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# FISCAL AUSTERITY MEASURES: SPENDING CUTS VS. TAX INCREASES

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We formulate an overlapping-generations model with household heterogeneity and productive and nonproductive government programs to study the macroeconomic and intergenerational welfare effects of risk premium shocks and government debt reductions. We demonstrate that in a small open economy with a high level of debt, a small increase in the risk premium of the interest rate leads to a substantial contraction in output and negative welfare effects. We then quantify the effects of reducing the debt-to-gross-domestic-product ratio using a wide range of fiscal austerity measures. Our results indicate trade-offs between short-run contractions and long-run expansions in aggregate output. In the short run, spending-based austerity reforms are worse than tax-based reforms in terms of lost income. However, in the long run, spending-based reforms produce higher output than tax-based reforms. In addition, welfare effects vary significantly across generations, skill groups, and working sectors. The current old and middle-aged generations experience welfare losses, whereas future generations are beneficiaries of the reforms.

**Keywords:** Fiscal Consolidation, Welfare, Distributional Effects, Overlapping Generations, Dynamic General Equilibrium

## 1. INTRODUCTION

Population aging and generous welfare systems have increased the national debt of many European Union (EU) countries. This has raised many questions about the sustainability of current fiscal policies [e.g., IMF (2010b)]. The recent recession has contributed to this problem by decreasing gross domestic product (GDP) and

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tax revenues while increasing the need for fiscal spending. Nowhere is this more evident than in Greece, where fiscal deficits have necessitated repeated bailout packages from the EU. These developments present governments with various unpleasant options, which include large tax increases, substantial expenditure cuts, or combinations of the two. The question as to which course of action is the most advisable is hotly debated among economists and policy makers.

A variety of factors and mechanisms determine the macroeconomic outcomes of austerity measures. These include (i) the composition of the austerity measures, (ii) the size of the consolidation, (iii) the state of the macro economy at the time of the consolidation, and (iv) monetary and fiscal policy interactions [see Alesina and Perotti (1995), Giavazzi and Pagano (1996), Strauch and Hagen (2001), Ardagna (2004), Guichard et al. (2007), Bi et al. (2011), Bi and Leeper (2012)]. The literature does not provide a clear answer concerning which factors ultimately determine the success of a consolidation, with Alesina and Ardagna (2010) arguing that the composition of the austerity measures matters for the success of the consolidations, whereas Ardagna (2004) argues that it does not.

Moreover, it has been documented in the previous literature that fiscal deficits and debt accumulation provide a means of redistributing income or tax distortions across generations and over time [e.g., Barro (1979), Lucas and Stokey (1983), Cukierman and Meltzer (1989), Alesina and Tabellini (1990), Tabellini (1991)]. Fiscal programs including social security, unemployment insurance, and public health insurance are emphasized as an important intergenerational redistribution mechanism in the public finance literature. To the best of our knowledge, such intergenerational welfare effects have not been analyzed quantitatively in the context of fiscal consolidations.

In this paper we study the implications of various austerity measures for macroeconomic outcomes and welfare. We focus on quantifying the intergenerational and distributional effects of sizable reductions of public debt. We construct an overlapping-generations model based on Auerbach and Kotlikoff (1987) including skill heterogeneity, private and public sector production, and a rich set of government expenditures, including transfers, government consumption, and government investment such as infrastructure. The model also includes a variety of tax instruments, such as progressive income taxes, consumption taxes, and the government's ability to issue debt.

The benchmark model is calibrated to Greece at the beginning of the twenty-first century. Greece is on the brink of bankruptcy, as it faces a large public debt and permanent fiscal deficits due to low growth rates and insufficient tax collection. Greece agreed to subject itself to tough conditions negotiated and applied by the IMF and the EU. In exchange for external aid, Greece agreed to implement fiscal adjustments worth about 12.5% of GDP spread over three years starting in 2009. This tightening is in addition to partly implemented reforms of about 6% of GDP. The goal was to reduce the deficit by 3% of GDP by 2014. The bulk of the measures focus on increases in the VAT rate and cuts to public sector wages, pensions, and employment numbers [Buiter and Rahbari (2010)].

We next demonstrate (and quantify) the trade-offs that are associated with elements of such packages in the context of a small open economy and while also accounting for intra- and intergenerational effects. We find that a small increase in the interest rate due to a risk premium shock leads to large negative macroeconomic and welfare effects in a small open economy where governments rely heavily on borrowing from international capital markets. Specifically, we find that a small premium shock can plunge an economy with a high debt-to-GDP ratio into a severe recession that is difficult to overcome even when resorting to severe fiscal austerity measures. Our findings quantify the real costs of external risk premium shocks for countries with high levels of public debt such as Greece.

Next, we quantify the effects of reducing the debt-to-GDP ratio from 105 percent of GDP to 85 percent of GDP in the long run using realistic fiscal austerity policies. In particular, we consider (i) tax-based austerity measures including increases in consumption or income taxes, (ii) spending-based austerity measures including cuts to public sector pensions and adjustments in public infrastructure investments, and (iii) a combination of tax increases and spending cuts. Our results are summarized as follows.

*First*, we find that the reforms result in immediate contractions but long-run expansions in aggregate output and consumption. The spending-based austerity measure, i.e., adjusted public investment in infrastructure, results in an increase in steady state output of around 5%, whereas the tax-based austerity measures lead to smaller increases in steady state output by around 3.5%. The analysis of the transition dynamics indicates trade-offs between short-run losses and long-run gains. We observe sharp declines in output by up to 2 percent in the first five years and then a strong recovery toward higher output in the long run.

*Second*, we calculate the size of the welfare gains or losses for all generations currently alive and born along the transition paths to the new steady state. At the aggregate level, the tax-based and spending-based austerity measures both result in welfare gains for high- and middle-income groups and welfare losses for low-income groups. The transition analysis indicates trade-offs between welfare gains in the new steady state and welfare losses along the transition paths. Whether an individual gains or loses from the reform depends on the particular austerity policy, the working sector, and the individual's remaining lifetime. More specifically, when infrastructure investments adjust to accommodate the debt reduction, the aggregate welfare effects are negative for all generations born 20 years before the reform is put in place. The same is true for the case when taxes adjust to accommodate the debt reduction. However, most newborn generations gain in the long run from the debt reduction, especially high-skilled agents. The opposing welfare outcomes across income groups and generations imply political challenges for the government in implementing fiscal austerity measures.

*Third*, we find that the spending-based austerity reform is slightly dominated by the tax-based reform in terms of the income and welfare effects in the short run. However, in the long run the effects of the spending-based austerity reform become dominant as the economy fully recovers. In addition, we find that a mixed reform combining the tax-based and spending-based measures results in the largest income and welfare effects.

Finally, we find that our results are fairly robust when the speed of fiscal consolidation is varied, as well as when negative fundamental shocks to the economy are allowed for.

There is a growing macroeconomic literature analyzing the effects of debt financing and fiscal consolidation. Erceg and Linde (2012) analyze how the effects of fiscal consolidation differ depending on whether monetary policy is constrained by a currency union membership or by the zero lower bound on policy rates. Bi and Leeper (2012) study the implication of fiscal behavior for sovereign risk. Bi et al. (2011) explore whether fiscal consolidation is driven by tax increases or expenditure cuts. Forni et al. (2010) quantify the macroeconomic implications of permanently reducing the public debt-to-GDP ratio in Euro Area countries. These papers build on New Keynesian models and emphasize the interactions between fiscal and monetary policies. However, this literature, with the exception of Forni et al. (2010), does not explicitly model the composition of government spending and tax revenues. It often neglects the trade-off between productive (education and public capital) and nonproductive government spending (pensions and to some extent medical insurance) or the trade-off between income taxes and consumption taxes. Moreover, because these papers use a representative agent framework, they often abstract from intergenerational and distributional effects of fiscal consolidations. Our paper is complementary to these papers, as we incorporate agent heterogeneity and a variety of government activities. We are able to analyze not only the aggregate welfare effects but also distributional effects within and across cohorts. The rich structure of household heterogeneity reveals more about the economic fundamentals behind potential political obstacles of implementing a fiscal austerity package.

There is a large literature analyzing the macroeconomic and distributional effects of fiscal policy. Baxter and King (1993) use an infinitely lived representative agent model to explore the general equilibrium effects of temporary and permanent changes in government spending and tax financing instruments. Heathcote (2005) investigates the effects of tax cuts in a heterogeneous agent model with infinitely lived agents and incomplete markets. Kitao (2010) uses a large-scale life-cycle model to quantify the effects of temporary tax cuts and rebate transfers in the United States. Auerbach and Kotlikoff (1987), Imrohoroglu et al. (1995), Imrohoroglu and Kitao (2009), and Jung and Tran (2010) formulate overlapping-generations models with heterogeneous agents and incomplete markets to analyze the distributional role of fiscal programs such as social security and health insurance. Glomm et al. (2009) and Glomm et al. (2010) quantify the macroeconomic and welfare effects of public pension reforms in an overlapping-generations model with productive governments. In this paper, we focus on fiscal consolidation and austerity measures and the role of the risk premium in economies with a large public debt.

There is a related literature investigating the growth effects of fiscal policy. Barro (1990), Glomm and Ravikumar (1994), and Glomm and Ravikumar (1997) analyze the implications of productive government expenditures for economic growth. The most recent studies incorporate government borrowing and study the growth implications of public investments. This literature argues that as government spending can itself be productive, the growth in public debt results in an expansion of production capacities. On the other hand, accumulating public debt crowds out private investment as it extracts resources from the private sector. Governments therefore face a trade-off: maintaining public debt sustainability while making sure that growth is promoted through productive investments [e.g., Moraga and Vidal (2004), Yakita (2008), Aghion, Pierre-Richard and Yilmaz (2011), Arai (2011)]. Ireland (1994) and Bruce and Turnovsky (1999) study the conditions under which a tax cut alone or a tax cut combined with expenditure cuts can improve the fiscal balance in the long-run. Because these studies aim to obtain analytical results, the models are fairly simplified versions of the neoclassical growth model. Our paper emphasizes quantitative results using a more complex model that accounts for more details of fiscal policy.

The paper is structured as follows. The next section describes the model. In Section 3 we calibrate the model to Greece and in Section 4 we conduct policy experiments. In Section 5 we present additional experiments and sensitivity analysis. Section 6 provides a discussion of the results and concludes. A separate Technical Appendix, available upon request from the authors, contains details of all simulation results and the welfare calculations.

## 2. THE MODEL

We formulate an overlapping-generations (OLG) model based on Auerbach and Kotlikoff (1987) containing descriptions of the private as well as the public sector and descriptions for public production of infrastructure and private production of the final consumption good. Individuals are heterogeneous with respect to their skills, ages, and working sectors. Imperfection in the credit market is modeled with a borrowing constraint. The economy is open with international capital mobility at the world interest rate, but international labor immobility.

### 2.1. Demographics

The economy is populated with overlapping generations of individuals who live to a maximum of $J$ periods. Individuals work for $J_1$ periods and then retire for $J - J_1$ periods. In each period, individuals of age $j$ face an exogenous survival probability $\pi_j$. Deceased agents leave an accidental bequest that is taxed and redistributed equally to all working-age agents alive. The population grows exogenously at an annual rate $n$. We assume stable demographic patterns, so that age-$j$ agents make up a constant fraction $\mu_j$ of the entire population at any point in time. The relative sizes of the cohorts alive, $\mu_j$, and the mass of individuals dying, $\tilde{\mu}_j$, in each period conditional on survival up to the previous period can be recursively defined as $\mu_j = \frac{\pi_j}{(1+n)^{\text{years}}}\mu_{j-1}$ and $\tilde{\mu}_j = \frac{1-\pi_j}{(1+n)^{\text{years}}}\mu_{j-1}$, where years denotes the number of years per model period.

### 2.2. Endowments and Preferences

Individuals are heterogeneous with respect to age, skill, working sector, and employment status. Individuals are born with specific skill types that determine their labor productivity. These skill types are fixed over the lifetime. Labor productivity, measured as the efficiency unit $e_j$, varies over the life cycle following the typical hump-shaped pattern. Newborn individuals are allocated to work either in the public sector or in the private sector. All individuals of a given age and type are equally productive regardless of whether they work in the public or private sector. In addition, individuals are exposed to exogenous unemployment shocks during their working lives.

Individuals are born with a specific skill type $\vartheta$ and sector type sec $\in$ {Private, Government} that cannot change over their life cycle and that together with their idiosyncratic long-term unemployment shock $\epsilon = \{0, 1\}$ determines their age-specific labor efficiency,

$$\tilde{e}_j(\vartheta, \text{sec}, \epsilon) = \begin{cases} e_j(\vartheta, \text{sec}) & \text{if } \epsilon = 0, \\ 0 & \text{if } \epsilon = 1, \end{cases}$$

where $\epsilon = 1$ indicates the unemployed state. The transition probabilities for $\epsilon$ follow an age-dependent Markov process with transition probability matrix $\Pi$. Let an element of this transition matrix be defined as the conditional probability $\Pr\left(\epsilon_{i,j+1}|\epsilon_{i,j}\right) \in \Pi$, where the probability of the next period's labor productivity $\epsilon_{i,j+1}$ depends on today's productivity shock $\epsilon_{i,j}$.

In each period individuals are endowed with one unit of time, whicht can be used for work $l$ or leisure. Individual utility is denoted by the function $u(c, l)$, where $u : R^2_{++} \to R$ is $C^2$, increases in consumption $c$, and decreases in labor $l$.

