fiscal episode (9.2% is the 10th percentile value of WAGE over all observations).

In columns (5) and (6) we introduce a new hypothesis, which brings a much more nuanced picture, and significant estimates for most fiscal policy variables. More precisely, we control in these columns for the level of public sector efficiency in administration (*PSEadm*)[61]. Our main finding is that cutting the public sector wage bill contributes directly to debt reduction only when public sector efficiency in administration is low. Evaluated at the median duration of consolidation periods (3 years), and at median *PSEAdm* (=1.69), we observe in column (6) a coefficient on *ΔWAGE* which is about zero. A positive coefficient on *ΔWAGE* emerges only at lower levels of *PSEadm*[62]. Conversely, when government efficiency is high, downsizing the public sector is not an effective way to bring down the public debt ratio. In this respect, our results are consistent with those of Angelopoulos *et al.* (2008) on growth. Extending the regression as in columns (5) and (6) also affects our estimates for the other fiscal variables. We now obtain significant positive effects on changes in subsidies (*ΔSUBS*) during consolidation, and significant negative effects on changes in public investment (*ΔINV)* and changes in nonwage consumption (*ΔNONWAGE*). The latter effect holds at low levels of public sector efficiency and median duration of consolidation periods. The coefficient on changes in social expenditures remains insignificant.

We conclude from Table 4 that permanent expenditure cuts and permanent tax increases contribute significantly to debt reduction in the longer run, with the effects of the former being stronger. In the short-run, by contrast, the effect of tax increases as a group (*ΔINCu*) may be better than the effect of expenditure cuts (*ΔNIEXPu*), but not much is significant here. We learn that the precise composition of expenditure cuts is very important, probably more important than the composition of taxes. Our results are in favour of cuts in subsidies and (when government efficiency is low) the public sector wage bill. Social benefit cuts may not have much effect during the consolidation period, but only matter in the longer run (by decreasing *AvgNIEXPu*). Reducing expenditures by means of public investment cuts, by contrast, is highly counterproductive when the aim is to bring down the public debt ratio. Overall, our evidence is broadly in line with the composition hypothesis, except when it comes to the effect of changes in government consumption and the government wage bill. Here, our results shed new light. Emphasizing the role of public sector efficiency, they may provide a way out of the existing ambiguity in the literature (see Section 3.1.).

5.2. The role of institutions

The literature shows a lot of ambiguity on the effects of institutions or institutional reform on the success of fiscal consolidation policies (see Sections 3.2. and 3.3.). In this section we study the possible role of institutions during consolidation from two major perspectives. The first perspective

[61] The difference between both columns is the included sample. Column (6) excludes observations where the size of the public sector wage bill is very low (below 9.2% of GDP, which is the 10th percentile). These are most likely the observations where *ΔWAGE<0* is not an option.

[62] Algebraically, and evaluated at *DURATION*=3, it is to see that $\frac{\partial(\Delta GD)}{\Delta(\Delta WAGE)} = 13.2 - 2.65.PSEAdm.DURATION$ is positive as soon as *PSEAdm*<1.66.

takes fiscal policies (in particular, consolidation policies) as given. One important question that we ask here is whether the influence of given consolidation policies on the public debt ratio is different depending on existing institutions. As an example, one may want to know whether the effect of a given consolidation effort on the debt ratio is stronger when labour markets are flexible rather than rigid, or when government efficiency is high rather than low. A second question is whether the effects of given consolidation policies are different when they are executed simultaneously with institutional reform. Given growing pressure on governments in many countries, mainly in Europe, to reform labour and product markets, one may want to know for example whether consolidation policies have more or less effect when at the same time employment protection legislation or product market regulation are reduced. The second perspective does not consider fiscal policies as given. Instead, we take into account the possibility that the institutions in a country affect the kind of consolidation policies adopted, for example their size or composition. An obvious example is that the ideology of the government or union power may affect the fraction of tax increases versus spending cuts to reduce the public deficit.

We test the role of institutions for given fiscal policies (first perspective) by adding institutional variables to the regression equation reported in Table 4, column (4). To begin, we extend this equation by $\sum_{R=c,e,n}\sum_j \gamma_{jR}\ INST_{jiT}.DURATION_{iT}$, where $INST_{jiT}$ indicates the level of institution *j* in country *i* during fiscal episode *T*. Included institutions are defined in Table 2. We add several institutional variables to the regression together. So, unlike what is done in the recent literature (e.g. Larch and Turrini, 2011; Alesina and Ardagna, 2012), we study the effect of each institution while controlling for others. We multiply by the length of the episode (*DURATION*) since the total contribution of an institution to the change of the debt ratio in a particular episode may obviously depend on the length of that episode. Later we further extend the regression by also adding changes in institutions ($\Delta INST_{jiT}.DURATION_{iT}$), in particular changes in employment protection legislation and changes in product market regulation[63]. Finally, like in the previous section, we again allow for different effects γ_j across policy regimes *R*, where *R* stands for consolidation (*c*), expansion (*e*) or neutral (*n*). The results that we show in Table 5 are the estimated coefficients for consolidation periods (γ_{jc})[64,65].

The effects of institutions or institutional change when we do not control for the characteristics of fiscal policy (second perspective) are reported in Table 6. In this table we do not include revenue or expenditure variables *(AvgNIEXPu, AvgINCu, ONEOFF, ΔTAXB*, *ΔTAXT*, etc.) in the

[63] As a rule, changes are computed as the level of the institution at the end of the fiscal episode minus the level in the last one or two years before the episode (see Appendix 2).

[64] Estimates for expansion and neutral periods are available upon request.

[65] For an assessment not only of the statistical significance, but also the economic importance of estimated effects, it is good to know the standard deviation of each institution. Computed over all countries and years they are as follows: *EPL* 1.03, *UNION* 21.5, *COOR* 1.45, *PMR* 1.45, *LEFT* 0.44, *PSEAdm* 0.93 and *PSEAvg* 0.50. Multiplication with the estimated coefficient γ_{jc} indicates the expected effect on the public debt ratio per year of consolidation when the level of the institution concerned is one standard deviation higher.

regression. Next to the institutional variables, the regressions underlying these results include only the level of *CAPBu* in the last year before the start of the fiscal episode (*CAPBuINIT*, times *DURATION*), *BURDEN* (times *DURATION*), *DEVAL*, the crisis dummies, and country-specific fixed effects (times *DURATION*). Note that with the exception of columns (8) and (9), the set of included institutions in each column of Table 6 is exactly the same as in Table 5. Differences in estimated coefficients may give an indication of the influence of these institutions on the evolution of the public debt ratio running via their effect on the characteristics of consolidation programmes.

Columns (1) to (3) in both tables include only levels of labour and product market institutions and a dummy variable *LEFT* which is 1 when the government is left-wing. In columns (4) and (5) we add government efficiency, in columns (6) and (7) institutional change. Columns (8) and (9) include all variables that show at least some significance in earlier columns. Our results demonstrate that institutions and institutional change matter for the evolution of the public debt ratio in consolidation periods. They matter from the two perspectives described above. Both the outcome of given consolidation policies and the kind of consolidation policies adopted, seem to be affected when the institutional environment is different. Not all institutions have an equally strong influence, however. The evidence is the least convincing when it comes to the effects of existing labour and product market institutions. The tendency of our results in Table 5 would be that the evolution of public debt during consolidation is less favourable in unionized and rigid labour markets and in more regulated product markets. *EPL*, *UNION* and *PMR* all get positive coefficients in Table 5. In general, however, they are not statistically significant, or only marginally significant at the 10% or 15% level. Moreover, taking into account the possible endogenous effect on adopted policies in Table 6, estimated coefficients are even less significant. This is the case especially for *EPL*. Its estimated coefficient in Table 6 also falls back to much less than one half of its value in Table 5. It seems that conflicting forces, as one can observe in the literature (see Tagkalakis, 2009), counteract each other. The only labour market institution for which we find a slightly more robust indication of significance in Tables 5 and 6, is the degree of wage bargaining coordination (*COOR*). Considering its negative coefficient, and with most of the effects already occurring in Table 5, we may conclude that a high degree of coordination has a favourable influence, mainly by improving the outcome of given consolidation policies. Internalization by key players of the long-run advantages of these policies (as well as the long-run costs of opposition to these policies) may be one element to explain this result.

In contrast to the level of labour and product market institutions, simultaneous institutional reform may have more effect on the outcome of fiscal consolidation episodes. Our evidence is strongly in favour of the hypothesis that complementary product market deregulation ($\Delta PMR<0$) contributes to the success of fiscal consolidation. Product market deregulation may strengthen the positive effects of given consolidation policies, for example by simultaneously enhancing competition, overall productivity and growth, as in Wölfl *et al.* (2010). Moreover, observing even stronger and more significant effects in Table 6, we conclude that deregulation may also improve the outcome of consolidation episodes by contributing to better adjustment policies, for example by reducing the power of special interest groups. Our results for the effects of labour market reform are

interesting from a different point of view. What is striking is the change of sign on *ΔEPL* from positive in Table 5 to negative in Table 6. Once we no longer control for the characteristics of consolidation policies, it seems that parallel labour market deregulation undermines the success of fiscal consolidation. Adverse consequences for the government's financial balance when firms find it easier to fire workers when (at least in the short run) demand for their product falls, may offer an explanation. So may negative effects on private consumption from increased uncertainty. Our evidence on this issue agrees with Bouis et al. (2012) when they find that deregulation of job protection pays off more quickly in good times but can entail short-term losses in depressed economies.

Table 5. Effect of institutions / institutional change on the public debt ratio during consolidation periods when we take fiscal policy as given

	Estimated effect of institutions or institutional change on *ΔGD* per year of consolidation (γ_{jc})								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
EPL	1.70*	1.68*	1.51°	1.76°	2.45**	1.05	1.12	1.45	2.02
UNION	0.04	0.04	-	-	-	-0.02	-0.01	-	-
COOR	-0.68	-	-0.89	-1.49**	-1.79**	-0.94	-0.78	-1.42*	-1.58*
PMR	0.35	0.13	0.52	0.85°	0.78	0.57	0.42	0.65	0.54
LEFT	-2.61**	-2.69***	-2.70***	-1.10	-0.89	-	-2.15*	-0.68	-0.62
PSEAdm	-	-	-	-3.30**	-	-	-	-2.70°	-
PSEAvg	-	-	-	-	-6.60*	-	-	-	-4.84
ΔEPL	-	-	-	-	-	1.87	0.95	1.94	1.92
ΔPMR	-	-	-	-	-	3.01**	3.08***	1.53	1.65
Numb. of Obs. (countries)	132 (21)	132 (21)	132 (21)	118 (19)	118 (19)	131 (21)	131 (21)	117 (19)	117 (19)

Notes: *** (**) (*) (°) indicates statistical significance at the 1% (5%) (10%) (15%) level. Underlying standard errorsare heteroscedasticity-consistent (White). Each column contains the estimated coefficients on the set of institutional variables (multiplied by *DURATION*) when added to the regression equation reported in Table 4, column (4). We allow different coefficients in consolidation, expansion and neutral periods. We here report coefficients during consolidation. For a definition of all institutional variables, see Table 2.

As to the other institutions, our results confirm that - all other things equal - left-wing governments (*LEFT*) may be more successful in bringing down public debt. Although not all estimated coefficients are statistically significant, it would seem from most regressions in Table 5 that these governments raise the effectiveness of given consolidation programmes. In this respect, we match with Ardagna (2004) suggesting that left-wing parties may be better able to convince key players (like unions) to accept the efforts and costs imposed by consolidation policies in return for improved long-run perspectives. Moreover, considering the even more negative and more significant coefficients in Table 6, left-wing governments may also adopt stronger programmes[66].

[66] We tested similar effects for right-wing governments but here we found no significant result at all.

Table 6. Effect of institutions / institutional change on the public debt ratio during consolidation periods when we do *not* control for fiscal policy

	Estimated effect of institutions or institutional change on *ΔGD* per year of consolidation								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
EPL	0.38	0.46	0.22	0.65	1.51	-0.15	-0.55	0.39	0.83
UNION	0.01	0.05	-	-	-	0.06	0.09°	0.09°	0.05
COOR	-1.31*	-	-1.57**	-1.13°	-1.26*	-1.04	-1.15°	-0.43	-0.49
PMR	0.76	0.50	0.81	0.85	0.62	0.15	0.06	0.09	0.11
LEFT	-3.17***	-3.18***	-3.66***	-2.98***	-1.59	-	-3.00**	-1.96	-0.76
PSEAdm	-	-	-	-3.76**	-	-	-	-2.48*	-
PSEAvg	-	-	-	-	-12.2***	-	-	-	-9.33***
ΔEPL	-	-	-	-	-	-1.62	-2.49°	-1.09	-0.26
ΔPMR	-	-	-	-	-	4.82***	4.51***	3.35**	2.29*
Numb. of Obs. (countries)	132 (21)	132 (21)	132 (21)	118 (19)	118 (19)	131 (21)	131 (21)	117 (19)	117 (19)

Notes: *** (**) (*) (°) indicates statistical significance at the 1% (5%) (10%) (15%) level. Underlying standard errors are heteroscedasticity-consistent (White). Each column contains the estimated coefficients for the set of institutional variables (multiplied by *DURATION*) when included in a regression explaining *ΔGD* by means of only *CAPBuINIT* (times *DURATION*), *BURDEN* (times *DURATION*), *DEVAL*, the crisis dummies and country-specific fixed effects (times *DURATION*). We allow different effects for the institutions in consolidation, expansion and neutral periods. We here report effects during consolidation.

Last but not least, our regressions reveal strong evidence on the importance for successful fiscal consolidation of public sector efficiency (*PSEAdm*, *PSEAvg*). Table 5 supports the hypothesis that a given consolidation programme is more effective in bringing down public debt when it is adopted by a more efficient government apparatus. One explanation for this favourable effect may be that consolidation policies executed by efficient governments are more credible, and believed to be more durable. Private consumers' and investors' responses may then be more positive[67]. Finally, not only may the effectiveness of given policies rise when government efficiency is higher, the strengthening of effects that we observe in Table 6 adds to this that more efficient governments may also adopt better consolidation programmes.

At several occasions above we argued that certain institutions, like a left-wing fiscal policy maker and an efficient government apparatus, may contribute to more effective consolidation policies, for example when it comes to size or composition. Table 7 summarizes the results of research into this hypothesis. In the first two equations, we regress the change in the *CAPBu* during a fiscal episode on a number of institutional variables and the fiscal position before the episode. The latter is measured by the underlying primary balance and by the public debt ratio in the last year before the episode (*CAPBuINIT, GDINIT*). The following four equations explain the change in government revenue (*ΔINCu*) and the change in non-interest expenditures (*ΔNIEXPu*) as functions of the same explanatory

[67] Note that a further extension of the estimated regression like in columns (5) and (6) of Table 4 confirms this result, with estimated coefficients on *PSEAdm*DURATION* between -3.15 and -4.04.

variables. The last two equations explain the change in public investment (*ΔINV*) during the episode. We regress this variable on the change in the *CAPBu* during the episode, and again a number of institutional variables. We pay separate attention to investment given its particular position as a category of expenditures that should not fall during consolidation. In all eight equations we control for country-specific fixed effects, and include the crisis dummies. When explaining *ΔCAPBu*, *ΔINCu* and *ΔNIEXPu*, we also control for the fact that a preceding devaluation may affect the need or the incentive to improve the *CAPBu*. There is no reason to expect any effect from *DEVAL* on the change in public investment once *ΔCAPBu* is controlled for. (When we test this, the data also confirm it). We report all estimated coefficients for the consolidation episodes[68]. As a rule, when institutions show up highly insignificant for a dependent variable (*p*-value >0.50), we drop them in the second regression for that variable.

The results confirm that public sector efficiency matters for the characteristics of the consolidation programmes that governments adopt. More efficient governments succeed in cutting non-interest expenditures significantly more than other governments. This contributes to larger consolidation programmes, although the effect on *ΔCAPBu* is not very significant. The lack of a significant effect here may be related to the negative sign on *PSEAvg* that we see in the equations for *ΔINCu.* Successful consolidation by efficient governments is not due to the choice of higher taxes. If there is an effect on taxes, it is rather the opposite. As a final observation, we see no significant effect from public sector efficiency on the share of investment in consolidation packages. On the impact of ideology, our results in Table 7 reveal that left-wing policy makers tend to adopt smaller consolidation packages. Mainly, this seems to be due to difficulty or hesitation among left-wing policy makers to cut expenditures. On government revenue we see no significant effect. An important element here, however, is that left-wing policy makers pay significantly more attention to safeguarding public investment, which may also explain part of their success during consolidation. We observe this effect on investment in the utter right column, at least when union density is not extreme (not above 60 to 70%)[69].

[68] Estimated coefficients for the other episodes are available from the authors upon request.

[69] When we do not include the interaction term *LEFT x UNION*, we also obtain a positive effect from *LEFT* on investment, but then this is not significant (see the first regression for *ΔINV*). On the other hand, if we neither include *UNION* in that first regression, the estimated coefficient on *LEFT* becomes significant (and equal to about 0.4). Positive correlation between *LEFT* and *UNION* may play a role here. All in all, our results favour the hypothesis that more (political or social) power from the left may be beneficial to public investment during fiscal consolidation. We tested for a role of this *LEFT x UNION* interaction term in our other regressions in Tables 5-7. It was never relevant.

Table 7. Effect of institutions on the size and composition of consolidation policies

	Dependent variable							
Explanatory variables	ΔCAPBu	ΔCAPBu	ΔINCu	ΔINCu	ΔNIEXPu	ΔNIEXPu	ΔINV	ΔINV
CRISIS08	0.12	0.35	1.50**	1.57**	0.75	0.67	0.49**	0.28°
CRISIS91sf	-2.18***	-2.69***	1.56	1.50	2.75	2.66	-0.39	-0.52
DEVAL	-0.19	-0.19	0.24	0.25	0.45***	0.45***	-	-
Consolidation								
Constant	-1.12	0.42	2.44	2.11	3.04	2.79	-	-
CAPBuINIT	-0.58***	-0.64***	0.28**	0.29**	0.72***	0.72***	-	-
GDINIT	0.043*	0.043***	-0.060***	-0.058***	-0.092***	-0.089***	-	-
ΔCAPBu	-	-	-	-	-	-	-0.11*	-0.13***
PSEAvg	2.55	2.98°	-3.11	-3.04	-5.88**	-5.98**	0.29	-
LEFT	-1.29*	-0.85	0.20	0.12	1.92**	1.81**	0.20	0.72**
EPL	0.80	0.66	0.22	-	-0.43	-	0.23	0.36*
UNION	0.01	-	-0.10*	-0.11**	-0.08	-0.08	0.03	0.03*
COOR	-0.27	-	-1.11***	-1.16***	-0.56	-0.65°	0.04	-
LEFT * UNION	-	-	-	-	-	-	-	-0.01°
PMR	-0.02	-	0.48	0.56**	0.18	-	-0.23**	-0.27***
Expansion								
…	-	-	-	-	-	-	-	-
Neutral								
…	-	-	-	-	-	-	-	-
Adjusted R-squared	0.83	0.84	0.47	0.48	0.52	0.55	0.29	0.37
Country fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Number of obs. (countries)	118 (19)	118 (19)	118 (19)	118 (19)	118 (19)	118 (19)	118 (19)	132 (21)

Notes: *** (**) (*)(°) indicates statistical significance at the 1% (5%) (10%)(15%) level. Underlying standard errors are heteroscedasticity-consistent (White).

