Fiscal Austerity Measures: Spending Cuts vs. Tax Increases

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Abstract

We study the macroeconomic and welfare effects of decumulating government debt in an overlapping generations model with skill heterogeneity and productive and non-productive government programs. Our results are: *First*, in the small open economy model calibrated to Greece, the spending-based austerity reform dominates the tax-based reform with respect to income effects but not with respect to the welfare effect. A mixed reform combining the tax-based and spending-based measures results in the largest welfare effects of up to 1.8 percent of pre-reform consumption. *Second*, the welfare effects vary significantly along the transition to the post reform steady state, depending not only on fiscal austerity measures, but also on skill types, working sectors and generations. When consumption taxes adjust the aggregate welfare effects are positive but the current old and middle age generations experience welfare losses while current young workers and future generations are beneficiaries. *Third*, interactions between fiscal distortions and the risk premium as well as accessibility to international capital markets strongly influence the effects of fiscal austerity. Larger growth and welfare effects are observed when the risk premium is larger than zero and when access to international capital markets is restricted.

JEL Classification: E21, E63, H55, J26, J45

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1 Introduction

Population aging and generous welfare systems have increased the national debt of many EU countries. This has raised many questions about the sustainability of current fiscal policies (e.g. see IMF (2010)). The recent recession has contributed to this problem by decreasing GDP and tax revenues while increasing the need for fiscal spending. Nowhere is this more evident than in Greece, where fiscal deficits have precipitated repeated bail out packages from the EU. These developments present governments with various unpleasant options which either include large tax increases or 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.

There are a variety of factors and mechanisms that determine the macroeconomic outcomes of austerity measures. Among others, these factors 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), Guichard et al. (2007), Ardagna (2004), Bi and Leeper (2012), and Bi, Leeper and Leith (2011)). 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, while 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. see Barro (1979), Lucas and Stokey (1983), Cukierman and Meltzer (1989), Alesina and Tabellini (1990) and Tabellini (1991)). Fiscal programs including social security, unemployment insurance and public health insurance are emphasized as an important inter-generational transfer and redistribution mechanism in the public finance literature. To the best of our knowledge, such distributional/welfare effects have not been analyzed quantitatively in the context of the fiscal consolidations.

In this paper we provide an analytical framework of an economy which can be used to study the implications of various austerity measures on economic outcomes and welfare. We focus on quantifying the inter-generational and distributional effects of sizeable reductions of public debt. We construct an overlapping generation model based on Auerbach and Kotlikoff (1987) including skill heterogeneity, private and public sector production, 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 consumption taxes, labor taxes and capital taxes as well as the government's ability to issue debt. We first analyze the macroeconomic and welfare effects in a small open economy where domestic agents face a fixed world interest rate (benchmark model). We then extend our analysis and allow for a risk premium. We also compare our results to a closed economy.

The benchmark model is calibrated to Greece at the beginning of the 21st 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 conditionality, negotiated and applied by the IMF and the EU. In exchange for external aid, Greece agreed to implement fiscal adjustments worth about 12.5 percent of 2009 GDP spread over three years. This tightening is in addition to partly implemented reforms of about 6 percent of GDP. The goal is to reduce the deficit by 3 percent of GDP by 2014. The bulk of the measures will focus on increases of the VAT rate from 21 to 23 percent and cuts to public sector wages, pensions and employment numbers (Buiter and Rahbari (2010)).

In our model we analyze the following policy reforms: reductions of the government debt-to-GDP ratio from 95 percent of GDP to 65 percent of GDP in the long run. We consider a number of fiscal austerity measures to support this target: (*i*) tax-based austerity measures including increases in consumption taxes, labor taxes and capital taxes, (*ii*) spending-based austerity measures including cuts in public sector pensions and adjustments in public infrastructure investments, and (*iii*) combination of tax increases and spending cuts. We calculate the new steady state aggregates, the transition paths to the new steady state, and the size of the welfare gains or losses from each reform. We also identify the socio-economic groups that stand to gain or lose from this reform (i.e. young vs. old, rich vs. poor, private vs. public sector employees).

Our results are summarized as follows: *First*, in the small open economy model calibrated to Greece, we find that the spending-based austerity measure, i.e. public investment in infrastructure, results in an increase in steady state output of around 1 percent, while the tax-based austerity measures lead to small declines in steady state output. However, the tax-based austerity measures create bigger welfare gains compared to the spending-based austerity measures. A mixed reform that combines tax-based austerity measures and spending-based austerity measures results in larger welfare effects of about 1.8 percent of pre-reform consumption.

Second, the analysis of the transition dynamics indicates trade-offs between short-run efficiency losses and long-run efficiency gains. Tax increases or spending cuts trigger immediate contractions and lower output in the short run. The welfare analysis also 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 of the individual, as well as on the individual's remaining lifetime. More specifically, when infrastructure investments adjust to accommodate the debt reduction, the aggregate welfare effects are negative for about 40 years after the reform and all generations born before the reform and the first generation born after the reform experience substantial welfare losses of up to 1.1 percent of pre-reform consumption. In contrast, when consumption taxes adjust to accommodate the debt reduction the aggregate welfare effects are negative only in the first 5 transitional years and then quickly turn positive. Retirees and workers who are close to their individual retirement age lose from the reform while middle-aged and young workers as well as future generations win.

Third, the positive effects on output and welfare, driven by the classic result of tax distortions and crowding-out effects, are magnified when a risk premium is included into the small open economy model. In this case, fiscal austerity measures, except for the capital tax case, lead to increases in steady state output of up to 3.6 percent.

Fourth, the substitutability of private capital and accessibility to international capital markets are important to determine the effects of the various fiscal austerity measures. All fiscal austerity measures result in positive effects on steady state output when the accessibility to the international capital market is removed (i.e. closed economy version). The size of these income effects is between 2.5 and 4.5 percent. The welfare effects are also more pronounced, especially for high income workers.

Our paper connects to several branches of the literature. 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 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, Leeper and Leith (2011) explore whether or not fiscal consolidation is driven by tax increases or expenditure cuts. Forni, Gerali and Pisani (2010) quantify the macroeconomic implications of permanently reducing the public debt-to-GDP ratio in euro area countries. These papers build on New Keynesian type models and emphasize the interactions between fiscal and monetary policies. However, that literature, with the exception of Forni *et al.* (2010), does not explicitly model the composition of government spending and tax revenues. They often neglect the trade-off between productive (education and public capital) vs. non-productive government spending (pensions and to some extent medical insurance) or the trade-off between labor taxes vs. capital taxes. Moreover, since these papers use a representative agent framework they often abstract from inter-generational 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.

Our paper is related to the large public finance literature analyzing the distributional role of fiscal programs such as social security, health insurance and unemployment insurance (e.g. see Auerbach and Kotlikoff (1987), Imrohoroglu, Imrohoroglu and Jones (1995), and Jung and Tran (2010)). Our paper follows a similar approach but focuses on the context of fiscal consolidation and austerity measures.

There is another strand of literature investigating the long run implications of fiscal austerity measures on economic growth. As governments accumulate public debt they extract resources from the private sector to service its interest payments. There is also a crowding in effect as government spending can itself be productive so that the growth in public debt results in an expansion of production capacities (i.e. growth effects of deficit spending). Moreover, the growth in public debt depends not only on the share of spending allocated to productive public goods but also on the share that is financed by tax revenues or bonds. In such a context, fiscal austerity measures force advanced economies to face a trade off: restoring public debt sustainability while making sure that growth is promoted through productive investments (e.g. Arai (2008), Yakita (2008) and Agénor and Yilmaz (2011)). Moraga and Vidal (2004) focus on fiscal sustainability where government spending influences the engine of endogenous growth via public investment in human capital formation. Ireland (1994) and Bruce and Turnovsky

(1999) study the conditions under which conditions a tax cut alone or a tax cut combined with expenditure cuts can improve the fiscal balance in the long-run. Since these papers aim to obtain analytical results, the models are fairly simplified versions of the neoclassical growth model. In this paper, we instead formulate a more complex model accounting for more details of fiscal policy so that we can add quantitative analyses of fiscal reform programs as well.

Finally, it has been argued that the shift in the demographic structure is one of the driving factors behind the recent fiscal developments. The life-cycle approach is essential to capture this driver of the fiscal non-sustainability problem. The changes in the tax base, the dynamic Laffer effects, and the fiscal limits will be substantially different in a finite horizon model than in an infinite horizon model with a representative agent. Bohn (2007) argues that households' domestic savings presents a natural limit for government borrowing and interest rates are therefore much more sensitive to changes in the fiscal policy in a finite lifetime model. Our paper introduces a quantitative version a finite lifetime model.

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. Section 5 provides a discussion of the results and concludes. The appendix contains all tables and figures. A separate technical appendix, available upon request from the authors, contains the details for all the model solutions 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 productions 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   Heterogeneity and demographics

The economy consist of a large number of individuals who live in an overlapping generations setting, and are heterogeneous in terms of age, skill types, and working sector. Individuals are born with a specific skill type that determines their labor productivities. This skill type is fixed over the life time. Newborn individuals are allocated to either work in the public sector or in the private sector. Individuals are endowed with age-dependent efficiency unit e_j each period. Note that e_j varies over the life-cycle following the typical hump-shaped pattern. We assume that all individuals of a given age and type are equally productive regardless of whether they work in the public or private sector.

We denote age as variable $j \in (1, ..., J)$, the skill type as variable $skill$ and the working sector as $sector \in \{Private, Government\}$. A typical agent is then characterized by age, income type, and working sector, that can be summarized in state vector $\theta = \{skill, sector\}$. Here and in

the rest of the paper the subscripts P and G denote private sector workers and public sector workers respectively. When we need to distinguish between the sectors we fix the sector variable to one of the sectors and use the following state vector notation $\theta_P = \{skill, sector = Private\}$ and $\theta_G = \{skill, sector = Government\}$.

Population grows exogenously at net rate n. Every period new agents arrive and possibly live for J periods. Since we model working life beginning at age 20 and life ending at age 90, the maximum lifetime is 70 years and each period accounts for $\frac{70}{J}$ years. Individuals face a age-dependent mortality shock with a given survival probability π_j.

Let variable $\mu_j(\theta)$ denote the mass of age j agents with characteristic θ. We assume stable demographic patterns so that, similar to Huggett (1996), age j agents make up a constant fraction $\mu_{j,t}$ of the entire population at any point in time t. The relative size of each age cohort $\mu_{j,t} = \sum_{\theta} \mu_{j,t}(\theta)$ is recursively defined as $\mu_{j,t} = \frac{\pi_j}{(1+n)}\mu_{j-1,t}$. It also is assume that $\sum_{j=1}^{J} \sum_{\theta} \mu_{j,t}(\theta) = 1$. Similarly, the cohort size of agents dying each period (conditional on survival up to the previous period) can be defined recursively as $\upsilon_{j,t} = \frac{1-\pi_j}{(1+n)}\mu_{j-1,t}$.

2.2 Preferences

Within each period of their lives agents value a consumption good $c_{j,t}(\theta)$ and leisure $l_{j,t}(\theta)$ according to the utility function $u(c_{j,t}(\theta), l_{j,t}(\theta))$. This function has the standard properties of monotonicity and quasi-concavity. Individuals discount their future utility using the same discount factor β and age dependent survival probabilities π_j.

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 $Y_t = F_P(G_t, K_{P,t}, H_{P,t})$. This production function is homogenous 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) and Turnovsky (1999) and others. Total factor productivity grows exogenously at rate g. Physical capital depreciates at rate δ 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 $G_t = F_G(K_{G,t}, H_{G,t})$. This production function is characterized by the properties of monotonicity, concavity, and homogeneity of degree one. Public capital evolves according to $K_{G,t+1} = \frac{1}{(1+n)(1+g)}((1-\delta_G)K_{G,t} + I_{G,t})$, where public capital is detrended by the exogenous population growth rate n and the exogenous technological growth rate g. Public capital depreciates at rate δ_G in each period and $I_{G,t}$ is government investment in the public capital.

2.4 Factor markets

In our benchmark model, capital is free to move across borders. Domestic agents can borrow at an effective interest rate r_t that is equal to the world capital market at interest rate $\bar{r}_t$ i.e. $r_t = \bar{r}_t$. In our extended model, we also consider the risk premium r_t^{risk} which will be a function of the current debt to GDP ratio so that $r_t = \bar{r}_t + r_t^{risk}$.

Labor is internationally immobile, so that individuals cannot migrate. At the beginning of their life, individuals are assigned employment in either the public or private sector. All agents will retire at age J_1 irrespective of the sector they are working in. In the private labor market firms can hire labor at the market wage rate. 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 are commonly observed in many countries. This assumption guarantees that all agents prefer public sector jobs to jobs in the private sector.

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

$$B_{t+1} = \frac{1}{(1+g)(1+n)} \left\{ (1+r_t) B_t + Spend_t - Tax_t \right\}, \tag{1}$$

where B_t is one-period government bonds issued at time t; r_t is the interest rate; $Spend_t$ is the total government spending; and 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 are endogenously determined so that the government budget constraint is cleared every period. Debt-to-GDP ratio is defined as $\frac{B_t}{Y_t}$, which is endogenously determined by equilibrium conditions.

Government expenditures. The government employes civil servants and uses physical capital K_g 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 $Wage_{G,t} = \sum_{\theta_G} \sum_{j=1}^{J_1} w_{G,t} h_{j,t} (\theta_G) \mu_{j,t} (\theta_G)$. 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 $\Delta_{G,t}$ for these purchases. The total government investment in this type of capital is $I_{G,t} = \Delta_{G,t} \times GDP$.

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 $\tau_{SS,t}^P$ and $\tau_{SS,t}^G$. When workers retire they stop paying labor taxes and social security taxes and are eligible to draw pension benefits. Let Ψ_P and Ψ_G denote for the pension replacement rate in the private and public sector. We summarize the payout formula to private sector retirees and for public sector retirees as $Pen_{j,t}(\theta_P) = \Psi_P \times \frac{1}{J_1} \sum_{j=1}^{J_1} w_{P,t-J_1+j} \times h_{i,t-J_1+j}(\theta_P,j)$ and $Pen_{j,t}(\theta_G) = \Psi_G \times \frac{1}{J_1} \sum_{j=1}^{J_1} w_{G,t-J_1+j} \times h_{i,t-J_1+j}(\theta_G,j)$, 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 $Pen_{P,t} = \sum_{\theta_P} \sum_{j=J_1+1}^{J} Pen_{j,t}(\theta_P)\mu_{j,t}(\theta_P)$ and $Pen_{G,t} = \sum_{\theta_G} \sum_{j=J_1+1}^{J} Pen_{j,t}(\theta_G)\mu_{j,t}(\theta_G)$, respectively.