### 2.3. Technologies

The final consumption good is produced from three inputs, a public good $G_t$, the private physical capital stock $K_{P,t}$, and effective labor (human capital) in the private sector $H_{P,t}$, according to the production function $Y_t = F_P\left(G_t, K_{P,t}, H_{P,t}\right)$. This production function is homogeneous of degree one in $K_{P,t}$, and $H_{P,t}$. The public good in the production function can be thought of as the stock of public infrastructure such as roads. This public good is made available to all firms at a zero price. Specifications of the technology similar to this one have been used by Barro (1990), Turnovsky (1999), and others. Total factor productivity grows exogenously at rate $g$. Physical capital depreciates at a rate $\delta$ each period.

The public good is produced from public capital $K_{G,t}$ and effective labor (human capital) of civil servants $H_{G,t}$ according to the production function

$G_t = F_G\left(K_{G,t}, H_{G,t}\right)$. This production function is characterized by the properties of monotonicity, concavity, and homogeneity of degree one. Public capital evolves according to $K_{G,t+1} = \frac{1}{(1+n)(1+g)}\left(I_{K_G,t} + (1-\delta_G)\,K_{G,t}\right)$, where public capital is detrended by the exogenous population growth rate $n$ and the exogenous technological growth rate $g$. Public capital depreciates at rate $\delta_G$ in each period and $I_{K_G,t}$ is government investment in the public capital.

## 2.4. Factor Markets

We assume a small open economy. Capital is free to move across borders. Domestic agents can borrow from the world capital market at an interest rate $r_t$, which consists of two components: the fixed world interest rate $\bar{r}_t$ and the country-specific risk premium $r_t^{\text{risk}}$,

$$r_t = f(\bar{r}_t, r_t^{\text{risk}}).$$

Note that we do not model the possibility of sovereign default. However, we are thinking of $r_t^{\text{risk}}$ as a proxy for a country's sovereign risk.

Labor is internationally immobile, so that individuals cannot migrate. We assume a simple mechanism to allocate workers across public and private sectors. That is, individuals are assigned employment in either the public or the private sector at the beginning of their lives. We assume that for all cohorts in all time periods, public sector wages exceed those in the private sector, in order to mimic the more generous public sector compensation schemes that are commonly observed in many countries. This assumption also guarantees that all agents prefer public sector jobs to jobs in the private sector. In the labor market, private firms can hire labor at the market wage rate. All agents will retire at age $J_1$ irrespective of the sector they are working in.

## 2.5. Government and Fiscal Policy

The government collects tax revenue to finance a number of fiscal programs. In the case of budget deficits, the government can borrow to cover its fiscal imbalances. The government budget constraint can be expressed as

$$B_{t+1} = \frac{1}{(1+g)(1+n)}\left\{(1+r_t)\,B_t + \text{Spend}_t - \text{Tax}_t\right\}, \qquad (1)$$

where $B_t$ is one-period government bonds issued at time $t$, $r_t$ is the interest rate, $\text{Spend}_t$ is the total government spending, and $\text{Tax}_t$ is the total tax revenue. Note that government bonds are detrended with the exogenous technological growth rate $g$ and the exogenous population growth rate $n$. Newly issued bonds $B_{t+1}$ are endogenously determined so that the government budget constraint is cleared in every period.

*Government expenditures.* The government employs civil servants and uses physical capital to produce a public good $G$. The fraction of civil servants is fixed exogenously at $N^G$ as a matter of government policy. The total wage bill of currently employed civil servants is $\text{Wage}_{G,t} = \sum_{j=1}^{J_1} \mu_{j,t} \int w_{G,t} h_{j,t}(\theta_{j,G}) d\Lambda(\theta_{j,\text{sec}=G})$. The wages of civil servants are set by the government using a markup $\xi^W > 1$ over private sector wages so that $w_{G,t} = \xi^W \times w_{P,t}$. Private sector wages are determined by the market. In addition, the government purchases physical capital $K_G$ for public production. We assume that the government allocates a fixed fraction of GDP, $\Delta_{K_G,t}$, for these purchases. The total government investment in this type of capital is $I_{K_G,t} = \Delta_{K_G,t} \times \text{GDP}$.

The government pays unemployment insurance benefits to long-term unemployed workers, $T_{\text{Ins},t} = \sum_{j=1}^{J_1} \mu_{j,t} \int \xi w_t(\theta_j) h_{j,t}(\theta_j) d\Lambda(\theta_{j,\epsilon=1})$, where $\xi$ is the replacement rate of the active wage that is paid out as insurance.

The government runs two separate pension programs, one for public sector workers and one for private sector workers. The pension scheme for public sector workers differs from the scheme for private sector workers in contribution rates and benefit payments. All workers of both sectors are required to participate in the pension program and consequently have to pay a social security tax, $\tau_{\text{SS},t}^P$ and $\tau_{\text{SS},t}^G$. When workers retire they stop paying income taxes and social security taxes and are eligible to draw pension benefits. Let $\Psi_P$ and $\Psi_G$ denote the pension replacement rates in the private and public sectors. We summarize the payout formulae to private sector retirees and for public sector retirees as $\text{Pen}_{j,t}(\theta_P) = \Psi_P \frac{1}{J_1} \sum_{j=1}^{J_1} w_{P,t-J_1+j} h_{j,t-J_1+j}(\theta_P)$ and $\text{Pen}_{j,t}(\theta_G) = \Psi_G \frac{1}{J_1} \sum_{j=1}^{J_1} w_{G,t-J_1+j} h_{j,t-J_1+j}(\theta_G)$, respectively. Note that the payout formula is a function of the workers' average earnings. The total pension payouts for private sector retirees and for public sector retirees are given by $\text{Pen}_{P,t} = \sum_{j=J_1+1}^{J} \mu_{j,t} \int \text{Pen}_{j,t}(\theta_{j,P}) d\ \Lambda(\theta_{j,\text{sec}=P})$ and $\text{Pen}_{G,t} = \sum_{j=J_1+1}^{J} \mu_{j,t} \int \text{Pen}_{j,t}(\theta_{j,G}) d\Lambda(\theta_{j,\text{sec}=P})$, respectively.

The remainder of government expenditure is government consumption, $C_G$. Government consumption is unproductive. We assume that the government allocates a fixed fraction of GDP $\Delta_{C_G}$ for its consumption, i.e., $C_G = \Delta_{C_G} Y$. The total government spending at time $t$ is given by the following identity:

$$\text{Spend}_t = \overbrace{I_{K_G,t} + \text{Wage}_{G,t}}^{\text{productive}} + \overbrace{T_{\text{Ins},t} + \text{Pen}_{P,t} + \text{Pen}_{G,t} + C_{G,t}}^{\text{nonproductive}}.$$

*Government income.* The government collects progressive income taxes from labor and capital income. Let $T(\widehat{y})$ denote the progressive tax function that determines the income tax for taxable income $\widehat{y}$. The government also taxes consumption at a rate $\tau_C$. The government collects social security taxes from all workers in the private and public sectors at rates of $\tau_{\text{SS}}^P$ and $\tau_{\text{SS}}^G$, respectively. Accidental

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bequests are taxed at $\tau_{\text{Beq}}$. The government's tax revenue at time $t$ is given by

$$\begin{aligned}\text{Tax}_t = & \overbrace{\sum_{j=1}^{J_1} \mu_{j,t} \int T\left(\widehat{y}_j(\theta)\right) d\Lambda\left(\theta_j\right)}^{\text{progressive income tax}} + \overbrace{\tau_{C,t} \sum_{j=1}^{J} \mu_{j,t} \int c_{j,t}(\theta)\, d\Lambda\left(\theta_j\right)}^{\text{consumption tax}} \\ & + \overbrace{\tau_{\text{SS},t}^{P} \sum_{j=1}^{J_1} \mu_{j,t} \int w_{P,t} h_{j,t}(\theta_P)\, d\Lambda\left(\theta_{j,\text{sec}=P}\right)}^{\text{soc. sec. tax from the private sector}} \\ & + \overbrace{\tau_{\text{SS},t}^{G} \sum_{j=1}^{J_1} \mu_{j,t} \int w_{G,t} h_{j,t}(\theta_G)\, d\Lambda\left(\theta_{j,\text{sec}=G}\right)}^{\text{soc. sec. tax from the public sector}} \\ & + \overbrace{\tau_{\text{Beq},t} \sum_{j=1}^{J} \mu_{j,t} \int a_{j,t}(\theta)\, \upsilon_{j,t}(\theta)\, d\Lambda\left(\theta_j\right)}^{\text{tax on bequests}}.\end{aligned}$$

## 2.6. Household Problem

In this section we drop time subscripts in order not to clutter the notation. A typical agent is characterized by age, capital assets, income type, working sector, and the unemployment shock, so that the state vector of an agent at each age $j$ is $\theta_j = \{a_j, \vartheta, \text{sec}, \epsilon_j\}$, where $a_j$ is the capital stock at the beginning of the period, $\vartheta$ is the skill type, $sec$ is the working sector and $\epsilon_j$ is the unemployment shock. Note that

$$\theta_j \in \begin{cases} R_+ \times \{1, 2, 3, 4\} \times \{P = \text{private}, G = \text{government}\} \\ \quad \times \{0 = \text{employed}, 1 = \text{unemployed}\} \quad \text{if } j \le J_1 \\ R_+ \times \{1, 2, 3, 4\} \times \{P = \text{private}, G = \text{government}\} \quad \text{if } j > J_1. \end{cases}$$

In general, households in the private and in the government sector have similar maximization problems. Households decide their consumption of final goods and leisure $\{c_j, l_j\}_{j=1}^{J}$ as a function of their asset, $a_{j,t}$, and skill type and working sector, as summarized in the state vector $\theta$. The household problem can be recursively formulated as

$$V\left(\theta_j\right) = \max_{\{a_{j,t}, c_{j,t}, l_{j,t}\}} \left\{u\left(c_j, l_j\right) + \beta \pi_j E\left[V\left(\theta_{j+1}\right) | \epsilon_j\right]\right\} \quad \textbf{(2)}$$

s.t.

$$(1 + \tau_C)\, c_j + (1 + g)\, a_{j+1} = \Upsilon_j,$$

$$a_{j+1} \ge 0,$$

$$0 < l_j \le 1,$$

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where

$$\Upsilon_j = \begin{cases} R_t a_j + (1-\tau_{SS})\left(1-l_j\right)\tilde{e}_j w + \left(1-\tau_{Beq}\right) T_{Beq} \\ \quad -T\left(\widehat{y}_j\right) + 1_{[\epsilon_j=1]} \times T_{Ins,t} \quad \text{if } j \le J_1, \\ R a_j + \left(1-\tau_{Beq}\right) T_{Beq} + \text{Pen}_j - T\left(\widehat{y}_j\right) \qquad \text{if } j > J_1, \end{cases}$$

is the household's after-tax income. Sector specific wages are are $w = \{w_P \text{ or } w_G\}$, $R$ is the after-tax interest rate, $T_{Beq}$ is transfers of accidental bequests, which are taxed at a rate $\tau_{Beq}$, and $\widehat{y}_j$ is taxable income at age $j$, where $\widehat{y}_{j,t} = (1-l_j)e_j w + r a_j + 1_{[\epsilon_j=1]} \times T_{Ins,t}$ if workers and $\widehat{y}_j = \text{Pen}_j + r a_j$ if retirees. Notice that $e_j$ varies over the life cycle following the typical hump-shaped pattern. Effective labor (or human capital) at each age is given by $h_{j,t} = (1-l_j)e_j$. The social security tax rate $\tau_{SS} = \{\tau_{SS}^P \text{ or } \tau_{SS}^G\}$ and pension payments $\text{Pen}_{j,t} = \{\text{Pen}_j^P \text{ or } \text{Pen}_j^G\}$ are sector-specific as well.

## 2.7. Firm Problem

Firms choose physical capital $K_{P,t}$ and effective labor services $H_{P,t}$ to solve the following profit maximization problem:

$$\max_{(H_{P,t}, K_{P,t})} \left\{ F_P\left(G_t, K_{P,t}, H_{P,t}\right) - w_{P,t} H_{P,t} - q_{P,t} K_{P,t} \right\},$$

taking the rental rate of private capital $q_{P,t}$, the labor market wage rate $w_{P,t}$, and public capital $G_t$ as given.