Table 7 reveals or confirms a number of other interesting regularities. We confirm that worse initial fiscal conditions (lower *CAPBuINIT*, higher *GDINIT*) typically trigger significantly larger consolidation programmes (see also Mierau *et al.*, 2007). We also confirm that (larger) consolidation programmes generally include (larger) cuts of public investment (see e.g. de Haan *et al.*, 1996). Public investment seems to suffer more also when product markets are highly regulated. If we can use *PMR* as a proxy for the power of special interest groups, an explanation may be that investment is the first victim when these interest groups all try to protect their share of government expenditures. Finally, we find that devaluations tend to be followed by more expansionary fiscal policies, increased expenditures in particular.

6. Conclusion

The sharp increase in public debt ratios since 2008 imposes the need for a significant fiscal consolidation and credible debt reduction strategies in almost all OECD countries.

Many countries have gained experience with fiscal consolidation programmes in the past two or three decades. In this paper we focus on 21 OECD countries in 1981-2008. We define 132 fiscal episodes, including 40 consolidation periods. We contribute to the literature by studying directly the evolution of the ratio of public debt to GDP during, and up to two years after, these fiscal episodes. For the consolidation periods, the data reveal a wide range of outcomes, with the change in the public debt ratio varying between about -25 and +35 percentage points. Our aim is to explain these outcomes, and the enormous differences that one can observe. Only one study has focused directly on the evolution of the debt to GDP ratio before (see Heylen and Everaert, 2000). Another value of this paper is in the way we define fiscal episodes. We use data on the evolution of underlying cyclically adjusted primary balances, and as such avoid the bias that may be induced by one-off budgetary measures (see IMF, 2010a). Our main contribution may be in the new evidence that we obtain on the role of public sector efficiency and a number other institutional variables for the success of consolidation policies. The role of public sector efficiency has not yet been studied before in the context of fiscal consolidation. As to other institutions, we study the effects of labour and product market characteristics and reform, and the role of the political ideology of the government. Rising pressure on governments, especially in Europe, to reform labour and product markets, and a growing ideological divide, show the importance of the topic. However, the existing evidence in the literature on the effects of these institutions and of institutional reform during fiscal consolidation, is highly ambiguous (see e.g. Tagkalakis, 2009, and Alesina and Ardagna, 2012).

Starting point of our analysis is the well-known composition hypothesis (Alesina and Perotti, 1995). Furthermore, we always control for the international macroeconomic environment, as reflected by international growth and interest rates, and for the possible contribution of a preceding devaluation to the evolution of the public debt ratio. Our main findings are as follows:

On composition, we find that both permanent expenditure cuts and permanent tax increases contribute significantly to debt reduction in the longer run, but the effects of the former are stronger. The precise composition of expenditure cuts is very important. Our results prefer cuts in subsidies and (conditionally) the public sector wage bill. Cutting the public wage bill contributes to a reduction of the debt ratio, but only when public sector efficiency in administration is low. According to our results, downsizing an efficient public sector will not 'work'. Social benefit cuts matter in the longer run, but they may not have much effect during the consolidation period. Finally, reducing expenditures by means of public investment cuts is highly counterproductive when the aim is to bring down the public debt ratio. Overall, our evidence is broadly in line with the composition hypothesis, except when it comes to the effect of changes in the public wage bill.

Next to its influence on the effects of policies involving changes in government wage consumption, public sector efficiency affects the outcome of fiscal consolidation along two other channels. We find first that the effectiveness of *given* consolidation programmes to reduce the debt

ratio rises when governments are more efficient. Given consolidation policies may be more credible, and believed to be more durable, when they are executed by efficient public authorities. Second, our results show that more efficient governments may also realize better and (maybe) larger consolidation programmes. Efficient governments succeed in cutting expenditures significantly more than other governments.

As to labour and product market institutions, we find that consolidation policies are significantly more successful when they are complemented by product market deregulation. Positive effects from the latter on competition, overall productivity and growth, may explain this. By contrast, we find little evidence for favourable effects from flexible labour markets, or complementary labour market reform. Parallel labour market deregulation may even raise the chances of failure for consolidation policies when firms find it easier to fire workers when demand for their product falls. A final result in this paper concerns the ideological orientation of the government. All other institutions equal, we find left-wing governments to be more successful in fiscal consolidation. It may be less difficult for them to convince key players (like unions) to accept the efforts and costs imposed by consolidation policies in return for improved long-run perspectives. Another explanation is that left-wing governments pay more attention to safeguarding public investment during consolidation.

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References

Afonso, A. and J.T. Jalles, J.T. (2012), Measuring the success of fiscal consolidations, *Applied Financial Economics*, 22, 1053-1061.

Alesina, A. and Ardagna, S. (1998) Tales of fiscal adjustment, *Economic Policy*, 27, 489-545.

Alesina, A. and Ardagna, S. (2012) The design of fiscal adjustments, *NBER Working Paper*, N° 18423.

Alesina, A., Ardagna, S., Perotti, R. and Schiantarelli, F. (2002) Fiscal policy, profits and investment, *American Economic Review*, 92, 571-589.

Alesina, A., and Perotti, R. (1995) Fiscal expansions and adjustments in OECD countries, *Economic Policy*, 21, 205-248.

Alesina, A. and Perotti, R. (1996) Fiscal adjustments in OECD countries: Composition and macroeconomic effects, *NBER Working Paper*, N° 5730.

Angelopoulos, K., Philippopoulos, A. and Tsionas, E. (2008) Does public sector efficiency matter? Revisiting the relation between fiscal size and economic growth in a world sample, *Public Choice*, 137, 245-278.

Angrist, J.D. and Pischke, J-S. (2009) Mostly Harmless Econometrics, Princeton University Press.

Ardagna, S. (2004) Fiscal stabilizations: when do they work and why?, *European Economic Review*, 48, 1047-1074.

Barro, R. (1989) The Ricardian approach to budget deficits, *Journal of Economic Perspectives*, 3(2), 37–54.

Beetsma, R., Giuliodori, M., and Klaassen, F. (2008) The effects of public spending shocks on trade balances and budget deficits in the European Union, *Journal of the European Economic Association*, 6, 414-423.

Berger, T. and Heylen, F. (2011) Differences in hours worked in the OECD: Institutions or fiscal policies, *Journal of Money, Credit and Banking*, 43, 1333-1369.

Blanchard, O. and Perotti, R. (2002) An empirical characterization of the dynamic effects of changes in government spending and taxes on output, *Quarterly Journal of Economics*, 117, 1329-1368.

Bofinger, P. (2000) The European Monetary System (1979-1988): Achievements, flaws and applicability to other regions of the world. Background Paper for Special Session IV on global financial issues, UN/ECE Conference " Financing for development", December.

Bouis, R., Causa, O., Demmou, L., Duval, R., Zdzienicka, A., 2012. The short-term effects of structural reforms: an empirical analysis. *OECD Economics Department Working Paper*, 949.

Calmfors, L. and Driffill, J. (1988) bargaining structure, corporatism and macroeconomic performance, *Economic Policy*, 3, 13–61.

Conway, P., de Rosa, D., Nicoletti, G., and Steiner, F. (2006) Regulation, competition, and productivity convergence, *OECD Economics Department Working Paper*, N° 509.

Davidson, R. and MacKinnon, J.G. (1993) *Estimation and Inference in Econometrics*, New York: Oxford University Press, 2nd edition.

de Haan, J., Sturm, J.E., and Sikken, B.J. (1996) Government capital formation: Explaining the decline, *Weltwirtschaftliches Archiv*, 132, 55-74.

de Haan, J., Jong-A-Pin, R. and Mierau, J.O. (2012) Do budgetary institutions mitigate the common pool problem? New empirical evidence for the EU, *Public Choice*, forthcoming.

Feldstein, M. (1982) Government deficits and aggregate demand, *Journal of Monetary Economics*, 9, 1-20.

Giavazzi, F. and Pagano, G. (1990) Can severe fiscal contraction be expansionary? Tales of two small European countries, National Bureau of Economic Research, *Macroeconomics Annual*, 5, Cambridge, MA: MIT Press, 75-111.

Giavazzi, F. and Pagano, G. (1996) Non-Keynesian effects of fiscal policy changes: international evidence and the Swedish experience, *Swedish Economic Policy Review*, 3(3), 76-103.

Guichard, S., Kennedy, M., Wurzel, E., and Andre, C. (2007) What promotes fiscal consolidation: OECD country experiences, *Economics Department Working Paper*, OECD, N° 553.

Haggard, S. and Webb, S. B. (1994) Voting for reform: Democracy, political liberalization, and economic adjustment, Washington: World Bank.

Heylen, F. and Everaert, G. (2000) Success and failure of fiscal consolidation in the OECD: a multivariate analysis, *Public Choice*, 105, 103–124.

Heylen, F., Hoebeeck, A. and Buyse, T. (2011) Fiscal consolidation, institutions and institutional reform: a multivariate analysis of government debt dynamics, *Working Paper*, Faculty of Economics and Business Administration, Ghent University, N° 2011/763.

Hjelm, G. (2002) Is private consumption growth higher (lower) during periods of fiscal contractions (expansions)?, *Journal of Macroeconomics*, 24, 17-39.

IMF (2010a) Will it hurt? Macroeconomic effects of fiscal consolidation, *World Economic Outlook*, October, Chapter 3.

IMF (2010b) Navigating the fiscal challenges ahead*, Fiscal Monitor*, May.

Kenworthy, L. (2001) Wage-Setting Coordination Scores, Department of Sociology, Emory University, http://www.emory.edu/SOC/lkenworthy.

Kneller, R., Bleaney, M. F., and Gemmell, N. (1999) Fiscal policy and growth: evidence from OECD countries,*Journal of Public Economics*, 74, 171-190.

Larch, M. and A. Turrini (2011) Received wisdom and beyond: lessons from fiscal consolidation in the EU, *National Institute Economic Review*, 217, N° 1, R1-R18.

McDermott, J. and Wescott, R. (1996) An empirical analysis of fiscal adjustments, *IMF Working Paper*, N° 96/59.

Mierau, J.O., Jong-A-Pin, R. and de Haan, J. (2007) Do political variables affect fiscal policy adjustment decisions? New empirical evidence, *Public Choice*, 133, 297-319.

OECD (1995) OECD Economic Surveys Finland.

OECD (2010a) Economic Outlook, Statistical Compendium, N° 88, December.

OECD (2010b) Fiscal consolidation: Requirements, timing, instruments and institutional arrangements, OECD Economic Outlook, N° 88, December.

Perotti, R. (1996) Fiscal consolidation in Europe: composition matters, *American Economic Review*, 86, 105-110.

Perotti, R. and Kontopoulos, Y. (2002) Fragmented fiscal policy. *Journal of Public Economics*, 86, 191-222.

Pozzi, L., Heylen, F. and Dossche, M. (2004) Government debt and excess sensitivity of private consumption: Estimates from OECD countries, *Economic Inquiry*, 42, 618-633.

Schaltegger, C. A. and Feld, L. P. (2009) Are fiscal adjustments less successful in decentralized governments? *European Journal of Political Economy*, 25, 115-123.

Staiger, D. and Stock, J.H. (1997) Instrumental variables regression with weak instruments, *Econometrica*, 65, 557-586.

Tagkalakis, A. (2009) Fiscal adjustment: do labor and product market institutions matter?, *Public Choice*, 139, 389-411.

Tavares, J. (2004) Does right or left matter? Cabinets, credibility and fiscal adjustment, *Journal of Public Economics*, 88, 2447-2468.

Volkerink, B. and de Haan, J. (2001) Fragmented government effects on fiscal policy: New evidence, *Public Choice*, 109, 221-242.

von Hagen, J., Hughes Hallett, A., and Strauch, R. (2002) Budgetary consolidation in Europe: Quality, economic conditions and persistence, *Journal of the Japanese and International economics*, 16, 512-535.

Wölfl, A., Wanner, I., Röhn, O. and Nicoletti, G. (2010) Product market regulation: extending the analysis beyond OECD countries, *OECD Economics Department Working Paper*, N° 799.

Appendix 1: Derivation of Equation (4)

We assume a fiscal episode which lasts for two years, *t* and *t+1*. Derivation for longer periods is totally analogous. Dropping the *CRISIS* dummy, Equation (3b) for these two years is:

$$GD_{i,t+1} - GD_{i,t} = \alpha_i + \beta_1 CAPBu_{i,t} + \beta_2\left(CAPBu_{i,t+1} - CAPBu_{i,t}\right) + \beta_3 BURDEN_{i,t+1} + \beta_5 ONEOFF_{i,t+1} + v_{i,t+1}$$

$$GD_{i,t} - GD_{i,t-1} = \alpha_i + \beta_1 CAPBu_{i,t-1} + \beta_2\left(CAPBu_{i,t} - CAPBu_{i,t-1}\right) + \beta_3 BURDEN_{i,t} + \beta_5 ONEOFF_{i,t} + v_{i,t}$$

To simplify further notation, we will specify $BURDEN_{i,t}$ as :

$$BURDEN_{i,t} = X_t . GD_{i,t-1}, \qquad \text{with: } X_t = \frac{\left(\frac{INTEREST_t}{100} - \frac{GROWTH_t}{100}\right)}{\left(1+\frac{GROWTH_t}{100}\right)}$$

Summing both equations then implies:

$$GD_{i,t+1} - GD_{i,t-1} = 2\alpha_i + \beta_1\left(CAPBu_{i,t} + CAPBu_{i,t-1}\right) + \beta_2\left(CAPBu_{i,t+} - CAPBu_{i,t-1}\right)$$
$$+\beta_3\left(X_{t+1}GD_{i,t} + X_t GD_{i,t-1}\right) + \beta_5\left(ONEOFF_{i,t+1} + ONEOFF_{i,t}\right) + v_{i,t+1} + v_{i,t}$$

Using $GD_{i,t-1}$ as a proxy for $GD_{i,t}$ at the RHS of this equation, we can rewrite this result as the two period specification for Equation (4):

$$\Delta GD_{i,T} = 2\alpha_i + 2\beta_1\left(AvgCAPBu_{i,T}\right) + \beta_2 \Delta CAPBu_{i,T} + 2\beta_3 AvgX_T . GD_{i,t-1}$$
$$+\beta_5 ONEOFF_{i,T} + v_{i,T}$$

with: $\Delta GD_{i,T} = GD_{i,t+1} - GD_{i,t-1}$

$$2\left(AvgCAPBu_{i,T}\right) = CAPBu_{i,t-1} + CAPBu_{i,t}$$

$$\Delta CAPBu_{i,T} = CAPBu_{i,t+1} - CAPBu_{i,t-1}$$

$$2AvgX_T = X_t + X_{t+1}$$

$$ONEOFF_{i,T} = ONEOFF_{i,t} + ONEOFF_{i,t+1}$$

$$v_{i,T} = v_{i,t} + v_{i,t+1}$$

We approximate $GD_{i,t}$ at the RHS by $GD_{i,t-1}$ for econometric reasons, which is to avoid the correlation that one has between $\left(X_{t+1}GD_{i,t} + X_t GD_{i,t-1}\right)$ and the error term $\upsilon_{i,t}$. Basically, this approximation comes down to instrumenting $GD_{i,t}$ by $GD_{i,t-1}$.

A more general specification for longer fiscal episodes will have *DURATION* instead of 2 in the equation. We use the same proxy $GD_{i,t-1}$ for each $GD_{i,t+z}$ at the RHS where $z \geq 0$.

The equation that we finally estimate will also include *CRISIS* dummies. Moreover, as we mention in the main text, to allow for possible lags in behavioural responses, we have extended in our regressions the period over which we compute the dependent variable $\Delta GD_{i,T}$ by two years.

Appendix 2: Data and data sources

Almost all data that we use in this paper are publicly available from OECD sources and from the Database Political institutions (DPI). Most OECD data have been taken from the *Statistical Compendium, Economic Outlook, N° 88*. We downloaded these data in January 2011. For the political variables we use the DPI version of December 2010. Details are described below. For a number of countries (e.g. Czech Republic, Germany, Hungary) data may not be available for the whole period 1980-2008. We give details in the data appendix to our companion working paper (Heylen *et al.,* 2011).

Fiscal Policy

Gross government debt in percent of GDP (GD):
Source: OECD (series GGFLQ and GDP). Data for the Czech Republic, Hungary, Ireland and Portugal have been taken from AMECO.

Underlying cyclically adjusted government primary balance in percent of potential GDP (CAPBu)
Source: OECD (series NLGXQU).

Cyclically adjusted government primary balance in percent of potential GDP (CAPB)
Source: OECD (series NLGXQA).

One-off measures in percent potential GDP (ONEOFF)
Calculation: CAPB-CAPBu

Underlying cyclically adjusted current government revenues in percent of potential GDP (INCu)
Source: OECD (series YRGTQU).

Underlying cyclically adjusted government non-interest expenditures in percent of potential GDP (NIEXPu).
Source: OECD (series YPGTXQ).

Cyclically adjusted taxes on business in percent of potential GDP (TAXB)
Source: OECD (series TYBA and GDPTR).
Cyclically adjusted indirect taxes in percent of potential GDP (component of TAXT)
Source: OECD (series TINDA and GDPTR).

Cyclically adjusted direct taxes on households in percent of potential GDP (component of TAXT)
Source: OECD (series TYHA and GDPTR).

Cyclically adjusted social security contribution received by general government in percent of potential GDP (component of TAXT)
Source: OECD (series SSRG and GDPTR).

Public sector wage consumption in percent potential GDP (WAGE)
Source: OECD (series CGW and GDPTR).

Government non-wage consumption in percent potential GDP (NONWAGE)
Source: OECD (series CGNW and GDPTR).

Government fixed capital formation in percent of potential GDP (INV)
Source: OECD (series IGAA and GDPTR).

Subsidies in percent potential GDP (SUBS)
Source: OECD (series TSUB and GDPTR).

Cyclically adjusted social expenditures in percent of potential GDP (SOCEXP)
OECD provides no direct series for this variable. Following Heylen and Everaert (2000), we computed it as SOCEXP = NIEXP – WAGE – NONWAGE – SUBS - other current transfers - property income paid (except interest payments), where NIEXP is cyclically adjusted current primary disbursements. Underlying this approach is a double assumption. First, we assume that one-off current disbursements are negligible. Second, we assume that the variables at the right hand side of this equation are not affected by the cycle.

Devaluation
Definition: percentage of official nominal exchange rate devaluation in the year before the fiscal episode (t_{s-1})
Sources: Bofinger (2000, Table 2); Bank for International Settlements; national sources (e.g. Riksbank, Norges Bank). Data available upon request.

International macroeconomic context
International nominal short term interest rate in percent (INTEREST)
Definition: see our note to Table 2.
Source: OECD (series IRS)

International nominal GDP growth rate in percent (GROWTH)
Definition: see our note to Table 2.
Source: OECD (series GDP)

Institutions

Employment protection legislation (EPL)

Definition: OECD summary indicator of the stringency of Employment Protection Legislation. We use the overall EPL strictness indicator (time series, version 1).

Source: OECD, Employment Outlook 2004; see also Online OECD Employment Database.