The remainder of government expenditure including healthcare and welfare programs is government consumption $C_{G,t}$. Government consumption is assumed to be unproductive. We assume that the government allocates a fixed fraction of GDP $\Delta_{G,t}$ for these activities, i.e. $C_{G,t} = \Delta_{C_G,t}Y_t$. The total government spending at time t is given by the following identity:

$$Spend_t = C_{G,t} + I_{G,t} + Wage_{G,t} + Pen_{P,t} + Pen_{G,t}.$$

Government income. The government collects labor income taxes at the rates $\tau_{L,t}^P$ and $\tau_{L,t}^G$ as well as social security taxes at the rates $\tau_{SS,t}^P$ and $\tau_{SS,t}^G$ from all workers in the private and public sector, respectively. The government also taxes consumption at rate $\tau_{C,t}$ and taxes capital income at rate $\tau_{K,t}$. Accidental bequests are taxed at $\tau_{Beq,t}$. The total tax revenue is given by

$$Tax_t = \overbrace{\left(\tau_{L,t} + \tau_{SS,t}^P\right)\sum_{\theta_P}\sum_{j=1}^{J_1} w_{P,t}h_{j,t}(\theta_P)\mu_{j,t}(\theta_P)}^{\text{labor and soc. sec. income tax from the private sector}}$$

$$+ \overbrace{\left(\tau_{L,t} + \tau_{SS,t}^G\right)\sum_{\theta_G}\sum_{j=1}^{J_1} w_{G,t}h_{j,t}(\theta_G)\mu_{j,t}(\theta_G)}^{\text{labor and soc. sec. income tax from the public sector}}$$

$$+ \overbrace{\tau_{Beq,t}\sum_{\theta}\sum_{j=1}^{J} a_{j,t}(\theta)\upsilon_{j,t}(\theta)}^{\text{tax on bequests}}$$

$$+ \overbrace{\tau_{K,t}(q_t - \delta)K_t}^{\text{capital tax}} + \overbrace{\tau_{K,t}r_t B_t}^{\text{tax on bonds' interest}}$$

$$+ \overbrace{\tau_{C,t}\sum_{\theta}\sum_{j=1}^{J} c_{j,t}(\theta)\mu_{j,t}(\theta)}^{\text{consumption tax}}.$$

2.6 Households' problem

In general, households in the private and 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 state vector θ.

The household problem can be recursively formulated as

$$V_t \left(a_{j,t}, \theta \right) = \max_{\{a_{j,t}, c_{j,t}, l_{j,t}\}} \left\{ u \left(c_{j,t}, l_{j,t} \right) + \beta \pi_j V_{t+1} \left(a_{j+1,t+1}, \theta \right) \right\} \tag{2}$$

s.t.

$$
\begin{aligned}
\left(1 + \tau_{C,t} \right) c_{j,t} + \left(1 + g \right) a_{j+1,t+1} &= \Upsilon_{j,t}, \\
a_{j+1,t+1} &\geq 0, \text{ and} \\
0 &< l_{j,t} \leq 1,
\end{aligned}
$$

where

$$\Upsilon_t = \begin{cases} R_t a_{j,t} + \left(1 - \tau_{L,t} - \tau_{SS} \right) \left(1 - l_{j,t} \right) e_j w_t + \left(1 - \tau_{Beq,t} \right) T_{Beq,t} & \text{if } j \leq J_1 \\ \left(1 + \tau_{C,t} \right) c_{j,t} + \left(1 + g \right) a_{j+1,t+1} = R a_{j,t} + \left(1 - \tau_{Beq,t} \right) T_{Beq,t} + Pen_{j,t} & \text{if } J_1 < j \end{cases}$$

is the household's after-tax income, $j = \{1, 2, ..., J\}$ is the individual age, $w_t = \{w_{P,t} \text{ or } w_{G,t}\}$ is the individual wage rate which is sector specific, R_t is the after tax interest rate, and T_{Beq} are transfers of accidental bequests that are taxed at rate $\tau_{Beq,t}$. 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 $h_{j,t} = \left(1 - l_{j,t} \right) e_j$.

2.7 Firms' problem

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

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

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 $\left\{ \tau_{C,t}, \tau_{L,t}, \tau_{SS}^P, \tau_{SS}^G, \tau_{B,t}, \tau_{K,t}, \Delta_{B,t}, \Delta_{G,t}, \Delta_{CG,t}, \xi_t^W, \Psi_{Pt}, \Psi_{G,t} \right\}_{t=0}^{\infty}$ and the exogenously given world interest rate $\{\bar{r}_t, \}_{t=0}^{\infty}$, a competitive equilibrium is a collection of sequences of households' decisions $\left\{ \{c_{j,t}, l_{j,t}, a_{j+1,t+1}\}_{j=1}^J \right\}_{t=0}^{\infty}$, 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 $\{K_{G,t}, H_{G,t}\}_{t=0}^{\infty}$, sequences of factor prices $\{q_{P,t}, w_{P,t}, w_{G,t}\}_{t=0}^{\infty}$ such that

(i) households' allocations $\left\{ \{c_{j,t}, l_{j,t}, a_{j+1,t+1}\}_{j=1}^J \right\}_{t=0}^{\infty}$ solves their recursive optimization prob-

lems (2),

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

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

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

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

$$r_t = \bar{r}_t = q_{P,t} - \delta, \text{ and } R_t = 1 + (1 - \tau_{K,t})\, r_t,$$

iii) aggregate variables are given by

$$A_t = \sum_\theta \sum_{j=1}^J a_{j,t}\left(\theta\right)\mu_{j,t}\left(\theta\right) + \overbrace{\sum_\theta \sum_{j=1}^J a_{j,t}\left(\theta\right) v_{j,t}\left(\theta\right)}^{\text{accidental bequests}},$$

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

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

$$H_t^P = \sum_{\theta_P} \sum_{j=1}^J \overbrace{\left(1 - l_{j,t}\left(\theta_P\right)\right) e_{j,t}\left(\theta_P\right)}^{h_{j,t}(\theta_P)} \mu_{j,t}\left(\theta_P\right),$$

$$H_t^G = \sum_{\theta_G} \sum_{j=1}^{J_1} \overbrace{\left(1 - l_{j,t}\left(\theta_G\right)\right) e_{j,t}\left(\theta_G\right)}^{h_{j,t}(\theta_G)} \mu_{j,t}\left(\theta_G\right),$$

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

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

(iv) commodity markets clear[1]

$$C_t + (1+g)\, S_t + I_{G,t} + C_{G,t} = Y_t + (1 - \delta_P)\, K_t + (1+n)\,(1+g)\, B_t + Beq_t,$$

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

$$T_{B,t} = \frac{\sum_{\theta_P} \sum_{j=1}^J a_{j,t}\left(\theta_P\right) v_{j,t}\left(\theta_P\right) + \sum_{\theta_G} \sum_{j=1}^J a_{j,t}\left(\theta_G\right) v_{j,t}\left(\theta_G\right)}{\sum_\theta \sum_{j=1}^J \mu_{j,t}\left(\theta\right)},$$

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[1] Since 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 percentage of GDP.

In addition, the aggregate S_t already incorporates the exogenous population growth rates via the population weight μ. We therefore only have to detrend with the exogenous technological growth rate g.

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

(vii) the current account is balanced and foreign assets, FA, freely adjust so that $1+r_t = 1+\bar{r}_t$.

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 in particular is induced to implement fiscal austerity measures to reduce deficits in order to receive international bail out packages by the international community. The Greek government agreed to subject itself to tough conditionality, negotiated and applied by the IMF. In our quantitative analysis, we choose Greece as a benchmark.

We solve the model numerically using an algorithm similar to Auerbach and Kotlikoff (1987). This algorithm solves non-linear equations using an iterative technique commonly referred to as the Gauss-Seidl method. The algorithm starts with a guess of 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 equals 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 to 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.[2]

We calibrate the baseline model to match the data from Greece in the beginning of 21st century. We use a number of sources to collect the aggregate data from Greece.[3] We summarize the structural parameter values in table 1, policy parameter values in table 2, and matched data moments in tables 3 and 4. We next describe briefly how we calibrated the model.

3.1   Heterogeneity and demographics

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.

We distinguish 2 skill groups of workers according to their educational levels, so that $skill = \{L, H\}$, where L stands for no education, primary education and some secondary education, and H stands for complete secondary education and tertiary education. We calibrate the

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[2] Our solution algorithm is locally stable. That is for changes in initial conditions the algorithm converges to the same steady state. We have no proof of global convergence. To our knowledge, there is no formal proof of uniqueness available for this type of Auerbach-Kotlikoff models (see Kotlikoff, Smetters and Walliser (2001)). Laitner (1984) provides a proof of uniqueness for a linearized version of the original Auerbach-Kotlikoff model.

[3] The sources are:OECD (2011a), OECD (2011b), HellasCountryFiche (2011), MOF (2011), Arghyrou and Tsoukalas (forthcoming), Koutsogeorgopoulou and Turner (2007), Monokroussos (2010), Rother, Schuknecht and Stark (2010), Buiter and Rahbari (2010), IMF (2006), BOG (2005), and Tsakloglou and Cholezas (2005).

efficiency profiles $e_j(\theta)$ for each skill type using data from Tsakloglou and Cholezas (2005). The efficiency profiles exhibit the typical hump-shaped pattern over the life cycle. We scale down the skill/efficiency profiles of public sector workers to match their lower rate of weekly hours of labor.

The annual population growth rate was $n = 0.2$ percent in 2006 according to UN Data Country Profiles. The survival probabilities are chosen so that the model matches the size of the various age groups in the population.

3.2 Preferences

Preferences are represented by the following utility function: $u(c,l) = \frac{\left(c^\gamma l^{1-\gamma}\right)^{1-\sigma}}{1-\sigma}$, where c and l is 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 the elasticity between consumption and leisure is one. The parameter γ measures the relative weight of consumption versus leisure. The parameter σ is the coefficient of relative risk aversion.

The consumption preference parameter $\gamma = 0.29$ is chosen to match labor supply to be around $30 - 35$ hours a week for agents in their prime working age from 25 to 55.[4] Both, the time preference parameter $\beta = 1.023$ and the inverse of the inter-temporal elasticity of substitution $\sigma = 2.3$ are chosen to match the capital output ratio and the capital import rate. Consequently, in our model the resulting capital output ratio is equal to 1.5. [5]

3.3 Technologies

The production function for the final good is $F_P(G_t,\ K_{P,t},\ H_{P,t}) = A_1 G_t^{\alpha_1} K_{P,t}^{\alpha_2} H_{P,t}^{\alpha_3}$, where $\alpha_i \in (0,1)$ for $i = 1, 2$, and 3, $\alpha_2 + \alpha_3 = 1$ and $A_1 > 0$. Total factor productivity A_1 is normalized to one. The estimates for α_1, the productivity parameter of the public good in the final goods production function, for the U.S. 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 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 and 0.20. For a cross-section of low income countries Hulten (1996) obtains an estimate for α_1 of 0.10. We use $\alpha_1 = 0.09$. The capital share of GDP is very high in Greece so we chose $\alpha_2 = 0.34$. Parameter $\alpha_3 = 0.66$ together with 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 the public good is $F_G(K_{G,t}, H_{G,t}) = A_3 K_{G,t}^\eta \left(\omega_h H_{G,t}\right)^{(1-\eta)}$, where $A_2 > 0$ and $\eta \in (0,1)$. The fraction of civil servants contributing to the production of the public good is denoted $\omega_h \in (0,1)$. The remaining civil servants produce government consumption that is not explicitly modeled. Total factor productivity $A_2 = 3$ is chosen to

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

[5] 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.

match the size of the public goods sector. We have little information about the parameters of the production technology of the public good. We view the choice of $\eta = 0.4$ and $\omega_h = 0.4$ 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. $g = .01$ (Akram et al. (2011)).

3.4   Factor markets

Since this is a small open economy model where capital can be traded at world market prices. In our benchmark model, we assume a zero risk premium and set the world interest rate at 4 percent, $\overline{r} = 0.04$. We adjust the discount factor to match capital import figures from Greece in 2008. The model results in a current account deficit of 14.8 percent of GDP which is close to the range of $10 - 14.4$ percent estimated by the Ministry of Finance (2011). (See also Akram et al. (2011)).

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

3.5   Government and fiscal policy

All government policy parameters are summarized in table 2. The debt-to-GDP ratio is between 90 and 100 percent at the beginning of 21st century (Arghyrou and Tsoukalas (forthcoming)). We assume a government debt level of 95 percent of GDP in our benchmark steady state model, i.e. $\frac{B}{Y} = 0.95$. To match that level the government borrows about 18.8 percent of GDP in every model period.

We impose that public sector workers earn on average up to 20 percent higher wages than private sector workers. We choose the pension replacement rates to match the size of the pension programs (public and private) as percent of GDP as well as the government revenue from payroll taxes paying for these pensions. We use replacement rates of $\Psi_P = 0.48$ and $\Psi_G = 1.10$ as well as payroll taxes of $\tau_{SS}^P = 10$ percent and $\tau_{SS}^G = 16$ 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 sector pensions and private sector pensions which results in pension deficits of $1 - 1.5$ percent of GDP for public sector pensions and $3 - 4$ percent 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 to be 7 percent of GDP in order to match the size of the public good production as a share of GDP. Residual government

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

consumption which plays no further role is 1 percent of GDP. The government raises taxes on labor income, consumption, bequests, and dividend income (in the model this is approximated using capital taxes[7]) to finance government consumption, investments into public capital, public pension benefits, wage payments for public sector workers, and service of its debt. We set the tax rates so that revenue streams from the various taxes match data on tax revenue from OECD (2011a) and Akram et al. (2011). According to Akram et al. (2011) total tax and non-tax revenues as fraction of GDP are between 32 to 34 percent of GDP in 2010. Table 4 presents the details of the tax revenues that are matched in our benchmark model. We are able to match the key features of Greek data at the beginning of 21st century (see tables 3 and 4).

4 Policy experiments and results

We study the macroeconomic and welfare effects of fiscal austerity measures. Our experiments are motivated by the recent fiscal development in Greece. The Greek government implemented tough fiscal austerity measures to reduce deficits in order to receive international bail out packages. Greece agreed to implement significant fiscal adjustments worth about 12.5 percent of 2009 GDP spread over three years.

