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WORKING PAPER

Leaving the empirical (battle)ground: Output and welfare effects of fiscal consolidation in general equilibrium

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Abstract

We study the effects of fiscal consolidation within a dynamic general equilibrium model with overlapping generations. Our contribution to the theoretical consolidation literature is threefold. (i) Individual decisions of time allocation between work, leisure and education are fully endogenous in our model. (ii) We pay particular attention to also modeling public employment and production. We distinguish public employees in the construction of infrastructure, in education, and in the production of useful public consumption goods. (iii) We go beyond the analysis of the usual economic aggregates (such as *GDP*) and also look at the welfare impact of different fiscal consolidation strategies on current and future generations of both high and low-ability individuals.

Our main findings are as follows. As to output effects, we confirm that expenditure based consolidation is better than labor or capital tax based consolidation. Truly expansionary output effects after spending cuts, however, can only be observed for private output. 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 on the possibility of expansionary fiscal consolidation. 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. Robustness tests by changing key assumptions of our model never imply changes of these conclusions, quite on the contrary.

Keywords: employment by age, endogenous growth, fiscal consolidation, overlapping generations
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1. Introduction

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. Many authors have focused on real output and growth effects since these are of crucial importance for the success or failure of consolidation. One hypothesis that has received particular attention in this context is that spending based fiscal consolidation has the highest probability to bring down the public debt ratio because it induces expansionary output effects, also in the short-run. This expansionary effect would most likely occur when social transfers or public employment and the public wage bill are diminished. Proponents of this view are for example Alesina and Perotti (1996) and Alesina and Ardagna (2010, 2012). Others however are more pessimistic and expect spending cuts to cause short-run output losses (e.g. IMF, 2010; Perotti, 2011). Still others present empirical evidence challenging the view that wage bill cuts raise the likelihood of successful consolidation (e.g. Heylen and Everaert, 2000; Tagkalakis, 2009). 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).

In contrast to the disagreement on the hypothesis that spending based consolidation is expansionary for output, more researchers will agree on the weaker hypothesis that the output effects of spending based consolidations are better (less negative) than those of tax based consolidations.

In this paper we leave the empirical (battle)ground and study the effects of fiscal consolidation within a theoretical dynamic general equilibrium model with overlapping 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 analysis and picture of the economic implications of fiscal consolidation becomes possible. Our analysis will allow an assessment of the hypothesis that spending based fiscal consolidations are expansionary in the short-run, or the hypothesis that tax based adjustments have more negative effects than spending based ones. It will also allow to assess the claim that public employment cuts raise the effectiveness of consolidation programmes, etc. Our analysis will not be limited to the implications for employment, private output and GDP, however. We are also able to study welfare effects. Existing empirical studies have very little to say about the latter, even though many will consider welfare effects to be most important. We can (and will) study welfare effects on both current and future generations of individuals with different innate ability.

This paper is not the first to study the effects of fiscal consolidation or fiscal sustainability in a theoretical model. Our setup however is richer and more realistic than is the case in existing studies. (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. (ii) When young, individuals allocate time to education, work or leisure. At older age, 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. (iii) We pay special attention to realistically modeling the public sector, in particular public employment. The reason for doing this is obvious from the data in Table 1. On average across European countries, the public sector wage bill has about the same size as total public expenditures on goods. Both account for 12% of GDP. If we further roughly distinguish three public subsectors - education, investment and public consumption – we observe that in absolute terms public wages are most important in the consumption sector. Their relative importance versus spending on goods is the highest in the education sector. We take these facts 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 partly bought on the market and partly produced by public employees. Realistically modeling public employment and production is crucial also given the disagreement in the empirical literature on the effects from reducing the public wage bill as instrument of fiscal adjustment.

Table 1 Government wage bill and goods expenditures (in % of GDP)

	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'.

Considering the existing literature, some recent studies (e.g. Forni *et al.*, 2010) analyze fiscal consolidation in an infinite horizon model, and thereby overlook the finite lifetime that every economic agent faces, as well as distributional issues between current and future generations. Moreover, there is a general tendency to neglect either the effects on labor supply or on tertiary education. Cournède and Gonand (2006), for instance, do not model the education decision and hence long-run growth in their analysis of fiscal consolidation. In Forni *et al.* (2010) growth is exogenous also. By contrast, 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. Furthermore, existing theoretical work has largely ignored distributional consequences. We mention Jensen and Rutherford (2002) as an important exception. These authors find that older generations will especially bear the burden of fiscal consolidation such that "inter- rather than intra-generational equity is most likely to pose the greatest obstacle to fiscal consolidation". Finally, despite the importance of public wage expenditures, only few studies have explicitly modeled public employment in a general equilibrium context. As exceptions, we mention Ardagna (2001, 2007), Cavallo (2005), 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. All in all, we are at this point not aware of any study explicitly focusing on fiscal consolidation in a context and model as rich as ours.