Data shortages and adjustments: see Berger and Heylen (2011) who also use and extended this dataset.

As indicator of institutional reform we compute the change in EPL (ΔEPL) as its level at the end of a fiscal episode minus its level two years before the episode.

Trade union density rate (UNION)

Definition: the share of workers affiliated to a trade union, in %.

Source: OECD, Employment Outlook 2004; see also Online OECD Employment Database.

Coordination of Wage Bargaining (COOR)

Definition: Index from 1 to 5 for the degree of intentional harmonization in the wage setting process, for the degree to which "minor players" deliberately follow along with what the "major players" decide. The coding for the index is based on structural characteristics of the wage bargaining process.

Source: Kenworthy (2001).

Data shortages and adjustments: see Berger and Heylen (2011) who also use (and extended) this dataset.

Product market regulation (PMR)

Definition: OECD summary indicator of regulatory impediments to product market competition in seven non-manufacturing industries (telecoms, electricity, gas, post, rail, air passenger transport, and road freight).

Source: Conway *et al.* (2006); see also OECD.Stat, Public Sector, Taxation and Market Regulation (REGREF dataset).

The data from Conway et al. are available only until 2003. We extrapolated them relying on more recent product market regulation data from OECD.stat for 2003 and 2008.

As indicator of institutional reform we compute the change in PMR (ΔPMR) as its level at the end of a fiscal episode minus its level in the last year before the episode.

Party orientation with respect to economic Policy (LEFT)

Definition: Dummy variable for parties that are defined as communist, socialist, social democratic, or left-wing.

Source: Database political institutions, 2010 (series EXECRLC)

Public sector efficiency (PSEAdm, PSEAvg)

Source: Angelopoulos *et al.* (2008). The authors provide period averages for *PSEAdm* and *PSEAvg* (among other variables) for 1980-85, 1985-90, 1990-95 and 1995-2000. For most countries observations are available for three or four of these periods. For a few countries (Czech Republic, Italy, Poland, Spain) data availability is more limited. When a fiscal episode falls nicely within one of these periods (e.g. a consolidation episode in 1982-84), we take the *PSE* values relating to that period (1980-85). When a fiscal episode overlaps two periods, but the overlap in the second period is less than three years (e.g. 1983-87) we take the *PSE* values relating to first of these periods (1980-85). When the overlap is at least three years (e.g. 1983-88) we take the average of the *PSE* data for both periods. In case *PSE* data for the period concerned are missing, we take the available data for the adjacent period as a proxy. We never take *PSE* data where the gap with the fiscal episode is more than five years.

Note on the construction of the PSE dataset.

Angelopoulos et al. (2008) construct a measure of public sector efficiency in various countries and time periods by calculating an output-to-input ratio. The methodology compares the performance of government in certain areas of economic activity to the associated expenditure that the government allocates to achieve this particular performance. The PSE index thus compares a measure of Public Sector Performance (PSP) and a measure of the associated Public Sector Expenditure (PEX) for each country in each policy area and each time period. PSE is then constructed as the ratio of PSP to PEX. We refer to the Appendix in Angelopoulos et al. (2008) for more details on the construction of PSP and PSE indexes in each policy area.

As the PSP and PEX measures are expressed in different units of measurement, they first have to be made comparable across countries. For this, the authors follow Afonso et al. (2005, 2006) by expressing each country's PSP and PEX relative to the average PSP and PEX of all countries in each period. In other words, each country's PSP and PEX are expressed as percentages of the respective average (normalized to be 1), and in turn the PSE is obtained as the ratio of these relative PSPs and PEXs. As such, PSE is an index that measures the efficiency of a country's government *relative to* governments in other countries in each period in a particular policy area. The larger the value, the more efficient the country's government is.

CHAPTER 6

Public employment and fiscal consolidation in general equilibrium

Public employment and fiscal consolidation in general equilibrium.

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Abstract

We study the effects of fiscal consolidation in a dynamic general equilibrium model with overlapping generations. We analyze the effectiveness of reducing public employment as a means for debt reduction in order to assess whether public employment cuts raise the effectiveness of consolidation programmes. We further compare these results to those of other consolidation instruments, such as taxes on labor or consumption or other government expenditures. Our contribution to the theoretical consolidation literature is threefold. (i) We assume individuals with finite lives, who have either high or low innate ability. This assumption is important for an appropriate analysis of distributional issues between current and future generations, and between individuals with high and low earning capacity. (ii) Individual decisions of time allocation between work, leisure and education are fully endogenous in our model. So is growth. (iii) We pay special attention to realistically modeling the public sector, in particular public employment and output. Our model contains various channels through which public employment may improve the economy's supply potential.

As to our main finding, our simulation results nuance the view that public employment cuts are efficient consolidation tools, definitely in the prevalence of significant labor reallocation costs. Second, although we confirm that expenditure based consolidation is better than labor or capital tax based consolidation, evidence for expansionary output effects after spending cuts is very limited. We do generally not observe them when we consider GDP and include the value added produced by public employees. Our results for welfare bring even more nuance. When aggregated over all generations that are alive at the time consolidation is started, almost all consolidation strategies bring about net negative welfare effects. Only the youngest and future generations experience positive welfare effects. Interestingly, the positive effects for these generations are smaller under spending based adjustments in the area of education, investment, and overall public employment, than under tax based adjustments.

Keywords: public employment, endogenous growth, fiscal consolidation, overlapping generations

JEL Classification: E62, H63, J22, 041

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1. Introduction and motivation

The drastic increase of public debt since 2008 and additional pressure on government budgets from rising health and pension costs due to ageing, pose a major challenge to policy makers in most OECD countries. Given the negative effects of high public debt on future potential growth and welfare, the need for effective fiscal adjustment strategies is beyond discussion.

Since the seminal work by Giavazzi and Pagano (1990) and Alesina and Perotti (1995), a huge empirical literature has studied the effects of fiscal consolidation. The focus is mostly on real output and growth effects as these are crucial for the success of consolidation. One hypothesis that has received particular attention is that spending based fiscal consolidation hurts growth less than tax based consolidations. If the government mainly tackles social spending and *public employment and the public wage bill*, some even expect expansionary output effects, also in the short run (Alesina and Perotti, 1996; Alesina and Ardagna, 2010). According to these authors, public wage bill cuts should therefore have a prominent role in consolidation programmes. Others however are more pessimistic. Perotti (2011) expects short-run output losses after spending cuts. Heylen and Everaert (2000), Tagkalakis (2009) and Larch and Turrini (2011) do not find that fiscal consolidation is more successful when it mainly relies on government wage bill cuts. More recently, Heylen *et al.* (2013) do find this, but only when public sector efficiency is low. The discussion has become particularly lively in the most recent years, as shown for example by the many contributions to the debate initiated by Corsetti (2012). Strong positions are being taken varying from 'austerity will increase confidence and encourage recovery' to 'austerity kills' (Krugman and Layard, 2012).

Table 1 Government wage bill and goods expenditures (in % of GDP, average for 11 European countries, 1995-2007)

	Education	Investment	Consumption	Total
Goods expenditures	1,48	2,17	8,32	11,96
Wage expenditures	3,62	1,77	6,89	12,27
% Wages	71	45	45	51

Note: Average data for 11 European countries, 1995-2007: Austria, Belgium, Denmark, Finland, France, Germany, Italy, The Netherlands, Norway, Sweden and the UK. To classify government expenditures, we have followed the functional approach of the OECD (code: COFOG). For education, we take function "Education (090)" while for investment we add up "Economic Affairs (040)" and "Public order and safety (030)". The remaining functions are classified under consumption expenditures. In every category, we classify "Final consumption expenditure (P3CG)" and 'Gross fixed capital formation (P51CG)' under 'Goods expenditures' and 'Total compensation of employees paid by the government (code: D1CG)' under 'Wage expenditures'.

Next to its (persisting) inconclusiveness, one may observe two other limitations in the existing empirical literature on the contribution of public wage bill cuts to successful fiscal consolidation. A first one is that public employment is generally taken as one homogenous category, whereas in reality this is not the case (see Table 1, where one can roughly distinguish three public subsectors: education, investment and public consumption). A second and major issue is that the empirical literature says nothing about the welfare effects of (different) programmes of fiscal consolidation.

Yet, given that public support is key to their success, it is important to know these welfare effects. Future generations are most likely to reap the benefits from fiscal adjustments. But what about current generations of different age and skill?

Given the above-mentioned limitations of empirical studies, we take a different road in this project. We propose a general equilibrium analysis where we also take into account the reality of different public subsectors. More precisely, our aim is to study the effects of fiscal consolidation within a theoretical overlapping generations model with 30 generations. By explicitly modeling the behavior of all relevant actors and their interaction on different markets in the short and the long-run, a well-structured and disciplined analysis of the economic and welfare implications of fiscal consolidation becomes possible. Our analysis will allow an assessment of the macroeconomic impact of reducing public employment as a means of debt reduction and thus allows to assess the claim that public employment cuts raise the effectiveness of consolidation programmes. Moreover, it will also allow to compare these results to those of using other consolidation instruments, such as other government expenditures or taxes on labor or consumption. Our analysis will not be limited to the implications for employment, private output and GDP, however. We will also study welfare effects on both current and future generations of individuals with different innate ability.

We are not the first to study the effects of fiscal consolidation in a theoretical model. Earlier work in this area has been done by among others Cournède and Gonand (2006), Forni *et al*. (2010) and Clinton *et al.* (2011). Building on our experience in Heylen and Van de Kerckhove (2013) and Buyse *et al.* (2012, 2013), our setup is richer and more realistic than is the case in these existing studies. The value added of what we want to do in this paper is threefold.

(i) We assume individuals with finite lives, who have either high or low innate ability. This assumption is important for an appropriate analysis of distributional issues between current and future generations, and between individuals with high or low earning capacity. Existing theoretical work has largely ignored distributional consequences. We mention Jensen and Rutherford (2002) as an important exception. These authors find that “inter- rather than intra-generational equity is most likely to pose the greatest obstacle to fiscal consolidation”.

(ii) When young, individuals allocate time to education, work or leisure. At older ages, individuals only work or have leisure. The labor-leisure choice is endogenous in our model. So is education. This approach is crucial to get a model with both endogenous employment by age and endogenous productivity and growth. Given the major importance of the evolution of employment and growth for the effectiveness of fiscal consolidation, it is important to model these carefully. Again, many existing studies do not model the education decision and/or assume exogenous growth (see for instance Cournède and Gonand, 2006, Forni *et al.*, 2010 and Clinton *et al.*, 2011). Fernandez-Huertas Moraga and Vidal (2010) do model endogenous growth coming from human capital formation through parental education and educational spending. Their model, however, does not have endogenous labor supply. Yakita (2008) and Agénor and Yilmaz (2011) also model an economy

with endogenous growth, coming from private and public capital accumulation, but they also disregard the labor-leisure choice and the endogeneity of labor supply.

(iii) We pay special attention to realistically modeling the public sector, in particular public employment and output. The reason for doing this is obvious from the data in Table 1. Despite the importance of public wage expenditures, very few studies have explicitly modeled public employment in a general equilibrium context, especially in the context of debt reduction. As exceptions, we mention Ardagna (2007), Finn (1998) and Pappa (2009). More recently, Afonso and Gomes (2008) and Gomes (2011) distinguish private and public employment in a model with search and matching frictions. In this project, we take the facts illustrated in Table 1 into account when we model public production in an investment sector, an education sector and a public consumption goods sector. In every sector, output is the result of goods bought on the market and production by public employees. The output of public employees may affect the private production function (via public capital), human capital formation (via education) and private utility (via public consumption goods, and aggregate output in general).

Although the modeling of a detailed public sector of production and employment is novel, there are still some important simplifications that deserve attention in future research. For instance, the government in our model does not optimally choose its inputs to efficiently produce the desired output, i.e. the input shares are exogenously pinned down. As a result, the relative share of high versus low-skilled workers in all public sectors is identical and not optimally chosen. Moreover, the output in each sector is not chosen in an optimal way. Furthermore, the production function in all public sectors is identical and simplified. Finally, all public workers receive the same wage (per unit of effective labor), although their economic contribution is different.

We stress that if the implicit assumption of an inefficient government were to generate artificial efficiency-improvements from downsizing the public sector, implementing a strong theoretic foundation for the public sector would be of prime importance. However, the results presented in this chapter tell a different story. That is, even though we have assumed an inefficient government, we do not find support that downsizing the public sector leads to unambiguous efficiency improvements, quite on the contrary. Intuitively, although the public sector does not exhibit efficient behavior, its production does result in added value for the general economy (through utility gains, more human capital accumulation or public capital). Despite the simplifications we have made in this chapter, we believe that the contribution of this study is still very significant, not at least in the way that it brings to the attention the modeling of public employment and production in theoretical macro-models.

We calibrate our model to a European benchmark and simulate nine different scenarios of temporary fiscal consolidation, relying on tax increases or expenditures cuts, to bring down the public debt ratio by 40%-points. Given an average public debt ratio in the euro area of about 100% today, this would be the required effort to return to a debt ratio of 60%. A special focus will be on overall cuts in the number of public employees or employment cuts in some public sectors. These

cuts may entail labor reallocation costs, about which we will also have to make assumptions (like a short-run period of unemployment). Our simulations are performed under perfect foresight in a non-stochastic setting. Throughout our study, we abstract from considerations related to a lack of credibility of fiscal policy, individual uncertainty or optimal Ramsey policy. We focus mainly on the effects on private output, GDP and the welfare of current and future generations of different abilities.

Our main findings are as follows. As to *output effects*, we confirm that expenditure based consolidation is less harmful than labor or capital tax based consolidation (at least when spending cuts do not concern public investment). Consolidation via consumption tax increases may slightly hurt the economy in the short-run, but is generally one of the more efficient policies in the long run. Evidence for truly expansionary output effects after spending cuts, however, is very limited. Moreover, we do not observe them when we consider GDP and include the value added produced by public employees. Cutting public employment is not expansionary in the short and medium run. It may be expansionary in the longer run, if public employment is reduced in public consumption goods production.

When it comes to *welfare effects*, we observe much bigger differences between different age groups than between different ability types of the same age. Here we confirm Jensen and Rutherford's (2002) conclusion that intergenerational heterogeneity is the most important obstacle to fiscal tightening. Our results for welfare bring even more nuance on the possibility of expansionary fiscal consolidation. When aggregated over all generations that are alive at the time consolidation is started, only one or two out of nine consolidation strategies bring about net positive welfare effects. We still observe, however, that spending based adjustments (except investment cuts) are better, i.e. they induce smaller losses for the aggregate of current generations. However, things are different for the youngest and future generations. For these generations, welfare effects from consolidation are positive rather than negative. Most interestingly, these positive effects are smaller under spending based adjustments in the area of education, investment, and overall public employment, than under tax based adjustments. Robustness tests by changing key assumptions of our model never imply changes of these conclusions, quite on the contrary.

In the remainder of this paper, we set out our model in Section 2 and calibrate it on actual data in Section 3. Section 4 explains our simulation strategy. In Section 5 we study the economic impact of alternative fiscal consolidation scenarios. We perform several robustness checks in Section 6. Section 7 concludes.

2. The model

We model an overlapping generations economy with endogenous employment and growth. The OLG 'finite life' framework implies that our model is non-Ricardian. Underlying the endogeneity of employment and growth is a rich specification of individuals' time allocation to either labor or leisure or (for individuals with high ability) education and human capital formation. Furthermore, we explicitly model public employment and production in three distinct public 'sectors': infrastructure,

education, and public consumption goods. We know of no paper in the fiscal consolidation literature with a similar realistic setup. In most of the paper we assume a closed economy such that the interest rate is endogenously determined. However, we relax this assumption in Section 6 and look at the small open economy (SOE) case. In the remainder of this section, we discuss demographics, household decisions, public and private production including the production of human capital, and the government budget.

2.1 Demographics

Population dynamics are kept as simple as possible. An individual lives for 30 periods, each representing two years in reality. At any period of time a new generation enters the model at the age of 19 and lives until the age of 78. As we do not intend to analyze the impact of demographic change, we set the rate of population growth to zero. Every generation consists of two types of individuals. Some have low ability, others have high ability. Heterogeneity relates to the innate ability to assimilate existing human capital as well as the ability to engage in tertiary education. We denote these groups as $s = L, H$. We normalize the size of every generation to 2 and assume that both ability groups are of equal size 1. Concerning notation, we use the following convention throughout this paper. Individual variables have a superscript (t) referring to the period of birth and two subscripts: the first one (j) is the age of the individual, the second one refers to the skill group (s) that the individual belongs to[1]. Aggregate variables have a subscript referring to the period in which they are considered.

2.2 Households

Household preferences are represented by the following time-separable utility function:

$$U^t = \sum_{j=1}^{30} \rho^{j-1} u\left(c_{j,s}^t, \ell_{j,s}^t, C_{t+j-1}^g\right) \tag{1}$$

where $c_{j,s}^t$ and $\ell_{j,s}^t$ are respectively consumption and leisure of an individual of generation t belonging to age group j and skill group s. C_t^g is the period-t utility-enhancing public consumption good. ρ is the discount factor.

Instantaneous utility is represented by the following functional form:

$$u\left(c_{j,s}^t, \ell_{j,s}^t\right) = \ln c_{j,s}^t + \gamma_j \frac{\left(\ell_{j,s}^t\right)^{1-\varrho}}{1-\varrho} + \mu \ln(C_t^g) \tag{2}$$

Preferences are logarithmic in private and public consumption and iso-elastic in leisure. Many authors also introduce utility-enhancing public spending separable from private consumption. While

[1] Variables per generation are then defined as the sum of both ability groups.

Baxter and King (1993) do not specify a functional form, Park and Philippopoulos (2004) and Dhont and Heylen (2009) also adopt a logarithmic specification on the public good. The intertemporal elasticity of substitution in consumption, both private and public, is 1. The intertemporal elasticity to substitute leisure is $1/\varrho$. Furthermore, μ expresses the relative value of public versus private consumption; γ specifies the relative value of leisure versus consumption. Note that γ may be different in each period of life (see also Buyse *et al.*, 2013). None of these preference parameters differ between ability types.

In each period of active life, an individual has an endowment of one unit of time. High-ability individuals allocate this time to working (n)[2], tertiary education (e) or leisure (ℓ). Time devoted to education represents human capital investment. For reasons explained later (see Section 3), we only allow schooling in the first 8 periods of life i.e. between the age of 19 and 34. Low-ability individuals only work or have leisure. Time constraints are represented in equations (3)-(5). We further distinguish the actual age of retirement from the age of pension eligibility. Although the statutory retirement age is 65 (that is from period j = 24 onwards), individuals may optimally choose to work up to (and including) the age of 68 (j = 1 to 25). They may also opt to retire sooner (this is, in the period when working hours fall to zero).

$1 = \ell_{j,s}^t + n_{j,s}^t + e_{j,s}^t$ for j=1:8 and where $e_{j,L}^t = 0$ (age 19-34) (3)

$1 = \ell_{j,s}^t + n_{j,s}^t$ for j=9:25 (age 35-68) (4)

$1 = \ell_{j,s}^t$ for j=26:30 (age 69-78) (5)

An individual born at time t chooses consumption, total hours worked and time investment in tertiary education to maximize Equation (1), subject to Equations (3)-(5) and the constraints described in (6)-(8).