In our economy, the government faces permanent fiscal deficits and a debt-to-GDP ratio of 95 percent. We consider reductions of debt-to-GDP ratios to 85 percent after 5 years, to 75 percent after 10 years and then to 65 percent in the long run. The government has three sets of policy instruments to implement this debt reduction: (i) a tax-based plan, (ii) a spending-based plan, and (iii) a combination of both, tax-based and spending-based plans. More specifically, we consider the following policy reforms: First, to reduce its fiscal deficits the government increases either labor taxes (τ_L) or consumption taxes (τ_C) or capital taxes (τ_K). Second, the government cuts public infrastructure investments (Δ_G). Third, the government reduces generosity of public pension payments and increases labor taxes (Ψ_G, τ_L) or reduces generosity of public pension and public investment (Ψ_G, Δ_G).

We report the results in table 5 with labor tax (τ_L) in column 1, consumption tax (τ_C) in column 2, capital tax (τ_K) in column 3, and public infrastructure investments (Δ_G) in column in column 4, public pension payments and increases labor taxes (Ψ_G, τ_L) in column 5, and public pension payments and increases labor taxes (Ψ_G, Δ_G) in column 6. Note that we report changes relatively to steady state levels before the reform, where the original steady state levels are normalized to 100.

4.1 Macroeconomic aggregates

Tax-based austerity measures. In our policy reform we decrease the debt-to-GDP ratio and let the government adjust taxes to clear its budget constraint. We find that a lower level of debt-to-GDP ratio is accompanied by lower tax rates in the long run. The intuition is

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[7]Capital taxes in the model are raised on asset returns of households and not on capital stock in the production sector.

simple. Once the government does not have to finance large debt services anymore, taxes can be reduced. In the new steady state economy with the level of debt-to-GDP ratio around 65 percent, the government can reduce the labor income tax rate by almost 20 percentage points or the consumption tax rate by over 10 percentage points (see columns 1 and 2 of table 5). These tax reductions, driven by lowering debt burdens, induce a very large increase in asset accumulation and consumption. As stated in column one in table 5, when labor income taxes decrease following the debt reduction, asset accumulation increases by almost 20 percent. Steady state consumption increases by over 2 percent due to a direct income effect.

Interestingly, the large increase in asset accumulation is not followed by a correspondingly large increase in output. In fact, it induces small decreases in steady state output when labor and capital tax adjustments are used to balance the government budget. This is due to the open economy feature of our model. Since capital is freely mobile and domestic and foreign assets are perfectly substitutable, increases in domestic assets do not always lead to increases in domestic capital employment and production. Indeed, large increases in domestic asset accumulation are offset by correspondingly large reductions in capital imports. Overall, the net change in capital used in final production is almost negligible (compare capital K_P used in production in table 5). On the other hand, reductions in tax rates result in substitution and income effects for households. In this case the income effects dominate the substitution effects, so that agents consume more and supply less labor. This results in a reduction in human capital in private production (compare H_P in table 5). The decreases in physical capital and human capital together are responsible for the slight decrease in domestic production. This result differs from standard results in the literature based on closed economy models where an increase in domestic capital accumulation invariably leads to an increase in domestic output. We will revisit this issue in section 4.4.

The qualitative effects on savings and consumption are similar across each one of these tax-based reforms. However, the size of these effects are not uniform. As seen in table 5, the increase in consumption is largest when the labor tax is reduced while the increase in asset accumulation is largest when capital tax is reduced. Notice also the large 5 percent drop in output when the capital tax rate adjusts.

We have seen that the permanent reduction in the debt-to-GDP ratio with tax-based adjustment policies can induce a significant long-run increase in economic activity. We next investigate the dynamics over transitions. When solving for transitions we impose that the adjustment to the new debt-to-GDP ratio of 65 percent is implemented gradually over 3 model periods (i.e. 15 years). We display the dynamics of the transition in figure 1. As displayed in panel 6 of figure 1, the labor tax rate would increase by about 30 percentage points in order to pay down debt during the first period adjustment phase (i.e. within the first 5 years of implementing the reform). If a consumption tax is used to pay down debt, then an increase of the consumption tax rate of about 15 percentage points would be necessary. As seen in panel 1 of figure 1, these tax increases, cause immediate contractions in output of about 5 percent in the labor tax case. The distortion by increases in the consumption tax rate are much smaller, so that output would only decrease by about 1 percent.

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The temporary tax increases result in strong disincentive effects on the households' labor supply decision. Hours of work and aggregate human capital both decrease during times of high labor and consumption taxes. On the other hand, households save more as they exploit the higher rate of returns to capital investments and the aggregate private capital stock rises. This, to a certain extent, offsets the reduction in human capital. Along the transition, the distortions caused by the tax increases are tapering off over time. Once its debt service payments are reduced, the government can start lowering tax rates and the economy can start growing again. After about 10 periods (i.e. 50 years) the economy settles down at the new steady state levels with a lower debt-to-GDP ratio and permanently lower tax rates.

Spending-based austerity measures. It is often argued that governments should not cut spending on infrastructure in order to improve their budget balance because such cuts would lower growth and thereby worsen the budget situation in the future. To investigate the productive role of government spending we next allow for cuts in public infrastructure investments in order to pay for the debt reduction. As seen in column 4 of table 5, lowering the debt-to-GDP ratio is accompanied by increases of public investments Δ_G of over 18 percent. Again, this is a long run result. The government simply has more funds available for infrastructure investment because its debt service payments are now reduced due to the lower debt level while taxes remain unchanged.

The increase in public investment results in increases in asset accumulation, human capital, output and consumption in the new state state. The key mechanism is the following: Public capital is productive and non-tradable. The increase in public investment in infrastructure enhances the productivity of the private sector, which in turn increases the marginal product of both, physical capital and human capital. This attracts more physical capital and human capital into the private production sector. The increases in private physical capital K_p and human capital H_p are 1 percent and 0.03 percent, respectively (column 4 of table 5). These increases augment output by about 1 percent. Asset accumulation and consumption also increase by 17 percent and 0.9 percent, respectively.

Compared to the tax-based form, the long-run effects of the spending-based reform on asset accumulation and consumption are very similar. However, the underlying mechanisms are quite different. The tax-based reform reduces the fiscal distortions on the households' inter-temporal allocations and the supply of production factors, while the spending-based reform works through improving production efficiency and the demand for factors of production. Comparing across the two types of reforms we can evaluate demand side effects (triggered by tax cuts in the long run) as opposed to supply side effects (triggered by higher infrastructure investments in the long run). The latter turn out to be stronger in improving production.

The short-run effects are quite different. As shown in panel 6 of figure 1 public investments drop by approximately 35 percent in the first period (i.e. for 5 years) after the reform. The freed up funds are used to pay down the debt level. As a consequence output decreases by about 2.5 percent in panel 1 of figure 1. The decrease in infrastructure investments lower private sector productivity as well as the rate of return to labor. In response households decrease

effective labor (human capital H_P panel 3) supplied. This decreases output. As time passes the economy gradually faces a lighter burden of debt so that the government can again increase public investments with funds that used to service the debt. As the stock of public capital rises, productivity in the private sector increases. Firms have again stronger incentives to hire more capital and labor, and the economy starts expanding. After initially overshooting, the economy will take about 15 periods (i.e. 75 years) to reach its new steady state with a permanently lower debt-to-GDP ratio, more investment in public capital, and higher output. Compared to the tax-based reform, it takes longer to transition to the new steady state.

The analysis of the transition dynamics indicates trade-offs between short-run efficiency losses and long-run efficiency gains. Comparing the transition path generated via tax based measures to the path generated by spending based measures we also see that the economy reacts strongest (in terms of output) to adjustments in the labor tax rate. This result is in line with recent findings in the literature (see Alesina, Favero and Giavazzi (2012)) that point out that adjustments based on spending cuts are much less costly in terms of output losses than tax-based ones.

A mix of tax-based and spending-based austerity measures. In our final experiment we study a mix of spending-based and tax-based measures and consider a public sector worker pension reform as a component of fiscal austerity. That is, in order to pay for lowering its debt the government cuts the generosity (measured by parameter Ψ_G) of the public sector pension program in addition to adjustments in either the labor tax rate τ_L or public investments Δ_G. We report the results of these experiments in the last two columns of table 5.

Specifically, we decrease the replacement rate for public sector pensions by 30 percent. This allows the government to lower its labor tax rate by about 27 percentage points. The effects are similar to the case when the government uses labor taxes only (column 1). The resulting change from this relatively drastic policy change in GDP is rather small, with GDP almost unchanged. However, when the government decreases the replacement rate Ψ_G and lets public investments Δ_G adjust to balance its budget GDP increases slightly (see column 6).

4.2   Welfare

We conduct welfare analysis based on compensating consumption units. For every agent type we calculate what fixed percentage of consumption, as a fraction of initial steady state GDP, has to be added or subtracted in each period to make her indifferent between the original steady state and the new steady state with the lower debt-to-GDP ratio. Negative values indicate welfare gains. Positive numbers indicate welfare losses. We next calculate compensating consumption as a percent of pre-reform consumption levels per agents type. This allows us to investigate the size of the welfare loss for each agent individually. We report the long-run welfare outcomes of both these measures in table 6.

Tax-based austerity measures. All reforms result in welfare gains in the long run. As stated in the first row in table 6 consumers, on average, gain 1.3 percent of pre-reform GDP

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in terms of compensating consumption when labor taxes adjust to accommodate the drop in government debt (column 1). The welfare effects vary substantially by government policy. When consumption taxes adjust, the welfare effects are slightly smaller (column 2). The largest long-run aggregate welfare gain appears when capital taxes adjust (column 3). The positive welfare outcomes are not surprising. The driving forces for welfare gains are lower taxes that trigger efficiency increases which in turn translate into higher consumption levels. We next decompose the welfare effects by working sector and skill level. We find that welfare gains are realized in all sectors and for all types whenever taxes are used to adjust for debt level decreases.

We next calculate compensating consumption for all generations alive at the time when the fiscal austerity measures are implemented and for all future generations. We describe the aggregate welfare effects over time and the generation-specific welfare effects when labor taxes and consumption taxes adjust in figures 4 and 5, respectively. From panel one of figure 4 we see that the aggregate welfare effects are negative in the first 4 model periods but, at less than 0.2 percent of pre-reform GDP levels, relatively small. The short-run welfare losses are driven by tax increases to pay for the gradual reduction of the debt-to-GDP ratio. High labor taxes introduce severe fiscal distortions into the economy which cause contractions in output and consumption levels. As seen in the second panel of figure 4, the middle-aged generations suffer most from the reform while the newly born and future generations are clear winners. The increases in labor tax rates immediately after the form is implemented forces the middle-aged generations who are on top of their career to pay a large share of the fiscal consolidation. In addition, welfare losses among the current poor and welfare gains among the future poor, both in the public and private sector, are only slightly larger than losses and gains among the rich.

When consumption taxes adjust to pay for the consolidation, the patterns of the welfare effects are quite different as illustrated in figure 5. With the exception of small losses in the first period after the reform, we do not observe any aggregate welfare losses in any of the other periods (top panel in figure 5). We find that consumers with shorter remaining lifetime suffer from this reform because they have to pay higher consumption taxes but do not live long enough to benefit from future growth effects. However, the welfare gains to future generations arrive significantly earlier than in the previous labor tax case.

Spending-based austerity measures. The aggregate welfare losses are the most severe when public investments are cut in order to pay for the debt reduction. Compare column 4 of table 6 for steady state welfare effects and figure 6 for welfare effects over transitions. Consumers, on average, gain only 0.55 percent of pre-reform GDP in terms of compensating consumption units when public investment adjusts to accommodate the drop in government debt (column 4). The reason is that higher levels of public capital increases rental rates and wage rates, which induces households to work longer, save more and consume less.

It is striking that initially the aggregate welfare effects are more negative and last longer up to 8 periods after the reform (see the first panel of figure 6). More importantly, we find that all generations born before the reform and the first generation born after the reform

experience substantial welfare losses up to 1.5 percent of pre-reform consumption (see the second panel). This result is driven by the negative efficiency effects caused by reductions in government investments in public capital. In the medium-run, as the government will be able to direct more spending back to public capital the negative effects decrease and the welfare losses become gradually smaller. In the long-run the government will invest more in public capital than in the pre-reform steady state creating welfare gains for all households.

A mix of tax-based and spending-based austerity measures. We report the steady state welfare results of these experiments in columns 5 and 6 of table 6. The aggregate welfare effects are at least 1.6 percent of the pre-reform GDP and are substantially larger in the new steady state (row 1 of columns 5 and 6), compared to either the tax-based reform (row 1 columns 1, 2 and 3) or the spending-based reform (row 1 column 4).

In terms of welfare by household type, the last two reforms are different. Since we also cut the generosity of pension payments to public sector retirees in addition to tax or infrastructure investment adjustments, we now observe clear winners and losers from the reform.

In general, individuals who work in the private sector benefit from this policy change. That is, after a brief initial transition, all workers in the private sector experience welfare gains, since high public sector pensions predominantly represent a tax burden to these individuals. For those working during the policy reform the welfare gains gradually increase to around 2 percent of annual consumption with further increases in welfare to around 3 percent of consumption to future private sector workers (compare row 4 and 5 in table 6). On the other hand, when the generosity of pensions to public sector employees is decreased we observe obvious welfare losses among public sector workers. These losses are highest for the high income public sector workers with a magnitude of 2.6 to 3.3 percent of pre-reform consumption (compare the last two rows in columns 5 and 6 in table 6).

Remark. In our benchmark model we consider a small open economy model. Our key assumption is that capital is freely mobile and that domestic and foreign capital are perfectly substitutable. As a result of these assumptions, changes in the rate of domestic capital accumulation have no effect on the domestic interest rate and rental rates. In addition, we assume away the risk premium, so that we abstract from the channel that links fiscal distortions, risk premium and the price of capital. In the next section we will extend our analysis to consider an open economy model with a risk premium. Section 4.4 presents results from a closed economy model.