We use our model to simulate nine scenarios intended to reduce public debt by about 40% of GDP. 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. Throughout this paper, we abstract from considerations related to a lack of credibility of fiscal policy, individual uncertainty, optimal Ramsey policy or the use of fiscal instruments to stabilize the business cycle. 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 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 may hurt the economy in the short-run, but is generally one of the more efficient policies in the longer run. Truly expansionary output effects after spending cuts, however, can only be observed for private output. We do not observe them when we consider *GDP* and include the value added produced by public employees. The only consolidation strategy which generates expansionary *GDP* effects at short horizons runs via a reduction of non-employment benefits. 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 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, 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 a robustness analysis 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:

$$U^t = \sum_{j=1}^{30} \rho^{j-1} u\left(c_{j,s}^t, \ell_{j,s}^t, C_{t+j-1}^g\right) \qquad (1)$$

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:

$$u\left(c_{j,s}^t, \ell_{j,s}^t\right) = \ln c_{j,s}^t + \gamma_j \frac{\left(\ell_{j,s}^t\right)^{1-\varrho}}{1-\varrho} + \mu \ln(C_t^g) \qquad (2)$$

[1] Variables per generation are then defined as the sum of both ability groups.

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 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.*, 2011). 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

$$\begin{aligned} a_{j,s}^t - a_{j-1,s}^t = {} & r_{t+j-1} a_{j-1,s}^t - (1+\tau_c) c_{j,s}^t + w_{t+j-1}^s \varepsilon_j h_{j,s}^t n_{j,s}^t (1-\tau_w) \\ & + b\, w_{t+j-1}^s \varepsilon_j h_{j,s}^t (1-\tau_w)\left(1 - n_{j,s}^t - e_{j,s}^t\right) + z_{t+j-1} + \pi_{t+j-1} \end{aligned} \tag{6}$$

For *j* = 24:25

$$a_{j,s}^t - a_{j-1,s}^t = r_{t+j-1} a_{j-1,s}^t - (1+\tau_c) c_{j,s}^t + w_{t+j-1}^s \varepsilon_j h_{j,s}^t n_{j,s}^t (1-\tau_w) + pp_{j,s}^t + z_{t+j-1} + \pi_{t+j-1} \tag{7}$$

For *j* = 26:30

$$a_{j,s}^t - a_{j-1,s}^t = r_{t+j-1} a_{j-1,s}^t - (1+\tau_c) c_{j,s}^t + pp_{j,s}^t + z_{t+j-1} + \pi_{t+j-1} \tag{8}$$

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 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 private savings at time *k* and w_k^s the

[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.

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 $b\, w_{t+j-1}^s \varepsilon_j h_{j,s}^t n_{j,s}^t (1-\tau_w)$ (see Buyse *et al.*, 2011).

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.*, 2011). 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.

$$pp_{j,s}^t = \sum_{i=1}^{j-1} accr_i w_{t+i-1}^s \varepsilon_i h_{i,s}^t n_{i,s}^t (1-\tau_w) \prod_{l=i}^{j} x_{t+l-1} \qquad \text{for } j=24{:}25 \tag{9a}$$

$$pp_{j,s}^t = \sum_{i=1}^{25} accr_i w_{t+i-1}^s \varepsilon_i h_{i,s}^t n_{i,s}^t (1-\tau_w) \prod_{l=i}^{j} x_{t+l-1} \qquad \text{for } j=26{:}30 \tag{9b}$$

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. We assume 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 $1-\theta_{1,s}-\theta_{2,s}$. The output of effective labor in each sector is defined a *CES* aggregate where v is the substitution elasticity and χ_H is the factor share of high-ability workers in output.