For j = 1:23

$$a_{j,s}^t - a_{j-1,s}^t = r_{t+j-1}a_{j-1,s}^t - (1+\tau_c)c_{j,s}^t + w_{t+j-1}^s \varepsilon_j h_{j,s}^t n_{j,s}^t (1-\tau_w) + b\, w_{t+j-1}^s \varepsilon_j h_{j,s}^t (1-\tau_w)\left(1 - n_{j,s}^t - e_{j,s}^t\right) + z_{t+j-1} + \pi_{t+j-1} \quad (6)$$

For j = 24:25

$$a_{j,s}^t - a_{j-1,s}^t = r_{t+j-1}a_{j-1,s}^t - (1+\tau_c)c_{j,s}^t + w_{t+j-1}^s \varepsilon_j h_{j,s}^t n_{j,s}^t (1-\tau_w) + pp_{j,s}^t + z_{t+j-1} + \pi_{t+j-1} \quad (7)$$

For j = 26:30

$$a_{j,s}^t - a_{j-1,s}^t = r_{t+j-1}a_{j-1,s}^t - (1+\tau_c)c_{j,s}^t + pp_{j,s}^t + z_{t+j-1} + \pi_{t+j-1} \quad (8)$$

where we denote by $a_{j,s}^t$ the end-of-period asset holdings of an individual of age group j and skill type s born at time t. The model assumes that individuals start from zero wealth and also die with

[2] Our model includes both private and public employment. As we make clear in later sections, the individual is indifferent between working in either sector.

zero wealth (i.e. $a_0 = a_{30} = 0$). Furthermore, $h_{j,s}^t$ is the human capital of the individual of age group *j* and skill group *s* born at *t*. As to aggregate variables, r_k is the real interest rate on financial assets at time *k* and w_k^s the real wage per efficiency unit of labor of skill type *s* at that time. τ_c, τ_w and b are respectively the effective tax rates on consumption expenditures and labor income and the net non-employment benefit replacement rate. The tax on labor income τ_w is the sum of two components: a labor tax τ_n and a social contribution tax cr. Additionally, at time *k,* households receive lump-sum transfers z_k from the government and profits π_k from firms. ε_j is an exogenous parameter linking productivity to age. It is constant over generations. While we use *human capital* to describe $h_{j,s}$, we will refer to $\varepsilon_j h_{j,s}$ as *productive efficiency*. In every possible period of activity (*j* = 1 to 25) an individual of generation *t* and skill type *s* works $n_{j,s}^t$ hours and earns a net wage $w_{t+j-1}^s \varepsilon_j h_{j,s}^t n_{j,s}^t (1 - \tau_w)$. Non-employment benefits, which are only received during the first 23 periods of life (i.e. before the statutory retirement age), are defined as a proportion of the after-tax wage of a full-time worker and are given by $b\, w_{t+j-1}^s \varepsilon_j h_{j,s}^t (1 - \tau_w)$ (see Buyse *et al.*, 2013).

In Equations (7) and (8), pp represents the per-period pension benefit received by an individual after the official retirement age. We explicitly account for a pensions-earnings link present in pension systems of many European countries (see e.g. OECD, 2011 and Buyse *et al.*, 2013). Net pension benefits are a function of lifetime after-tax labor earnings as shown in Equations (9a-b). $accr_j$ is the pension accrual rate on net income earned at age j.

$$pp_{j,s}^t = \sum_{i=1}^{j-1} accr_i w_{t+i-1}^s \varepsilon_i h_{i,s}^t n_{i,s}^t (1 - \tau_w) \prod_{l=i}^{j} x_{t+l-1} \qquad \text{for } j\text{=24:25} \tag{9a}$$

$$pp_{j,s}^t = \sum_{i=1}^{25} accr_i w_{t+i-1}^s \varepsilon_i h_{i,s}^t n_{i,s}^t (1 - \tau_w) \prod_{l=i}^{j} x_{t+l-1} \qquad \text{for } j\text{=26:30} \tag{9b}$$

where net wages are revalued in line with average economy-wide wage growth x. Thanks to this revaluation, 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. This follows practice in many OECD countries (OECD, 2005; Whiteford and Whitehouse, 2006).

2.3 Public sector output

A substantial fraction of workers are employed in the public sector. A major novelty in our model is that we explicitly take this fact into account. In line with Table 1, it is our assumption that the government provides three kinds of 'useful' goods: (i) investment goods J_t such as infrastructure (e.g. bridges and roads), (ii) education goods E_t like school buildings and other education equipment, books and teachers' lectures, and (iii) utility-enhancing consumption goods C_t^g such as recreation facilities and public administration. One part of these goods is bought on the market (respectively G_t^J, G_t^E and G_t^C), while the other part is produced by public employees. Equations (10)-(12) describe the supply of these goods, with the underlying production functions. $H_{H,t}^g$ and $H_{L,t}^g$ represent respectively total effective public labor of high and low-ability individuals. We define these variables

in section 2.7. The pool of public workers is allocated to the three sectors: $\theta_{1,s}$ and $\theta_{2,s}$ are the fractions of the public employees of a certain skill-type employed in the investment and the education sector. It follows that the fraction of public employees of a certain skill type that produce consumption goods is $1-\theta_{1,s}-\theta_{2,s}$. We now define the output of effective labor in each sector as a *CES* aggregate where v is the substitution elasticity and χ_H is the factor share of high-ability workers in output.[3]

$$J_t = \omega\left[\chi_H\left(\theta_{1,H}H_{H,t}^{g}\right)^{1-\frac{1}{v}} + (1-\chi_H)\left(\theta_{1,L}H_{L,t}^{g}\right)^{1-\frac{1}{v}}\right]^{\frac{v}{v-1}} + G_t^J \tag{10}$$

$$E_t = \omega\left[\chi_H\left(\theta_{2,H}H_{H,t}^{g}\right)^{1-\frac{1}{v}} + (1-\chi_H)\left(\theta_{2,L}H_{L,t}^{g}\right)^{1-\frac{1}{v}}\right]^{\frac{v}{v-1}} + G_t^E \tag{11}$$

$$C_t^g = \omega\left[\chi_H\left((1-\theta_{1,H}-\theta_{2,H})H_{H,t}^{g}\right)^{1-\frac{1}{v}} + (1-\chi_H)\left((1-\theta_{1,L}-\theta_{2,L})H_{L,t}^{g}\right)^{1-\frac{1}{v}}\right]^{\frac{v}{v-1}} + G_t^C \tag{12}$$

Finally, ω is a *TFP*-parameter capturing the efficiency with which public sector employees produce a specific output. All workers are paid the competitive wage determined in the private sector (cfr. infra). As in Ardagna (2001) and Forni *et al.* (2010), an individual is indifferent between working in the private or the public sector.

2.4 Private production

Private firms act competitively on output and input markets and maximize profits. All firms are identical. Total private output is given by the production function in Equation (13). It exhibits constant returns in three productive factors: physical capital K_t^p, private effective labor H_t^p and public capital K_t^g. As in Futagami *et al.* (1990), the stock of public capital acts as a public good and augments the productivity of private inputs. This framework differs from the original setting in Barro (1990) in that not the *flow* of public expenditures, but the *stock* of public infrastructure influences private production. β measures the elasticity of public capital in the production of private goods. Private effective labor in Equation (13) is represented by the same constant elasticity of substitution (*CES*) function as in the public sector[4].

[3] Turnovsky and Pintea (2006) assume that public production requires the use of both labor and capital as inputs. The authors model a public firm that produces a given amount of public investment goods at minimum cost. As such, they impose a certain J (in % of GDP) in line with real data on public investment-to-GDP. As public investment (and the two other public outputs) is endogenous in our model, and as we use a simpler production function, we introduce the parameter ω which will be calibrated in Section 3.

[4] Many studies incorporating public expenditures (flow) or capital (stock) into the production function assume constant returns to scale in the private inputs (e.g. Ardagna, 2001, 2007). We require constant returns in all inputs in order to generate a Balanced Growth Path. As such, in our model, public capital is a public input of the unpaid-factor variant (Feehan and Batina, 2007, Agénor, 2008).

$$Y_t^p = \left(K_t^p\right)^{\alpha}\left(K_t^g\right)^{\beta}\left(H_t^p\right)^{1-\alpha-\beta} \tag{13}$$

with: $H_t^p = \left[\chi_H\left(H_{H,t}^p\right)^{1-\frac{1}{\nu}} + (1-\chi_H)\left(H_{L,t}^p\right)^{1-\frac{1}{\nu}}\right]^{\frac{\nu}{\nu-1}}$

and where K_t^p follows from savings decisions in the private sector. The public capital stock K_t^g is constructed in the government sector according to the following accumulation rule:

$$K_{t+1}^g - K_t^g = J_t - \delta_g K_t^g \tag{14}$$

where δ_g is the public capital depreciation rate. Competitive behavior implies in Equation (15) that firms carry physical capital to the point where its after-tax marginal product net of depreciation equals the real interest rate.[5] Physical capital depreciates at rate δ_k. Similarly, Equation (16) states that for both ability levels, the wage per unit of effective labor is determined by its marginal product.

$$\left[\alpha\left(\frac{H_t^p}{K_t^p}\right)^{1-\alpha}\left(\frac{K_t^g}{H_t^p}\right)^{\beta} - \delta_k\right](1-\tau_k) = r_t \tag{15}$$

$$(1-\alpha-\beta)\left(\frac{K_t^g}{H_t^p}\right)^{\beta}\left(\frac{K_t^p}{H_t^p}\right)^{\alpha}\chi_H\left(\frac{H_t^p}{H_{s,t}^p}\right)^{\frac{1}{\nu}} = w_t^s \qquad \forall\, s = L, H \tag{16}$$

It should be stressed that the non-standard production factor, public capital, has no market price. Indeed, the cost of public infrastructure is paid by the government. As such, the rent generated by this factor is not assigned to either of the two other, private, factors, leading to positive profits Π_t in Equation (17). In our model, these profits are distributed equally to all households (j=1:30 and s=L,H).

$$\Pi_t = \beta Y_t^P \text{ and } \pi_t = \frac{\Pi_t}{60}. \tag{17}$$

2.5 Human Capital Technology

The human capital of an individual of ability type s evolves according to Equations (18)-(20). Equation (18) states that, when they enter the model at the age of 19, young workers inherit a fraction ϑ_s of the aggregate human capital of the active population in the period before their entrance (H_{t-1}^*). This externality à la Azariadis and Drazen (1990) will generate in Equation (19) a first difference between low-ability and high-ability workers. The former may experience more difficulty to learn and accumulate knowledge at primary and secondary school, which explains why they enter our model with a smaller fraction of existing human capital. In their first eight periods of active life, high-ability individuals may increase their human capital through tertiary education. It is our assumption in

[5] Note that our model does not include a tax on private capital earnings. Instead, we assume that firms pay a tax on capital returns.

Equation (20) that $h_{j,H}^t$ rises in privately invested education time ($e_{j,H}^t$) and, following among others Glomm and Ravikumar (1998), publicly provided education goods (E_t). In previous work we have shown that introducing productive government expenditures as an input in the human capital production function helps in explaining the cross-country variation in tertiary education and growth rates in OECD countries (Buyse *et al.*, 2013). It is also consistent with empirical evidence showing a positive correlation in developed countries between public education expenditures on the one hand and growth and human capital on the other (Heylen and Pozzi, 2007; Blankenau *et al.*, 2007). We differ from previous studies by explicitly modeling the production of public education goods E_t (cf. supra).

For reasons that we explain in Section 3, we do not allow high-ability individuals to spend time in education after the age of 34. Hence high-ability workers' human capital remains constant from this age onwards (j = 9). Since low-ability individuals do not engage in tertiary education at all, this result holds for them in Equation (20") from the age of 19 onwards (j = 1). Note however that a constant human capital does not exclude variation in *productive efficiency* due to the (exogenous) age-productivity link ε_j. The latter can be thought of as reflecting learning-by-doing. It generates the usually observed hump-shaped age-earnings profile.

$$h_{1,s}^t = \vartheta_s \, H_{t-1}^* \text{ with } H_{t-1}^* = \sum_s \sum_{j=1}^{25} h_{j,s}^{t-j} \tag{18}$$

$$\vartheta_L = \varsigma \, \vartheta_H \text{ with } \varsigma < 1 \tag{19}$$

$$h_{j+1,H}^t = \psi\left(e_{j,H}^t, E_t, h_{j,H}^t\right) \quad \text{for } j = 1{:}8 \tag{20}$$

$$= h_{j,H}^t \quad \text{for } j \geq 9 \tag{20'}$$

$$h_{j+1,L}^t = h_{j,L}^t \quad \text{for } j \geq 1 \tag{20''}$$

The specification and parameterization of the human capital production function (20) 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, 1998; Docquier and Michel, 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, 1998; Docquier and Michel, 1999; Blankenau and Simpson, 2004; Annabi *et al.*, 2011). We follow the latter approach and assume a Cobb-Douglas function as in Equation (21).

$$\psi\left(e_{j,H}^t, E_t, h_{j,H}^t\right) = h_{j,H}^t + \phi\left(e_{j,H}^t\right)^{\sigma} (E_t)^{\kappa} \left(h_{j,H}^t\right)^{1-\kappa} \tag{21}$$

where ϕ is an efficiency parameter, σ represents the elasticity of human capital with respect to the education effort and κ is the elasticity with respect to available public education goods.

2.6 Government budget and public debt

For an adequate analysis of realistic fiscal consolidation scenarios, it is important to specify a rich and realistic fiscal block. The government in our model raises taxes on labor income, capital income and consumption. It buys education goods G^E, non-wage consumption goods G^C, and investment goods G^J on the market. Moreover, it also pays public wages, benefits related to non-employment NEB, and lump sum transfers Z. It may also issue debt. We denote public debt at the beginning of period t as D_t, while D_{t+1} is public debt at the end of this period (the beginning of period $t+1$). Equation (22) describes the general government budget constraint. It states that the change in government debt is equal to the primary deficit *plus* interest expenditures.

$$\Delta D_{t+1} = D_{t+1} - D_t = r_t D_t + C_t^C + G_t^E + G_t^J + w_t^H H_{H,t}^g + w_t^L H_{L,t}^g + NEB_t + Z_t - T_{nt} - T_{kt} - T_{ct} \tag{22}$$

with: $G_t^E = g_E GDP_t$

$G_t^C = g_C GDP_t$

$G_t^J = g_J GDP_t$

$H_{s,t}^g = \lambda_s H_{s,t}$

$$\begin{aligned} NEB_t = & \sum_{j=1}^{23} b\,(1-\tau_w)\left(1 - n_{j,L}^{t+1-j}\right) w_t^L \varepsilon_j h_{j,L}^{t+1-j} \\ & + \sum_{j=1}^{8} b\,(1-\tau_w)\left(1 - n_{j,H}^{t+1-j} - e_{j,H}^{t+1-j}\right) w_t^H \varepsilon_j h_{j,H}^{t+1-j} \\ & + \sum_{j=9}^{23} b\,(1-\tau_w)\left(1 - n_{j,H}^{t+1-j}\right) w_t^H \varepsilon_j h_{j,H}^{t+1-j} \end{aligned}$$

$T_{nt} = \sum_{j=1}^{25} \sum_s n_{j,s}^{t+1-j} w_t^s \varepsilon_j h_{j,s}^{t+1-j} \tau_n$

$T_{kt} = \tau_k \left[\alpha Y_t^P - \delta_k K_t^p\right]$

$T_{ct} = \tau_c \sum_{j=1}^{30} \sum_s c_{j,s}^{t+1-j}$

$z_t = Z_t/60.$

Following among others Turnovsky (2000) and Dhont and Heylen (2009), we assume that the government claims given fractions g_E, g_C and g_J of GDP for expenditures on education goods, non-wage consumption and investment goods. As to employment, we assume that the government decides on the fraction λ_s of the total supply of hours worked that it wishes to employ in the public sector (see e.g. Ardagna, 2001 and 2007; Cavallo, 2005; and Forni *et al.*, 2010) and on its allocation to

the three public subsectors. We denote total effective labor (per ability level) in the public sector at time t as $H_{s,t}^{g}$. As we have mentioned before, work in the public sector is paid the same real wage w_t^s as in the private sector.[6] Individuals are hence indifferent between the two sectors. Non-employment benefits (NEB) are an unconditional source of income support related to inactivity. 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. Finally, the government pays the same lump sum transfer z_t to all individuals living at time t.

The pension system is not embedded in the government budget. Pension benefits are paid on a pay-as-you-go basis and financed by contributions from working individuals. We assume a balanced system in which the uniform contribution rate cr endogenously adapts to satisfy the budget constraint in Eq. (23).

$$\sum_s \sum_{j=24}^{30} pp_{j,s}^{t+1-j} = cr_t \sum_s \sum_{j=1}^{25} n_{j,s}^{t+1-j} w_t^s \varepsilon_j h_{j,s}^{t+1-j} \tag{23}$$

2.7 Model Closure

Equation (24) describes labor market equilibrium. Total employed effective labor of skill group s is equal to aggregate effective labor supply over all individuals of all active age groups of that skill type. Hours worked are multiplied by productive efficiency. We formalize our assumption that the government hires away a fraction λ_s of total labor supply in Equations (25) and (25'). This results in an expression for the effective labor employed privately ($H_{s,t}^{p}$) and publicly ($H_{s,t}^{g}$)

$$H_{s,t} = \sum_{j=1}^{25} n_{j,s}^{t-j+1} h_{j,s}^{t-j+1} \varepsilon_j \tag{24}$$

$$\left(n_{j,s}^{t-j+1}\right)^{g} = \lambda_s n_{j,s}^{t-j+1} \quad \forall\, j\text{=1:25 and } s = L, H \text{ such that } H_{s,t}^{g} = \lambda_s H_{s,t} \tag{25}$$

$$\left(n_{j,s}^{t-j+1}\right)^{p} = (1-\lambda_s)\, n_{j,s}^{t-j+1} \quad \forall\, j\text{=1:25 and } s = L, H \text{ such that } H_{s,t}^{p} = (1-\lambda_s) H_{s,t} \tag{25'}$$

Given our definition of θ_1 and θ_2 in Section 2.3, we can express the fractions of all employees at work in the public investment, education and consumption goods sectors as respectively $\theta_{1,s}\lambda_s$, $\theta_{2,s}\lambda_s$ and $(1-\theta_{1,s}-\theta_{2,s})\lambda_s$.

[6] We acknowledge that public sector wages may differ from private sector wages. However, this difference may be small after all. Ardagna (2007) shows for a benchmark of 10 European countries that in 1991-95 public sector wages were only 4.59% higher than private sector wages.

The law of motion describing the evolution of the private capital stock is described in Equation (26) where I_t are private investments in period t and δ_k is the private capital depreciation rate.

$$K_{t+1}^{p} = (1 - \delta_k)K_t^p + I_t \tag{26}$$

In a closed economy, government bonds and firms' physical capital are perfect substitutes in the portfolios of households. Therefore, capital market equilibrium satisfies:

$$\sum_s \sum_j a_{j-1,s}^{t-j} = K_t^p + D_t \tag{27}$$

We define GDP in equation (28). As our model includes public employment, we follow common practice in national accounts and include public wage expenditures in the definition.

$$GDP_t = C_t + G_t^C + G_t^E + G_t^J + I_t + w_t^H H_{H,t}^g + w_t^L H_{L,t}^g \tag{28}$$

Finally, the model is closed with the introduction of a fiscal policy rule to assure that the *no-Ponzi game* condition holds. We assume that the government uses a single instrument to keep debt in line with the target. At this point, we do not make any specification about this rule. Here, we just note that one requires such a rule for closure of our model. In section 4, we will elaborate on this.