## 2.8. Competitive Equilibrium

Given the distribution of skills, allocation of workers between public and private sectors, the government policy

$$\left\{ \begin{array}{c} \tau_{C,t}, \tau_{L,t}, \tau_{SS}^P, \tau_{SS}^G, \tau_{Beq,t}, \tau_{K,t}, \\ \Delta_{K_G,t}, \Delta_{C_G,t}, \xi_t^W, \Psi_{Pt}, \Psi_{G,t}, T_{Ins,t} \end{array} \right\}_{t=0}^{\infty},$$

and the exogenously given world interest rate $\{\bar{r}_t, \}_{t=0}^{\infty}$, a competitive equilibrium is a collection of sequences of households' decisions $\{\{c_{j,t}, l_{j,t}, a_{j+1,t+1}\}_{j=1}^{J}\}_{t=0}^{\infty}$, sequences of aggregate stocks of private physical capital and private human capital $\{K_{P,t}, H_{P,t}\}_{t=0}^{\infty}$, sequences of aggregate stocks of public physical capital and public human capital $\{K_{G,t}, H_{G,t}\}_{t=0}^{\infty}$, and sequences of factor prices $\{q_{P,t}, r_t, w_{P,t}, w_{G,t}\}_{t=0}^{\infty}$ such that

(i) households' allocations $\{\{c_{j,t}, l_{j,t}, a_{j+1,t+1}\}_{j=1}^{J}\}_{t=0}^{\infty}$ solve their recursive optimization problems (2);

(ii) rental rates, wages, and domestic interest rate are determined competitively by

$$q_{P,t} = \frac{\partial F_P\left(G_t,\ K_{P,t},\ H_{P,t},\ M_{P,t}\right)}{\partial K_{P,t}},$$

$$w_{P,t} = \frac{\partial F_P\left(G_t,\ K_{P,t},\ H_{P,t},\ M_{P,t}\right)}{\partial H_{P,t}},$$

$$w_{G,t} = \xi^W w_{P,t},$$

$$r_t = f(\bar{r}_t, r_t^{\text{risk}}) = q_{P,t} - \delta_K,\ \text{and } R_t = 1 + r_t;$$

(iii) aggregate variables are given by

$$A_t = \sum_{j=1}^{J} \mu_{j,t} \int a_{j,t}(\theta)\, d\Lambda\left(\theta_j\right) + \overbrace{\sum_{j=1}^{J}{}_{j,t}\upsilon_{j,t} \int a_{j,t}(\theta)\, d\Lambda\left(\theta_j\right)}^{\text{accidental bequests}},$$

$$\text{CA} = \overbrace{(A_t - B_t)}^{\text{domestic capital supply } K \text{ from HH}} - \overbrace{K_{P,t}}^{\text{domestic capital demand from firms}},$$

where CA is the current account, defined as the trade surplus plus interest from foreign assets, and

$$H_t^P = \sum_{j=1}^{J} \mu_{j,t} \int \overbrace{\left[1 - l_{j,t}(\theta_P)\right] e_{j,t}(\theta_P)}^{h_{j,t}(\theta_P)} d\Lambda\left(\theta_{j,\text{sec}=P}\right),$$

$$H_t^G = \sum_{j=1}^{J_1} \mu_{j,t} \int \overbrace{\left[1 - l_{j,t}(\theta_G)\right] e_{j,t}(\theta_G)}^{h_{j,t}(\theta_G)} d\Lambda\left(\theta_{j,\text{sec}=G}\right),$$

$$S_t = \sum_{j=1}^{J} \mu_{j,t} \int a_{j+1,t+1}(\theta)\, d\Lambda\left(\theta_j\right),$$

$$C_t = \sum_{j=1}^{J} \mu_{j,t} \int c_{j,t}(\theta)\, d\Lambda\left(\theta_j\right);$$

(iv) commodity markets clear,[1]

$$C_t + (1+g) S_t + I_{K_G,t} + C_{G,t} = Y_t + (1-\delta_P) K_t + (1+n)(1+g) B_t + \text{Beq}_t;$$

(v) taxed accidental bequests are returned in lump-sum transfers to surviving agents,

$$T_{\text{Beq},t} = \frac{\sum_{j=1}^{J} \upsilon_{j,t} \int a_{j,t}(\theta_P)\, d\Lambda\left(\theta_{j,\text{sec}=P}\right) + \sum_{j=1}^{J} \upsilon_{j,t} \int a_{j,t}(\theta_G)\, d\Lambda\left(\theta_{j,\text{sec}=G}\right)}{\sum_{j=1}^{J} \mu_{j,t} \int d\Lambda\left(\theta_j\right)};$$

(vi) the government budget constraint (1) holds; and

(vii) the current account is balanced and foreign assets, FA, freely adjust so that the domestic interest rate is determined by $r_t = f(\bar{r}_t, r_t^{\text{risk}})$.

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**TABLE 1.** Model parameters

| Parameter | Model | Observation/source |
|---|---|---|
| | Preferences | |
| Discount factor | $\beta = 0.9975$ | To match $\frac{K}{Y}$ and $R$ |
| Inverse of intertemp. | $\sigma = 2.5$ | To match $\frac{K}{Y}$ and $R$ |
| Weight on consumption | $\gamma = 0.24$ | To match average hours worked |
| | Private production | |
| TFP | $A_P = 1$ | Normalization |
| Productivity of public good $G$ | $\alpha_1 = 0.09$ | |
| Capital productivity | $\alpha_2 = 0.33$ | |
| Human capital productivity | $\alpha_3 = 0.67$ | |
| Capital depreciation | $\delta = 8\%$ | |
| Long-run growth rate | $g = 1.0\%$ | Akram et al. (2011, p. 312) |
| | Public production | |
| TFP for public good production | $A_G = 4.80$ | To match public sector size |
| | $\eta = 0.42$ | Sensitivity analysis |
| Productive civil servants | $\omega_h = 45\%$ | Normalized together with $A_G$ |
| Public capital depreciation | $\delta_G = 10\%$ | To match public sector size |
| | Human capital | |
| Efficiency profile | $e_j(\theta)$ | To match size of public good sector and hours worked |
| Population growth rate | $n = 0.2\%$ | UN Data Country Profile |

## 3. PARAMETERIZATION AND CALIBRATION

We parameterize the model and calibrate the baseline model to match the data from a small open economy. The recent fiscal developments in Europe have put several small European economies, including Greece, Spain, Portugal, and Italy on the brink of bankruptcy. Greece stands out as an example of public debt crisis followed by fiscal austerity policies. In 2010 Greece was induced to implement fiscal austerity measures to reduce deficits in order to receive international bailout packages by the international community. In our analysis, we choose Greece as a benchmark.

We calibrate the baseline model to match the data from Greece at the beginning of the twenty-first century. We use a number of sources for the aggregate data from Greece.[2] We summarize the structural parameter values in Table 1, the policy parameter values in Table 2, and matched data moments in Tables 3 and 4. We solve the model numerically using an algorithm similar to that of Auerbach and Kotlikoff (1987). We next describe briefly the calibration of the model.

**TABLE 2.** Policy parameters

| Policy parameter | Model | Observation/source |
|---|---|---|
| | Labor allocation | |
| Fraction of gov't employees | $N^G = 20\%$ | 18% in OECD (2011b, p. 12) and 24% in OECD (2011a, p. 8) |
| Private sector employees | $N^P = 80\%$ | OECD (2011, p. 8) |
| Retirement age | 60 | 62.4 for men and 60.9 for women OECD (2011, p. 9) |
| Proportion working age | 67% | BOG (2005) |
| | Expenditures | |
| Public wages markup | $\xi^W = 20\%$ | To match public sector wage bill |
| Replacement rates (generosity of pensions) | $\Psi_P = 50\%$ $\Psi_G = 87\%$ | OECD (2011) or to match pension sizes |
| Investment in public good (in % of priv. sector output) | $\Delta_{K_G} = 5\%$ | 2% of GDP in capital expenditure, Koutsogeorgopoupou and Turner (2007) to match $G/Y$ of 40% |
| Residual gov't consumption (in % of priv. sector output) | $\Delta_{C_G} = 0.01\%$ | Residual (thrown into ocean), to match income tax revenue |
| | Taxes | |
| Marginal income tax rates for four income groups | $\tau_I = [0, 0.27, 0.37, 0.4]$ | http://www.taxexperts.eu/ |
| Income tax polynomial | $\beta_0 = 0.24$ $\beta_1 = -0.005$ $\beta_2 = 3.0 \times 10^{-5}$ | |
| Consumption tax rate | $\tau_C = 18.9\%$ | 21% but collection is low (about 50%) share in tax rev. of VAT: 6–7% of GDP OECD (2011, p. 13) |
| Tax on bequests | $\tau_{\text{Beq}} = 15\%$ | To match tax revenue of income tax |
| Social security tax—private | $\tau_{SS}^P = 12\%$ | To match pension deficit 3–4% of GDP |
| Social security tax—public | $\tau_{SS}^G = 15\%$ | To match pension deficit $1 - 1.5\%$ of GDP |

## 3.1. Demographics and Heterogeneity

Agents become economically active at age 20 and die for sure at age 90. We calibrate the OLG model with $J = 14$ periods. Thus, each model period corresponds to 5 years. The annual population growth rate was $n = 0.2\%$ in 2006, according to the UN Data Country Profiles. The survival probabilities are chosen so that the model matches the size of the various age groups in the population.

We distinguish four skill groups of workers according to their educational levels: (i) no education or primary education only, (ii) some secondary education, (iii) complete secondary education, and (iv) complete tertiary education. We calibrate the efficiency profile $e_j(\theta)$ for each skill type using data from Tsakloglou and Cholezas (2005). The efficiency profiles exhibit the

**TABLE 3.** Macroeconomic aggregates: Model outcomes vs. Greek data

| Moments I | Model | Data | Observation/source |
|---|---|---|---|
| Capital output ratio: $\frac{K}{Y}$ | 1.56% | 1.54 | IMF (2006, p. 31) |
| Annual interest rate: $r$ | 4.0% | 4.5% | OECD (2011b, p. 5) |
| Debt-to-GDP ratio: $\frac{B}{Y}$ | 105% | 105% | Eurostat (2009) |
| Public sector share of GDP: $\frac{G}{Y}$ | 40.1% | 40% | Based on *Economy of Greece* |
| Hours worked/week | 37.6 | 38.64 | 42 hours according to OECD StatExtracts |
| Hours worked/week, private | 38.7 | 38.64 | 75% of average work hours, OECD (2011b, p. 12) |
| Hours worked/week, public | 37.6 | 38.64 | 75% of average work hours, OECD (2011b, p. 12) |
| CA deficit as % of GDP | −14% | 10–14.4% | CA balance as % of GDP Akram et al. (2011, p. 309) and Ministry of Finance (2011, p. 15) |

typical life-cycle hump-shaped pattern. We scale down the skill/efficiency profiles of public sector workers to match their lower rate of weekly hours of labor. The transition probabilities for the unemployment shocks $\Pr\left(\epsilon_{i,j+1}|\epsilon_{i,j}\right) \in \Pi$ are calibrated to match a long-term (five-year) unemployment percentage of 3%, 2%, 1%, 1%, 2%, 2%, 3%, and 3% for each of the eight working generations [compare Gradín et al. (2012) and Table 5].

## 3.2. Preferences

Preferences are represented by the utility function $u(c,l) = \frac{\left(c^{\gamma} l^{1-\gamma}\right)^{1-\sigma}}{1-\sigma}$, where $c$ and $l$ are consumption and leisure, respectively, and $0 < \gamma < 1$ and $\sigma > 0$. Motivated by the real business cycle literature [e.g., Kydland and Prescott (1996)], we assume that the elasticity between consumption and leisure is one. The parameter $\gamma$ measures the relative weight of consumption versus leisure. The parameter $\sigma$ is the coefficient of relative risk aversion.

The consumption preference parameter $\gamma$ is chosen to match labor supply of around 30–35 hours a week for agents in their prime working age from 25 to 55.[3] Both the time preference parameter $\beta = 1.03$ and the inverse of the intertemporal elasticity of substitution $\sigma = 2.5$ are chosen to match the capital–output ratio and the capital import rate. Consequently, in our model the capital output ratio is 1.56.[4]

## 3.3. Technologies

The final goods production function is $F_P\left(G_t, K_{P,t}, H_{P,t}\right) = A_P G_t^{\alpha_1} K_{P,t}^{\alpha_2} H_{P,t}^{\alpha_3}$, where $\alpha_i \in (0,1)$ for $i = 1, 2,$ and 3, $\alpha_2 + \alpha_3 = 1$, and $A_P > 0$. Total factor

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**TABLE 4.** Fiscal activities: Model vs. Greek data

| Moments II | Model | Data | Observation/source |
|---|---|---|---|
| | Tax revenues (all as % of GDP) | | |
| Total tax revenue | 36.6% | 32–34.2% | OECD (2011, p. 13) and Akram et al. (2011, p. 308) |
| Income tax revenue | 13.4% | 7% | OECD (2011, p. 13) |
| Consumption tax revenue | 12.9% | 7% | OECD (2011, p. 13) |
| Soc. Sec. rev.: private sector | 7.8% | | To match pension deficit |
| Soc. Sec. rev.: public sector | 1.8% | | To match pension deficit |
| Bequest tax revenue | 0.7% | 1% | Property tax, OECD 2011, p. 13 |
| | Expenditures (all as % of GDP) | | |
| Wage bill public sector | 7.5% | 11.5% | Koutsogeorgopoulou and Turner (2007, p. 8) 33% of total wage bill, OECD (2011, p. 8) |
| Wage bill private sector | 65.0% | 20% | 33% of total wage bill, OECD (2011, p. 8) |
| Private pensions | 10.4% | 8.5% | Residual from below |
| Public pensions | 3.4% | 2.5–5% | Hellenic Country Fiche (2011, p. 19) |
| All pension payments | 13.9% | 11.5–13.9% | OECD (2011, p. 9) and Hellenic Country Fiche (2011, p. 19) |
| Debt-to-GDP ratio | 105% | 105% | http://stats.oecd.org |
| | Pension deficits (all as % of GDP) | | |
| Pension deficit | −4.2% | −4% to −5% of GDP | O'Donnel and Tinios (2003) and Greek Finance Ministry (2012) |
| Pension deficit priv. sector | −2.64% | −3% to −4% of GDP | Own calculations |
| Pension deficit pub. sector | −1.6% | −1 to −1.5% of GDP | Own calculations |

productivity $A_P$ is normalized to one. The estimates for $\alpha_1$, the productivity parameter of the public good in the final goods production function, for the United States cluster around 0 when panel data techniques are used [e.g., Hulten and Schwab (1991) and Holtz-Eakin (1994)] and they cluster around 0.2 when GMM is used to estimate the Euler equations [e.g., Lynde and Richmond (1993) and Ai and Cassou (1995)]. Calderon and Serven (2003) estimate this parameter to be around 0.15 to 0.20. For a cross section of low-income countries, Hulten (1996) obtains an estimate for $\alpha_1$ of 0.10. We use $\alpha_1 = 0.09$. The capital share of GDP is very high in Greece so we chose $\alpha_2 = 0.35$. Parameter $\alpha_3 = 0.65$ together with

**TABLE 5.** Long-term unemployment transition probabilities

| | | $\epsilon' = 0$ | $\epsilon' = 1$ |
|---|---|---|---|
| $j = 2$ | $\epsilon = 0$ | 0.990 | 0.010 |
| | $\epsilon = 1$ | 0.314 | 0.686 |
| $j = 3$ | $\epsilon = 0$ | 0.994 | 0.006 |
| | $\epsilon = 1$ | 0.317 | 0.683 |
| $j = 4$ | $\epsilon = 0$ | 0.997 | 0.003 |
| | $\epsilon = 1$ | 0.319 | 0.681 |
| $j = 5$ | $\epsilon = 0$ | 0.997 | 0.003 |
| | $\epsilon = 1$ | 0.319 | 0.681 |
| $j = 6$ | $\epsilon = 0$ | 0.994 | 0.006 |
| | $\epsilon = 1$ | 0.317 | 0.683 |
| $j = 7$ | $\epsilon = 0$ | 0.994 | 0.006 |
| | $\epsilon = 1$ | 0.317 | 0.683 |
| $j = 8$ | $\epsilon = 0$ | 0.990 | 0.010 |
| | $\epsilon = 1$ | 0.314 | 0.686 |

the preference parameter for leisure $(1 - \gamma)$ determines average hours worked. Private capital depreciates at a rate of 10 percent per year, i.e., $\delta_K = 0.1$.