$$J_t = \omega\left[\chi_H\left(\theta_{1,H}H^g_{H,t}\right)^{1-\frac{1}{v}} + (1-\chi_H)\left(\theta_{1,L}H^g_{L,t}\right)^{1-\frac{1}{v}}\right]^{\frac{v}{v-1}} + G^J_t \tag{10}$$

$$E_t = \omega\left[\chi_H\left(\theta_{2,H}H^g_{H,t}\right)^{1-\frac{1}{v}} + (1-\chi_H)\left(\theta_{2,L}H^g_{L,t}\right)^{1-\frac{1}{v}}\right]^{\frac{v}{v-1}} + G^E_t \tag{11}$$

$$C^g_t = \omega\left[\chi_H\left((1-\theta_{1,H}-\theta_{2,H})H^g_{H,t}\right)^{1-\frac{1}{v}} + (1-\chi_H)\left((1-\theta_{1,L}-\theta_{2,L})H^g_{L,t}\right)^{1-\frac{1}{v}}\right]^{\frac{v}{v-1}} + G^C_t \tag{12}$$

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). An individual is hence indifferent between working in the private or the public sector as in among others Ardagna (2001) and Forni *et al.* (2010)[3].

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^p_t, private effective labor H^p_t and public capital K^g_t. 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].

$$Y^p_t = \left(K^p_t\right)^{\alpha}\left(K^g_t\right)^{\beta}\left(H^p_t\right)^{1-\alpha-\beta} \tag{13}$$

with: $H^p_t = \left[\chi_H\left(H^p_{H,t}\right)^{1-\frac{1}{v}} + (1-\chi_H)\left(H^p_{L,t}\right)^{1-\frac{1}{v}}\right]^{\frac{v}{v-1}}$

and where K^p_t follows from savings decisions in the private sector. The public capital stock K^g_t is constructed in the government sector according to the following accumulation rule:

[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).

$$K_{t+1}^{g} - K_{t}^{g} = J_t - \delta_g K_t^g \tag{14}$$

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.

$$\left[\alpha\left(\frac{H_t^p}{K_t^p}\right)^{1-\alpha}\left(\frac{K_t^g}{H_t^p}\right)^{\beta} - \delta_k\right](1-\tau_k) = r_t \tag{15}$$

$$(1-\alpha-\beta)\left(\frac{K_t^g}{H_t^p}\right)^{\beta}\left(\frac{K_t^p}{H_t^p}\right)^{\alpha}\chi_H\left(\frac{H_t^p}{H_{s,t}^p}\right)^{\frac{1}{v}} = w_t^s \qquad \forall\, s = L, H \tag{16}$$

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*).

$$\Pi_t = \beta Y_t \text{ and } \pi_t = \frac{\Pi_t}{60}. \tag{17}$$

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 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.*, 2011). 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).

[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.

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 results 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.

$$h_{1,s}^{t} = \vartheta_s \, H_{t-1}^{*} \text{ with } H_{t-1}^{*} = \sum_s \sum_{j=1}^{25} h_{j,s}^{t-j} \tag{18}$$

$$\vartheta_L = \varsigma \, \vartheta_H \text{ with } \varsigma < 1 \tag{19}$$

$$h_{j+1,H}^{t} = \Omega\left(e_{j,H}^{t}, E_t, h_{j,H}^{t}\right) \quad \text{for } j = 1{:}8 \tag{20}$$

$$= h_{j,H}^{t} \quad \text{for } j \geq 9 \tag{20'}$$

$$h_{j+1,L}^{t} = h_{j,L}^{t} \quad \text{for } j \geq 1 \tag{20''}$$

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).

$$\Omega\left(e_{j,H}^{t}, E_t, h_{j,H}^{t}\right) = h_{j,H}^{t} + \phi\left(e_{j,H}^{t}\right)^{\sigma} (E_t)^{\kappa} \left(h_{j,H}^{t}\right)^{1-\kappa} \tag{21}$$

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 B_t, while B_{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.

$$\Delta B_{t+1} = B_{t+1} - B_t = r_t B_t + C_t^C + G_t^E + G_t^J + w_t^H H_{H,t}^g + w_t^L H_{L,t}^g + NEB_t + Z_t - T_{nt} - T_{kt} - T_{ct} \quad (22)$$

with: $G_t^E = g_E Y_t$

$$G_t^C = g_C Y_t$$

$$G_t^J = g_J Y_t$$

$$H_{s,t}^g = \lambda_s H_{s,t}$$

$$\begin{aligned} NEB_t = & \sum_{j=1}^{25} b\,(1-\tau_w)\left(1 - n_{j,L}^{t+1-j}\right) w_t^L \varepsilon_j h_{j,L}^{t+1-j} \\ & + \sum_{j=1}^{8} b\,(1-\tau_w)\left(1 - n_{j,H}^{t+1-j} - e_{j,H}^{t+1-j}\right) w_t^H \varepsilon_j h_{j,H}^{t+1-j} \\ & + \sum_{j=9}^{25} b\,(1-\tau_w)\left(1 - n_{j,H}^{t+1-j}\right) w_t^H \varepsilon_j h_{j,H}^{t+1-j} \end{aligned}$$

$$T_{nt} = \sum_{j=1}^{25} \sum_s n_{j,s}^{t+1-j} w_t^s \varepsilon_j h_{j,s}^{t+1-j} \tau_n$$