3. Parameterization and replication of macro facts

In this section we first discuss the parameterization of our model. While some of the parameters are commonly used in the literature, many are calibrated to replicate important data for the average of 11 European countries (Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Sweden, United Kingdom) in the period 1995-2007. At the end of the section we confront our model's predictions with key macro facts.

3.1 Parameterization

The values that we adopt for the preference and common technology parameters are standard in the literature. For the discount factor ρ, we impose 0.96, which is equivalent to a rate of time preference equal to 2 % per year (see e.g. Barro, 1990). The value of ϱ, i.e. the reciprocal of the intertemporal elasticity to substitute leisure, is 2. Estimates for this parameter used in the literature, lie somewhere between 1 and 10. Micro studies often reveal very low elasticities (i.e. high ϱ). 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 ϱ from 1 to 3 (Rogerson, 2007, p. 12).

As to technology, we assume for private physical capital a share coefficient α of 0.3 and a depreciation rate of 7.5% per year. For the share of the public inputs in private production β, we assume a value of 0.15. This value is fully in line with what we observe in the literature. We also find

it in Agénor (2011), Easterly and Rebelo (1993) and Bose *et al.* (2007, Table 3). Canning (1999) estimates an elasticity of output per worker with respect to infrastructure (as measured by the number of telephone lines) equal to on average 0.14 for his full sample, and close to 0.26 for higher-income countries. Cerra *et al.* (2008) also use 0.15 for the elasticity of non-traded output with respect to government spending in their simulations. Turnovsky and Pintea (2006) adopt a slightly higher value of 0.20 whereas Baier and Glomm (2001), Rioja and Glomm (2003) and Chen (2003, 2007) use a slightly lower value of 0.1. Finally, Hulten (1996) estimated a value of 0.11. The public capital depreciation rate is assumed to be 4% per year. We set the elasticity of substitution between low and high-ability workers at 1.441. This is the estimated value of Heckman *et al.* (1998a). Finally, we calibrate the input parameter χ_H such that the predicted initial wage differential between low and high-income earners $w^L h_{1,L}/w^H h_{1,H}$ is equal to 66% (i.e. the average relative wage in our set of countries in 2005/2007, see OECD, Education at a Glance 2009, p. 144-145 Table 7.1A).

Following Lucas (1990) we put the elasticity of human capital production with respect to education time σ equal to 0.8. This value is again in the middle of existing studies. It coincides with the value used by Glomm and Ravikumar (1998), is slightly higher than the one used by Lau (2000) and Fougère *et al.* (2009) but slightly lower than the estimate of Heckman *et al.* (1998b). The value of the elasticity of human capital production with respect to publicly provided education goods κ is much more debatable. The available evidence in the literature concerns estimates for the elasticity with respect to public education spending rather than publicly provided education goods, which is mainly our theoretical concept. These available estimates range from 0 (Coleman *et al.*, 1996) to 0.12 (Card and Krueger, 1992) or even higher (Blankenau *et al.*, 2007). Blankenau and Simpson (2004) use a value of 0.10 while Fougère *et al.* (2009) and Annabi *et al.* (2011) adopt 0.18. Given the uncertainty surrounding this parameter and the lack of empirical evidence on the relationship between public education spending and public education goods, we choose a moderate value of 0.12 for κ in order to avoid overestimating the effects of public education expenditures on human capital and growth. Sensitivity analysis to which we refer later reveals that our main results are robust to limited changes in κ (see footnote 8 below).

Table 2

Model parameterization

Parameter	Symbol	Value
Preference parameters		
Discount factor	ρ	0.96
Inter-temporal elasticity of substitution in leisure	$1\backslash\varrho$	0.5
Leisure preference	γ_j	See text
Preference for public goods	μ	0.11
Technological parameters		
Physical capital elasticity in output	α	0.30
Public capital elasticity in output	β	0.15
Input share of high-ability workers	χ_H	0.63
Elasticity of substitution between high and low-ability workers	ν	1.441
Efficiency parameter in the public production function	ω	0.45
Private capital depreciation rate per year (in %)	δ_k	7.5
Public capital depreciation rate per year (in %)	δ_g	4
Human capital technology		
Efficiency parameter	ϕ	14.84
Elasticity with respect to time input	σ	0.8
Elasticity with respect to public spending on education	κ	0.12
Share of human capital inheritance of high-ability individuals (in %)	ϑ_H	6.24
Innate ability of low-ability individuals vis-à-vis high-ability workers (in %)	ς	67
Government policy parameters		
Expenditure on education goods (in % of GDP)	g_E	1.48
Expenditure on government consumption goods (in % of GDP)	g_C	8.32
Expenditure on public investment goods (in % of GDP)	g_J	2.17
Capital tax rate (in %)	τ_k	21.71
Consumption tax rate (in %)	τ_c	14.96
Labor tax rate (high-ability individuals, in %)	τ_w^H	53.20
Labor tax rate (low-ability individuals, in %)	τ_w^L	50.71
Non-employment benefit replacement rate (high-ability individuals, in %)	b^H	45.14
Non-employment benefit replacement rate (low-ability individuals, in %)	b^L	65.73
Pension accrual rate (in %)	$accr$	2.39
Fraction of government employment (in %)	$\lambda_{H,L}$	20.27
Share of public employees in investment sector	θ_1	0.14
Share of public employees in education sector	θ_2	0.30
Public debt-to-GDP ratio (in %)	d_t	70.36

The human capital inheritance parameter of high-ability individuals ϑ_H is calibrated to match an average European real per capita growth rate of 1.96% per year over the same period 1995-2007. Van de Kerckhove and Heylen (2011) state that OECD PISA-scores for low-ability individuals (17th percentile) are approximately 67% of PISA-scores for high-ability individuals (83th percentile). We follow their approach and take this value as a measure of the relative innate ability of low-ability workers in our model (i.e. ς). The efficiency parameter ϕ in the human capital accumulation function is calibrated to match average European tertiary education rates over the period 1995-2006. Data are only available for the age group 20-34. This value is 16.97% and is taken from Heylen and Van de Kerckhove (2013). The age group 20-34 exactly matches the first 8 periods in our model (j = 1 to 8).

Therefore, we have imposed zero education after the age of 34 (j = 9). Extensive analysis on this point, i.e. allowing for education after this age, reveals that the results reported in the next sections are robust to this assumption. Finally, the preference for leisure parameters γ_j are determined such that our model correctly predicts average employment rates in hours by age in Europe (average over all skill types). For the age-productivity profile, we follow among others Miles (1999) and Cournède and Gonand (2006) in assuming the following function of the age: $\varepsilon(age) = \exp(0.05age - 0.0006age^2)$, resulting in an inverted U-shaped pattern.[7] Finally, we set the relative preference for public goods μ at the average leisure preference observed in our model. As such, we follow Turnovsky (2000) and Dhont and Heylen (2009). In our model, this implies μ=0.11. To check the sensitivity of our results with respect to this parameter, we will use alternative values (higher: 0.25, and lower: 0). Note that Turnovsky (2000) imposes a value of 0.30. Park and Philippopoulos (2004) choose 0.25, Dhont and Heylen (2009) 0.26.

The parameters of the government accounts are based on the average data of 11 European countries (Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Sweden, United Kingdom) in the period 1995-2007. Most of the data come from our previous study (Buyse *et al.*, 2013) and from Van de Kerckhove and Heylen (2013). Note that, following the latter study, we allow for different tax rates and non-employment benefit rates for low and high-ability workers. As there is no detailed data available, the fraction of government employment in total employment is set equal for both ability types ($\lambda_H = \lambda_L$) and calibrated to match the observed average ratio of public wage expenditures to GDP of 12.27% in this group of countries and period (see Table 1). What follows is a predicted employment (in hours) share in the public sector equal to about 20% of total employment (in hours). We can only compare this figure with data on public sector employment as a share of the labor force. For instance, Ardagna (2007) shows a value of 18.7% for a benchmark of 10 European countries over the period 1991-1995. The fractions θ_1 and θ_2 of public employees employed in respectively the investment and education sector are calibrated using data on relative public wage expenditures in these categories (see Table 1). Again we assume that these shares are equal for both ability types. Consequently, we find that $\theta_{1,s}\lambda_s$ =3%, $\theta_{2,s}\lambda_s$ =6% and $(1 - \theta_{1,s} - \theta_{2,s})\lambda_s$ =11%, representing the share of all workers that are employed in the respective public good sectors. Finally, the efficiency/normalization parameter ω is calibrated such that public production in investment goods is equal in size to public wage expenditures in the investment sector (i.e. 1.77% of GDP in the countries and time period under consideration; see Table 1). This also implies that total production in the public education sector is equal to total public wage expenditures in this sector (=3.62% of GDP, see Table 1) and similar for the public consumption sector. We further assume a pension accrual rate of 2.39% per period, which translates into a net income-related pension replacement rate of 59.8% observed in Europe. Finally, we set lump sum transfers in the initial steady state such that the initial

[7] We would like to emphasize that our model is not sensitive at all to the specific efficiency pattern imposed, due to the fact that leisure preference parameters γ_j are also assumed to be age-specific. Both parameter sets together make sure our model correctly predicts observed age-specific employment rates.

debt-to-GDP ratio $d_t = D_t/GDP_t$ is equal to 70.36%, the average value of the 11 European countries in the period 1995-2007.

3.2 Model predictions

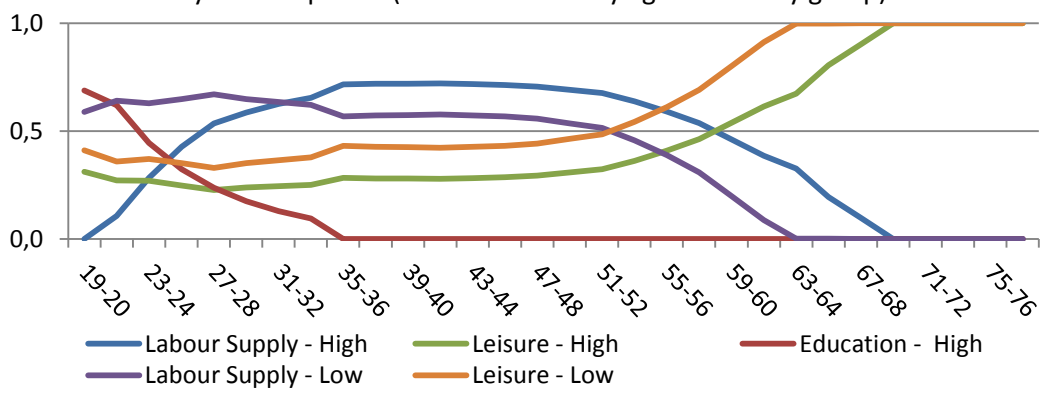
Table 3 shows the predictions of our model concerning some important macro aggregates. All figures are in line with actual data for developed countries. The private physical capital-output ratio is 2.25; the private consumption-to-GDP ratio is about 58%. We observe a private investment-to-GDP ratio of 18.2%, which is in line with many developed countries' private investment rates (Kamps, 2005). Finally, our model predicts a real interest rate of about 4.67% per year. As the debt-to-GDP ratio in the benchmark economy is approximately 70%, interest payments come down to 3.22% of GDP per year.

Table 3 Steady-state value of main variables in the baseline model.

Variable	$\frac{K^p}{Y^p}$	$\frac{C}{GDP}$	$\frac{I}{GDP}$	Real interest rate
Value	2.25	0.576	0.182	0.0467

Figure 1 includes our model's predictions for the life-cycle time profile of low and high-ability individuals. A first restriction underlying this figure is that the average of the fractions of time worked by high and low-ability individuals in a certain age group matches the true data for that age group (see also Appendix A, Table A.1). The underlying data per ability group are unrestricted. As can be seen, our model realistically predicts that low-ability individuals allocate more time to work when young than high-ability individuals. However, the latter work more during most of their active life and also retire later. A second restriction concerns education. We calibrated our model to match an average education rate over the first 8 periods of life of 16.97% of available time. Predictions are as one would expect. Young high-ability individuals spend on average a significantly higher fraction of time to education at the age of 20 than later in life. We observe 69% in the first period. As the individual ages, this fraction decreases gradually to reach only 10% at the age of 33 and 34, and then drops to zero.

Figure 1
Household life-cycle time profile (fraction of time by age and ability group).



4. Simulation strategy

The aim of this paper is to analyze the influence of different fiscal consolidation policies on real macro variables like output and employment, and how all this affects the welfare of current and future generations. We define fiscal consolidation as a set of policies that reduce public debt from the initial level by 40% of GDP. In this section, we explain our simulation strategy.

When simulating fiscal consolidation in general equilibrium models, one should be aware that the instrument or combination of instruments used to realize primary surpluses, need not be the same as the instrument(s) to which the ex-post budgetary savings are allocated. For the purpose of this paper, and in order to allow clear comparisons between different policies, we choose to conduct experiments that *differ only in the type of instrument used for consolidation*, and not in the use of the ex-post savings. More precisely, we execute our simulations as follows.

(1) The government introduces at time $t = 1$ a *temporary* tax increase or expenditure decrease in order to bring back its debt level to 30% of GDP, i.e. a reduction by 40% of GDP.
(2) The ex-ante effort of each fiscal austerity measure is 2% of GDP. Hence, instead of imposing an exogenous debt path or a pre-specified fiscal rule, we keep the speed of adjustment of public debt to its target endogenous and only impose the size of the adjustment (in ex-ante terms). Given that a certain amount of budgetary effort is set forth, we believe that this set-up corresponds more closely to real policy-making. Moreover, as all plans are assumed to be of equal ex-ante size, we can make straightforward comparisons of the effects of different debt reduction strategies on output, welfare etc.
(3) Initially, i.e. at the time of introducing the consolidation programme, we do not impose any fiscal rule. Hence we allow the reversed snowball to take full effect. At the time the gap between the actual debt ratio and its new target value is small enough (we say smaller than 5% of GDP), the instrument used for consolidation returns to its pre-consolidation value. From then onwards, we adjust lump-sum transfers to ensure stable debt dynamics in the long run, i.e. to ensure that debt is brought further in line with the new debt target.

Let us now look at this fiscal rule in more detail. Remember that we determine lump sum transfers in the initial steady state such that the initial debt-to-GDP ratio is constant. We keep these transfers constant at their value for all periods during the adjustment until the gap between the actual debt-to-GDP ratio and its target falls below 5% of GDP. At that moment, the instrument used for fiscal consolidation returns to its initial value and lump-sum transfers are adjusted to ensure that the *no-Ponzi game* condition holds. More specifically, we make the simple assumption in Equation (29) that lump-sum transfers change in order to close half of the remaining (and small) gap between actual and targeted debt. As a result of Equation (29), the surplus resulting from a lower debt level is in every simulation recycled through an increase in lump-sum transfers.

Fiscal rule: z_{t+1} is such that $(d_{t+1} - d^*) = \frac{d_t - d^*}{2} \quad iff \quad d_t - d^* < 0.05$ (29)

where we set d^*= 30% of GDP.

Two remarks are important here. First, the simulation results reported in the next sections are robust to changes in the exact timing when the fiscal rule in (29) takes effect, i.e. they are robust to choosing a slightly lower or higher threshold value. Second, due to the perfect foresight nature of our model, the specific allocation of budgetary savings *after* fiscal consolidation has short-run behavioral implications. As such, choosing a different surplus allocation will imply different economic dynamics. We have chosen to allocate the budgetary savings to lump-sum transfers as they are the most neutral fiscal instrument. Note, however, that we could have complicated the rule in Equation (29) to include other budget items (some other expenditure category or tax rate) or a combination of several fiscal instruments. This would, however, only change the way in which budgetary savings are allocated in the long-run, and not how the initial primary surpluses are generated. Although these alternative assumptions do influence the quantitative nature of our transitional results due to the forward-looking character of the model, the qualitative nature (i.e. the relative effect of one scenario compared to another) remains unchanged. Simulation results in which budgetary savings are recycled through decreasing taxes or increases in other expenditures are available upon request.

5. Effects of fiscal consolidation

Using the simulation methodology described above, we implement nine distinct policies, each resorting to a different unique instrument for consolidation. Table 4 summarizes for each policy the required change in the budget instrument in order to achieve an expected ex-ante change of 2% of GDP in the associated revenue or expenditure category. For instance, to achieve an ex-ante increase of 2% of GDP in consumption tax revenues, it is required to increase the consumption tax rate by 3.5%-points. An equal-size increase in labor tax revenues would require a rise in the labor tax rate by 3.3%-points[8]. We are especially interested in four policies related to public employment. Consolidation through '*public employment*' is simulated through a reduction in λ. It thus concerns an overall cut in the number of public employees. In all three public sectors (investment, education and consumption goods) the same fraction of employees is laid off. An ex-ante reduction of public wage expenditures by 2% of GDP is according to Table 4 achieved when public employment is reduced by 2.8% of the labor force, i.e. a reduction from 20.3% of the labor force to 17.5%. In the final three scenarios (*public investment expenditures*, *public education expenditures* and *public consumption expenditures*), it is our assumption that consolidation occurs partly through a reduction in the number of public employees and partly through a reduction in goods expenditures (resp. g_J, g_E and g_C). As can be seen in Table 1, in the investment sector, 45% of public expenditures are wages. Consequently, the 2% consolidation programme is imposed for 45% through a reduction in public

[8] Note that, although our model has different labor tax rates and non-employment benefit rates for low and high-ability individuals, we assume that consolidation falls equally on both groups.

employment in this sector while the remaining 55% will be achieved through a reduction in investment goods bought on the market. We proceed similarly for consolidation through public education and public consumption expenditures. Given these required changes in Table 4, we perform our simulations as described in the previous section.

Table 4
Required change in policy variable(s) to achieve a 2% of GDP ex-ante change in the corresponding revenue/expenditure category.

Consolidation scenario	Change in instrument (%-points)	
Lump-sum transfers/tax	Δz	-2.0
Consumption tax rate	$\Delta\tau_c$	+3.5
Capital tax rate	$\Delta\tau_k$	+12.8
Labor tax rate	$\Delta\tau_w^L = \Delta\tau_w^H$	+3.3
Non-employment benefit replacement rate	$\Delta b^L = \Delta b^H$	-10.7
Public employment [a]	$\Delta\lambda_s$	-2.8
Public investment expenditures [a]	Δg_J	-1.1
	$\Delta(\theta_{1,s}\lambda_s)$	-1.5
Public education expenditures [a]	Δg_E	-0.6
	$\Delta(\theta_{2,s}\lambda_s)$	-2.4
Public consumption expenditures [a]	Δg_C	-1.1
	$\Delta(\theta_{3,s}\lambda_s)$	-3.3

Note: [a] changes in employment are imposed for both high-ability and low-ability workers; $\theta_3 = 1 - \theta_1 - \theta_2$.