The production function for infrastructure is $F_G(K_{G,t}, H_{G,t}) = A_G K_{G,t}^{\eta}(\omega_h H_{G,t})^{(1-\eta)}$, where $A_G > 0$ and $\eta \in (0, 1)$. The fraction of civil servants contributing to infrastructure production is $\omega_h \in (0, 1)$. The remaining civil servants produce government consumption, which is not explicitly modeled. Total factor productivity $A_G = 4.25$ is chosen to match the size of the public goods sector. We have little information about the parameters of the infrastructure production technology. We view the choice of $\eta = 0.42$ and $\omega_h = 0.35$ as our benchmark and we perform sensitivity analysis on these parameters. Public capital $K_G$ depreciates at 10 percent per year, i.e., $\delta_{K_G} = 0.1$. The exogenous rate of growth is 1 percent, i.e., $g = 0.01$ [Akram et al. (2011)].

## 3.4. Factor Markets

As in Bernoth et al. (2012), we use the interest rate spread as a proxy for the risk premium, $r_t^{\text{risk}} = \frac{r_t - \bar{r}_t}{1+\bar{r}_t}$. It is widely documented in the previous literature that a higher level of government debt is associated with a higher risk premium on government borrowing. We follow Bernoth et al. (2012) and define the risk premium as a function of the debt-to-GDP ratio,

$$r_t^{\text{risk}} = \beta_0 + \beta_1 \left(\frac{B_t}{Y_t}\right) + \beta_2 \left(\frac{B_t}{Y_t}\right)^2.$$

To estimate this polynomial, we use monthly OECD data from 2000 to 2008.[5] We first construct an interest rate spread $\frac{(r_t-\bar{r}_t)}{1+\bar{r}_t}$, where $r_t$ is the Greek long-run interest rate and $\bar{r}_t$ is the German long-run interest rate, which serves as a proxy for the risk-free interest rate. We estimate the risk premium polynomial and obtain $\beta_0 = 0.2437$, $\beta_1 = -0.00538$, and $\beta_2 = 3.0 \times 10^{-5}$. These coefficients capture the long-run relationship between the risk premium and the debt-to-GDP ratio. The domestic interest rate is determined by

$$r_t = f(\bar{r}_t, r_t^{\text{risk}}) = \frac{\bar{r}_t + r_t^{\text{risk}}}{1 - r_t^{\text{risk}}}.$$

Based on OECD (2011a) and OECD (2011b), public sector employment as a fraction of total employment is approximately 20 percent. We therefore set the fraction of public sector workers to $N^G = 0.2$. According to OECD (2011b), the average retirement age is 62.4 for men and 60.9 for women. In our calibration, we assume that all agents retire at age 60, or model period $J_1 = 8$.

## 3.5. Government and Fiscal Policy

All government policy parameters are summarized in Table 2. According to Eurostat, the debt-to-GDP ratio was on the average 105 percent in the ten-year precrisis period. We target this ratio in our benchmark steady state model, i.e., $\frac{B}{Y} = 1.05$.

We assume that public sector workers earn on the average up to 20 percent higher wages than private sector workers. We calibrate the replacement rate for unemployment benefits to match the size of the unemployment insurance program as a percentage of GDP. Similarly, we choose the pension replacement rates to match the size of the public and private sector pension programs as percentage of GDP as well as the government revenue from payroll taxes paying for these pensions. We use replacement rates of $\Psi_P = 0.5$ and $\Psi_G = 0.87$ and payroll taxes of $\tau_{SS}^P = 12$ percent and $\tau_{SS}^G = 15$ percent in the private and public sectors, respectively. Ad hoc subsidies to the public pension system in Greece amounted to about 3 percent of GDP in early 2000 [O'Donnel and Tinios (2003)]. More recent information from the Greek Finance Ministry indicates that the state subsidizes pensions with over 13 billion euros every year, a figure that exceeds 5 percent of GDP.[6] We assume that these subsidies are proportionally assigned to public and private sector pensions, which results in pension deficits of 1–1.5% of GDP for public sector pensions and 3–4% of GDP for private sector pensions. We match these pension deficit figures as shown in Table 4. We calibrate purchases of private capital for public production $\Delta_{K_G}$ to be 5% of GDP in order to match the size of the public good production as a share of GDP. Residual government consumption $C_G$ is set to match the size of government.

The government raises a progressive income tax on labor and dividend income.[7] Using the formula in Miguel and Strauss (1994), we calculate the progressive

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federal income tax as

$$\tilde{\tau}(\tilde{y}) = \kappa_0 \left[ \tilde{y} - \left( \tilde{y}^{-\kappa_1} + \kappa_2 \right)^{-1/\kappa_1} \right],$$

where $\tilde{y}$ is taxable income. The parameter estimates for this tax polynomial are $\kappa_0 = 0.258$, $\kappa_1 = 0.768$, and $\kappa_2 = 0.75$. In addition, the government raises a proportional consumption tax and a proportional tax on bequests to finance investments into public capital $K_G$, public pension benefits, wage payments for public sector workers, unemployment compensation, service of its debt, and government consumption $C_G$. According to Akram et al. (2011), total tax and nontax revenues as fractions of GDP are between 32 and 34 percent of GDP in 2010. The revenue streams from the various taxes match data on tax revenue from Akram et al. (2011) and OECD (2011a). Table 4 presents the details of the tax revenues that are matched in our benchmark model.

## 4. POLICY EXPERIMENTS AND RESULTS

The motivation behind fiscal austerity is that a high debt-to-GDP ratio increases risk and therefore imposes an economic cost. As a consequence, many economists recommend keeping this ratio below a certain limit. We first explore the potential cost of a risk premium shock when the government is borrowing heavily from the international capital market in Section 4.1. We then quantify the macroeconomic and intergenerational welfare effects of reducing public debt in Section 4.2.

### 4.1. Underreporting Public Debt and Risk Premium Effects

In this section we quantify the macroeconomic and welfare effects of a risk premium shock. In Greece this happened because Greece was caught repeatedly underreporting its deficit prior to 2010.[8] In our experiment we assume a conservative 2 percent intentional underreporting of public debt. This 2 percent underreporting is in accordance with a report by the European Commission (2010) for the three years 2006–2008 just prior to the crisis.[9] The years 2006–2008 are years of relative macroeconomic stability before spikes in the debt-to-GDP ratio and the risk premium, and before precipitous drops in GDP.

We implement the risk premium shock by assuming that the economy is initially in a steady state with a "true" debt-to-GDP ratio of 105 percent. However, the government underreports its debt-to-GDP ratio as 103 percent. This will lower the risk premium that is charged by lenders in the domestic and the international market. We calibrate the model to data prior to the crisis and solve for this initial steady state (i.e., period 0). In this initial steady state the government pays an interest rate of 4.6% rather than the 5% it would have paid had it reported the true debt level of 105% of GDP. In period 1, we assume that the government reveals its "true" debt-to-GDP ratio of 105%. As news of the misreporting spreads, lenders update the risk premium from period 1 onward so that the domestic interest rate

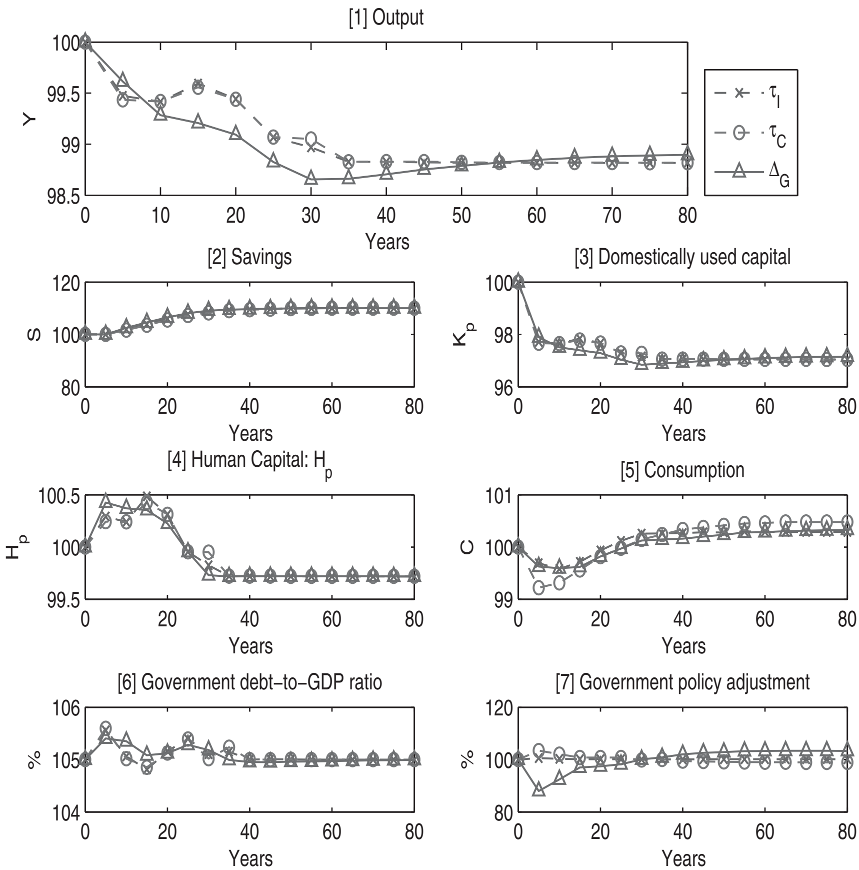


**FIGURE 1.** Risk-premium shock and the transition dynamics of key aggregates. Either [1] income tax $\tau_I$, [2] consumption tax $\tau_C$, or [3] public investment $\Delta_{K_G}$ adjusts to accommodate the increase in the risk premium due to truthful reporting of the debt level of 105 percent of GDP.

adjusts to reflect the true level of the risk premium. Revising the debt-to-GDP ratio in this way simply introduces an unanticipated risk premium shock into our framework.[10]

The rise in the risk premium will require some adjustments in the government budget, because the increased risk premium represents an increase in the cost of debt services. We first assume that the government keeps debt-to-GDP ratio constant at 105%. The government uses one of three financing options: (i) a change in the income tax function $\tilde{\tau}\,(\tilde{y})$; (ii) a change in the consumption tax rate $(\tau_C)$; or (iii) a change in public capital investment in infrastructure $\left(\Delta_{K_G}\right)$. We report the steady state results in Table 6 and the transition dynamics in Figure 1. Note that all initial steady state levels are normalized to 100.