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

$$T_{ct} = \tau_c \sum_{j=1}^{30} \sum_s c_{j,s}^{t+1-j}$$

$$z_t = Z_t / 60.$$

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 output 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).

$$\sum_s \sum_{j=24}^{30} pp_{j,s}^{t+1-j} = cr_t \sum_s \sum_{j=1}^{25} n_{j,s}^{t+1-j} w_t^s \varepsilon_j h_{j,s}^{t+1-j} \quad (23)$$

[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.

2.7 Model Closure

Equation (24) describes the 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 $(1-\theta_{1,s}-\theta_{2,s})\lambda_s$.

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, bonds and firms' physical capital are perfect substitutes in the portfolios of households. Therefore, capital market equilibrium satisfies:

$$\sum_s \sum_j a_{j-1,s}^{t-j} = K_t^p + B_t \tag{27}$$

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

The goal of this paper is to analyze the economic and welfare consequences of fiscal consolidation. 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 %)	λ_H, λ_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 %)	B_t/GDP_t	70.36

The human capital inheritance parameter of high-ability individuals ϑ_H is calibrated to match an average European real 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 (2010). 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). Table A.1 in Appendix A contains the data and details on their construction. Preference for leisure is very stable before the age of 50 and then increases sharply (see Figure A.1 in Appendix A). 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. Note that our model is not sensitive at all to the specific efficiency pattern as leisure preference parameters γ_j are also age-specific. 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.*, 2011) and from Van de Kerckhove and Heylen (2011). 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 debt-to-GDP ratio 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
Household life-cycle time profile (fraction of time by age and ability group).

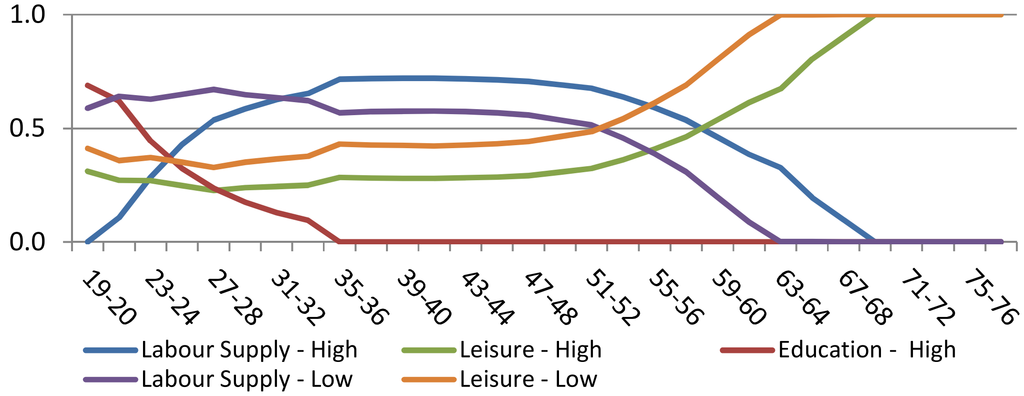


Figure 1 includes our model's predictions for the life-cycle time profile of low and high-ability individuals. A first restriction underlying this figure is that the average of the fractions of time worked by high and low-ability individuals in a certain age group matches the true data for that age group (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 34% in the first period. As the individual ages, this fraction decreases gradually to reach only 4.5% at the age of 33 and 34, and then drops to zero.

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 70.36% of GDP to 30% 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.
(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). We believe that this set-up corresponds more closely to real policy-making. Moreover, as all plans are 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 equal to 70.36%. 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 $(b_{t+1} - b^*) = \frac{b_t - b^*}{2} \;\; iff \; b_t - b^* < 0.05$ (29)

where we set b^*= 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 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[7]. 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

[7] 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.