4.3   Risk premium effects

It is widely documented that a higher level of government debt is associated with a higher risk premium on government borrowing (see for example Bernoth, von Hagen and Schuknecht (2004)). In this section we study how the presence of a risk premium changes the effects of reducing the burden of public debt. We assume that agents can borrow from the world capital market at 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^{risk}, so that total domestic borrowing costs

are: $r_t = \bar{r}_t + r_t^{risk}$. Even though we do not model the possibility of sovereign default, we are thinking of r_t^{risk} as a proxy for a country's sovereign risk. We model the risk premium as a function of the government debt-to-GDP ratio according to the following polynomial structure:

$$r_t^{risk}(\Delta_{B,t}) = \beta_0 + \beta_1 \times \Delta_{B,t} + \beta_2 \times \Delta_{B,t}^2,$$

where $\Delta_{B,t}$ is the debt-to-GDP ratio.[8]

We keep the world interest rate at 4 percent and assume that the risk premium is one percent, i.e. $\bar{r}_t = 0.04$ and $r_t^{risk} = 0.01$. This one percent risk premium may appear rather low for a country with a debt-to-GDP ratio of more than 90 percent. The reason is that when joining the EMU Greece has, at least initially, considerably reduced its risk of sovereign default. In fact, the average risk premium on 10-year bonds (judged relative to German bonds) narrowed from 220 basis points over the three years prior to joining EMU to an average of only 35 basis points. Nevertheless, it has been shown that a risk premium that is some multiple of 10 basis points can still add to a substantial deadweight debt service cost when debt remains a high share of GDP over a period of decades (see Koutsogeorgopoulou and Turner (2007)).

We calibrate the parameters of the risk premium function, $\{\beta_0, \beta_1, \beta_2\}$, so that the risk premium in the pre-reform steady state at a government debt level of 95 percent of GDP is matched at one percent. The calibrated values of the risk premium function are within the range estimated in Bernoth, von Hagen and Schuknecht (2004). In the benchmark economy, the domestic interest rate including the risk premium is 5 percent, $r = 0.05$. We then conduct the identical experiment from before and cut government debt levels from 95 to 65 percent of GDP and report the results in table 7. A comparison of tables 5 and 7 reveals the impact of the risk premium on steady state outcomes. The results are summarized as follows:

First, when a risk premium is present, decreasing the debt-to-GDP ratio leads to decreases in the domestic interest rate. The risk premium drops by almost 16 percentage points and triggers a decrease in the internal interest rate of about 3.5 percent when labor and consumption taxes adjust.

Second, the presence of the risk premium effect mitigates the effect on asset accumulation. Domestic assets do not accumulate by as much as in the small open economy without the risk premium. The increase in domestic assets is only about 14 percent and 8 percent (compare row 2 in columns 1 and 2 of table 7) as opposed to 20 percent and 16 percent when the risk premium is removed (compare row 2 in columns 1 and 1 in table 5). The decrease in the domestic interest rate due to the lower risk premium induces households to save less relative to the case without a risk premium.

Third, we observe output increases in the labor and consumption tax case. These growth

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[8]Alternatively one could calculate the risk premium term as a non-linear function of the ratio of debt service to government (tax) revenue as in Koutsogeorgopoulou and Turner (2007) which is based on empirical work by Bernoth, von Hagen and Schuknecht (2004):

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

effects dominate the modest growth effects observed in the model without the risk premium. Comparing table 5 and table 7, we find that the effects on output are at least 2 percent higher, except for the capital tax case. So the additional kick that the economy now gets from reductions of the risk premium translates directly into positive growth effects. The lower risk premium decreases the domestic interest rate and the rental rate. In response to a lower interest rate, the firm hires relatively more capital and labor. As a consequence, more of the asset accumulation is retained in domestic production and capital imports fall by less, compared to the case with no risk premium where the additional capital was not used in domestic production but simply used to substitute capital imports. Notice that this mechanism does not work for the case with the capital tax. In fact, the output effect is even more negative in this case. That is, capital tax rate turns negative and becomes essentially a subsidy for capital accumulation. Greece then turns from a net capital importer to a net exporter of capital. The drain of physical capital will has negative growth effects in the long run.

Fourth, comparing welfare gains in table 8 with welfare gains from the previous experiment without the risk premium table 6, we observe that the long-run welfare effects are now more pronounced across the board over all experiments. As described in figures 7 and 8, during the transition there is an analogous pattern of welfare dynamics for the open economy with the risk premium. More specifically, when labor taxes adjust the aggregate welfare effects are initially negative and relatively small in early transition periods. Notice that the welfare losses in figure 7 last only 2 periods relative to the 4 periods of losses in figure 4. Also the long run gains are larger at 2 percent of pre-reform GDP than in the economy without the risk premium.

Again, the current middle-aged working generations lose from the reform as they pay most of the cost of the fiscal consolidations (see panel 2 and 3 of figure 7). Generations born after the reform experience welfare gains. Finally, we observe a similar pattern of negative welfare effects when public investments adjust during the transition. That is, the negative efficiency effects caused by reductions in public capital investments result in negative welfare outcomes in the early transition periods.

Our results highlight the importance of accounting for the transmission mechanism operating through the interactions between fiscal distortions caused by fiscal deficits and debt accumulation and risk premiums. We find that such fiscal distortions can augment the classic results from tax distortions and crowding-out effects. The negative externality generated by accumulating a large public debt is sizeable when accounting for a risk premium. In the policy experiments of this section, we only consider a very conservative risk premium of one percent. Higher risk premiums will result in larger efficiency and welfare gains from risk premium adjustments.

4.4 Fiscal consolidation in the closed economy

As argued earlier, the capacity to access international capital markets plays an important role in determining the effects of fiscal austerity measures. In this section we assume the economy is closed and agents can no longer borrow/lend from/to international capital markets. The

domestic capital market clears as: $A_t = B_t + K_{P,t}$. The firm can rent capital at the rental rate $q_{P,t}$. The firm's demand for capital is determined by the firm's FOC. The non-arbitrage condition that links the rental rate to the interest rate in equilibrium is: $r_t = q_{P,t} - \delta$.

We next re-calibrate our model and keep all values of fundamental parameters and of government policy variables unchanged except for the discount factor β. We recalibrate β to match the interest rate at 4 percent as in the open economy case earlier. We then repeat our tax-based and spending based reforms as reported in the previous sections. Table 9 and figures 10 and 11 present the new results.

In the closed economy version where interest rates decrease as more capital is accumulated, the aggregate capital stock increases only between 4 and 8 percent, depending on the policy regime. The real interests rate falls by between 2.5 to 7.5 percent as more capital is accumulated, depending on which fiscal policy adjusts to accommodate the drop in government debt. The decrease in the interest rate reduces the households' incentive to save. Thus, decreases in the market interest rate keep the increase in capital accumulation in check.

The difference in the steady state effects between the tax-based reforms and the spending-based reform is smaller than before. The increase in output is 3.3 percent when public investment adjusts (column 4 in table 9), compared to 3.0, 2.4 or 3.4 percent when either labor taxes (column 1), consumption taxes (column 2) or capital taxes (column 3) adjust to clear the government budget. The effects on steady state output are much larger in the closed economy than those in the small open economies (compare tables 5, 7 and 9) and always positive. For example, the tax-based reforms result in significant increases in aggregate output between 3.0 and 3.3 percent in the closed economy (see columns 1, 2 and 3 in table 9), compared to a decrease of -0.1 percent and a small increase of 0.08 percent in columns 1 and 2 in table 5, respectively. These increases are a direct consequence of a lack of access to the international capital markets so that the higher levels of asset accumulation by the households directly increase the level of capital used in domestic production rather than reducing capital imports as in the small open economy case.

The spending-based reform results in steady state increases of GDP of about 3.3 percent. Finally, the mixed reform where public sector pensions are cut, produces the largest growth effects. A combination of public pension cuts and investment increases in public capital can deliver an increase in the steady state output as high as 4.6 percent (see column 5 in table 9).

We next compare the transitional dynamics of three regimes, (i) the open economy without a risk premium in figure 1, (ii) the open economy with a risk premium in figure 2 and (iii) the closed economy in figure 3. The differences between the closed economy and the open economy versions are large. In the closed economy the drop in capital is substantially smaller than the drop in capital in the open economy. The drop in output in the closed economy is also smaller than in the open economy. Since the drop in output is smaller, the labor tax rate in the closed economy only increases by about 20 percent compared to about 30 percent in the open economy without the risk premium. Since the adjustment of the labor tax in the closed economy is smaller, the drop in consumption in the closed economy is also smaller.

The welfare results are summarized in table 10 and figures 10, 11 and 12. The welfare

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gains are quite similar to those generated in the small open economy version of the model (compare table 10 and table 5). The pattern of welfare dynamics are quite different in the closed economy. In the consumption tax case we observe positive welfare effects in every period along the transition (see panel 1 of figure 11). The generation-specific welfare effects vary significantly across income types. The differences in the welfare effects between low and high income workers are more pronounced, especially for newborn generations after the reform. This is a divergence that we have not observed in the open economy experiments.

5   Conclusion

We construct a dynamic general equilibrium, overlapping generations economy model to study the macroeconomic and welfare effects of fiscal austerity measures that can be used to reduce the debt-to-GDP ratio. Our model incorporates intra- cohort heterogeneity and a productive government sector as well as key government investment and entitlement programs. We calibrate our model to data from Greece and conduct a quantitative analysis of various fiscal austerity measures.

We find that a spending-based austerity reform dominates the tax-based reform with respect to growth effects but not with respect to welfare effects. Meanwhile, a mixed reform that combines tax adjustments and cuts in public pensions results in the larger growth effects. Moreover, we find the analysis of transition dynamics indicates trade-offs between long-run and short-run efficiency. The welfare effects vary significantly across skills, working sectors, age groups and generations along the transition to the post reform equilibrium, and dependent on fiscal austerity measures. It appears that the current old generations and low skill workers tend to benefit less while the future generations are benefit more from the fiscal consolidations. More importantly, we find that risk premia and accessibility to international capital markets strongly influence the outcomes of fiscal austerity measures. We observe larger growth and welfare effects when a risk premium is included or when access to international capital markets is restricted.

Our model can be extended to analyze a number of fiscal policy issues. Inclusion of population ageing in the model could allow us to analyze fundamentals factor driving a country's fiscal limit i.e. the dynamic links between ageing, pay-as-you-go social benefit and fiscal limit. An extension to include a voting mechanism would be useful to study the political economy of fiscal limit as well as fiscal austerity measures. Disturbances like technology shocks or policy shocks are important to understand fiscal behavior. Accounting for such exogenous economic disturbance allows us to study the possibility of government default on its bond interest payments. We leave these issues for future research.

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6   Appendix: Tables and figures

Parameters	Model:	Observation/Source:
Preferences		
Discount factor	$\beta = 1.035$	To match $\frac{K}{Y}$ and R
Inverse of inter-temp. elast. of subst.	$\sigma = 2.6$	To match $\frac{K}{Y}$ and R
Weight on consumption	$\gamma = 0.29$	To match average hours worked.
Private Production:		
TFP	$A_1 = 1$	Normalization
Productivity of public good G	$\alpha_1 = 0.09$	
Capital productivity	$\alpha_2 = 0.34$	
Human capital productivity	$\alpha_3 = 0.66$	
Capital depreciation	$\delta = 10\%$	
Long run growth rate	$g = 1.0\%$	Akram et al. (2011, p. 312)
Public Production:		
TFP for public good production	$A_3 = 4.9$	To match public sector size
	$\eta_3 = 0.4$	Sensitivity analysis
Productive civil servants	$\omega_h = 40\%$	Sensitivity analysis
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

Table 1: **Model Parameters**

Policy parameters	Model:	Observation/Source:
Labor Allocation:		
Fraction of gov't employees	$N^G = 25\%$	18% in OECD (2011b, p. 12) and 24% 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	$\Psi_P = 60\%$	OECD (2011) or
(generosity of pensions)	$\Psi_G = 110\%$	to match pension sizes
Investment in public good (in % of private sector output)	$\Delta_G = 7\%$	2% of GDP in capital expenditure, Koutsogeorgopoupou and Turner (2007, p 5) to match G/Y of 40%
Residual gov't consumption (in % of private sector output)	$\Delta_{C_G} = 1\%$	Residual (thrown into ocean), to match labor tax revenue
Government bonds (in % of private sector output)	$\Delta_B = 18.8\%$	To match debt level of $95 - 100\%$ of GDP, Arghyrou and Tsoukalas (2010)
Taxes:		
Labor tax rate; private	$\tau_L^P = 12\%$	Adjusts endogenously
Labor tax rate; public	$\tau_L^G = 12\%$	Adjusts endogenously
Consumption tax rate	$\tau_C = 24\%$	21% but collection is low (about 50%) share in tax revenue of (VAT: 6-7% ofGDP) OECD (2011,p. 13) or to match consumption tax
Capital/profit tax rate	$\tau_K = 5\%$	To match capital/profit tax share in tax revenue
Tax on bequests	$\tau_{Beq} = 8\%$	To match tax revenue of labor tax
Social security tax-private	$\tau_{SS}^P = 12\%$	To match pension deficit $3 - 4\%$ of GDP
Social security tax-public	$\tau_{SS}^G = 12\%$	To match pension deficit $1 - 1.5\%$ of GDP

Table 2: **Policy Parameters**

Moments I	Model:	Data:	Observation/Source:
Capital output ratio: $\frac{K}{Y}$	1.53	1.54	IMF (2006, p. 31)
Annual interest rate: r	4.0	4.5%	OECD (2011b, p. 5)
Debt to GDP ratio:	95%	$95 - 100\%$	Arghyrou and Tsoukalas (2010)
Public sector share of GDP: $\frac{G}{Y}$	40.5%	40%	Based on Economy_of_Greece
Hours worked/week:	37.5	38.64	42 hours according to OECD StatExtracts
Hours worked/week, private:	38.0	38.64	
Hours worked/week, public:	33.9	28.98	75% of average work hours, OECD (2011b, p. 12)
CA deficit in % of GDP	-14.8%	$10 - 14.4\%$	CA balance in % of GDP Akram et al. (2011, p. 309) and Ministry of Finance (2011, p. 15)

Table 3: **Macroeconomic Aggregates: Model Outcomes vs. Greek Data**

Moments II	Model:	Data:	Observation/Source:
Tax Revenues:			
(all in % of GDP)			
Total tax revenue	32.3%	$32 - 34.2\%$	OECD 2011, p. 13 and Akram et al. (2011, p. 308)
Labor tax revenue	8.7%	7%	OECD 2011, p. 13
Consumption tax revenue	14.6%	7%	OECD 2011, p. 13
Capital/profit tax revenue	0.75%	1%	OECD 2011, p. 13
Soc.Sec.Rev.:private sector	6.5%		To match pension deficit
Soc.Sec.Rev.:public sector	1.2		To match pension deficit
Bequest tax revenue	0.5%	1%	Property tax, OECD 2011, p. 13
Expenditures:			
(all in % of GDP)			
Wage bill public sector	7.5%	11.5%	Koutsogeorgopoulou and Turner (2007, p 8) 33% of total wage bill in OECD (2011, p. 8)
Wage bill private sector	66.0%	20%	33% of total wage bill, OECD (2011, p. 8)
Private pensions	10.1%	8.5%	residual from below
Public pension	2.6%	$2.5 - 5\%$	Hellenic Country Fiche (2011, p. 19)
All pension payments	12.9%	$11.5 - 13.9\%$	OECD 2011, p. 9 and Hellenic Country Fiche (2011, p. 19)
Pension Deficit:			
(all in % of GDP)			
Pension deficit	-5.0%	-4 to -5% of GDP	O'Donnel and Tinios (2003) and Greek Finance Ministry (2012)
Pension deficit priv. sector	-3.5%	-3 to -4% of GDP	own calculations
Pension deficit pub. sector	-1.4	-1 to -1.5% of GDP	own calculations