**TABLE 6.** Risk-premium shock and the long-run aggregate effects with debt at 105 percent of GDP

| | (1) $\tau_I$ | (2) $\tau_C$ | (3) $\Delta_{K_G}$ |
|---|---|---|---|
| Output $Y$ | 98.31 | 98.39 | 98.59 |
| Capital $K$ | 109.98 | 109.40 | 109.96 |
| Capital in final $K_P$ | 96.72 | 96.81 | 97.01 |
| Human capital private $H_P$ | 99.25 | 99.33 | 99.34 |
| Human capital public $H_G$ | 98.96 | 99.08 | 99.08 |
| Public good $G$ | 99.40 | 99.46 | 100.88 |
| Consumption $C$ | 99.56 | 100.11 | 99.89 |
| Current account CA | −76.95 | −78.04 | −77.68 |
| Interest rate $r$ | 103.78 | 103.78 | 103.78 |
| Risk premium | 121.97 | 121.97 | 121.97 |
| Wages $w$ | 99.05 | 99.06 | 99.25 |
| Income tax $\tau_I$ | 100.37 | 100.00 | 100.00 |
| Consumption tax $\tau_C$ | 100.00 | 97.19 | 100.00 |
| Infrastruc. inv. $\Delta_{K_G}$ | 100.00 | 100.00 | 104.89 |
| Debt-to-GDP ratio in % | 105.00 | 105.00 | 105.00 |
| Total govt. spending | 98.78 | 98.86 | 99.34 |
| Bonds | 98.31 | 98.39 | 98.59 |
| Govt. consumption $C_G$ | 100.00 | 100.00 | 100.00 |
| Govt. investment $I_{K_G}$ | 100.00 | 100.00 | 103.42 |
| Pub. sect. wages | 98.02 | 98.14 | 98.34 |
| Pensions | 98.26 | 98.35 | 98.53 |
| Tax revenue | 100.05 | 99.14 | 100.21 |
| Bequest tax rev. | 104.87 | 104.41 | 104.90 |
| Consumpt. tax rev. | 99.56 | 97.28 | 99.89 |
| Soc. sec. tax rev. | 98.25 | 98.35 | 98.54 |
| Income tax rev. | 101.55 | 101.20 | 101.45 |
| Taxable inc.: all | 99.71 | 99.76 | 99.98 |
| Taxable inc.: labor | 98.12 | 98.22 | 98.42 |
| Taxable inc.: pension | 98.30 | 98.39 | 98.58 |
| Taxable inc.: asset | 109.74 | 109.44 | 109.86 |
| Welfare measures | | | |
| Aggregate comp. consumpt. as % of GDP | 0.22 | −0.09 | 0.05 |
| Aggregate—private as % of GDP | 0.16 | −0.09 | 0.02 |
| Aggregate—public as % of GDP | 0.06 | −0.00 | 0.03 |
| Private—low income: Ave.%$\Delta$ in $C$ | −0.07 | −0.48 | −0.28 |
| Private—high income: Ave.%$\Delta$ in $C$ | 0.47 | 0.00 | 0.21 |
| Public—low income: Ave.%$\Delta$ in $C$ | 0.14 | −0.28 | −0.07 |
| Public—high income: Ave.%$\Delta$ in $C$ | 0.81 | 0.27 | 0.51 |

*Notes*: Greece now reports its true debt level, so that the risk premium increases. The government does not adjust the debt level as yet and lets either taxes or public spending adjust to clear the government budget in reaction to the higher risk premium. $\tau_I$ is income tax, $\tau_C$ is consumption tax, and $\Delta_{K_G}$ is public investment. The benchmark steady state is normalized to 100. All results are in relation to this steady state.

*Macroeconomic aggregates.* The premium shock leads to an increase in the risk premium by about 22%, which corresponds to a 3.8% increase in the interest rate. The government needs to adjust taxes or spending to finance additional borrowing costs. We find that the risk premium shock leads to a contraction in output in the new steady state. This is driven by a higher interest rate and distortions created by changes in government policies.

The higher interest rate leads to a higher rental cost for physical capital in the domestic market, which subsequently causes a contraction in the domestic production sector. As seen in row 3 of Table 6, capital employed in the domestic production sector $K_P$ drops by almost 3%. This subsequently causes a fall in demand for labor, which leads to lower human capital $H_P$ and a lower wage rate in the labor market. Overall, production drops by 1.2%. Moreover, the higher interest rate has implications for the household sector. Because the return on savings is now higher, it induces households to save more. This leads to a large increase in household assets ($K$ increases by around 10%). The additional savings from households are therefore not used productively any more but simply used to decrease capital imports (the current account decreases by almost 20%; that is, Greece lowers its capital imports).

The distortions created by tax vs. spending adjustments are quite similar. The differences in output contractions across the three policies are negligible. Note, however, that the channels through which these policies work are quite different. The spending-based policy directly influences efficiency in domestic production as well as the demand for production factors, whereas the tax-based policy leads to distortions of individuals' intertemporal allocation of decisions and the supply of production factors.

When the income tax adjusts to balance the budget, output decreases by 1.2% (first column in Table 6). As the risk premium rises, the incentive to save becomes stronger, so that the capital income tax base grows by almost 10%. This large increase allows a relatively modest increase in the income tax to balance the budget. The required increase in income tax revenue is only around 0.08%. Given the modest increases in income taxation, the long-run effects of the risk premium shock on output and consumption are relatively modest. When the consumption tax adjusts to balance the budget, the increase in the interest tax base allows the consumption tax rate to fall by almost 1.2% (compare the second column in Table 6). Because the consumption tax rate and revenue fall (by almost 0.5% each), aggregate consumption rises 0.27%, even though output drops by about 1.2%.

Finally, when public investment adjusts to balance the budget (third column in Table 6), the effects on output and consumption are of similar magnitude to those in the earlier cases. In this case the additional tax revenue from the larger interest tax base allows a 1.4% increase in infrastructure investments, which in return increases productivity in the private sector. However, this increase is not enough to offset the contraction in the private sector due to larger capital rental rates (note that physical capital used in domestic production $K_P$ decreases by over 2.8%), so that ultimately output drops by about 1.1%. The adverse effect on GDP is smaller when public investment in infrastructure adjusts to pay for the additional cost of borrowing.

Next, we explore the transitional dynamics following the policy reforms. In Figure 1, we plot the transitions for output, savings, domestically used capital, employed human capital, and consumption after the risk premium adjusts to reflect the true 105 percent debt-to-GDP ratio. We show the transition for the case in which the income tax rate, the consumption tax rate, and the investment in infrastructure adjust to balance the budget after the misreporting of the deficit is revealed.

The increase in the domestic interest rate results in two opposing effects on savings. On one hand, the new high rate of return encourages households to increase savings; on the other hand, the negative income effect decreases savings. It is clear that the price effect is dominant and persistent, so that savings increase gradually to the new steady state of about 110 percent of the preshock level. In our small open economy model, higher domestic savings do not immediately result in an increase in capital accumulation. In fact, the capital stock employed in domestic production falls by 2 percent immediately after the increase in the risk premium, and then gradually decreases to about 3 percent below the preshock level. The immediate fall in capital stock in production is driven mainly by the lower demand for capital in response to the high rental cost of capital and the low level of human capital. In the context of a small open economy, the high savings and low demand for capital in domestic production induces capital exports (that is, a lowering of very high capital imports from the benchmark level).

Interestingly, there are significant differences in the convergence patterns along transitions. Output drops more during the early stage of the transition and then gradually increases when the investment in public infrastructure adjusts to balance the budget. Meanwhile, output decreases more slowly when taxes adjust.

*Welfare.* We next conduct welfare analysis. For every agent type we calculate the consumption equivalent variation (CEV), which is the fixed percentage of lifetime consumption that has to be added or subtracted in each period to make an individual indifferent between the original steady state and the new steady state. A negative CEV reflects a welfare loss and a positive CEV indicates a welfare gain due to the premium shock. We calculate CEV as a percent of prereform consumption levels per agents type. This allows us to investigate the size of the welfare loss for each group separately.

Figure 2 illustrates the welfare costs/benefits associated with this adverse shock and the associated necessary adjustment of the income tax along the transitions. We track the welfare effects by generation, skill type, and sector. Current retirees experience welfare gains from the risk premium shock. The intuition is that the premium shock increases the domestic interest rate, which then generates a positive wealth effect for those agents who rely on savings income. On the other hand, the welfare effects on the working population and future generations are nonlinear

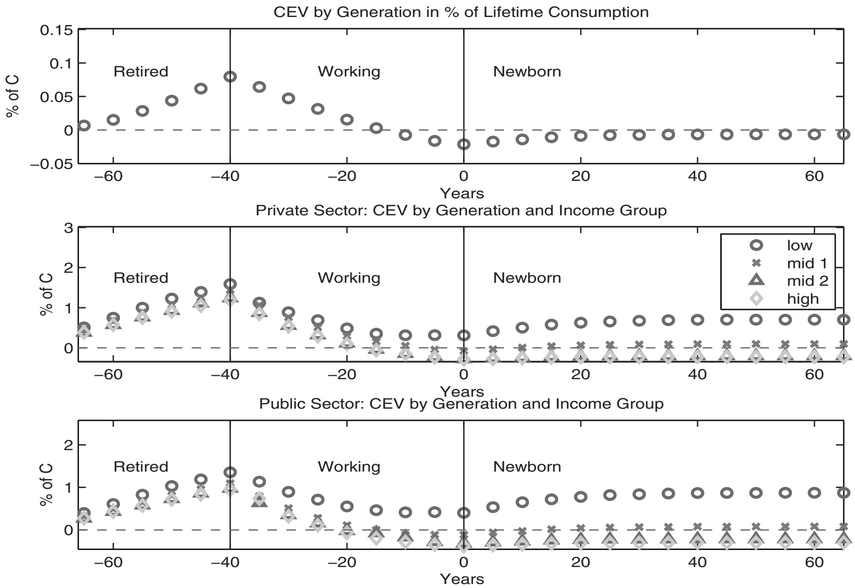


**FIGURE 2.** Risk-premium shock and welfare dynamics. Income taxes adjust to accommodate the increase in the risk premium due to truthful reporting of the debt level of 105 percent of GDP.

and depend on skill type and working sector. High-skilled workers will experience welfare losses, whereas most low-skilled workers will experience welfare gains during the transition. Welfare losses of high skill workers converge to about 0.1 and 0.3% of consumption for private and public sector workers, respectively. Simultaneously, the welfare gains for the low-skilled types remain below 1.0%. The welfare gains for public sector workers are larger than those for low-income private sector workers. The welfare effects are caused by the contraction in domestic production and higher taxes along the transition. High-skilled workers suffer more from high income taxes than low income workers because of tax progressivity.

We have thus demonstrated that a small risk premium shock can plunge an economy with a high debt-to-GDP ratio into a recession that is difficult to overcome. This result highlights the high real costs of being exposed to external shocks for countries that currently have very high levels of debt, such as Greece and other southern European countries. We next study the macroeconomic and welfare implications of reducing public debt.

## 4.2. Reducing Public Debt

Over a concern for nonsustainability of fiscal policy, more drastic reform measures with the goal of reducing the debt burden were discussed and implemented in Greece. In 2009 the Greek government agreed to implement significant fiscal

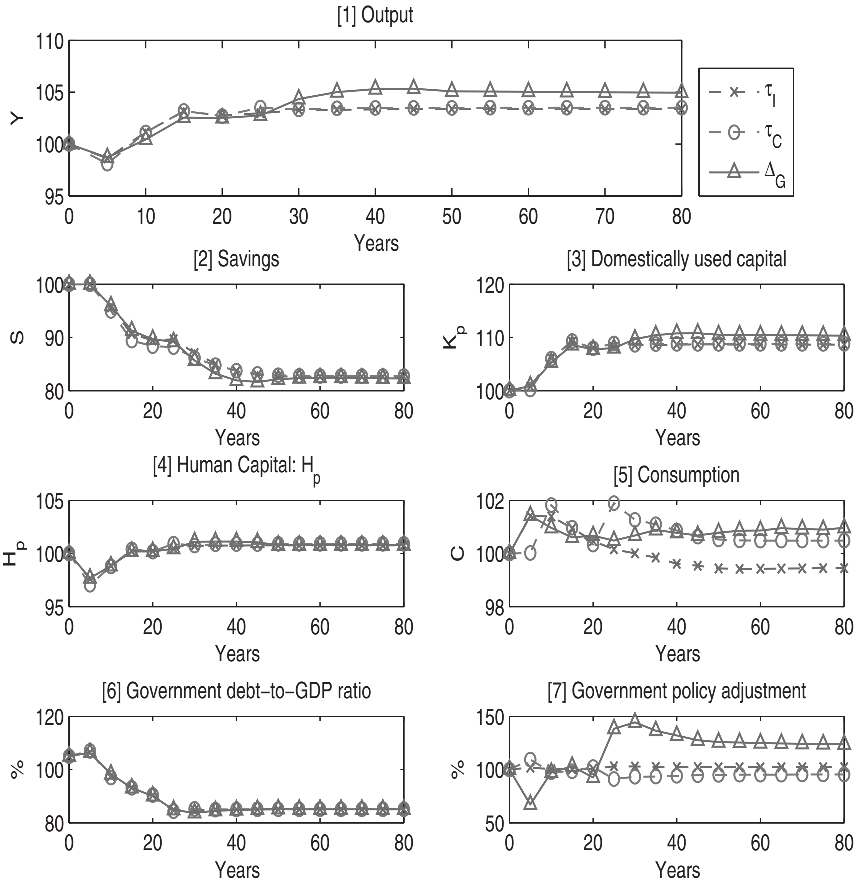


**FIGURE 3.** Risk-premium shock, debt reduction, and the transition dynamics of key aggregates. Either [1] income tax $\tau_I$, [2] consumption tax $\tau_C$, or [3] public investment $\Delta_{K_G}$ adjusts to accommodate the reduction of debt to to 85 percent of GDP and the risk premium shock.

adjustments worth about 12.5% of GDP in order to receive international bailouts [IMF (2010a)].

Motivated by the fiscal developments in Greece, we consider a hypothetical fiscal austerity plan that aims to reduce the debt-to-GDP ratio from 105 to 85% over a fifteen-year period. After the first five years debt-to-GDP ratio will be reduced to 100%, after ten years to 95%, and after fifteen years to the long-run target of 85%. As before, we impose that the government can use r one of three policy instruments to implement this debt reduction: (i) tax-based measures, (ii) spending-based measures, or (iii) a combination of both. We report steady state results in Table 7 and transition dynamics in Figure 3. Note that all initial steady state levels are normalized to 100. We first describe the long-run effects.