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 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	$\Delta\tau_n^L = \Delta\tau_n^H$	+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

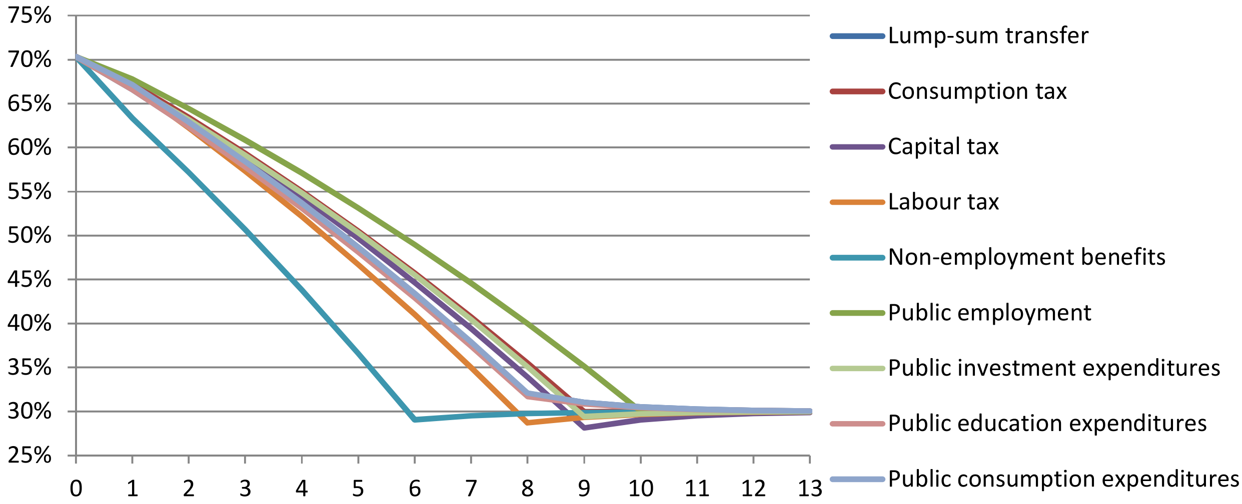
Note: [a] changes in employment are imposed for both high-ability and low-ability workers; $\theta_3 = 1 - \theta_1 - \theta_2$.

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.

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

Figure 2

Evolution of the debt-to-GDP ratio in different fiscal consolidation scenarios.



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.

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 had assumed that the redundant employees move more gradually to the private sector, private output would probably have declined on impact.

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).

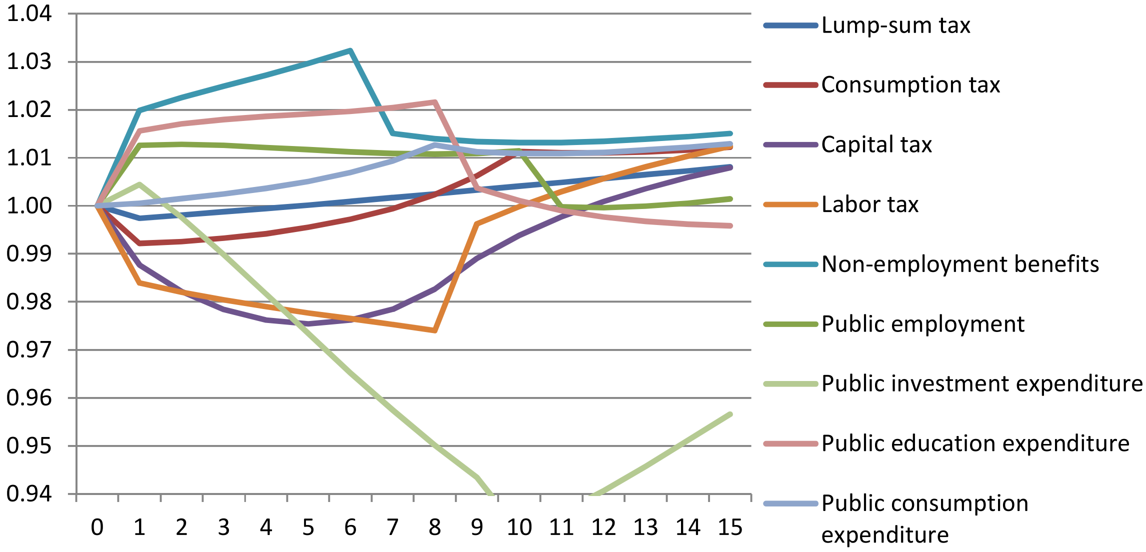
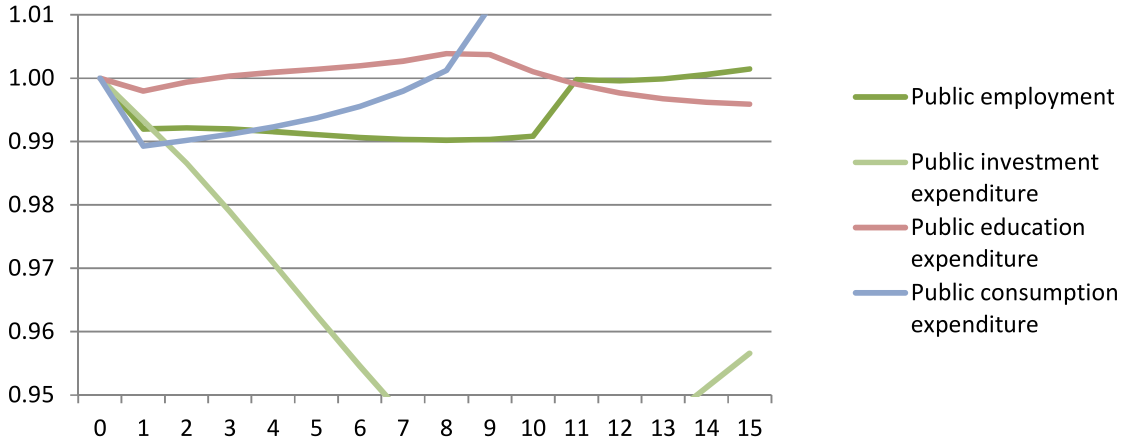