5.1 Debt evolution

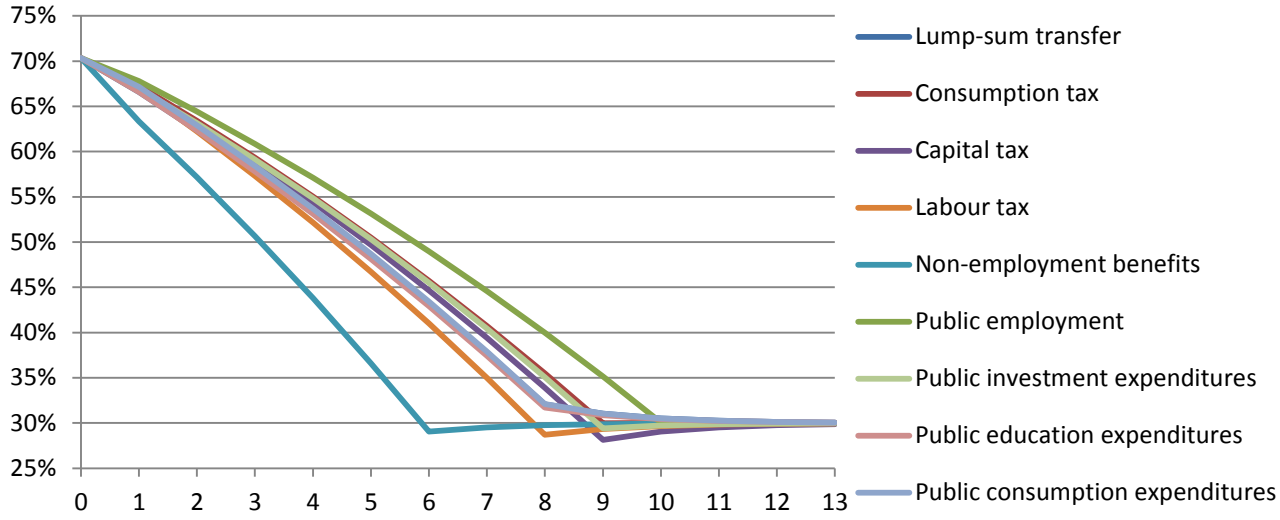
Figure 2 shows the evolution of the debt-to-GDP ratio in these nine scenarios. We report the evolution of time on the horizontal axis where 1 period represents 2 years in reality. We observe, as expected, a gradual decline in public debt in all scenarios. With the exception of two, all strategies reach the new debt target of 30% in about 8 or 9 periods. The exceptions are fiscal consolidation implemented by reducing public employment (which takes at least 1 period longer) and consolidation by means of cutting non-employment benefits (which proceeds much faster and reaches the new target in 6 periods). If speed of consolidation were the only criterion for policy makers, governments should resort especially to a reduction in non-employment benefits. Cutting public employment would then be the least advisable strategy.

5.2 Private output and GDP

Given the same ex-ante policy size, the different debt dynamics observed in Figure 2 can be explained by different short run economic dynamics in response to each of the policy changes. We show in Figures 3 and 4 the evolution of private output and GDP relative to the unchanged policy benchmark. Moreover, we report in Table 5 cumulative GDP effects (in % compared to the benchmark) over alternative time horizons. For most policies, the evolution of private output and GDP is identical. However, as public wage expenditures enter directly into the definition of GDP (see Equation (28)), those consolidation programmes that resort (partly) to reductions in public

employment are characterized by a different evolution of private output and GDP. This is the case for the final four strategies in Table 4. Only for those do we report the GDP level evolution in Figure 4.

Figure 2
Evolution of the debt-to-GDP ratio in different fiscal consolidation scenarios.



First inspection of our results in Figure 3 confirms the positive expectations formulated by many researchers about expenditure based fiscal adjustments, as well as the negative ones about tax based adjustments (e.g. Alesina and Perotti, 1995; von Hagen *et al.*, 2002; Schaltegger and Feld, 2009; Alesina and Ardagna, 2010). All but one consolidation strategies that reduce public expenditures imply an expansion of private output. This expansion is the strongest when non-employment benefits are reduced. Lower benefits raise the relative gain from work, which explains the strong increase in labor supply and hours worked underlying the rise in output (see Figure B.1 in Appendix B). The exception concerns public investment cuts. Observing negative output effects here – at least from the second period onward – is also fully in line with the literature. By contrast, when consolidation relies on tax increases, private output falls during at least five periods (or ten years). The output loss is particularly strong and long-lasting in the cases of labor tax increases and capital tax increases. It is apparent that the main factor driving this result for labor taxes is the drop in labor supply and hours worked (see also Figure B.1 in Appendix B). Capital tax increases mainly undermine investment in physical capital. They also affect hours worked to the extent that a reduction in physical capital implies lower real wages and labor supply.

An interesting observation is the rise in private output when the expenditure cut concerns a reduction in the overall number of public employees. Given our assumption of a perfectly competitive labor market, those employees who are laid off by the government are immediately hired by private firms (i.e. within 1 period of 2 years). Hence, there is an immediate crowding-in effect on private employment with an instantaneous positive impact on private output. This is also true for the three other simulations which rely partly on a reduction in public employment. Although our assumption might be somewhat strong, it is probable that governments will not be able to

reduce their employment base without some guarantees that their employees will soon find another job. Unions may otherwise strongly act against it. Overall, we find a net positive private output effect in the first ten periods after reducing the overall number of public employees. However, with the above in mind, this positive effect should be regarded as an upper bound for this private output effect. If we assume that the redundant employees move more gradually to the private sector, private output will decline on impact. We do this in Section 6.4 where we impose a labor reallocation cost. More specifically, we assume that employees who are laid off by the government, remain unemployed during a period of 2 years, after which they move to the private sector.

The effects of a reduction in public education expenditures are also interesting. Here as well, the immediate result is a significant rise in private output. Although lower education expenditures discourage education (and encourage work) among the youngest generations, aggregate labor supply remains practically unaffected (see Figure B.1). Again, however, public employees previously employed in public education shift to the private sector. So private effective labor increases. Unfortunately, the resulting fall in tertiary education (not reported) implies a temporary decline in the growth of knowledge, which negatively affects private output and GDP over longer horizons. After the consolidation period, i.e. when education expenditures return to their pre-consolidation level, private output in Figure 3 indeed ends up below the benchmark. The economy's stock of human capital is significantly lower.

A more nuanced picture on the effects of expenditure based fiscal consolidation emerges in Figure 4, where the focus is on GDP. If we also take into account public employees' value-added, we no longer observe an expansion after consolidation strategies that include public employment cuts, at least not during the first eight periods. It is clear from our results and our summary in Table 5 that the case can still be made that spending based fiscal adjustments cause smaller recessions than labor and capital tax based adjustments, but it becomes hard to make a case for expansionary spending cuts. It is only when output effects after 20 periods are included in the computation that we observe a positive cumulative result for consumption expenditure cuts. At the revenue side, note that consolidation via an increase of consumption taxes puts much less negative pressure on the economy than via labor or capital taxes. Although there is still an initial loss of GDP during a consumption tax based consolidation, over a 20 or 30 period horizon cumulative net effects are positive.

Our baseline model also emphasizes the importance of public investment for the economy's supply potential. Fiscal tightening resorting only to reductions in public investment leads to the biggest losses in GDP in Figure 4 and Table 5. Over any horizon cumulative GDP effects are very negative. These results confirm the importance of public investment in general and during consolidation times in particular (see also Baxter and King, 1993 and Heylen *et al.*, 2011).

Figure 3
Evolution of the level of private output in different consolidation scenarios (index: benchmark=1).

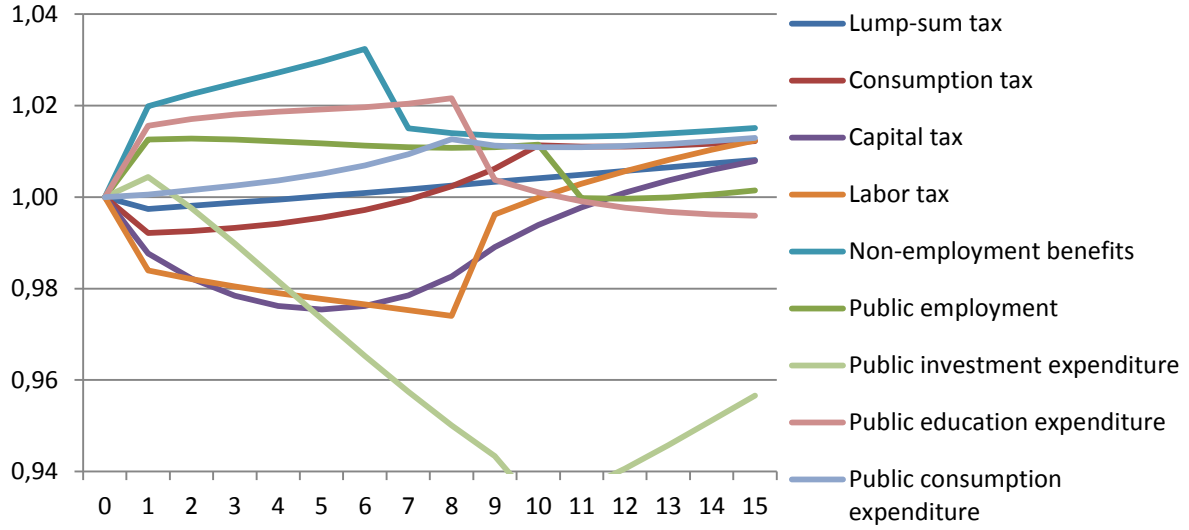
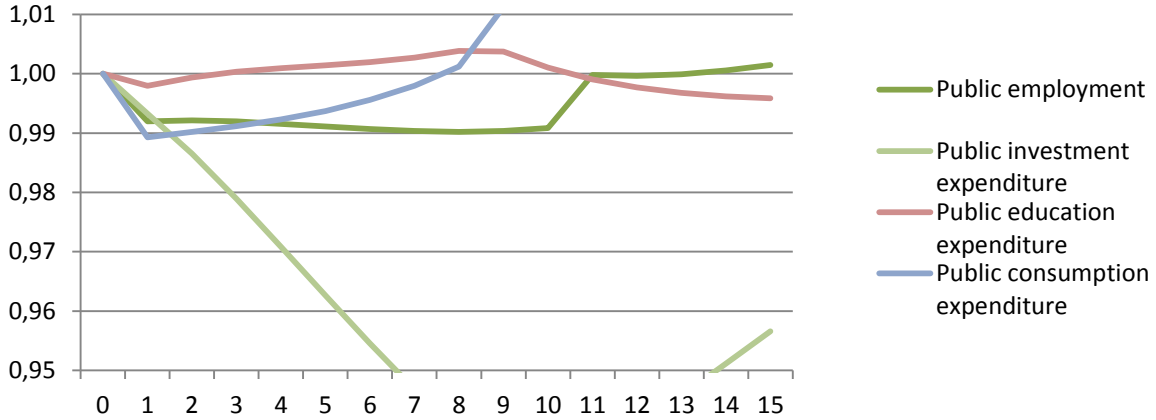


Figure 4
Evolution of the level of GDP in different consolidation scenarios (index: benchmark=1).



Note: In the other consolidation scenarios the evolution of real GDP matches the one of private output in Figure 3.

5.3 Welfare effects

In Figure 5 and Table 6 we report the welfare effects of the nine programmes of fiscal tightening that we focus on. In almost all existing (mainly empirical) work on fiscal consolidation an evaluation of welfare effects is missing. A rare exception is Jensen and Rutherford (2002). The issue is double. First, there is an important intergenerational issue. While the burden of fiscal consolidation falls especially on current generations, it will be future generations that reap most of the benefits of improvements in the government balance. Second, as acknowledged by e.g. Jensen and Rutherford (2002), there is also a possible intragenerational issue. Given for instance different income profiles over life, it is possible that some individuals suffer more from consolidation than others. Our model allows to assess whether this is true for individuals with different abilities to study. The upper part of Figure 5 shows welfare effects for high-ability individuals, the lower part for low-ability individuals. More

precisely, we report on the vertical axis the welfare effect on individuals of the generation born *k* periods after the start of the policy reform, where *k* is indicated on the horizontal axis. So, the data at *k=0* for example concern the newborns in the period the policy is initiated. The data at *k=-29* concern the oldest generations, those who were born 29 periods ago. All data for *k>0* relate to future generations. 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 individuals' hours worked and the public good at the benchmark.

Table 5

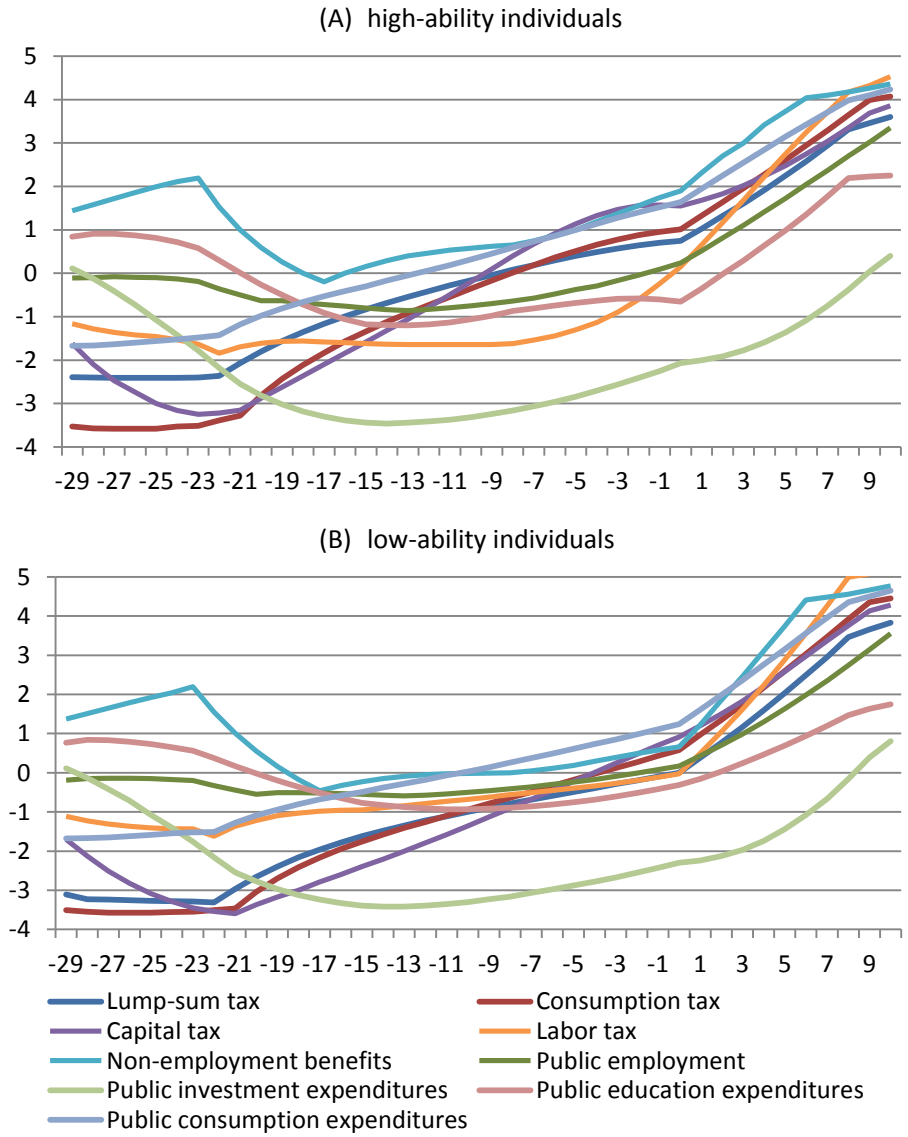
Cumulative real GDP effect over alternative time horizons (compared to benchmark, in %, negative numbers indicate GDP losses).

Time horizon	1:5	1:10	1:20	1:30
Lump-sum transfers	-0,5	-0,1	1,9	3,8
Consumption tax	-2,5	-2,3	1,0	3,4
Capital tax	-7,5	-11,3	-10,1	-7,7
Labor tax	-7,3	-11,4	-8,9	-5,7
Non-employment benefits	9,3	13,3	17,3	20,1
Public employment	-3,1	-5,1	-5,1	-3,5
Public investment	-7,7	-19,0	-32,7	-33,1
Public education	-0,1	0,5	-0,1	-0,1
Public consumption	-3.4	-3.2	0.2	2.9

Note: We report the presented discounted value of real GDP effects. As discount rate we use the benchmark real interest rate of 4.67% per year.

When it comes to *intra-cohort welfare effects* of fiscal consolidation, a quick glance at Figure 5 is enough to see that the effects are very similar for low and high-ability individuals within the same generation. In general, high-ability individuals seem slightly better (or less worse) off than low-ability individuals, except in the case of labor tax increases, but all in all there is very little difference. We may conclude that intra-generational equity is not likely to pose the greatest obstacle to fiscal tightening. In this sense we confirm Jensen and Rutherford (2002), even if their model was much smaller than ours.

Figure 5 Welfare effects of different fiscal consolidation policies (expressed as % of benchmark consumption)



Note: The vertical axis indicates the welfare effect for individuals belonging to the generation born *k* periods after the start of the fiscal consolidation. The horizontal axis indicates *k*. Negative numbers for *k* point at generations born before the consolidation starts.

Welfare differences are much bigger between generations. To analyze these, we integrate the welfare effects induced by each policy reform into a single aggregate summary measure in Table 6. 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/her equally well-of as under the policy. The basis of our computation are the data that we report in Figure 5. But now we also take into account differences in the length of remaining life. For newborn individuals the data in Figure 5 apply to 30 periods, whereas for the oldest generations they apply to only 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. We do this for different generations of individuals. The first column in Table 6 includes those generations of both ability groups which are retired at the moment of the start of the consolidation programme (i.e. between ages 65 and 78). The second column considers individuals between ages 35 and 64 (the active non-studying population). The third column considers individuals of age 19 to 34. The sum of the first three columns gives us the aggregate consumption gain for all generations alive when the consolidation programme is introduced. We show these in column 4. Finally, the last column computes aggregate welfare effects for 10 future generations. Note that our welfare measure for policies that imply a change in public consumption is very much influenced by our value of μ (the relative preference for public consumption goods). We have therefore performed our analysis also with lower and higher values of this parameter.

Welfare analysis imposes even more nuance on our earlier findings about the possibility of expansionary fiscal consolidation. When aggregated over all generations that are alive at the time consolidation is started, only two consolidation strategies bring about net positive welfare effects. In line with our earlier findings for output, we observe again the most positive outcome after a reduction of non-employment benefits. The second strategy with positive consequences for the aggregate welfare of all living generations runs via a reduction of public consumption. For these positive effects to show up, however, it is required that the relative value of public consumption μ is low. Conclusions here crucially depend on the utility-enhancing nature of the produced consumption goods. All other strategies imply lower aggregate welfare for the generations that live when consolidation is started. Even if most of the evidence points at welfare losses for these generations, note that the case can still be made that these losses are smaller under spending based than under tax based fiscal adjustments. The only exception again concerns cuts in public investment.