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**TABLE 7.** A risk-premium shock and the long-run aggregate effects with debt reduced to 85 percent of GDP

| | (1) $\tau_I$ | (2) $\tau_C$ | (3) $\Delta_{K_G}$ |
|---|---|---|---|
| Output $Y$ | 103.67 | 104.34 | 105.34 |
| Capital $K$ | 109.07 | 105.74 | 106.72 |
| Capital in final $K_P$ | 108.40 | 109.10 | 110.15 |
| Human capital private $H_P$ | 100.95 | 101.71 | 101.72 |
| Human capital public $H_G$ | 103.18 | 101.80 | 101.80 |
| Public good $G$ | 101.83 | 101.04 | 108.27 |
| Consumption $C$ | 102.56 | 103.97 | 103.94 |
| Current account CA | −107.40 | −114.11 | −115.26 |
| Interest rate $r$ | 89.78 | 89.78 | 89.78 |
| Risk premium | 40.16 | 40.16 | 40.16 |
| Wages $w$ | 102.69 | 102.58 | 103.57 |
| Income tax $\tau_I$ | 102.81 | 100.00 | 100.00 |
| Consumption tax $\tau_C$ | 100.00 | 93.84 | 100.00 |
| Infrastruct. inv. $\Delta_{K_G}$ | 100.00 | 100.00 | 111.91 |
| Debt-to-GDP ratio as % | 85.02 | 85.02 | 85.02 |
| Total govt. spending | 93.96 | 93.91 | 96.29 |
| Bonds | 83.94 | 84.48 | 85.30 |
| Govt. consumption $C_G$ | 100.00 | 100.00 | 100.00 |
| Govt. investment $I_{K_G}$ | 100.00 | 100.00 | 117.89 |
| Pub. sect. wages | 105.95 | 104.43 | 105.43 |
| Pensions | 104.24 | 104.34 | 105.36 |
| Tax revenue | 101.84 | 99.32 | 102.18 |
| Bequest tax rev. | 95.31 | 93.66 | 94.55 |
| Consumpt. tax rev. | 102.56 | 97.59 | 103.94 |
| Soc. sec. tax rev. | 104.10 | 104.35 | 105.36 |
| Income tax rev. | 99.88 | 97.67 | 98.61 |
| Taxable inc.: all | 96.30 | 97.20 | 98.14 |
| Taxable inc.: labor | 98.89 | 100.68 | 101.65 |
| Taxable inc.: pension | 95.80 | 93.34 | 94.25 |
| Taxable inc.: asset | 82.56 | 81.68 | 82.45 |
| Welfare measures | | | |
| Aggregate comp. consumpt. as % of GDP | −0.82 | −1.63 | −1.61 |
| Aggregate—private in % of GDP | −0.59 | −1.34 | −1.32 |
| Aggregate—public in % of GDP | −0.23 | −0.29 | −0.29 |
| Private—low income: Ave.%$\Delta$ in $C$ | −0.81 | −1.79 | −1.76 |
| Private—high income: Ave.%$\Delta$ in $C$ | −1.14 | −2.56 | −2.54 |
| Public—low income: Ave.%$\Delta$ in $C$ | −1.45 | −1.60 | −1.57 |
| Public—high income: Ave.%$\Delta$ in $C$ | −2.29 | −3.11 | −3.08 |

*Notes*: Greece now reports its true debt level so that the risk premium increases. Note that the government now reduces the debt level to 85 percent of GDP and lets either taxes or public spending adjust to clear the government budget in reaction to the higher risk premium. $\tau_I$ is income tax, $\tau_C$ is consumption tax, and $\Delta_{K_G}$ is public investment. The benchmark steady state is normalized to 100. All results are in relation to this steady state.

*Macroeconomic aggregates.* Reducing the long-run debt-to-GDP ratio to 85% leads to a significant decrease in the risk premium by about 60% with an associated decrease in the interest rate by 10% in the new steady state. The rental rate of capital is now lowered because of the smaller risk premium. The permanent reduction in the debt-to-GDP ratio induces a significant expansion in economic activities. In particular, these tax revenue reductions induce a modest increase in labor supply and a very large increase in capital employed.

Specifically, capital employed in production ($K_P$) increases by at least 8.6% in all cases, columns (1)–(3). The biggest increase in capital employed occurs when infrastructure investment adjusts [i.e., a 10% increase in column (3) of Table 7]. This is due to the complementary relationship between capital and infrastructure. Because capital and labor are also complements, we observe an increase in the demand for effective labor. The magnitude of the increase in human capital employed in the economy depends on the size of the changes in the policy instruments. In general, the increase in human capital employed in the private sector $H_P$ remains around 0.7%. This in turn increases the real wage by more than 2.5%.

As both capital input and labor input rise in all three cases, output increases as well. It is clear from Table 7 that these policy experiments increase both output and consumption in the long-run regardless of which policy instrument adjusts. The output gains are between 3 and 5%, with the smallest gains being realized when the income tax rate adjusts and the largest gains being realized when infrastructure investment adjusts. Consumption increases by 0.4% when the consumption tax adjusts and by 1.0% when public investment adjusts. Conversely, we observe a small drop in consumption, around 0.5%, in the case of income tax adjustments.

As a direct consequence of the debt reduction, the government does not have to finance the large debt service any more, so more funds become available to reduce taxes or increase spending. As can be seen from column (2) in Table 7, the consumption tax rate falls by almost 5.0%. This has to do with a broadening of the consumption tax base as aggregate consumption increases by almost 0.5%. When public capital investments adjust to accommodate the lower debt level and the resulting lower debt service, we see that government investments in public capital as a percentage of GDP increase by almost 29%.

Notice that debt reduction does not always lead to lower taxes in our general equilibrium model [column (1) in Table 7]. In this case income taxes increase. This outcome is driven by two factors. First, the lost interest revenue due to the lower interest rate shrinks the tax base for interest income. Second, because the economy grows by 3.4%, so do the government spending programs that are indexed to GDP, such as the public sector wage bill and public pensions. (Note: Only infrastructure investments $\Delta_{K_G}$ are pegged at prereform levels.)

Over transitions, the temporary tax increases result in strong disincentives to the households' labor supply and savings decisions (Figure 3). Hours of work and aggregate human capital decrease during the years of high taxes. Aggregate human capital subsequently decreases by about 2% in the first period after the shock. On impact, savings drop by about 5% before converging to about an 18% decrease compared with prereform levels. As illustrated in panel 1 of Figure 3, following the immediate decline in inputs in the early transition years, output drops by around 1.5% as well. This drop in output occurs regardless of the fiscal policy instrument that is used to balance the budget and implies that fiscal distortions drive the economy into a recession. The recession lasts for five years. Thereafter production expands quickly, so that output rises to about 5% above prereform levels.

Most importantly, the transition dynamics highlights trade-offs between short-run losses and long-run gains in aggregate output. We find that in our model the short-run fiscal multipliers are much smaller than the long-run multipliers. Comparing the transition path generated via tax-based measures with the path generated by spending-based measures, we also see that the economy reacts most strongly (in terms of output) to adjustments in public investment in public capital. This result is in line with recent findings by Alesina et al. (2015), who point out that adjustments based on spending cuts are much less costly in terms of lost output than losses triggered by increases in tax rates. Note that we only focus on productive government spending and that the underlying mechanisms are different in our framework. The tax-based reform reduces the fiscal distortions of individuals' intertemporal allocation and the supply of production factors, whereas the spending-based reform works through improving production efficiency and the demand for factors of production. The latter turns out to be stronger in enhancing production activities in the long run. This result highlights that the type of fiscal austerity measure that gets implemented matters for domestic production in an open economy setting.

*Welfare.* We report the welfare effects during the transition of a tax-based reform in Figure 4 and a spending-based reform in Figure 5. Figure 4 depicts the welfare gains/losses associated with income tax adjustments to accommodate the decrease of debt. The welfare effects vary across generation, skill type, and sector. Old and middle-aged generations experience welfare losses. These groups pay higher taxes during the fiscal austerity period and do not live long enough to benefit from long-run efficiency gains and future tax cuts. Interestingly, we observe welfare gains for high-skilled workers and welfare losses for low-skilled workers. In addition, the spending-based austerity reform dominates the tax-based reform in terms of income and welfare in the long run.

## 5. EXTENSIONS AND SENSITIVITY ANALYSIS

### 5.1. Alternative Austerity Measures to Reduce Public Debt

We next consider alternative fiscal policies to pay for the debt reduction. Specifically, we study a mix of spending-based and tax-based reforms in which the

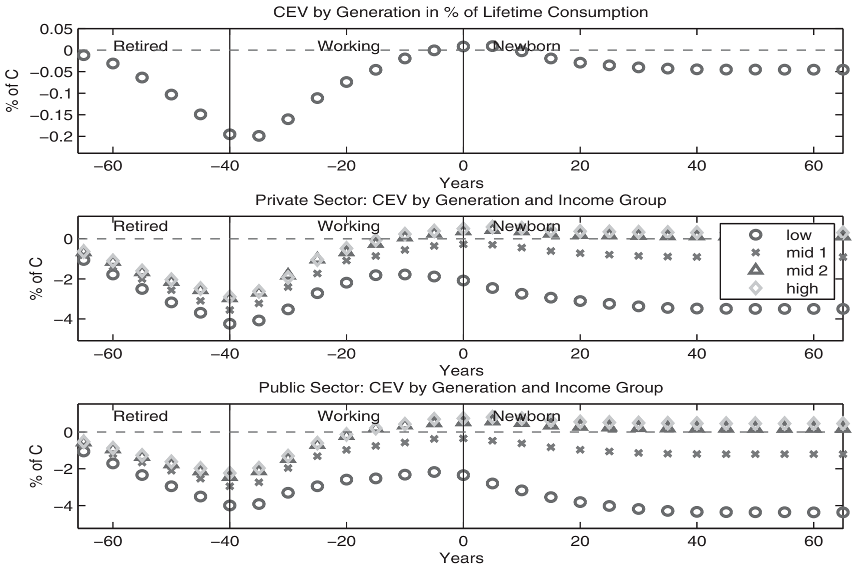


**FIGURE 4.** Risk-premium shock, debt reduction, and welfare dynamics: Tax measures. Income taxes adjust to accommodate the decrease of debt to 85 percent of GDP and the risk premium shock.

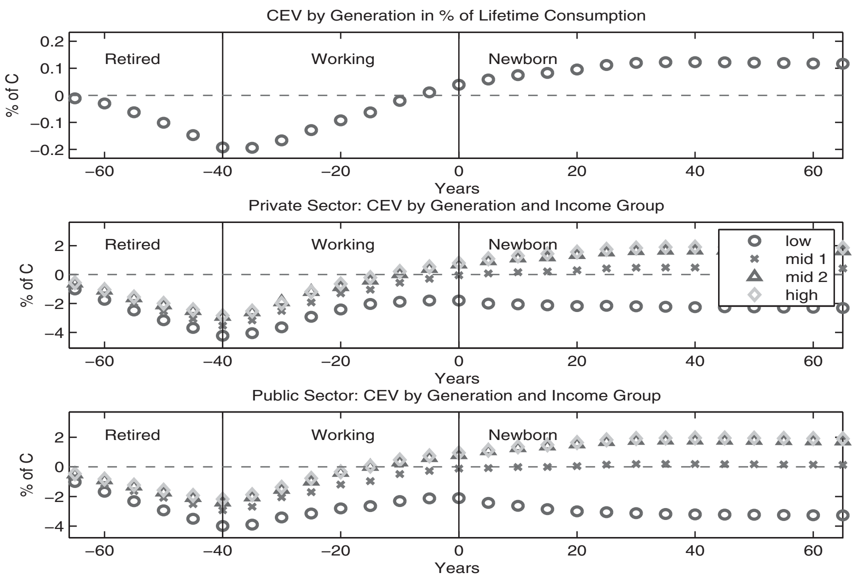


**FIGURE 5.** Risk-premium shock, debt reduction, and welfare dynamics: Spending measures. Government investments adjust to accommodate the decrease of debt to 85 percent of GDP and the risk premium shock.

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government cuts either the size of the public sector workforce $N_G$ by 15 percent, public sector wages $w_G$ by 15 percent, or the replacement rate (measured by parameter $\Psi_G$) of public sector pensions by 15 percent. In all three cases, the government also adjusts either the income tax or public investments $\left(\Delta_{K_G}\right)$ in order to balance the government budget. The steady state implications of these reforms are illustrated in Table 8. A sizable reduction in the debt-to-GDP ratio generates a large output expansion and can lead to welfare gains in the long run, depending on the chosen policy.

The best policy in terms of steady state output is to cut public sector wages while letting public infrastructure investment adjust to balance the budget [columns (4) and (5)] in Table 8]. This policy reform raises steady state output by over 9 percent. Welfare gains are obtained for almost all groups, except the low-income workers. Welfare gains of richer workers exceed the gains of poorer workers as a percentage of their lifetime consumption. High-income public sector workers experience gains of over 3 percent of consumption.

Cuts to public sector employment [columns (1) and (2) in Table 8] produce results similar to those of cuts in public sector pensions [columns (5) and (6) in Table 8]. Adjustments in infrastructure investments dominate tax adjustments in both cases in terms of output and overall welfare.

## 5.2. Alternative Adjustment Speed for Debt Reduction

In our benchmark experiments we assume that the government implements its fiscal austerity plan over fifteen years. In many advanced economies with high public debt, the debate on the speed of fiscal consolidation, front-loading vs. back-loading, is often about the value of fiscal multipliers. When fiscal multipliers are large, government spending cuts and tax increases have a large adverse effect on output in the short run. In our benchmark experiments we observe that GDP initially drops. Arguably, large multipliers do not necessarily affect the optimal timing of fiscal consolidation. If they remain just as large in the future, the adjustment will be as painful later. However, the timing of fiscal consolidation matters when it concerns the issue of implementing a policy, as current households might be affected differently than future households.

In this section, we analyze how different adjustment horizons for the debt reduction affect welfare and compare three alternative experiments where the government reduces debt to 85 percent of GDP over a fifteen, twenty, or twenty-five year horizon. Each time the income tax adjusts to clear the government budget. We report the welfare results in Figure 6. We find that the speed of the debt reduction has a relatively small effect on household welfare. More aggressive downsizing of the public debt leads to more severe welfare losses of the grandfathered generations, especially the retired. These welfare differences range between 0.01 and 0.05% of CEV.