Figure 4

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.

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

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

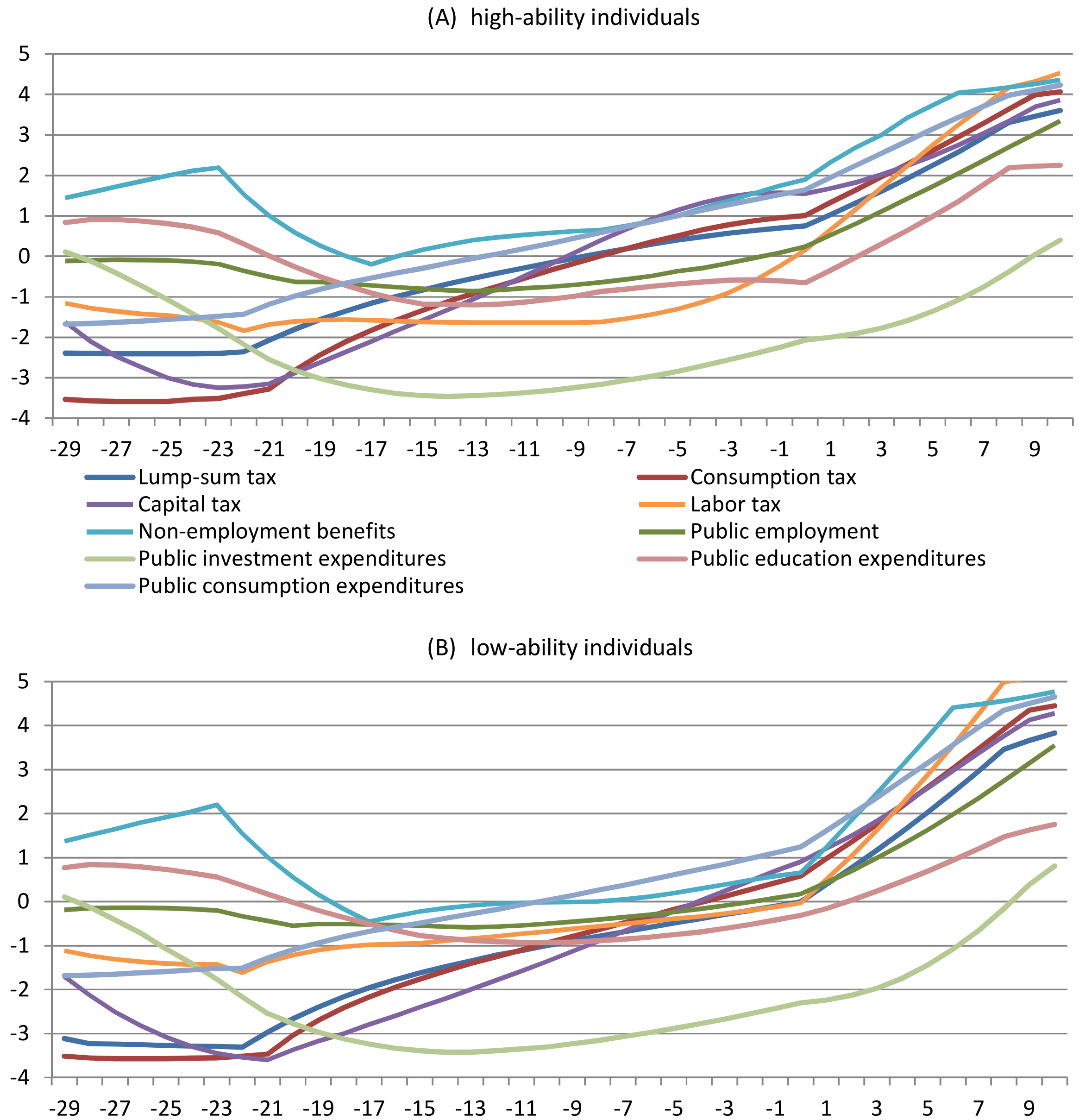
Note: We report the presented discounted value of real GDP effects. As discount rate we use the benchmark real interest rate of 4.67% per year.