Table 6 Aggregate welfare effect after compensating welfare transfers (expressed as a % of initial GDP)

Included generations	t-29:t-23	t-22:t-8	t-7:t	t-29:t	t+1:t+10
Lump-sum transfers	-4.2	-8.8	0.6	-12.4	8.2
Consumption tax	-5.4	-11.4	1.7	-15.1	9.9
Capital tax	-4.4	-12.9	3.3	-14.1	9.8
Labor tax	-2.2	-9.8	-2.7	-14.7	10.4
Non-employment benefits	2.9	2.1	3.8	8.8	13.0
Public employment	-0.2	-4.6	-0.7	-5.5	6.6
Public investment expenditures	-1.6	-23.2	-11.3	-36.1	-4.4
Public education expenditures	1.1	-5.4	-2.8	-7.1	3.3
Public consumption expenditures (μ=0.11)	-2.4	-2.5	4.3	-0.6	11.7
Public consumption expenditures (μ=0)	0.1	4.9	7.0	12.0	12.2
Public consumption expenditures (μ=0.25)	-5.6	-12.0	0.9	-16.7	11.2

Things change significantly when we focus on the youngest living generations in column 3 and on future generations in column 5. For these generations most welfare effects are positive. But now it is much less obvious to prefer expenditure based consolidations. Consolidation by means of temporary public employment reductions or by cuts in public investment or public education expenditures create smaller welfare gains (larger losses) for young and future generations than most tax based consolidations. A key element here is that these expenditure cuts in some way affect physical or human capital formation in the economy. The opposite applies to public consumption cuts. Future generations will prefer these from a welfare perspective above all other strategies. We test the robustness of all these results in the next section.

6. Robustness tests

In this section, we first check if the results that we obtained above survive if we independently kill two channels present in the model: the interest rate channel and the education channel. Second, we perform an extensive sensitivity analysis with respect to the public production part of the model. More specifically, we analyze the sensitivity of our results to a change in the output elasticity of public capital β, a change in the efficiency parameter in the production of public goods ω, and a change in the way we introduce public capital as an input (stock or flow) in the private production function[9]. We focus exclusively on the evolution of GDP and welfare.

6.1 Open vs. closed economy: allowing for international mobility of physical capital.

The model presented above assumes a closed economy. In such a set-up, public debt has a direct crowding-out effect in the domestic capital market. Here we modify this assumption and allow for perfect international mobility of physical capital. It implies that the equilibrium interest rate r in our economy is no longer obtained from Equations (15) and (27). Instead, it is determined by the exogenous world real interest rate r_t^* in Equation (27'):

$$r_t = r_t^* \tag{27'}$$

In our simulations we set r_t^* equal to its level in the benchmark economy, i.e. 4.67% per year. Private capital will flow into the economy according to Equation (15) when its net marginal product after taxes exceeds this exogenous interest rate level (K^P will then rise), and vice versa.

[9] We have also analyzed the sensitivity of our results to changes in the value of κ, the elasticity of human capital accumulation to changes in public education expenditures. Effects were very small. Only for the consolidation policy resorting to decreases in public education expenditures did this lead to slight changes in the results (available upon request).

Table 7

Effects of fiscal consolidation assuming an exogenous and constant interest rate (small open economy)

	Cumulative GDP effect compared to benchmark, in %, time horizon:		Aggregate welfare effect after compensating welfare transfers (in % of initial GDP) Included generations				
	1:5	1:30	t-29:t-23	t-22:t-8	t-7:t	t-29:t	t+1:t+10
Lump-sum transfers	0.9	1.1	-3.8	-10.0	-1.7	-15.4	2.3
Consumption tax	-0.4	-2.0	-4.6	-13.1	-3.3	-21.1	1.3
Capital tax	-17.4	-25.6	-3.7	-11.3	-4.8	-19.7	3.4
Labor tax	-9.9	-7.2	-3.4	-11.9	-4.0	-19.2	7.7
Non-empl. benefits	15.2	19.4	3.5	-0.5	0.4	3.4	5.6
Public employment	0.9	-5.7	0.4	-6.6	-4.4	-10.5	-0.8
Public investment	-4.6	-42.6	-0.3	-23.8	-17.0	-41.1	-12.1
Public education	5.9	-4.6	2.1	-7.9	-7.7	-13.5	-6.7
Public consumption (μ=0.11)	-0.3	-1.1	-1.7	-4.3	-0.1	-6.0	3.9

We have simulated all nine fiscal consolidation scenarios again under the assumption of a small open economy with exogenous and constant real interest rate. In Table 7 we report the results for GDP and welfare, following the setup that we adopted before in Tables 5 and 6. We observe three changes compared to our baseline simulations in these earlier tables. First, assuming an open economy with perfect capital mobility somewhat restores the sharp contrast in short-run output effects between contractionary tax based adjustments and the possibility of expansionary spending based adjustments (except public investment cuts). Short-run output effects from capital tax and labor tax increases are much more negative in Table 7 than in Table 5. Both policies reduce the net return to investment in physical capital, which causes capital outflow[10]. Unlike in a closed economy, there is no offsetting fall in the interest rate. Spending cuts however bring about more positive short-run output effects. The increase in labor supply when non-employment benefits or education expenditures are reduced, or the reallocation of labor to the private sector when the government is downsized, raise the marginal productivity of physical capital in that sector and the return to investment. In this case capital flows in, and there is no offsetting interest rate increase. Second, in a small open economy cumulative long-run output effects over 30 periods are more negative (less positive) in all consolidation scenarios including those that are spending based. If there was a bias in our results for output in the previous sections, it will certainly not have been a negative one. The reason is again the exogenous interest rate. Unlike closed economies, a small open economy cannot benefit from a lower interest rate and its positive effects on tertiary education, human capital accumulation, and private investment in physical capital[11]. The third important change concerns

[10] In the case of higher labor taxes, hours worked will fall, which affects physical capital's gross marginal product.

[11] We could alternatively have assumed that there exists a link between fiscal sustainability and sovereign risk such that the domestic interest rate is equal to the world interest rate plus a risk premium depending on the

welfare. If we first focus on aggregate welfare effects for all current generations, we observe that these are generally much worse than in Table 6. The main reason is weaker output. There is only one remaining policy (non-employment benefit cuts) with expansionary consequences for welfare, and even here the positive effect has been reduced by more than half. If we look at specific generations, the hypothesis of expansionary welfare effects has to be rejected now also for the youngest of the current generations. Even nearby future generations may be worse off, especially so in some of the expenditure based consolidations. In this respect, the results in Table 7 confirm our earlier findings. What is better for output need not be better for welfare.

6.2 Exogenous education.

In our baseline simulations, all consolidation programmes (except the one relying on a reduction in public education expenditures) induce a rise in tertiary education rates both during the transition and in the long-run. The fall in interest rates is a major explanation. As tertiary education is both an important substitute for employment and an important driver of economic growth, taking it into account in the analysis of fiscal consolidation (or fiscal policy in general) is clearly important to obtain realistic simulation effects. We have made a similar argument in an earlier paper showing the crucial importance of considering education when analyzing the macroeconomic effects of pension reform (Buyse *et al.*, 2013). As a second extension, we therefore analyze in this section how our results change when we follow practice in most of the literature and shut down the education channel. We report cumulative GDP-effects over horizons of 5 and 30 periods, and welfare effects, in Table 8.

Table 8

Effects of fiscal consolidation assuming exogenous investment in tertiary education.

	Cumulative GDP effect compared to benchmark, in %, time horizon:		Aggregate welfare effect after compensating welfare transfers (in % of initial GDP) Included generations				
	1:5	1:30	t-29:t-23	t-22:t-8	t-7:t	t-29:t	t+1:t+10
Lump-sum transfers	1.0	5.7	-3.9	-10.8	-2.6	-17.3	3.5
Consumption tax	-0.2	5.6	-4.9	-14.5	-2.7	-22.1	4.1
Capital tax	-3.8	-3.7	-3.6	-16.7	-1.3	-21.6	3.4
Labor tax	-3.7	-2.9	-1.3	-14.7	-9.1	-25.1	2.7
Non-empl. benefits	12.0	22.1	3.6	-1.7	-1.0	0.9	6.7
Public employment	-1.9	-1.5	0.1	-6.3	-4.3	-10.5	1.6
Public investment	-6.0	-31.1	-1.1	-25.9	-15.8	-42.9	-10.2
Public education	-1.3	1.0	0.9	-3.4	-3.1	-5.6	1.3
Public consumption	-0.8	5.2	-1.8	-6.1	-0.5	-8.3	5.1

Comparing the results in Table 8 to those in Table 5, it seems clear that GDP effects may be biased upwards when the education channel is disregarded. This holds also for shorter time-horizons. In our

level of government debt. This would reconstitute the link between government debt and the domestic interest rate. We expect results to be somewhere between those of the closed and the open economy.

baseline simulations, individuals react to all policies (except a reduction in public education) by increasing time invested in education. While this is positive for growth and human capital in the long-run, it also implies an initial drop in effective labor supply. As such, the initial drop in GDP is smaller when education is exogenous and it takes less time for output to recover. Despite this short-run output bonus, however, our observation of generally negative short-run output effects in Table 5 does not disappear in Table 8. As to welfare effects, however, disregarding the education channel in Table 8 would seem to imply a negative bias. One reason is that individuals are now constrained in the sense that they are not able to optimally choose time investment in education.

6.3 Sensitivity analysis

In this section we analyze the sensitivity of our results to a change in the output elasticity of public capital β, a change in the way we introduce public capital as an input (stock or flow) in the private production function, and a change in the efficiency parameter in the production of public goods ω.

6.3.1 Elasticity of output with respect to public capital (β)

The assumption that all public capital enters as an input for private production is important in our model. It implies that reducing public investment affects output not only directly, but also indirectly via its influence on the marginal productivity of both private physical capital and human capital. In this section we investigate the robustness of our results to this assumption. A first issue is to have a correct estimate for the elasticity of private production with respect to public inputs β. A sensitivity analysis is required. We focus exclusively on the GDP-effects from two consolidation programmes: public employment and public investment reductions. Effects for all other scenarios are hardly affected by the choice of β. Figure 7 shows the results. In Appendix C we report welfare effects.

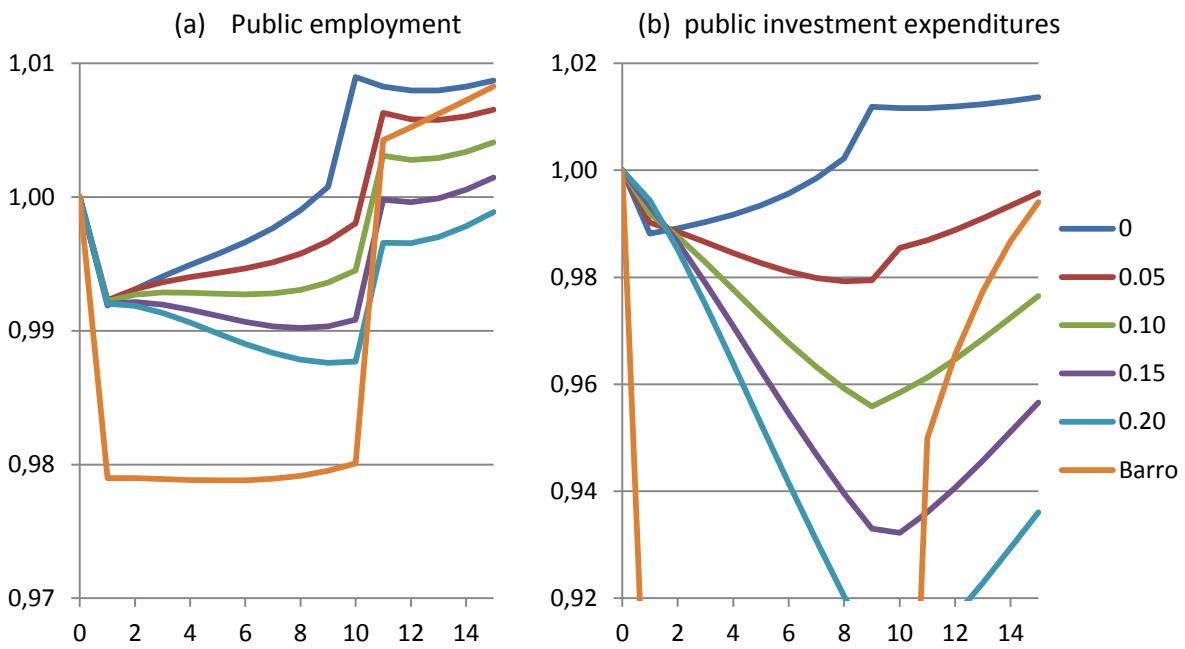
Whatever the value that we impose for β, our earlier conclusion that short-run *GDP* effects are negative after a public employment or a public investment cut survives. The higher β, the larger is the loss of GDP on impact, and the more persistent is this loss[12]. Ardagna (2001, 2007) obtained similar findings. As a second extension, we replace Equation (13) by (13'). In Equation (13') we adopt the Barro (1990) framework such that the flow of public investment J_t, rather than the stock of public capital K_t^g, enters the production function:

$$Y_t = \left(K_t^p\right)^{\alpha} (J_t)^{\beta} \left(H_t^p\right)^{1-\alpha-\beta} \tag{13'}$$

[12] Simulations for private output under alternative values of β also confirm our earlier findings (see Figure 3). Short-term effects from cutting public employment are generally positive over a horizon of 5 periods, even with values of β around 0.20. By contrast, the effects of cutting public investment on private output are generally negative over a horizon of 5 years, except when β is close to zero.

Under this assumption, and given our baseline estimate for β (=0.15), we find a much more negative impact on GDP from a reduction in the number of public employees, even when we allow for direct crowding-in of employees into the private sector as present in our model. Moreover, the total GDP loss during times of fiscal austerity is now the largest of all possible strategies (compare Figures 4 and 7). Effects on welfare in Appendix C are consistent with the observed GDP evolution. The higher the value of β, the higher (lower) the aggregate welfare losses (gains) from fiscal consolidation. This holds for all generations under consideration. Under the Barro framework, welfare losses from both reductions in public employment and public investment expenditures are unprecedented. We conclude that it was not due to the particular choice of β that we found no expansionary output and welfare effects after public employment or investment cuts in Tables 5 and 6 (at least for all current generations).

Figure 7
Evolution of the level of GDP under alternative values of β and under the Barro (1990) framework (index: benchmark=1)



6.3.2 Efficiency of government production (ω)

Finally, we have checked the sensitivity of our results with respect to the value for the efficiency parameter in the production of public goods ω. We report the results for the cumulative GDP effect and the welfare effects in Table 9 below. We focus exclusively on a reduction in public employment. We find that reducing public employment leads to more optimistic GDP effects when government efficiency is lower. However, this is only true for long enough time horizons. The initial effect consistently remains negative. Concerning welfare, results are more clear: when government efficiency is lower, reducing public employment considerably improves welfare even in the short run.

Table 9
Effect of reducing public employment on cumulative GDP and welfare.

	ω	1:5	1:10	1:20	1:30	
Cumulative GDP effect (in % compared to initial benchmark)	baseline	-3.1	-5.1	-5.1	-3.5	
	50% Lower	-3.1	-4.7	-3.8	-1.9	
	Zero	-3.4	-4.4	-1.1	1.7	
		t-29:t-23	t-22:t-8	t-7:t	t-29:t	t+1:t+10
Aggregate welfare effect after compensating welfare transfers (in % of initial GDP)	baseline	-0.2	-4.6	-0.7	-5.5	6.6
	50% Lower	0.2	-1.6	1.1	-0.4	8.2
	Zero	0.9	5.6	5.8	12.3	12.5

6.4 Labor reallocation cost

In this section we leave the assumption of a perfect labor market when the government lays off employees and assume the existence of a labor reallocation cost. More specifically, it is our assumption that individuals who are laid off by the government are not directly employed in the private sector. Instead, they remain inactive for exactly one period (i.e. 2 years in reality). After this period, they find a job in a private firm. Figure 8 focusses on the evolution of private output under the above assumption. The dashed lines show the impact under our baseline assumption of perfect labor markets (as observed in Figure 3). The solid lines show the impact under an imperfect labor market. As expected, due to a temporary employment loss, we now find that the initial output effect is negative and much worse than documented above. As a result, GDP and welfare effects will also be more negative. The latter is documented in Table 10 which shows that especially current generations will suffer significantly more under stronger reallocation costs. These results nuance even more the possible existence of non-Keynesian effects of fiscal consolidation for these expenditure-based policies.

Figure 8
Evolution of private output in case of an imperfect labor market (index: benchmark=1)

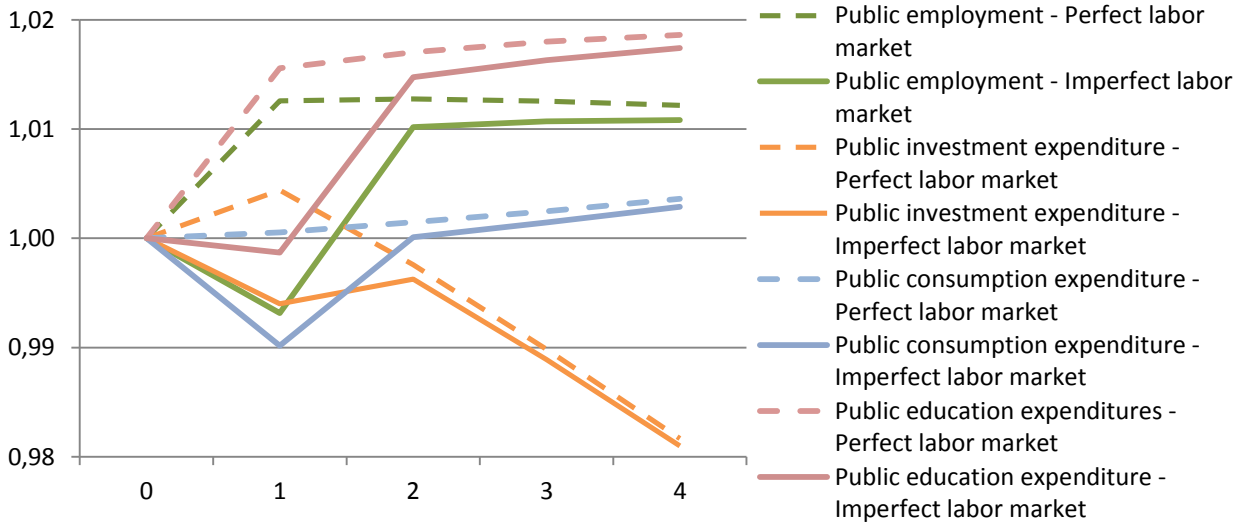


Table 10
Aggregate welfare effect after compensating welfare transfers when labor markets are (im)perfect (in % of initial GDP)

	Perfect labor market		Imperfect labor market	
	t-29:t	t+1:t+10	t-29:t	t+1:t+10
Public employment	-5.5	6.6	-7.4	6.1
Public investment	-36.1	-4.4	-37.1	-4.6
Public education	-7.1	3.3	-8.7	3.0
Public consumption	-0.6	11.7	-1.7	11.5

7. Conclusion

Macroeconomists disagree heavily on the output effects of fiscal consolidation, and on related determinants of the effectiveness of consolidation to bring down the public debt-to-GDP ratio. Different datasets, different methodologies, and sometimes ideologically inspired considerations, are employed to fight an empirical battle. The debate has become particularly lively since the financial crisis of 2008-09.