Table 4: **Fiscal Activities: Model vs. Greek Data**

	(1)	(2)	(3)	(4)	(5)	(6)
	τ_L	τ_C	τ_K	Δ_G	Ψ_G, τ_L	Ψ_G, Δ_G
Output Y	99.937	100.078	95.203	101.035	99.969	100.169
Capital K	119.830	115.915	151.162	116.844	129.609	123.881
Capital in final K_p	99.937	100.078	95.203	101.035	99.969	100.169
Human capital private H_p	99.917	100.082	95.802	100.032	99.583	99.803
Human capital public H_g	100.280	99.906	95.927	100.010	104.707	104.319
Public good G	100.142	99.975	95.637	107.350	102.785	102.639
Consumption C	102.293	101.958	101.668	100.910	103.431	102.934
Current account: CA	-69.243	-75.643	-8.868	-76.641	-54.237	-63.582
Interest rate r	100.000	100.000	116.628	100.000	100.000	100.000
Risk premium						
Wages w	100.020	99.996	99.375	101.002	100.387	100.367
Labor tax τ_L	80.742	100.000	100.000	100.000	73.085	100.000
Consumption tax τ_C	100.000	89.870	100.000	100.000	100.000	86.039
Capital tax τ_K	100.000	100.000	-245.742	100.000	100.000	100.000
Infrastruc. Inv. Δ_G	100.000	100.000	100.000	118.160	100.000	100.000
Debt to GDP ratio in %	64.996	64.996	64.996	64.996	64.996	64.996

Table 5: **The Long Run Aggregate Effects in an Open Economy WITHOUT a Risk Premium.** Note that the government decreases the Debt-to-GDP ratio to 65 percent and lets either taxes or public spending adjust to clear the government budget constraint. τ_L is labor tax, τ_C is consumption tax, τ_K is capital tax, and Δ_G is public investment, (Ψ_G, τ_L) are public pension payments and labor tax, and (Ψ_G, Δ_G) are public pension payments and labor tax. The benchmark steady state is normalized to 100, all results are in relation to this steady state.

	(1)	(2)	(3)	(4)	(5)	(6)
	τ_L	τ_C	τ_K	Δ_G	Ψ_G, τ_L	Ψ_G, Δ_G
Aggregate Comp.Cons. in % of GDP	-1.3310	-1.1670	-1.3594	-0.5563	-1.8562	-1.6094
Aggregate-Private in % of GDP	-1.1675	-1.0311	-1.1444	-0.4922	-1.9935	-1.8042
Aggregate-Public in % of GDP	-0.1636	-0.1358	-0.2151	-0.0641	0.1373	0.1948
Private-Low income: Avge.%Δ in C	-2.1376	-1.7165	-3.3190	-0.7897	-3.7056	-3.1362
Private-High income: Avge.%Δ in C	-2.0325	-1.8735	-1.4987	-0.9196	-3.3805	-3.1680
Public-Low income: Avge.%Δ in C	-2.1612	-1.7084	-4.0508	-0.7945	0.9079	1.7064
Public-High income: Avge.%Δ in C	-2.0256	-1.7824	-1.5112	-0.8654	2.5604	3.2965

Table 6: **The Long Run Welfare Effects in an Open Economy WITHOUT a Risk Premium.** In the first three rows we report compensating consumption units as fraction of pre-reform steady state GDP. In the last four rows we report compensating consumption units as percentage of pre-reform steady state consumption per household type. Negative numbers represent welfare gains.

	(1)	(2)	(3)	(4)	(5)	(6)
	τ_L	τ_C	τ_K	Δ_G	Ψ_G, τ_L	Ψ_G, Δ_G
Output Y	102.202	102.362	94.402	103.645	102.224	102.384
Capital K	114.291	108.190	169.683	110.626	123.688	116.782
Capital in final K_p	103.816	103.977	95.892	105.281	103.837	104.000
Human capital private H_p	101.070	101.243	94.363	101.357	100.788	100.972
Human capital public H_g	101.326	101.031	94.081	101.065	104.977	104.554
Public good G	101.675	101.561	94.209	110.094	103.867	103.681
Consumption C	103.172	102.677	103.173	101.719	104.427	103.715
Current account: CA	-90.084	-98.455	0.834	-98.276	-77.816	-87.246
Interest rate r	96.550	96.549	115.267	96.548	96.550	96.548
Risk premium	84.324	84.324	84.324	84.324	84.324	84.324
Wages w	101.121	101.105	100.042	102.258	101.425	101.399
Labor tax τ_L	77.366	100.000	100.000	100.000	68.590	100.000
Consumption tax τ_C	100.000	89.048	100.000	100.000	100.000	84.850
Capital tax τ_K	100.000	100.000	-311.890	100.000	100.000	100.000
Infrastruc. Inv. Δ_G	100.000	100.000	100.000	120.769	100.000	100.000
Debt to GDP ratio in %	64.996	64.996	64.996	64.996	64.996	64.996

Table 7: **The Long Run Aggregate Effects in an Open Economy WITH a Risk Premium.** Note that the government decreases the Debt-to-GDP ratio to 65 percent and lets either taxes or public spending adjust to clear the government budget constraint. τ_L is labor tax, τ_C is consumption tax, τ_K is capital tax, and Δ_G is public investment, (Ψ_G, τ_L) are public pension payments and labor tax, and (Ψ_G, Δ_G) are public pension payments and labor tax. The benchmark steady state is normalized to 100, all results are in relation to this steady state.

	(1)	(2)	(3)	(4)	(5)	(6)
	τ_L	τ_C	τ_K	Δ_G	Ψ_G, τ_L	Ψ_G, Δ_G
Aggregate Comp.Cons. in % of GDP	-2.0728	-1.6946	-1.8082	-0.9699	-2.7839	-2.2532
Aggregate-Private in % of GDP	-1.8366	-1.5144	-1.4892	-0.8729	-2.7544	-2.3107
Aggregate-Public in % of GDP	-0.2363	-0.1803	-0.3189	-0.0970	-0.0295	0.0575
Private-Low income: Avge.%Δ in C	-2.9240	-2.3201	-4.3638	-1.1591	-4.5929	-3.6159
Private-High income: Avge.%Δ in C	-3.2779	-2.7561	-1.8188	-1.6841	-4.7372	-4.1054
Public-Low income: Avge.%Δ in C	-2.7263	-1.9397	-5.2323	-0.9040	-0.5282	0.6088
Public-High income: Avge.%Δ in C	-3.1539	-2.5735	-2.6679	-1.5377	-0.2200	0.8376

Table 8: **The Long Run Welfare Effects in an Open Economy WITH a Risk Premium:** In the first three rows we report compensating consumption units as fraction of pre-reform steady state GDP. In the last four rows we report compensating consumption units as percentage of pre-reform steady state consumption per household type. Negative numbers represent welfare gains.

	(1)	(2)	(3)	(4)	(5)	(6)
	τ_L	τ_C	τ_K	Δ_G	Ψ_G, τ_L	Ψ_G, Δ_G
Output Y	103.018	102.413	103.394	103.289	104.559	103.770
Capital K	105.106	103.993	107.822	104.892	107.799	106.302
Capital in final K_p	105.106	103.993	107.822	104.892	107.799	106.302
Human capital private H_p	101.542	101.305	100.740	101.263	101.934	101.644
Human capital public H_g	101.768	101.097	100.648	101.187	107.058	106.175
Public good G	102.266	101.621	101.738	108.248	106.051	105.206
Consumption C	102.433	101.989	101.999	101.179	103.577	103.028
Current account: CA						
Interest rate r	94.921	96.157	97.948	96.182	92.478	94.067
Risk premium						
Wages w	101.454	101.094	102.635	102.001	102.576	102.091
Labor tax τ_L	83.807	100.000	100.000	100.000	78.885	100.000
Consumption tax τ_C	100.000	90.863	100.000	100.000	100.000	87.820
Capital tax τ_K	100.000	100.000	-92.619	100.000	100.000	100.000
Infrastruc. Inv. Δ_G	100.000	100.000	100.000	115.963	100.000	100.000
Debt to GDP ratio in %	64.996	64.996	64.996	64.996	64.996	64.996

Table 9: **The Long Run Aggregate Effects in a Closed Economy (no Risk Premium).** Note that the government decreases the Debt-to-GDP ratio to 65 percent and lets either taxes or public spending adjust to clear the government budget constraint. τ_L is labor tax, τ_C is consumption tax, τ_K is capital tax, and Δ_G is public investment, (Ψ_G, τ_L) are public pension payments and labor tax, and (Ψ_G, Δ_G) are public pension payments and labor tax. The benchmark steady state is normalized to 100, all results are in relation to this steady state.

	(1)	(2)	(3)	(4)	(5)	(6)
	τ_L	τ_C	τ_K	Δ_G	Ψ_G, τ_L	Ψ_G, Δ_G
Aggregate Comp.Cons. in % of GDP	-1.3192	-1.1568	-1.2360	-0.6449	-1.8086	-1.6163
Aggregate-Private in % of GDP	-1.1832	-1.0478	-1.1071	-0.5943	-1.9966	-1.8388
Aggregate-Public in % of GDP	-0.1360	-0.1091	-0.1289	-0.0506	0.1880	0.2225
Private-Low income: Avge.%Δ in C	-1.4045	-1.1034	-1.3557	-0.4154	-2.5312	-2.1706
Private-High income: Avge.%Δ in C	-2.1439	-1.9672	-2.0000	-1.2157	-3.4867	-3.2984
Public-Low income: Avge.%Δ in C	-1.1815	-0.8975	-1.2794	-0.2140	2.1402	2.5059
Public-High income: Avge.%Δ in C	-1.9476	-1.6233	-1.7078	-0.9483	2.2580	2.7363