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.

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.

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

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.

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 (i.e. those individuals who are still in tertiary education). 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.

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.

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

6. Additional results and 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[8]. 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'):

$$r_t = r_t^* \qquad (27')$$

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.

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

[8] 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).

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[9]. 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[10]. The third important change concerns 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.*, 2011). As a second extension, we therefore analyze in this section how our results change when we

[9] In the case of higher labor taxes, hours worked will fall, which affects physical capital's gross marginal product.

[10] 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 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.

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 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.

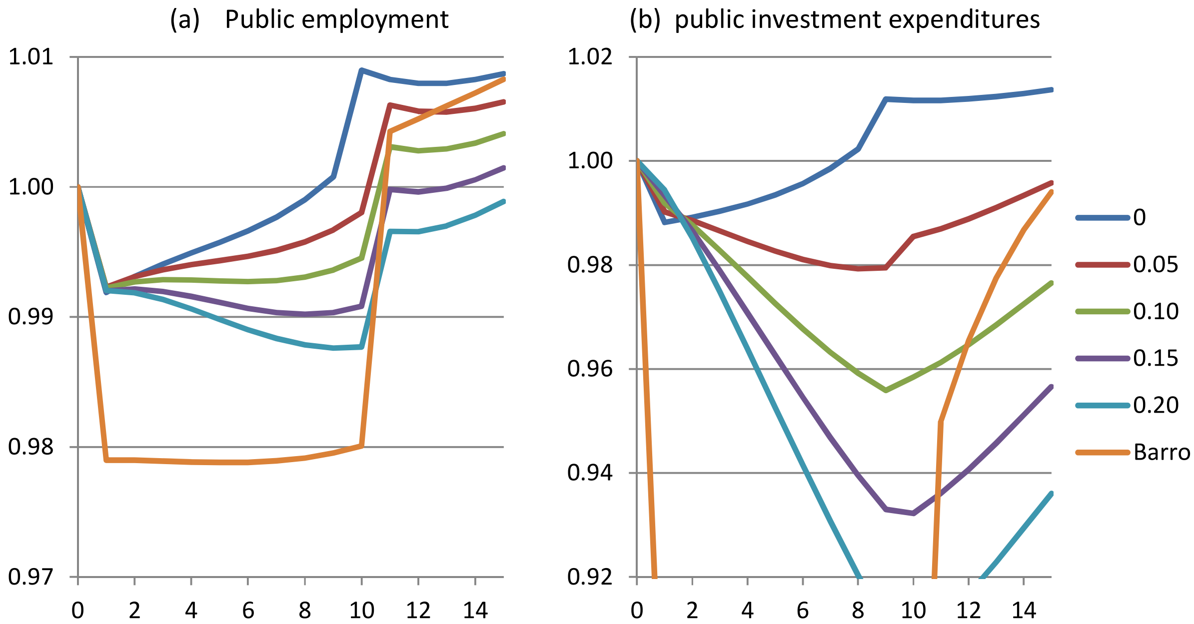
6.3 Sensitivity analysis

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.