In this paper we study the effects of fiscal consolidation within a rich theoretical dynamic general equilibrium model of a perfectly competitive economy. The main characteristics of our model are the following. (i) We specify overlapping generations of individuals with either high or low innate ability. (ii) Low-ability individuals allocate their time to either work or leisure. High-ability individuals also allocate time to education and human capital accumulation. These allocation decisions are fully endogenous in our model. (iii) We can study effects of consolidation not only on private output and GDP, but also on the welfare of current and future generations of high and low-ability individuals. (iv) Whereas most theoretical macro models reduce the role of the government at the expenditure side to purchasing goods and paying transfers, we pay particular attention to also modeling public employment and production. Given the empirical discussion on the role of public wage bill cuts for the success of fiscal consolidation, this was important to do. We realistically distinguish public employees in the production of investment goods, in education, and in the production of useful public consumption goods. As such, public sector output contributes to the construction of public capital and the accumulation of human capital, which both raise private sector output and productivity, and to the provision of direct utility. We test the robustness of our results for the way in which we introduce public capital as an input (stock or flow) in the private production function, for the output elasticity imposed and for frictions in the labor market. (v) We basically assume a closed economy where the real interest rate is fully endogenous. As a robustness test we alternatively assume a small open economy where the interest rate is constant at the world level. We know of no paper in the theoretical fiscal consolidation literature with a setup as rich as ours in (i)-(iv).

We use our model to simulate nine scenarios intended to reduce public debt by 40% of GDP. Given current levels of public debt in many OECD countries close to 100% (on average in the euro area) or even above 100% (in the US and the UK) a targeted reduction by 40%-points cannot be called an

exaggeration. These scenarios include both tax based consolidations and expenditure based consolidations. Among the former we consider increases of labor taxes, capital taxes and consumption taxes. Among the latter we include reductions of non-employment benefits, public employment, public investment, and expenditures on goods in the different public subsectors. We run these simulations under perfect foresight in a non-stochastic setting. The use of a rigorous theoretical model has the advantage that it yields a well-structured analysis and picture of the economic implications of fiscal consolidation, and that the sensitivity of results to the assumptions made can easily be analyzed.

The empirical literature has focused on a few key hypotheses. A strong one is that tax based fiscal consolidation is contractionary, whereas spending based adjustment induces expansionary output effects, also in the short-run. Expansionary effects would most likely occur when social transfers or public employment and the public wage bill are diminished. A weaker hypothesis is that the output effects of spending based consolidations are better (less negative) than those of tax based consolidations.

Our simulations of *output effects* generally confirm the weaker hypothesis. Expenditure based consolidation is better than labor or capital tax based consolidation (at least when spending cuts do not concern public investment). This conclusion applies to both the short-run and the long-run. Consolidation via consumption tax increases also hurt the economy in the short-run, but is generally one of the more efficient policies in the longer run. Confirmation of the stronger hypothesis, however, is much more difficult to find. Truly expansionary output effects after spending cuts can only be observed for private output. We generally do not observe them when we consider GDP and include the value added produced by public employees. Cutting public employment is not expansionary for GDP in the short and medium run. It may be expansionary for GDP in the longer run, but only if public employment is reduced in public consumption goods production.

When it comes to *welfare effects*, we observe much bigger differences between different age groups than between different ability types of the same age. Here we confirm Jensen and Rutherford's (2002) conclusion that intergenerational heterogeneity is the most important obstacle for fiscal tightening. Our results for welfare bring even more nuance on the possibility of expansionary fiscal consolidation. When aggregated over all generations that are alive at the time consolidation is started, the net welfare effect of all strategies to reduce the public debt ratio by 40%-points is negative, except one: a reduction of non-employment benefits. Consolidation via a reduction of public consumption may also be expansionary for welfare, but only when the relative utility value of public consumption goods is very low. As to the weaker hypothesis, we still observe that spending based adjustments (except investment cuts) are better than tax based ones, i.e. they induce smaller losses for the aggregate of current generations. However, things are different when we focus on the youngest and future generations. For these generations, welfare effects from consolidation are positive rather than negative. Most interestingly, these positive effects are smaller under spending based adjustments in the area of education, investment, and overall public

employment, than under tax based adjustments. Robustness tests by changing key assumptions of our model never imply changes of these conclusions, quite on the contrary.

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References

Afonso, A. and Gomes, P. (2008) Interactions between private and public sector wages, *ECB Working Paper Series 971.*

Agénor, P.R. (2008). Fiscal policy and endogenous growth with public infrastructure. *Oxford Economic Papers*, 60, 57–88.

Agénor, P.R. (2011) Schooling and public capital in a model of endogenous growth, *Economica*, 78(309), 108-132.

Agénor, P.R. and Yilmaz, D. (2011) The simple dynamics of public debt with productive public goods. University of Manchester Discussion Paper.

Alesina, A., and Perotti, R. (1995) Fiscal expansions and adjustments in OECD countries, *Economic Policy*, 21, 205-248.

Alesina, A., and Perotti, R. (1996) Fiscal adjustments in OECD countries: Composition and macroeconomic effects, *NBER Working Paper*, N° 5730.

Alesina, A., and Ardagna, S. (2010) Large changes in fiscal policy: Taxes versus spending, in J. R. Brown (ed.), *Tax Policy and the Economy*, Vol. 24, The University of Chicago Press, p. 35-68.

Alesina, A., and Ardagna, S. (2012) The design of fiscal adjustments, *NBER Working Paper,* N° 18423.

Annabi N., Harvey S. and Lan, Y. (2011) Public expenditures on education, human capital and growth in Canada: An OLG model analysis, *Journal of Policy Modeling*, 33(6), 852-865.

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

Ardagna, S. (2001) Fiscal policy composition, public debt and economic activity, *Public Choice*, 109(3-4), 2001, 301-325.

Ardagna, S. (2007) Fiscal policy in unionized labor markets, *Journal of Economic Dynamics and Control*, Elsevier, 31(5), 1498-1534.

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

Baxter, M. and King, R.G. (1993) Fiscal policy in general equilibrium, *American Economic Review*, 83, 315-334.

Baier, S. L. and Glomm, G. (2001) Long-run growth and welfare effects of public policies with distortionary taxation. *Journal of Economic Dynamics and Control*, 25, 1007–42.

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

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

Blankenau W.F. and Simpson N.B. (2004) Public education expenditures and growth, *Journal of Development Economics*, 73(2), 583-605.

Blankenau, W.F., Simpson, N.B. and Tomljanovich, M. (2007) Public education expenditures, taxation,and growth: Linking data to theory, *American Economic Review*, Papers and Proceedings, 97, 393-397.

Bose, N., Haque, M. E. and Osborn, D. R. (2007) Public expenditure and economic growth: a disaggregated analysis for developing countries. *Manchester School*, 75, 533–56.

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

Buyse, T., Heylen, F. and Van de Kerckhove, R. (2012) Pension reform in an OLG model with heterogeneous abilities, Working Papers of Faculty of Economics and Business Administration, Ghent University, Belgium 12/810.

Buyse, T., Heylen, F. and Van de Kerckhove, R. (2013) Pension reform, employment by age, and long-run growth, *Journal of Population Economics*, 26, 769–809.

Canning, D. (1999) Infrastructure's contribution to aggregate output. *Policy Research Working Paper* no. 2246, World Bank.

Card, D. and Krueger, A. B. (1992) Does School Quality Matter? Returns to Education and the characteristics of Public Schools in the United States, *Journal of Political Economy*, 100(1), 1-40.

Cavallo, M. (2005) Government employment expenditure and the effects of fiscal policy shocks, *Federal Reserve Bank of San Francisco Working Paper*, No. 2005-16.

Cerra, V., Tekin, S. and Turnovsky, S. J. (2008) Foreign aid and real exchange rate adjustments in a financially constrained dependent economy. Working Paper. 08/204, International Monetary Fund.

Chen, B.-L. (2003) Tax evasion in a model of endogenous growth, *Review of Economic Dynamics*, 6, 381–403.

Chen B.-L. (2007) Factor taxation and labor supply in a dynamic one-sector growth model, *Journal of Economic Dynamics and Control*, 31, 3941–64.

Clinton, K., Kumhof, M., Laxton, D. and Mursula, S. (2011) Deficit reduction: Short-term pain for long-term gain, *European Economic Review*, 55(1), 118-139.

Coleman, J.S., Campbell, E.Q., Hobson, C.J., McPartland, J., Mood, A.M., Weinfeld, F.D. and York, R.L. (1996) *Equality of educational opportunity*, U.S. Government Printing Office, Washington, D.C.

Corsetti, G. (2012) “Has austerity gone too far?”, *Vox,* Research-based policy analysis and commentary from leading economists, 2 April.

Cournède, B., and Gonand, F. (2006) “Restoring Fiscal Sustainability in the Euro Area: Raise Taxes or Curb Spending”?, *OECD Economics Department Working Papers* n° 520.

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

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

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

Easterly, W. and Rebelo, S. (1993) Fiscal policy and economic growth: an empirical investigation, *Journal of Monetary Economics*, 32, 417–58.

Feehan, J. and Batina, R. (2007) Labor and Capital Taxation with Public Inputs as Common Property, *Public Finance Review*, 35, 626-642.

Fernández-Huertas Moraga, J. and Vidal, J.-P. (2010), Fiscal sustainability and public debt in an endogenous growth model, *Journal of Pension Economics and Finance*, 9(2),277-302.

Finn, M.G. (1998) Cyclical effects of Government’s employment and goods purchases, *International Economic Review*, 39(3).

Forni, L., Gerali, A. and Pisani, M. (2010) The macroeconomics of fiscal consolidations in euro area countries, *Journal of Economic Dynamics and Control*, 34(9), 1791-1812.

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

Futagami, K., Morita, Y. and Shibata, A. (1993) Dynamic analysis of an endogenous growth model with public capital. In T. M. Andersen and K. O. Moene (eds), Endogenous Growth. Oxford: Basil Blackwell.

Giavazzi, F., and Pagano, G. (1990) Can severe fiscal contraction be expansionary? Tales of two small European countries, National Bureau of Economic Research, *Macroeconomics Annual*, 5, Cambridge, MA: MIT Press, 75-111.

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

Glomm, G. and Ravikumar, B. (1998) Flat-rate taxes, government spending on education, and growth, *Review of Economic Dynamics*, 1, 306– 325.

Gomes, P. (2011) Fiscal policy and the labour market: the effects of public sector employment and wages, *European Economy. Economic Papers 439.*

Heckman, J. J., Lochner, L., and Taber, C. (1998a) Tax Policy and Human-Capital Formation, *American Economic Review*, 88(2), 293-297.

Heckman, J. J., Lochner, L. and Taber,. C. (1998b) Explaining Rising Wage Inequality: Explorations with a Dynamic Equilibrium Model of Labor Earnings with Heterogeneous Agents, *Review of Economic Dynamics*, 1, 1-58.

Heylen, F. and Everaert, G. (2000) Success and failure of fiscal consolidation in the OECD: a multivariate analysis. *Public Choice*, 105(1), 103-124.

Heylen, F., Hoebeeck, A. and Buyse, T. (2013) Government efficiency, institutions, and the effects of fiscal consolidation on public debt, *European Journal of Political Economy*, 31, 40-59.

Heylen, F. and Van de Kerckhove, R. (2013) Employment by age, education, and economic growth: effects of fiscal policy composition in general equilibrium, *The B.E. Journal of Macroeconomics*, 13(1), 49-103.

Hulten, C. R. (1996) Infrastructure capital and economic growth: how well you use it may be more important than how much you have. Working Paper no. 5847, National Bureau of Economic Research.

IMF (2010) Will it hurt? Macroeconomic effects of fiscal consolidation, *World Economic Outlook*, October, Chapter 3.

Jensen, S.E.H and Rutherford, T.F. (2002), Distributional effects of fiscal consolidation, *Scandinavian Journal of Economics*, 104, 471-493.

Kamps, C. (2005) New estimates of government net capital stocks for 22 EOCD countries, 1960-2001, *IMF Staff Papers,* 53(1).

Krugman, P. and Layard, R. (2012) *A Manifesto for Economic Sense*.

Larch, M. and A. Turrini (2011) Received wisdom and beyond: lessons from fiscal consolidation in the EU, *National Institute Economic Review*, 217(1), R1-R18.

Lau, M. I. (2000) Assessing Tax Reforms when Human Capital is Endogenous. In Harrison, G., Jensen, S. E. H., Pedersen, L. H., and Rutherford T. F. (eds), *Using Dynamic General Equilibrium Models for Policy Analysis*, North Holland.

Lucas, R.E. (1988) On the mechanics of economic development, *Journal of Monetary Economics*, 22, 3-42.

Moraga, J.F.-H. and Vidal, J.-P. (2010) Fiscal sustainability and public debt in an endogenous growth model, *Journal of Pension Economics and Finance,* 9(02), 277-302.

Miles, D. (1999) Modelling the impact of demographic change upon the economy, *Economic Journal* 109, 1-36.

OECD (2005) Pensions at a Glance: Public policies across OECD countries, OECD, Paris.

OECD (2011) Pensions at a Glance 2011: Retirement-Income Systems in OECD and G20 Countries, OECD, Paris.

Pappa, E. (2009) The Effects of Fiscal Shocks on Employment and the Real Wage, *International Economic Review*, 50(1), 217-244.

Park, H. and Philippopoulos, A. (2004) Indeterminacy and fiscal policies in a growing economy, *Journal of Economic Dynamics and Control*, 28, 645-660.

Perotti, R. (2011) The "austerity myth": gain without pain?, *CEPR Discussion Paper*, N° 8658.

Rioja, F.K. and Glomm, G. (2003) Populist budgets and long run growth. *Unpublished*, Indiana University.

Rogerson, R. (2007) Taxation and market work: Is Scandinavia an outlier?, *NBER Working Paper*, N° 12890.

Rogerson, R. and Wallenius, J. (2009) Micro and macro elasticities in a life cycle model with taxes, *Journal of Economic Theory*, 144, 2277-2292.

Schaltegger, C. A. and Feld, L.P. (2009) Are fiscal adjustments less successful in decentralized governments? *European Journal of Political Economy*, 25, 115-123.

Tagkalakis, A. (2009) Fiscal adjustment: do labor and product market institutions matter?, *Public Choice,* 139, 389-411.

Turnovsky, S.J. (2000) Fiscal policy, elastic labor supply, and endogenous growth, *Journal of Monetary Economics*, 45, 185-210.

Turnovsky, S. and Pintea, M. (2006) Public and private production in a two-sector economy, *Journal of Macroeconomics*, 28(2), 273-302.

Van de Kerckhove, R. and F. Heylen (2011) Heterogeneous ability and the effects of fiscal policy composition on employment and growth, Paper presented at the *16th World Congress of the International Economics Association*, Beijing.

Whiteford, P. and Whitehouse, E. (2006) Pension Challenges and Pension Reforms in OECD Countries, *Oxford Review of Economic Policy*, 22(1), 78-94.

Yakita, A. (2008) Sustainability of Public Debt, Public Capital Formation, and Endogenous Growth in an Overlapping generations Setting. *Journal of Public Economics* 92(3-4), 897-914.

von Hagen, J., Hughes Hallet, A., and Strauch, R. (2002) Budgetary consolidation in Europe: Quality, economic conditions and persistence, *Journal of the Japanese and International economics*, 16, 512-535.

Appendix A

Table A.1

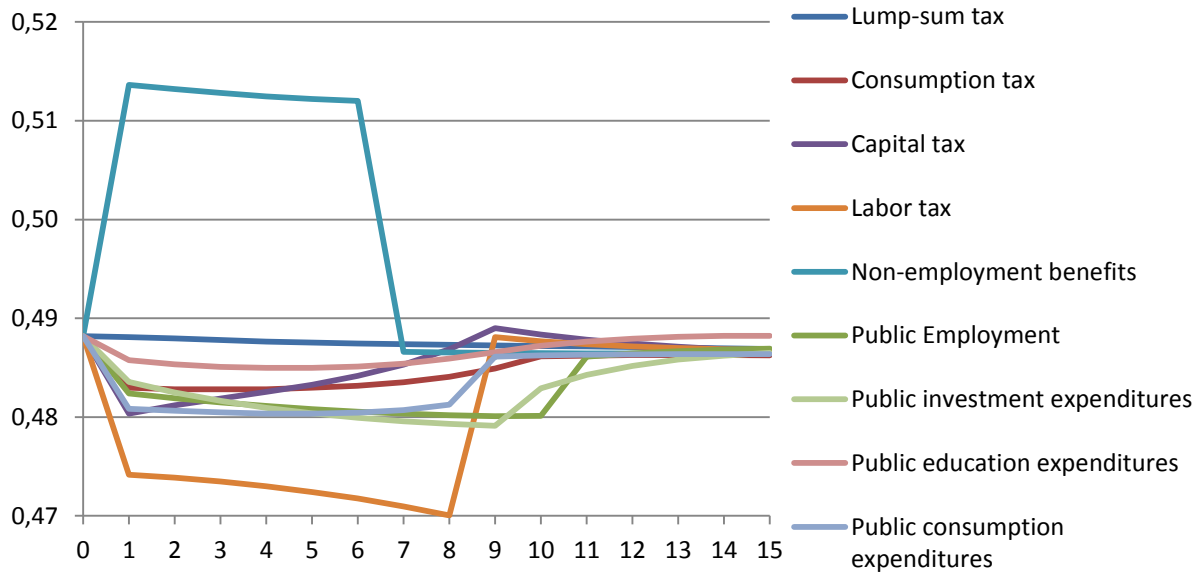
Employment rates in hours by age, 1995-2007, in %

Age	n_j	*Age*	n_j
19-20	29.44%	45-46	64.07%
21-22	37.44%	47-48	63.26%
23-24	45.61%	49-50	61.40%
25-26	53.85%	51-52	59.54%
27-28	60.36%	53-54	54.75%
29-30	61.73%	55-56	48.98%
31-32	63.09%	57-58	42.33%
33-34	63.77%	59-60	33.02%
35-36	64.24%	61-62	23.72%
37-38	64.61%	63-64	16.44%
39-40	64.73%	65-66	9.83%
41-42	64.84%	67-68	4.87%
43-44	64.53%		

Source: OECD.Stat – authors' calculations. Average employment rates in hours over all skill groups in 11 European countries (Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Sweden, UK).

Appendix B

Figure B.1
Aggregate employment evolution after different fiscal consolidation scenarios.



Appendix C

Table C.1
Aggregate welfare effect after compensating welfare transfers (expressed as % of initial GDP)
Sensitivity to the output elasticity to public capital

Included generations	β	t-29:t-23	t-22:t-8	t-7:t	t-29:t	t+1:t+10
Public employment	0	-0.5	-3.3	0.8	-3.0	8
	0.5	-0.4	-3.6	0.3	-3.7	7.8
	0.1	-0.3	-4.0	-0.2	-4.5	7
	0.15	-0.2	-4.6	-0.7	-5.5	6.6
	0.2	-0.1	-5.2	-1.3	-6.6	6
	Barro	-1.6	-8.9	-2.3	-12.8	7
Public investment expenditures	0	-0.3	3.5	6.6	9.8	12
	0.5	-0.7	-4.6	1.1	-4.2	7.6
	0.10	-1.1	-13.8	-5.1	-20.0	1.5
	0.15	-1.6	-23.2	-11.3	-36.1	-4.4
	0.20	-2.2	-32.8	-17.7	-52.7	-10.4
	Barro	-14.3	-69.3	-32.5	-116.1	-8.6