Table 10: **The Long Run Welfare Effects in a Closed Economy (no Risk Premium):** In the first three rows we report compensating consumption units as fraction of pre-reform steady state GDP. In the last four rows we report compensating consumption units as percentage of pre-reform steady state consumption per household type. Negative numbers represent welfare gains.
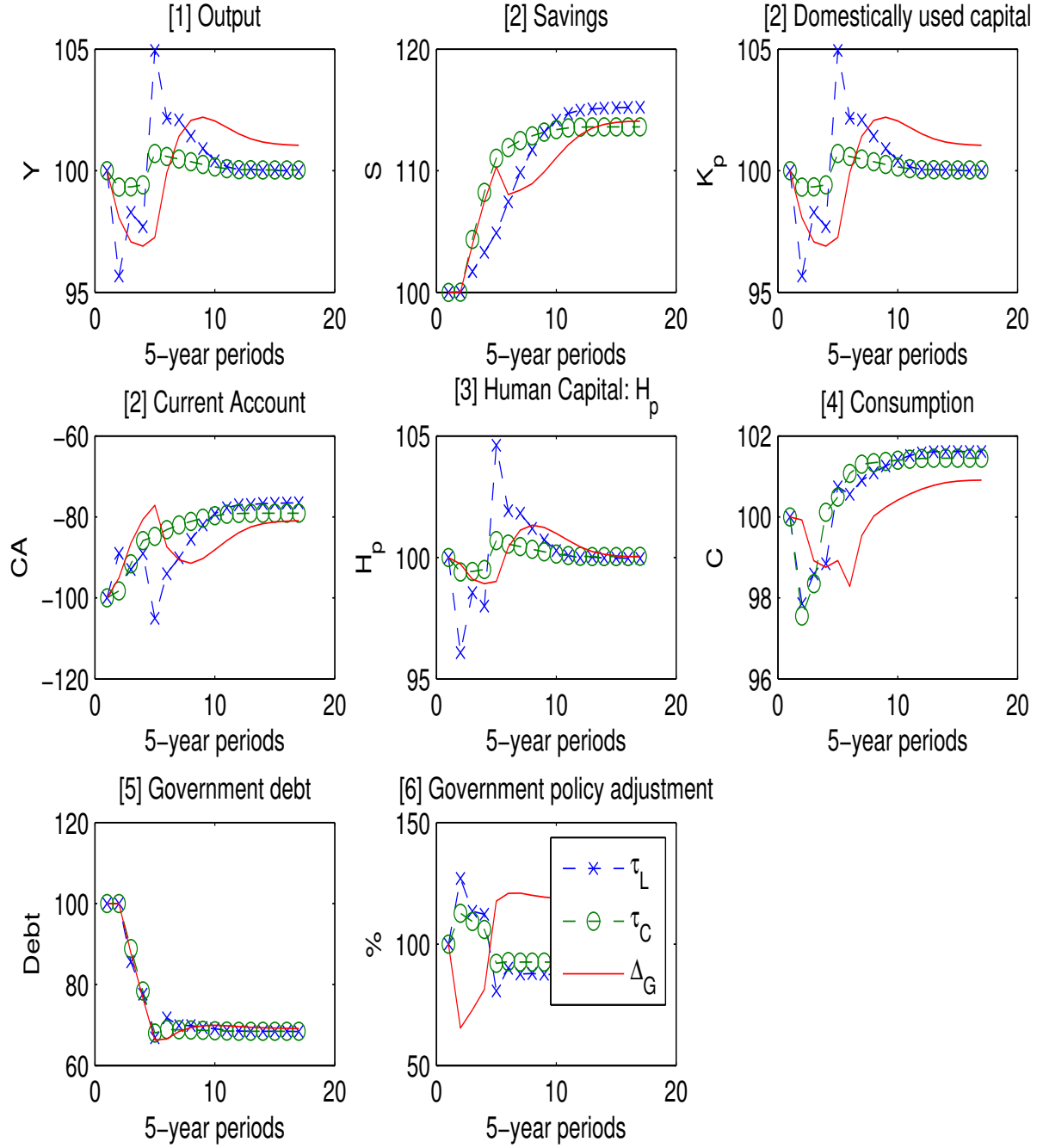
Figure 1: **The Transition Dynamics of Key Aggregates in an Open Economy WITHOUT Risk Premium.** Either labor tax τ_L or consumption tax τ_C or public investment Δ_G adjusts to accommodate the drop in government debt
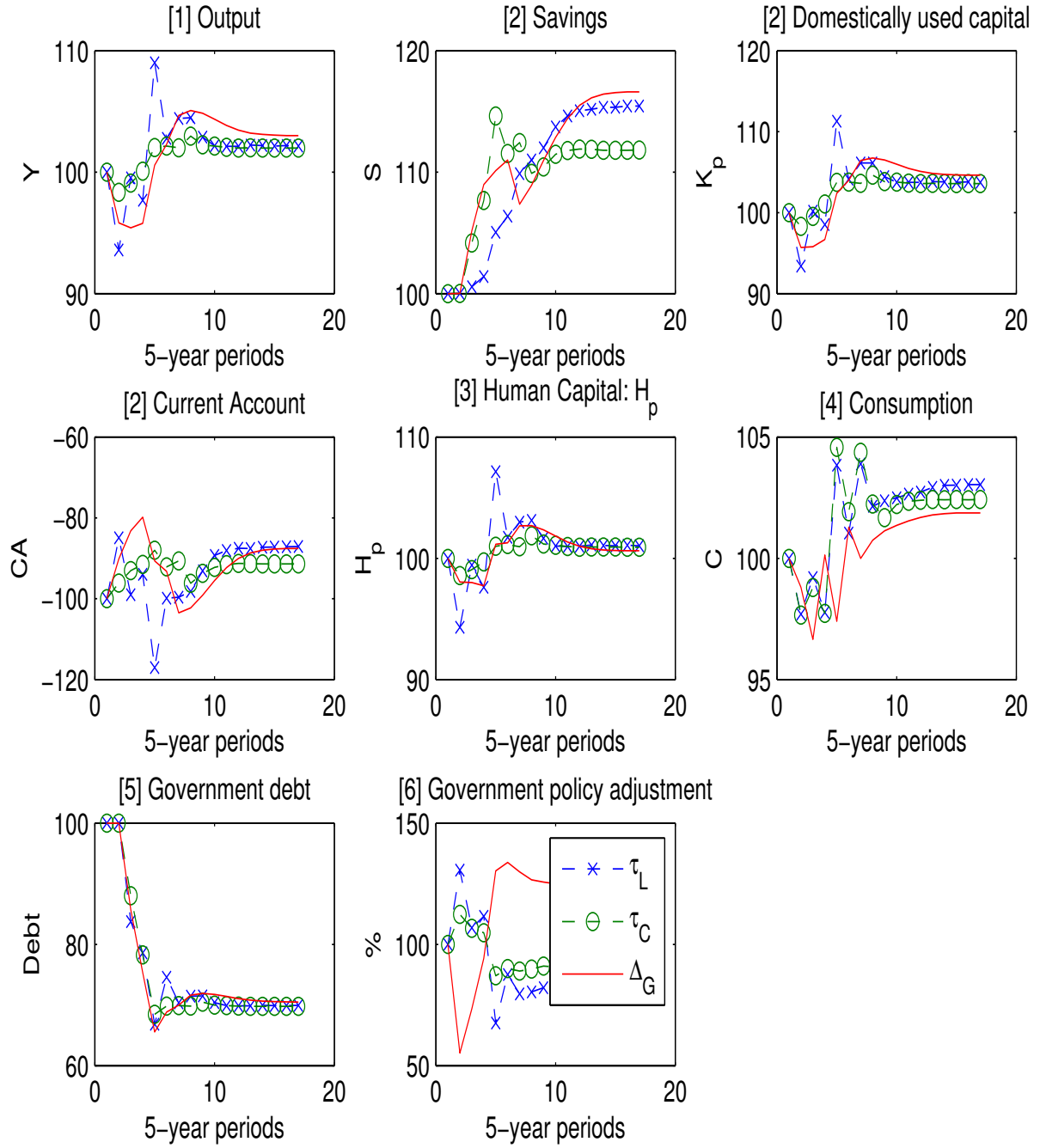
Figure 2: **The Transition Dynamics of Key Aggregates in an Open Economy WITH Risk Premium.** Either labor tax τ_L or consumption tax τ_C or public investment Δ_G adjusts to accommodate the drop in government debt