Figure 7
Evolution of the level of GDP under alternative values of β and under the Barro (1990) framework (index: benchmark=1)



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[11]. 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:

$$Y_t = \left(K_t^p\right)^\alpha (J_t)^\beta \left(H_t^p\right)^{1-\alpha-\beta} \tag{13'}$$

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

[11] 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.

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).

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

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, and for the output elasticity imposed. (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. With one exception, we do not observe them when we consider *GDP* and include the value added produced by public employees. The exception comes from consolidation via a reduction of non-employment benefits. 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. The exception again concerns consolidation running via 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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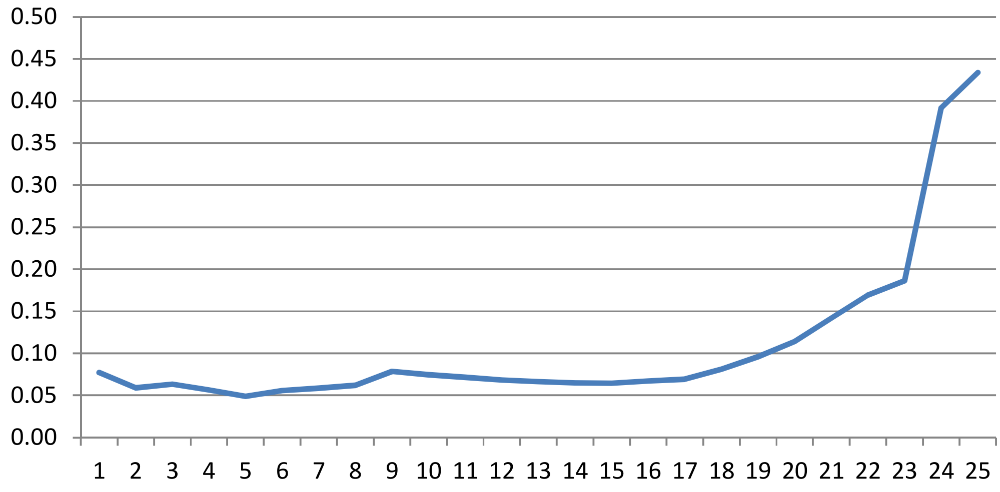
Appendix A

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%		

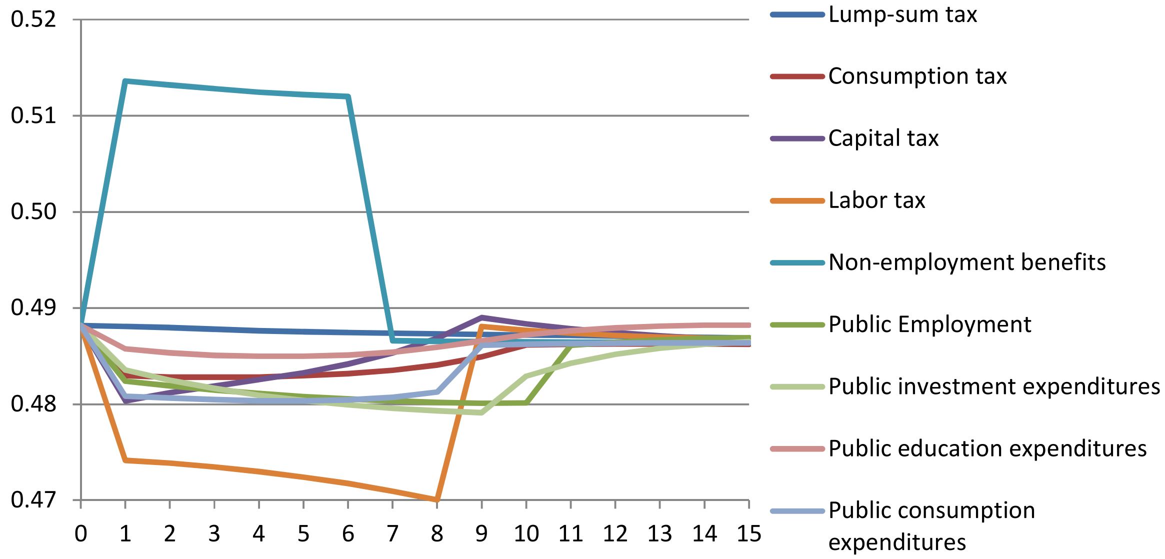
Source: OECD.Stat – authors' calculations. Average employment rates in hours over all skill groups in 11 European countries (Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Sweden, UK).

Figure A.1
Preference for leisure by age γ_j (calibrated to match the data on average employment rates in Table A.1)



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