**TABLE 8.** Risk-premium shock and the long-run aggregate effects with debt reduced to 85 percent of GDP

| | (1) $N_G, \tau_I$ | (2) $N_G, \Delta_{K_G}$ | (3) $w_G, \tau_I$ | (4) $w_G, \Delta_{K_G}$ | (5) $\Psi_G, \tau_I$ | (6) $\Psi_G, \Delta_{K_G}$ |
|---|---|---|---|---|---|---|
| Output $Y$ | 103.366 | 104.893 | 105.244 | 109.590 | 103.429 | 105.165 |
| Capital $K$ | 82.600 | 82.094 | 82.244 | 84.979 | 85.103 | 84.770 |
| Capital in final $K_P$ | 108.652 | 110.249 | 110.626 | 115.201 | 108.710 | 110.530 |
| Public good $G$ | 100.707 | 112.194 | 91.283 | 123.832 | 101.328 | 117.203 |
| Consumption $C$ | 99.472 | 101.007 | 98.138 | 102.357 | 99.350 | 101.159 |
| Current account CA | −142.867 | −147.227 | −147.902 | −154.895 | −139.715 | −144.363 |
| Income tax $\tau_I$ | 102.215 | 100.000 | 107.253 | 100.000 | 103.443 | 100.000 |
| Infrastruct. inv. $\Delta_{K_G}$ | 100.000 | 123.348 | 100.000 | 188.836 | 100.000 | 134.016 |
| Aggregate CEV as % of GDP | −0.8237 | 0.0751 | −1.6740 | 0.8139 | −1.2680 | −0.1346 |
| Aggregate CEV % of lifetime C | −0.0431 | 0.1192 | −0.1978 | 0.2818 | −0.0567 | 0.1619 |
| Private sect.: % of lifetime C | −0.3610 | 1.0752 | −1.7420 | 2.5042 | −0.1881 | 1.7488 |
| Public sect.: % of lifetime C | −0.4583 | 0.9638 | −1.7677 | 2.4290 | −1.7504 | 0.1540 |
| Private—low income: % of lifetime $C$ | −3.4672 | −2.3026 | −4.4129 | −0.4252 | −3.0241 | −1.3915 |
| Medium income | −0.8894 | 0.4444 | −2.1460 | 1.9721 | −0.6455 | 1.1833 |
| High income | 0.1589 | 1.6658 | −1.3243 | 3.0560 | 0.2706 | 2.3154 |
| Very high income | 0.3255 | 1.8863 | −1.1983 | 3.1140 | 0.4177 | 2.4342 |
| Public—low income: % of lifetime $C$ | −4.3364 | −3.2690 | −5.1158 | −1.2607 | −4.9882 | −3.5157 |
| Medium income | −1.1791 | 0.1647 | −2.3623 | 1.6967 | −2.3329 | −0.5316 |
| High income | 0.2169 | 1.7424 | −1.1334 | 3.1654 | −1.1386 | 0.8369 |
| Very high income | 0.4709 | 1.9327 | −1.1021 | 3.2457 | −1.0900 | 0.9673 |

*Notes*: Greece now reports its true debt level, so the risk premium increases. The government now reduces the debt level to 85 percent of GDP and lets a mix of taxes and public spending adjust to clear the government budget: (1) public sector size reduced by 15 percent with income tax adjustment; (2) public sector size reduced by 15 percent and infrastructure investments adjusted; (3) public sector wages reduced by 1 percent and income tax adjusted; (4) public sector wages reduced by 15 percent and infrastructure investments adjusted; (5) public sector pensions reduced by 15 percent and income tax adjusted; and (6) public sector pensions reduced by 15 percent and infrastructure investments adjusted. The benchmark steady state is normalized to 100. All results are in relation to this steady state. Welfare results are reported as compensating consumption units as a fraction of prereform steady state GDP or lifetime consumption per household type.

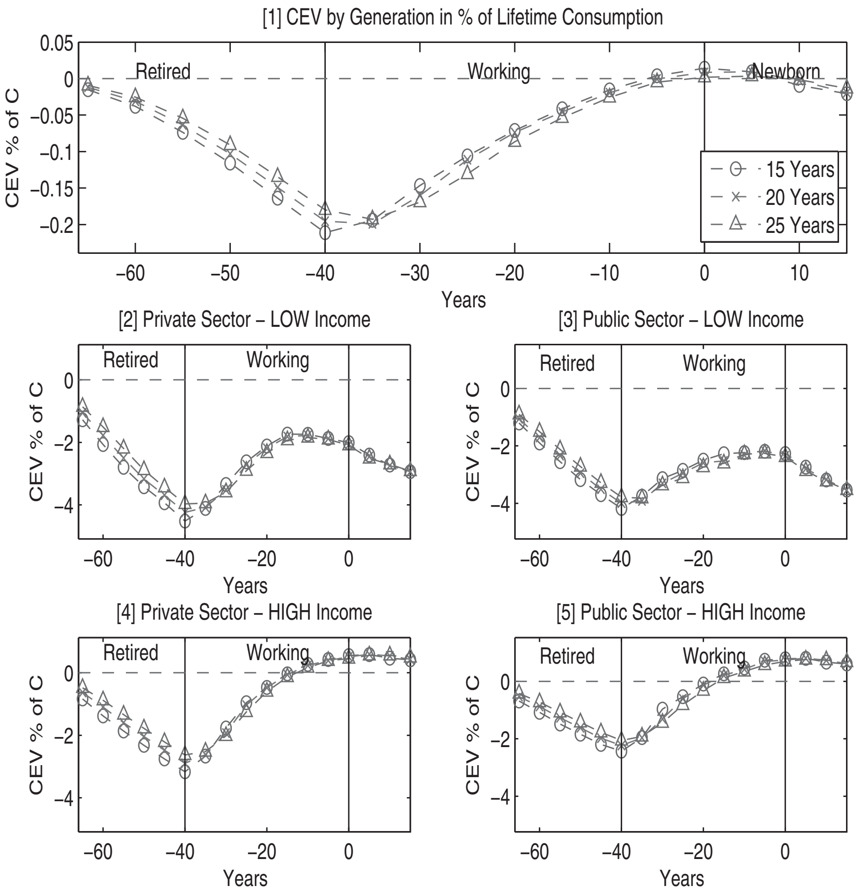


**FIGURE 6.** Alternative adjustment speed for debt reduction: Welfare dynamics with debt reduction to 85 percent of GDP over 15, 20, or 25 years.

## 5.3. Fiscal Austerity in Bad Times

In this set of experiments the government implements a fiscal consolidation to achieve a debt reduction to 85 percent of GDP while facing negative fundamental shocks to the economy. These negative fundamental shocks are introduced in the form of more probable long-term idiosyncratic unemployment shocks that will increase the long-term unemployment rate to 6 percent from the status quo value of 4 percent. In an additional debt reduction experiment under even worse conditions, we impose a long-term unemployment rate of 8 percent. We implement this increase in unemployment by appropriately scaling the transition probabilities of the unemployment shocks. We then quantify the combined effects and report market aggregates in Figure 7 and welfare results in Figure 8.

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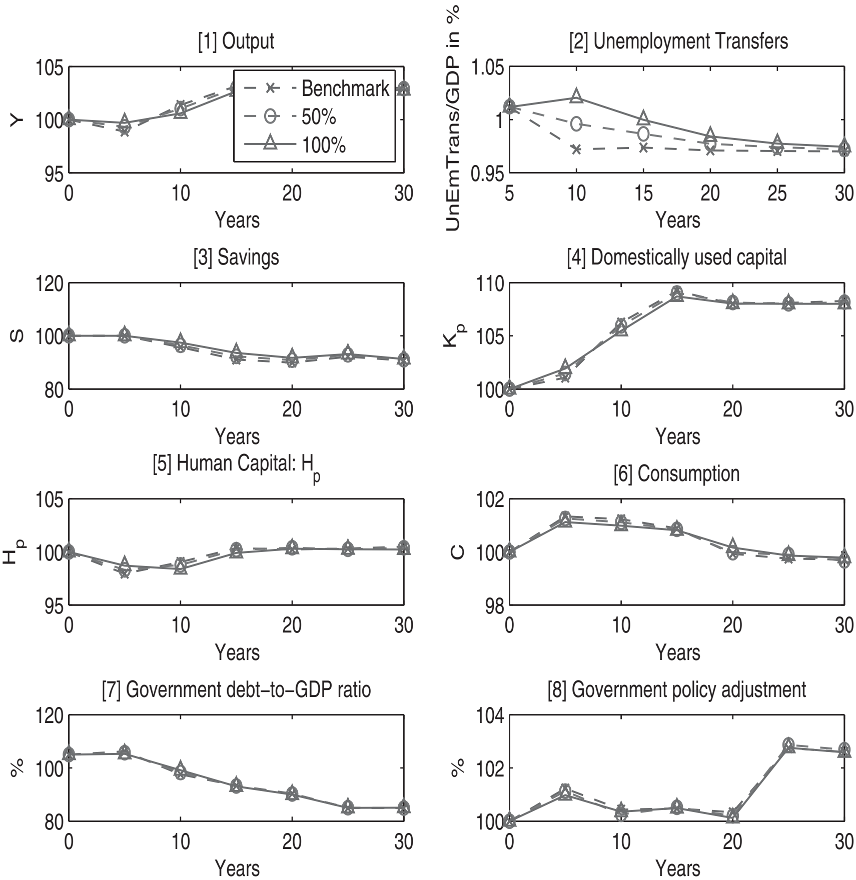


**FIGURE 7.** Austerity in bad times, I. Transitions with debt reduction to 85 percent of GDP and a temporary five year increase in unemployment.

A tax increase or spending cut that reduces disposable household income is more painful if implemented when negative shocks to the economy have already strained the budgets of many households. Gradín et al. (2012) show that the per capita unemployment spells in a recession tend to become larger and that the average unemployment spell in Greece was between 16 and 18 months for the years 2007–2011. In this situation the government faces not only a contraction in production capacity but also increased unemployment payments. Understanding the combined effects of the fiscal adjustments and the unemployment shocks triggered by the recession is crucial for deciding on the timing of fiscal austerity measures.

In our experiment we first note that unemployment insurance transfers become larger if debt reduction is combined with an increase in long-run involuntary unemployment [see Panel (2) in Figure 7]. These differences in unemployment

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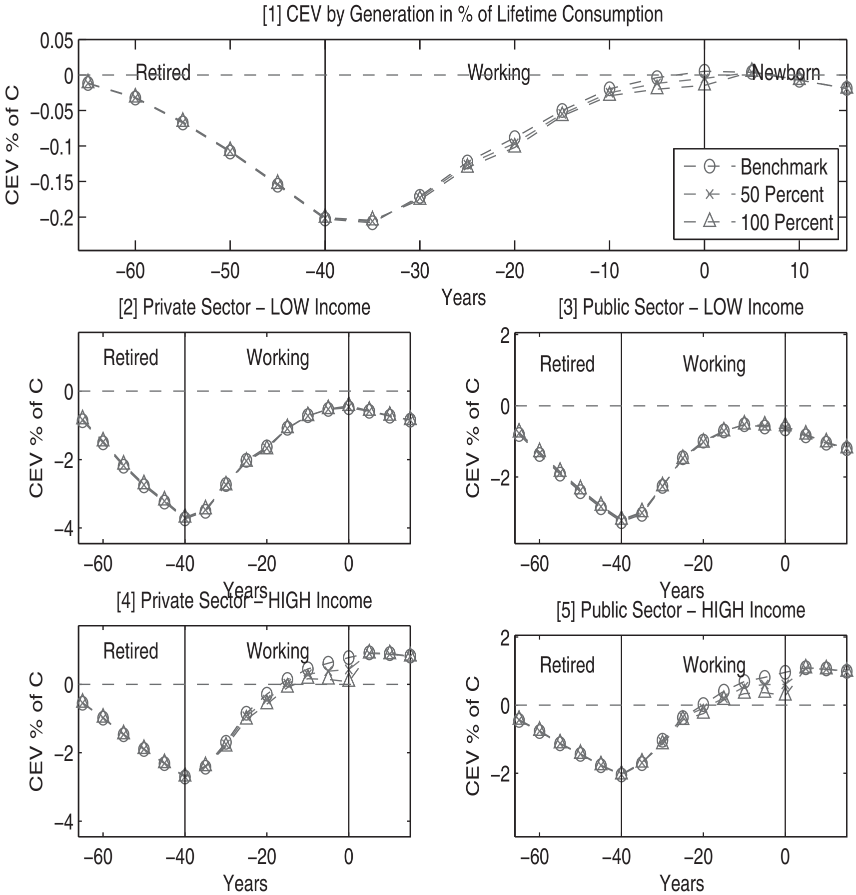


**FIGURE 8.** Austerity in bad times, II. Welfare dynamics with debt reduction to 85 percent of GDP and a temporary five year increase in unemployment.

insurance transfers are quite persistent and last for about fifteen years. Because the involuntary long-term unemployment rate affects only a relatively small segment of the population, the aggregate effects tend to be rather small. In terms of welfare, we observe that increases in involuntary long-term unemployment decrease the welfare of workers more if the unemployment shocks become more likely. Because private and public sector workers are similarly affected by these shocks, we do not observe large differences in their welfare.