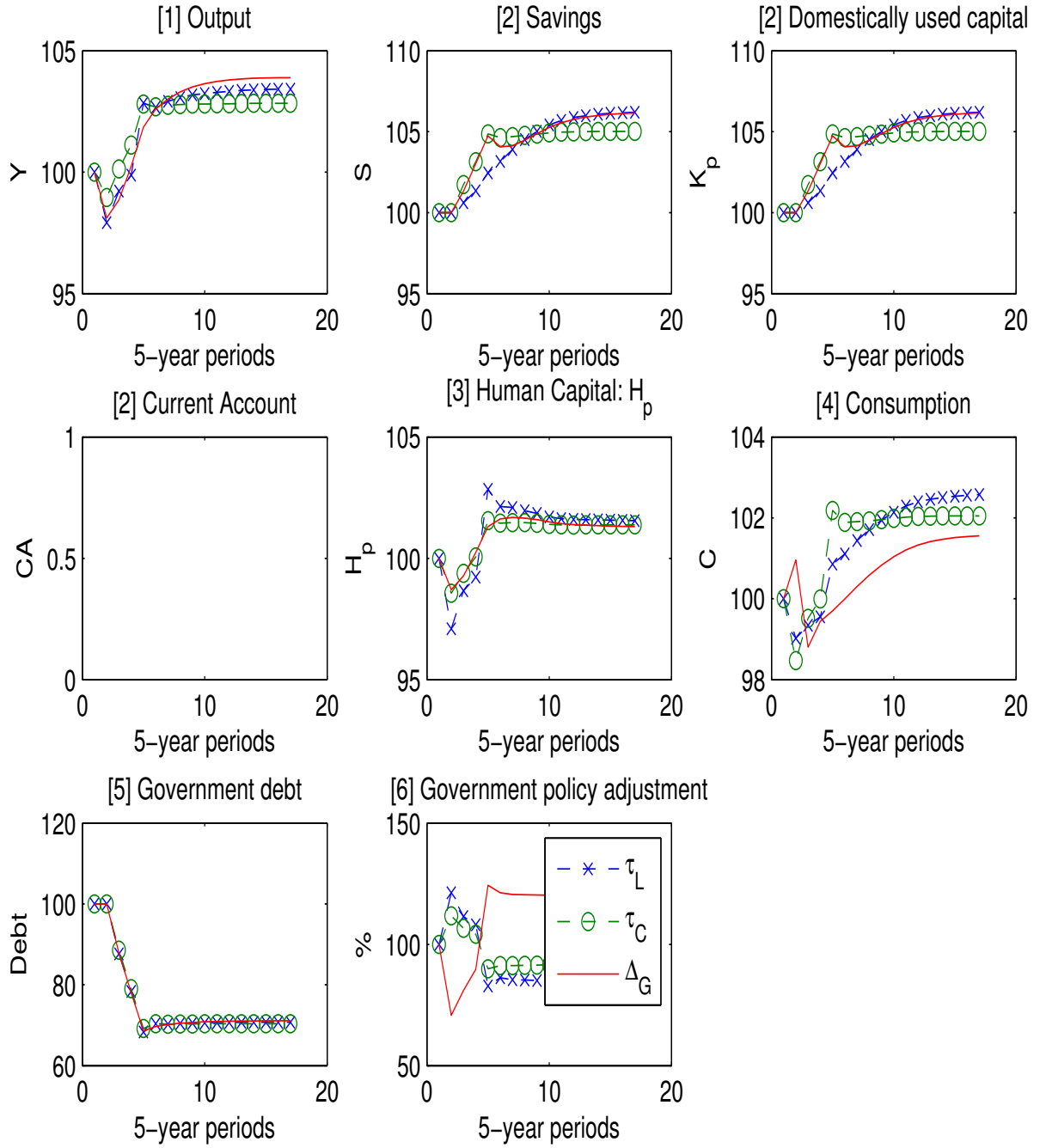
Figure 3: **The Transition Dynamics of Key Aggregates in a Closed Economy.** Either labor tax τ_L or consumption tax τ_C or public investment Δ_G adjusts to accommodate the drop in government debt
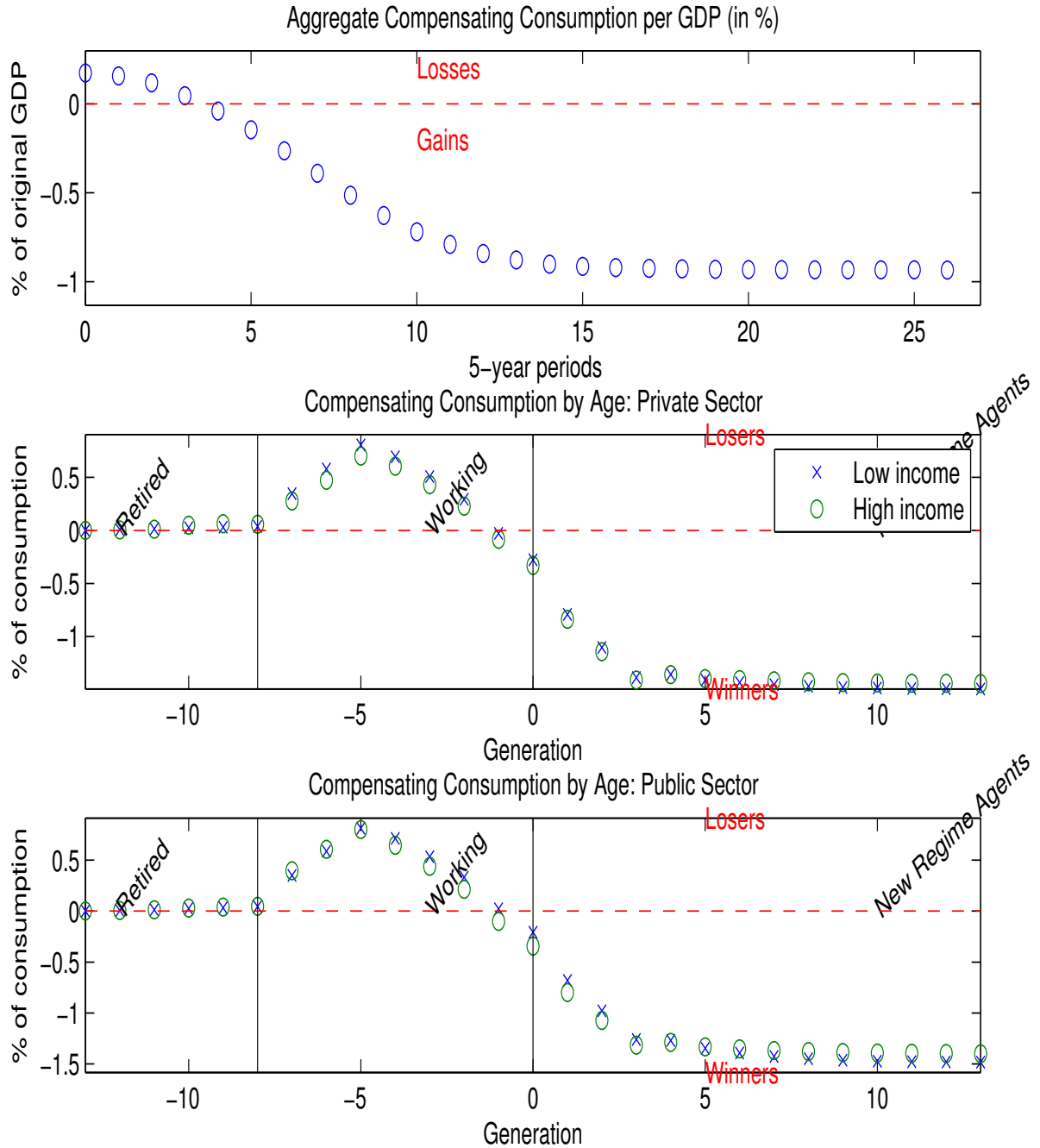
Figure 4: **Welfare Dynamics in an Open Economy WITHOUT Risk Premium.** Labor tax adjusts to accommodate the drop in government debt.
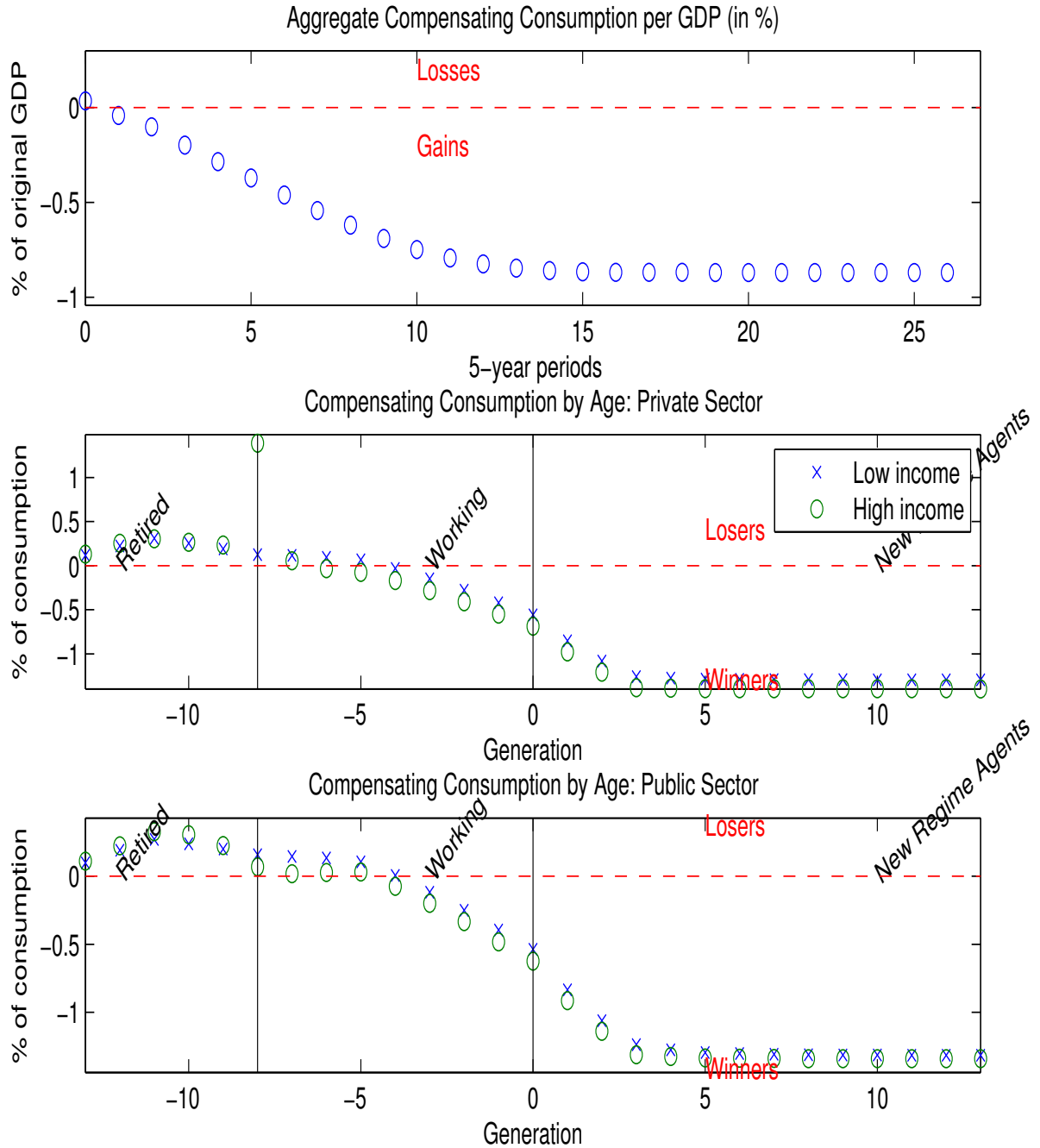
Figure 5: **Welfare Dynamics in an Open Economy WITHOUT Risk Premium.** Consumption tax adjusts to accommodate the drop in government debt.
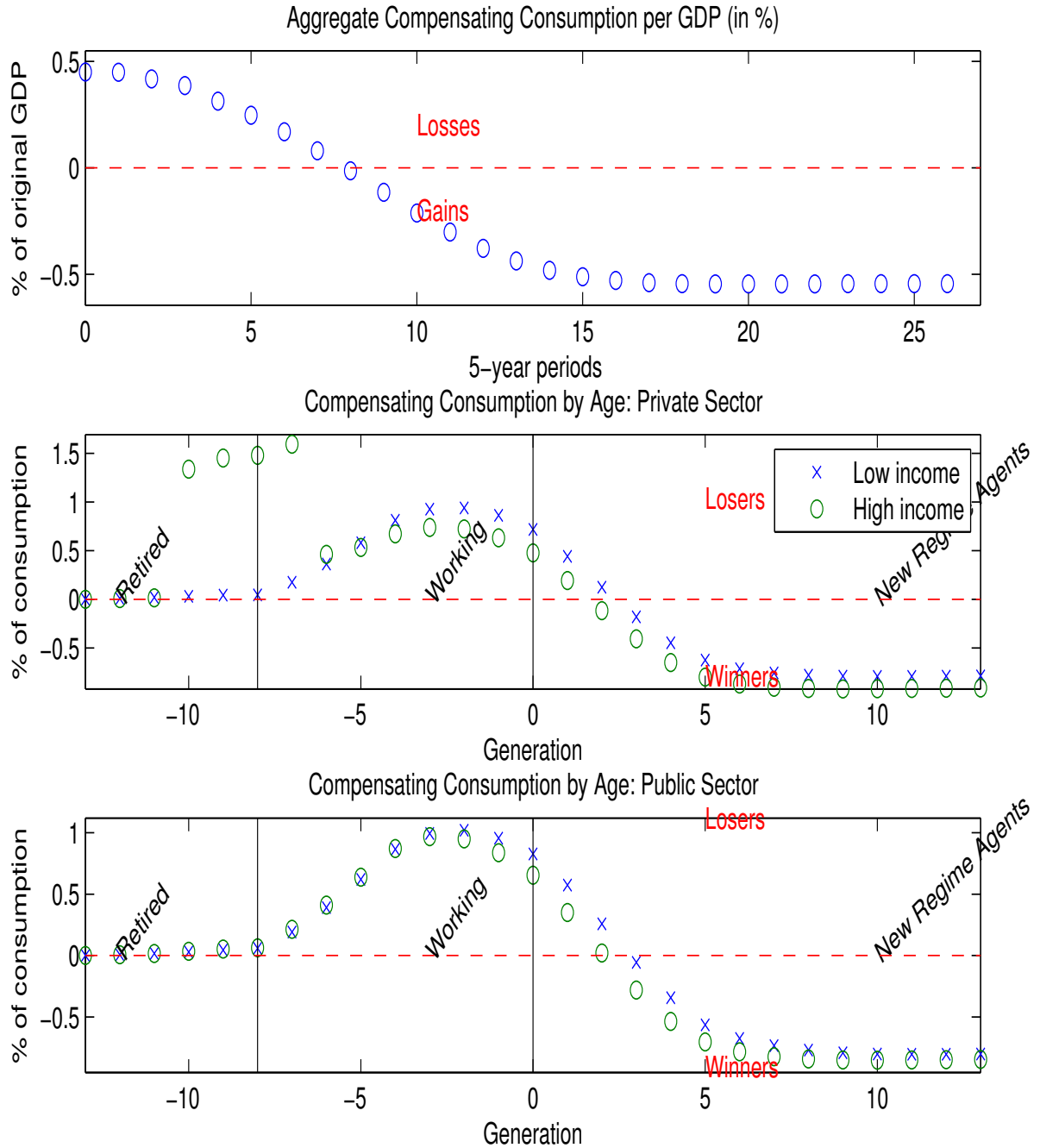
Figure 6: **Welfare Dynamics in an Open Economy WITHOUT Risk Premium.** Public investment adjusts to accommodate the drop in government debt.
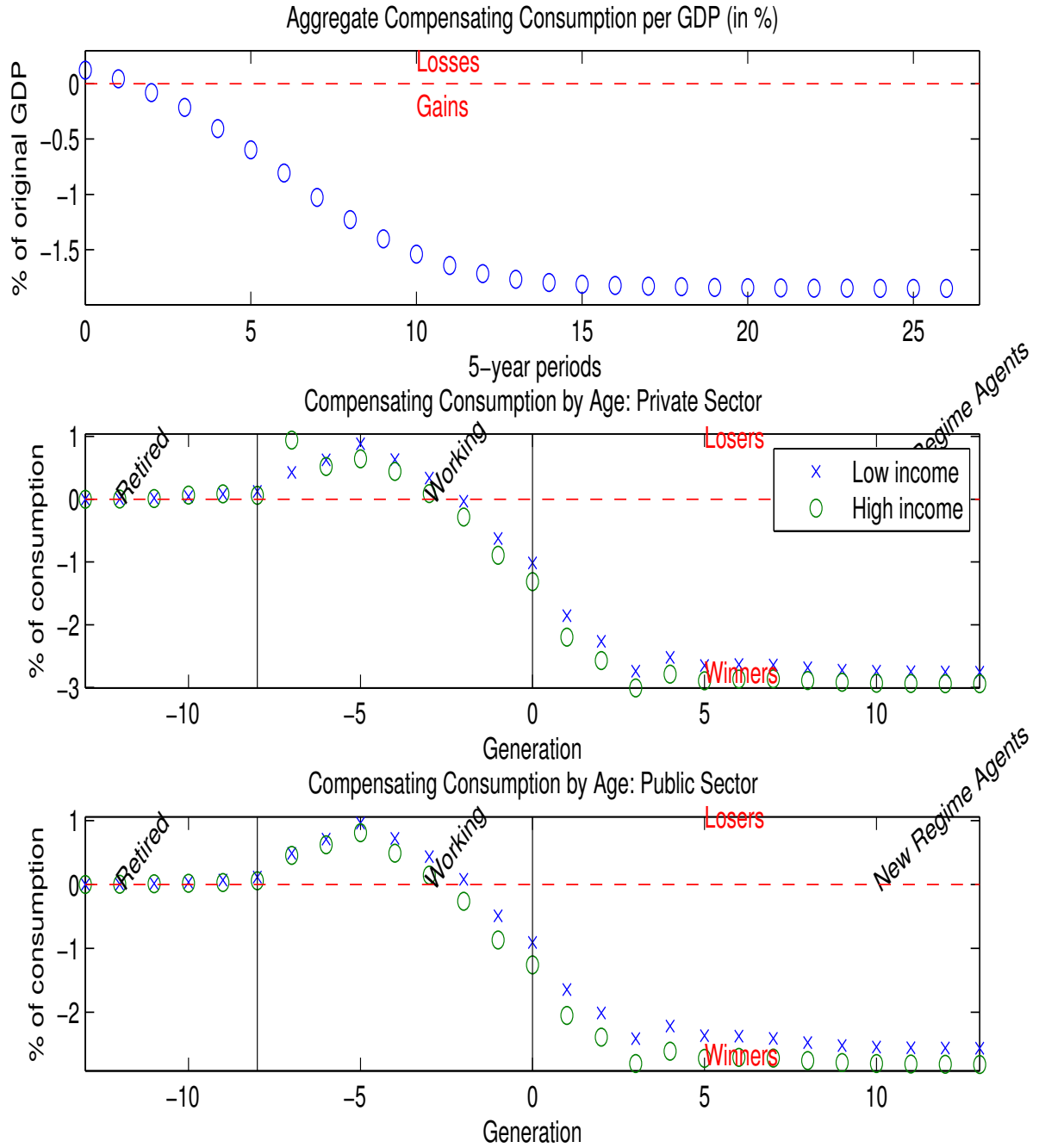
Figure 7: **Welfare Dynamics in an Open Economy WITH Risk Premium.** Labor tax adjusts to accommodate the drop in government debt.
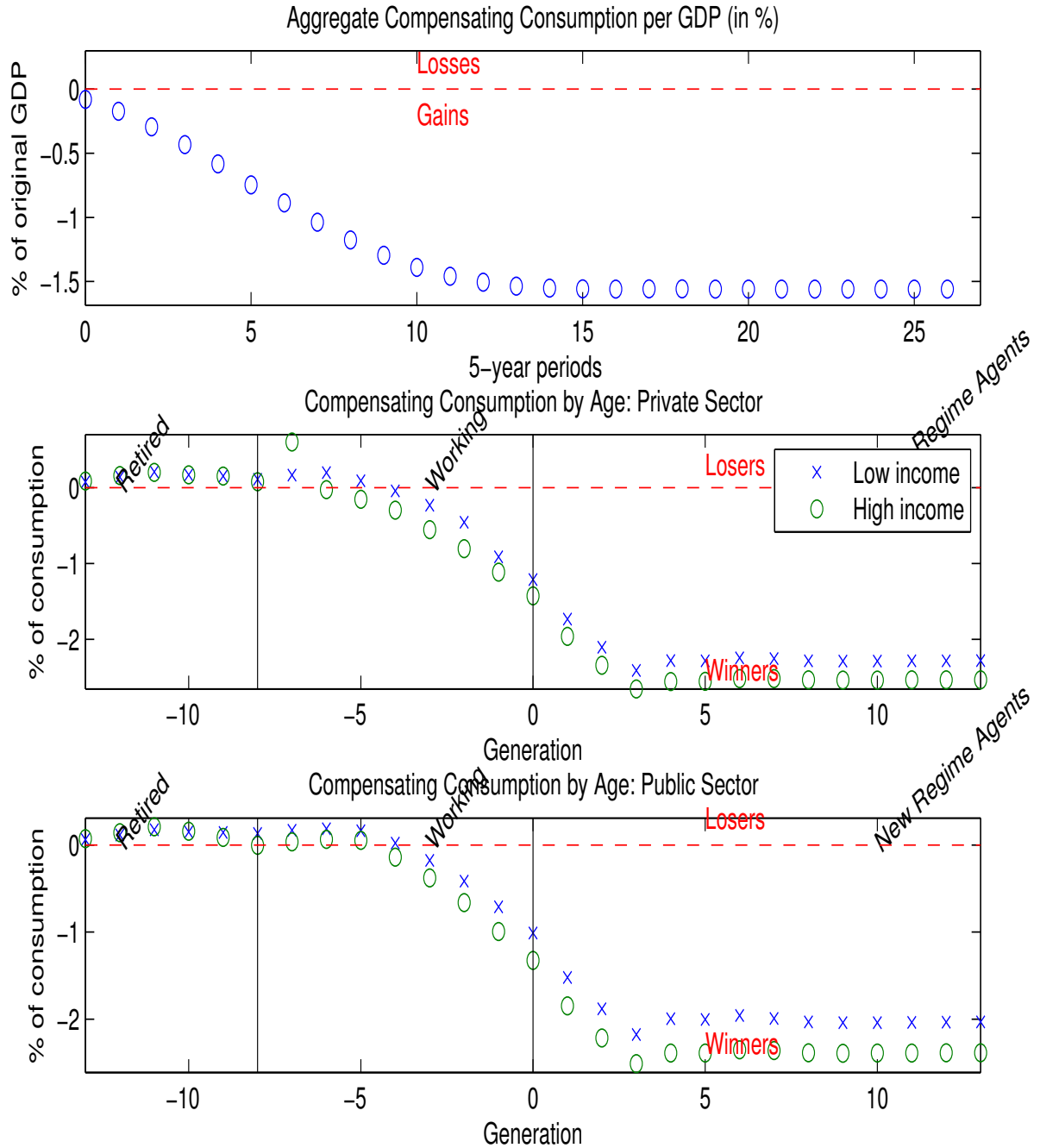
Figure 8: **Welfare Dynamics in an Open Economy WITH Risk Premium.** Consumption tax adjusts to accommodate the drop in government debt.
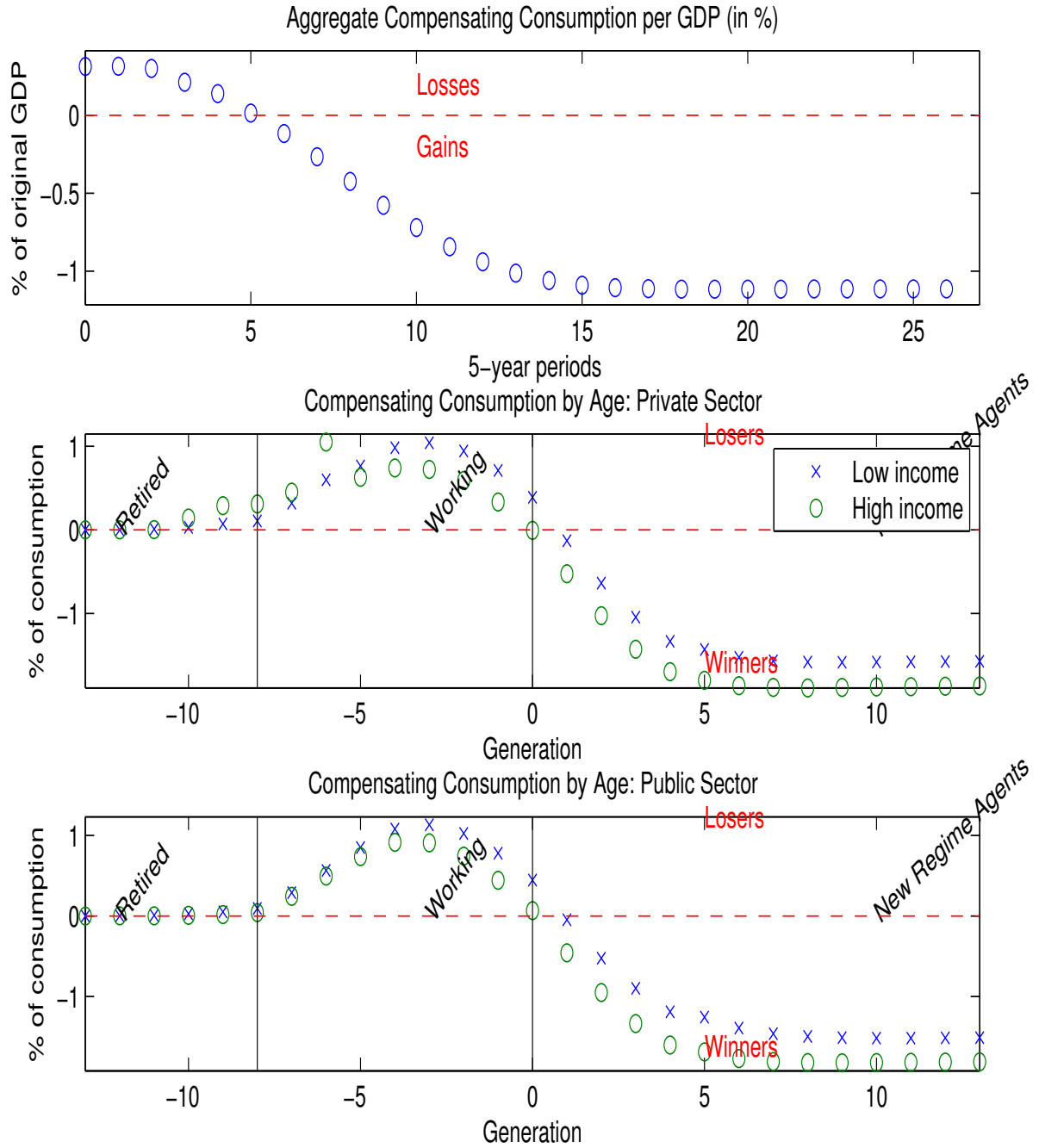
Figure 9: **Welfare Dynamics in an Open Economy WITH Risk Premium.** Public investment adjusts to accommodate the drop in government debt.
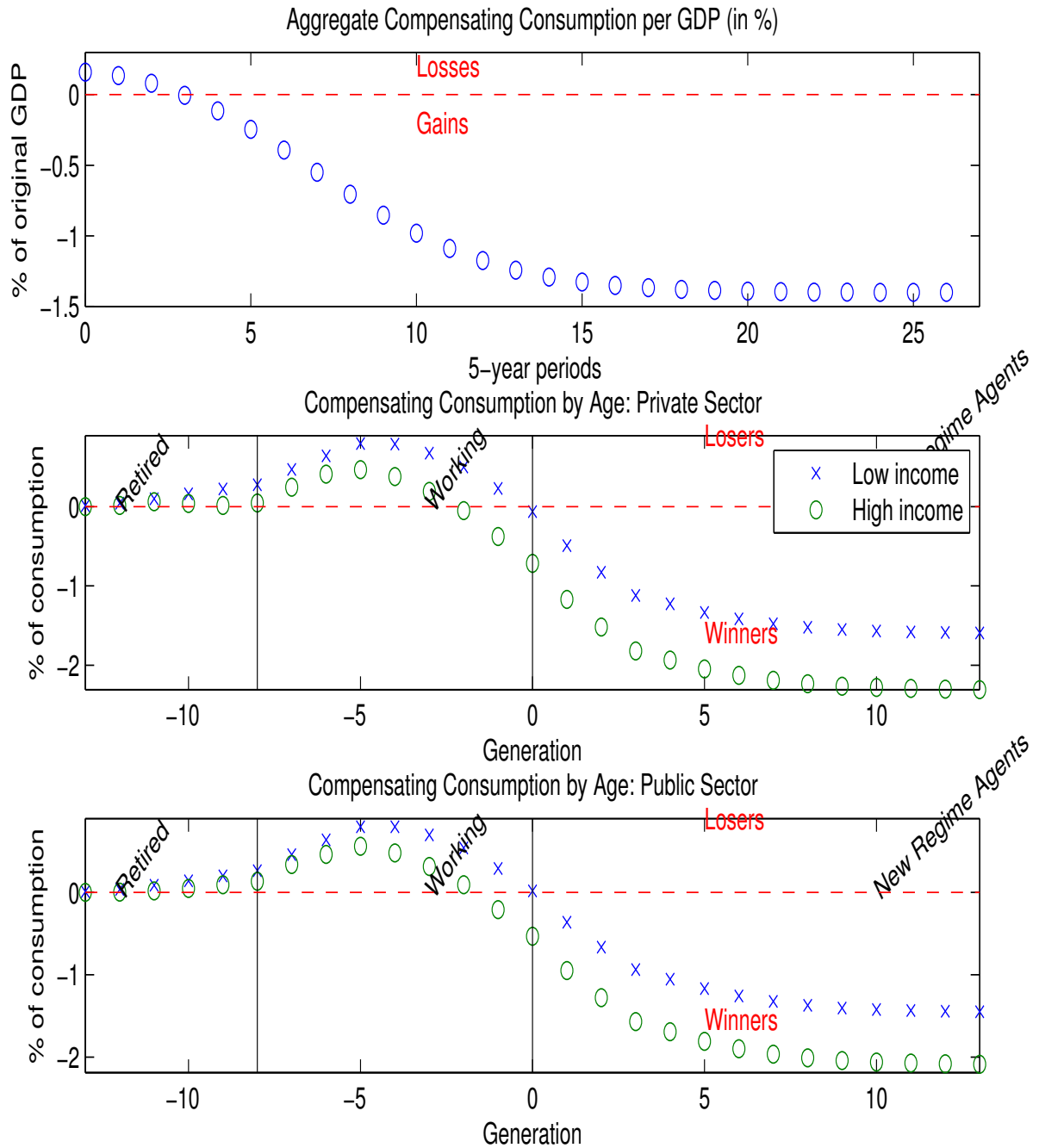
Figure 10: **Welfare Dynamics in a Closed Economy.** Labor tax adjusts to accommodate the drop in government debt.
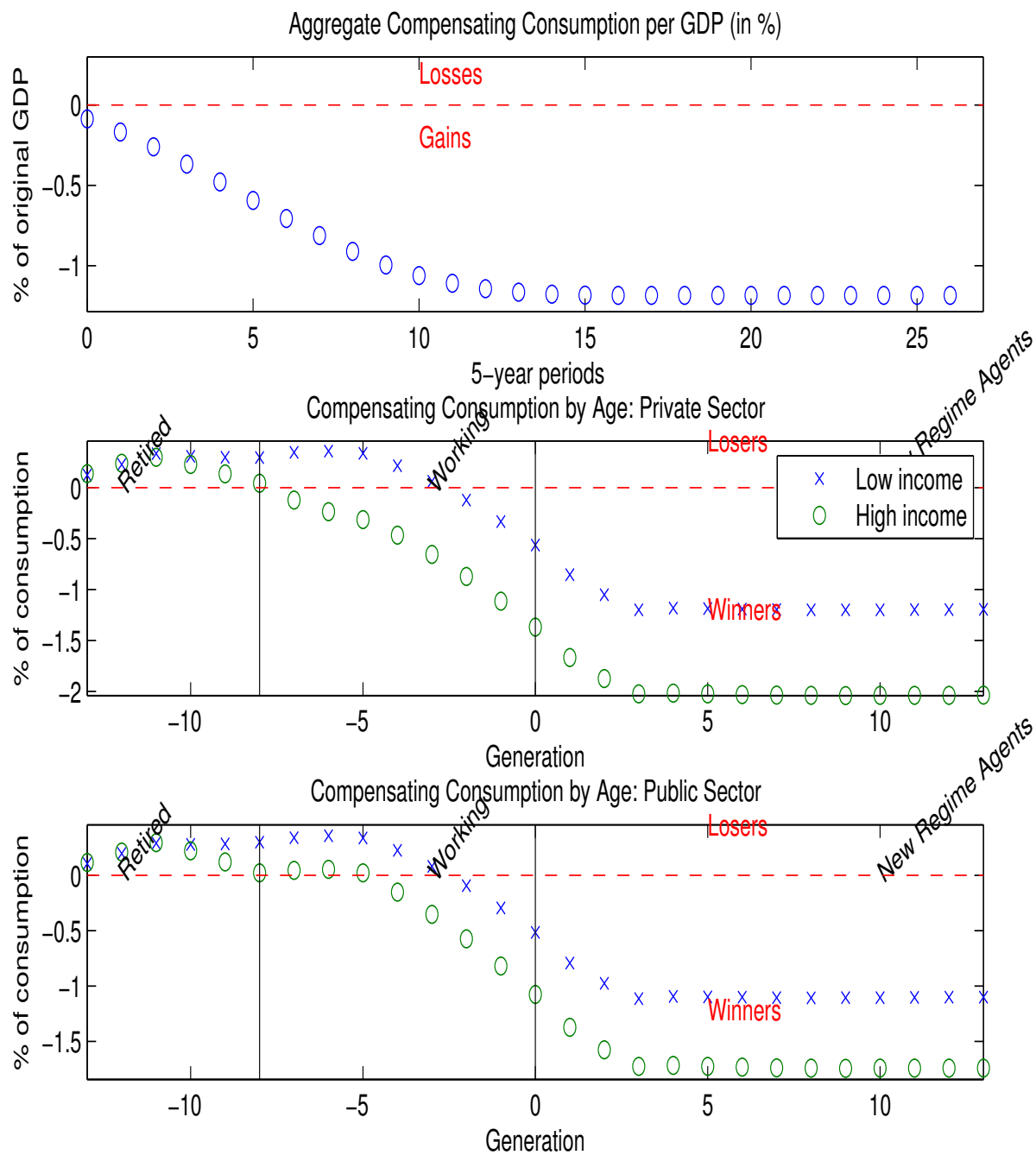
Figure 11: **Welfare Dynamics in a Closed Economy.** Consumption tax adjusts to accommodate the drop in government debt.
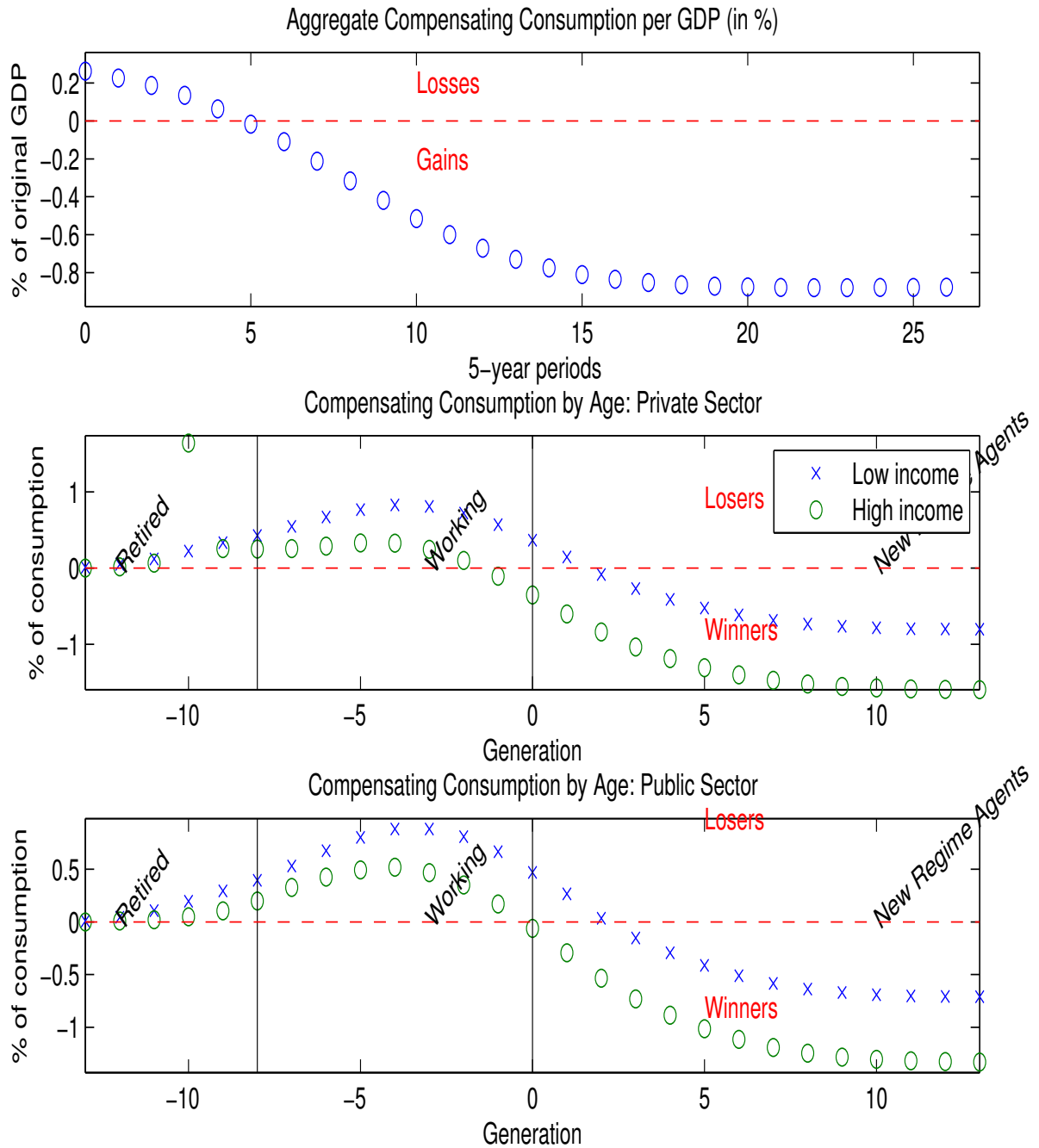
Figure 12: **Welfare Dynamics in a Closed Economy.** Public investment adjusts to accommodate the drop in government debt.