## 5.4. Alternative Parameterization

We finally provide a sensitivity analysis for a selection of critical parameters for which empirical estimates either do not exist or vary greatly. For the benchmark case we calibrated these parameters to data from Greece. In this section we vary some of these parameters to test the robustness of our results. More specifically, we run the model with alternative values for the (inverse of the) intertemporal elasticity of substitution parameter $\sigma$, the infrastructure productivity parameter $\eta$, and the capital share parameter $\alpha_2$.[11] The results of the sensitivity analysis are summarized in Table 9. Our results are fairly robust to the suggested parameter changes.[12]

## 6. CONCLUSION

We construct a dynamic general equilibrium overlapping-generations economy model to study the macroeconomic and welfare effects of fiscal austerity measures in a small open economy with a high level of government debt. Our model incorporates intracohort heterogeneity and a productive government sector as well as government investment and entitlement programs. We calibrate our model to data from Greece and conduct a quantitative analysis of various fiscal austerity measures that will reduce the level of government debt.

We first consider a risk premium shock that leads to decreases in output and negative welfare effects. We then consider a wide range of tax-based and spending-based austerity measures to reduce the long-run debt-to-GDP ratio. We find that these reforms result in a trade-off between short-run losses and long-run gains. Welfare effects vary significantly across generation and household type. The current old and middle-aged generations experience welfare losses, whereas future generations benefit. High-skilled workers gain more from the reforms. Interestingly, we find that spending-based reforms are dominated by tax-based reforms in terms of income and welfare in the short run, but lead to better outcomes in the long run. A mixed reform that combines tax-based and spending-based measures results in the largest welfare effects. Most importantly, our results highlight the political obstacles driven by the trade-off between short-run losses and long-run gains that governments have to face when introducing a fiscal consolidation program.

In this paper, we have abstracted from the existence of an informal sector. Although informal sector effects are clearly important [Schneider (2005) estimates its size to be close to 30 percent of the official economy in Greece], we face some serious conceptual issues. First, there is some evidence that the relative size of the informal sector in Greece actually fell at the onset of the crisis [Manolas et al. (2013), Schneider (2013)]. Because intuition suggests that an economic crisis might increase the size of the shadow economy relative to that of the official economy, there are clearly some conceptual issues to be worked out. Second, it seems difficult to ascertain what fraction of the officially unemployed are employed in the shadow economy and how this employment pattern changes over time and is influenced by fiscal policy reform. For these challenging conceptual reasons we leave the incorporation of an informal sector into our analysis for future work.

**TABLE 9.** Sensitivity analysis

| | | Debt-to-GDP ratio: 105% | | | Debt-to-GDP ratio: 85% | | |
|---|---|---|---|---|---|---|---|
| Benchmarks | | (1) $\tau_I$ | (2) $\tau_C$ | (3) $\Delta_{K_G}$ | (4) $\tau_I$ | (5) $\tau_C$ | (6) $\Delta_{K_G}$ |
| $\sigma = 2.50$ | Output $Y$ | 98.811 | 98.811 | 98.884 | 103.366 | 103.500 | 104.893 |
| $\beta = 0.998$ | Capital $K$ | 110.056 | 110.056 | 110.020 | 82.600 | 82.705 | 82.094 |
| $\eta = 0.42$ | Cap. dom. prod. $K_P$ | 97.042 | 97.043 | 97.120 | 108.652 | 108.794 | 110.249 |
| $A_G = 4.8$ | Consumption $C$ | 100.273 | 100.475 | 100.328 | 99.472 | 100.496 | 101.007 |
| $\alpha_2 = 0.33$ | Income tax $\tau_I$ | 100.148 | 100.000 | 100.000 | 102.215 | 100.000 | 100.000 |
| | Consumption tax $\tau_C$ | 100.000 | 98.864 | 100.000 | 100.000 | 95.433 | 100.000 |
| | Govt. investment $I_{K_G}$ | 100.000 | 100.000 | 101.443 | 100.000 | 100.000 | 129.384 |
| | Sensitivity analysis: $\sigma$ | | | | | | |
| $\sigma = 2.00$ | Output $Y$ | 98.509 | 98.510 | 98.695 | 103.128 | 103.153 | 104.636 |
| $\beta = 0.995$ | Capital $K$ | 113.331 | 113.344 | 113.286 | 86.741 | 87.005 | 87.068 |
| | Cap. dom. prod. $K_P$ | 96.727 | 96.727 | 96.947 | 108.438 | 108.478 | 110.014 |
| | Consumption $C$ | 100.257 | 100.588 | 100.381 | 99.329 | 100.532 | 100.865 |
| | Income tax $\tau_I$ | 100.232 | 100.000 | 100.000 | 102.052 | 100.000 | 100.000 |
| | Consumption tax $\tau_C$ | 100.000 | 98.120 | 100.000 | 100.000 | 94.531 | 100.000 |
| | Govt. investment $I_{K_G}$ | 100.000 | 100.000 | 104.038 | 100.000 | 100.000 | 130.279 |
| $\sigma = 3.00$ | Output $Y$ | 98.961 | 98.962 | 99.257 | 103.780 | 103.782 | 105.290 |
| $\beta = 1.001$ | Capital $K$ | 111.246 | 111.247 | 111.091 | 85.070 | 85.101 | 84.339 |
| | Cap. dom. prod. $K_P$ | 97.177 | 97.178 | 97.510 | 109.109 | 109.114 | 110.535 |
| | Consumption $C$ | 100.371 | 100.786 | 100.593 | 99.712 | 100.892 | 100.935 |
| | Income tax $\tau_I$ | 100.321 | 100.000 | 100.000 | 102.293 | 100.000 | 100.000 |
| | Consumption tax $\tau_C$ | 100.000 | 97.725 | 100.000 | 100.000 | 93.935 | 100.000 |
| | Govt. investment $I_{K_G}$ | 100.000 | 100.000 | 106.182 | 100.000 | 100.000 | 133.826 |

**TABLE 9.** Continued

| Benchmarks | | Debt-to-GDP ratio: 105% (1) $\tau_I$ | Debt-to-GDP ratio: 105% (2) $\tau_C$ | Debt-to-GDP ratio: 105% (3) $\Delta_{K_G}$ | Debt-to-GDP ratio: 85% (4) $\tau_I$ | Debt-to-GDP ratio: 85% (5) $\tau_C$ | Debt-to-GDP ratio: 85% (6) $\Delta_{K_G}$ |
|---|---|---|---|---|---|---|---|
| | | Sensitivity analysis: $\eta$ | | | | | |
| $\eta = 0.35$ | Output $Y$ | 98.782 | 98.782 | 98.817 | 103.316 | 103.448 | 104.435 |
| $A_G = 4.8$ | Capital $K$ | 109.697 | 109.697 | 109.691 | 82.399 | 82.497 | 82.456 |
| | Cap. dom. prod. $K_P$ | 97.011 | 97.011 | 97.059 | 108.612 | 108.756 | 109.790 |
| | Consumption $C$ | 100.205 | 100.388 | 100.223 | 99.334 | 100.408 | 100.609 |
| | Income tax $\tau_I$ | 100.135 | 100.000 | 100.000 | 102.192 | 100.000 | 100.000 |
| | Consumption tax $\tau_C$ | 100.000 | 98.970 | 100.000 | 100.000 | 95.107 | 100.000 |
| | Govt. investment $I_{K_G}$ | 100.000 | 100.000 | 101.039 | 100.000 | 100.000 | 130.164 |
| $\eta = 0.50$ | Output $Y$ | 98.832 | 98.834 | 98.911 | 103.342 | 103.473 | 105.238 |
| $A_G = 4.99$ | Capital $K$ | 109.927 | 109.936 | 109.908 | 82.651 | 82.743 | 82.284 |
| | Cap. dom. prod. $K_P$ | 97.046 | 97.048 | 97.141 | 108.632 | 108.776 | 110.631 |
| | Consumption $C$ | 100.346 | 100.525 | 100.391 | 99.454 | 100.492 | 101.236 |
| | Income tax $\tau_I$ | 100.134 | 100.000 | 100.000 | 102.163 | 100.000 | 100.000 |
| | Consumption tax $\tau_C$ | 100.000 | 99.003 | 100.000 | 100.000 | 95.300 | 100.000 |
| | Govt. investment $I_{K_G}$ | 100.000 | 100.000 | 101.427 | 100.000 | 100.000 | 130.633 |
| | | Sensitivity analysis: $\alpha_2$ | | | | | |
| $\alpha_2 = 0.30$ | Output $Y$ | 99.032 | 99.032 | 99.060 | 102.872 | 102.901 | 105.255 |
| $\beta = 0.996$ | Capital $K$ | 109.341 | 109.344 | 109.350 | 86.156 | 86.496 | 92.954 |
| | Cap. dom. prod. $K_P$ | 97.254 | 97.254 | 97.296 | 108.128 | 108.147 | 110.693 |
| | Consumption $C$ | 100.242 | 100.405 | 100.249 | 99.381 | 100.649 | 101.832 |
| | Income tax $\tau_I$ | 100.116 | 100.000 | 100.000 | 102.615 | 100.000 | 100.000 |
| | Consumption tax $\tau_C$ | 100.000 | 99.116 | 100.000 | 100.000 | 94.109 | 100.000 |
| | Govt. investment $I_{K_G}$ | 100.000 | 100.000 | 100.802 | 100.000 | 100.000 | 141.608 |

*Notes*: Experiments with and without debt reduction and adjustments in taxes or infrastructure investment using alternative parameter values. The prereform steady states have been recalibrated for each case separately.

The model can also be extended to analyze additional fiscal policy issues. Inclusion of population aging into the model could allow us to analyze fundamental factors driving a country's fiscal limit, i.e., the dynamic links between aging, pay-as-you-go social benefits, and fiscal sustainability. Including a voting mechanism could be used to study the implementability of fiscal austerity measures. Random disturbances such as technology shocks or policy shocks are important to understand fiscal behavior. Accounting for such exogenous economic disturbances would allow us to study the possibility of government default as well as the full spectrum of welfare effects due to the reduction of risk. We leave these issues for future research.

## *NOTES*

1. Because the public good $G$ is an input into private sector production of $Y$, the public sector wage bill is already contained in the measure of $Y$. For simplicity, we do not take net exports into account when expressing policy parameters as percentages of GDP. In addition, the aggregate $S_t$ already incorporates the exogenous population growth rates via the population weight $\mu$. We therefore only have to detrend with the exogenous technological growth rate $g$.

2. The sources include BOG (2005), Tsakloglou and Cholezas (2005), IMF (2006), Koutsogeorgopoulou and Turner (2007), Buiter and Rahbari (2010), Monokroussos (2010), Rother et al. (2010), HellasCountryFiche (2011), MOF (2011), OECD (2011a), OECD (2011b), and Arghyrou and Tsoukalas (2011).

3. See OECD.StatsExtract at http://stats.oecd.org/Index.aspx?DataSetCode=ANHRS, factoring in an unemployment rate of 8 percent, and http://www.google.com/publicdata/directory.

4. It is clear that in a general equilibrium model every parameter affects all equilibrium variables. Here we associate parameters with those equilibrium variables that they affect the most quantitatively.

5. Source: http://stats.oecd.org.

6. http://www.ekathimerini.com/4dcgi/_w_articles_wsite1_1_06/03/2012_431420.

7. http://www.taxexperts.eu/en/GUIDE/TaxExperts_Guide.

8. After the new Greek government took over in 2010 ot revised the 2009 deficit from a previously estimated range of 3.7–5% to an alarming 12.7% of GDP. In April 2010, the reported 2009 deficit was further increased to 13.6%, and at the time of the final revised calculation by Eurostat it ended at 15.6% of GDP. These revisions are of course largely due to Greece not having correctly anticipated the magnitude of the crisis in its original projections for 2009. There has been speculation about earlier underreporting of the deficit, but no exact estimates are available.

9. Compare http://epp.eurostat.ec.europa.eu/.

10. Alternatively, we could consider an exogenous change in the country credit rating as a source of the risk premium shock. We could model it by shifting the estimated risk premium function.

11. Whenever we change one of these parameters, we need to adjust other parameters to keep the model output aligned to data from Greece. In a general equilibrium model, a change in one parameter does affect all model-generated data moments to some extent. So when we recalibrate the model we choose parameters that "most directly" affect the data moment that we target. If, for instance, we change the parameter value $\sigma = 2.5$ to $\sigma = 3.0$ in the sensitivity analysis, the capital–output ratio rises to unrealistic levels. We therefore search for a lower time preference parameter $\beta$ until the model matches the capital–output ratio again. A similar argument can be made for the pairs $(\eta, A_G)$ and $(\alpha_2, \beta)$.

12. If in addition the government cuts either public sector employment, public sector wages, or public sector pensions, the robustness of our results is also fairly strong, that is, qualitatively identical with small quantitative deviations from our benchmark experiments. More detailed results for these cases are available upon request.

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# APPENDIX: COMPUTATION OF THE STEADY STATE AND TRANSITION PATH

We solve the model numerically, using an algorithm similar to that of Auerbach and Kotlikoff (1987). This algorithm solves nonlinear equations using an iterative technique commonly referred to as the Gauss–Seidl method. The algorithm starts with a guess at various endogenous variables and treats them as exogenous. Then, after solving all individual household maximization problems and imposing the budget constraints and market clearing conditions, the algorithm solves for a new set of endogenous variables. If the new set of endogenous variables equal the original guesses, a solution to the system has been found and the algorithm stops. Otherwise, we take linear combinations of the guessed variables and the new solutions for the variables and start all over. Once the algorithm converges to a steady state, we compare the model's outcome with moments in the data. We use a similar algorithm to solve for transitions between two steady states that result from changes in policy variables. We check for uniqueness of equilibrium by trying various starting points for the algorithm. Notice that our solution algorithm is locally stable. We have no mathematical proof of global convergence. To our knowledge, there is no formal proof of uniqueness available for this type of Auerbach–Kotlikoff models [see Kotlikoff et al. (2001)].