Saving Europe?:
The Unpleasant Arithmetic of Fiscal Austerity in Integrated Economies

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Abstract

This paper studies the effects of tax adjustments in response to large debt shocks using a two-country Neoclassical model with endogenous capital utilization and a fully-specified fiscal sector. Income tax hikes have adverse effects on macro aggregates and welfare, and trigger strong cross-country externalities, because countries that raise taxes become less competitive and less efficient. Quantitative analysis calibrated to European data shows that unilateral increases in capital taxes cannot restore fiscal solvency in the region with larger debts shocks (the "GIIPS"), because the dynamic Laffer curve peaks below the required revenue increase. Unilateral labor tax hikes can restore solvency, but still have negative effects on the GIIPS allocations and welfare, and positive effects on their trading partners (the "EU10"). Adjusting to the debt shock with unilateral tax hikes is much less costly for GIIPS under autarky than with free trade. Strategic incentives are strong, and hence one-shot Nash tax competition in which both regions adjust taxes in response to their observed debt shocks produces a "race to the bottom" in capital taxes and higher labor taxes. The two regions do better in Cooperative equilibria, but capital (labor) taxes are still lower (higher) than at present, and the welfare cost of adjusting to the debt shocks is lower under either Nash or Cooperative equilibria than with unilateral tax hikes under free trade or autarky.

Keywords: European debt crisis, tax competition, capacity utilization, fiscal austerity
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1 Introduction

The world's advanced economies are in the midst of a major fiscal crisis. The majority of these countries experienced large increases in their public debt in the aftermath of the 2008 global financial crisis. As data from the International Monetary Fund (2012) show, gross public debt as a share of GDP for all advanced economies reached 82 percent in 2011 and rose by nearly 24 percentage points in the preceding three years. The increases have been particularly large in Europe, where debt rose 30 percentage points of pre-crisis GDP in the countries that are now at the center of the European debt crisis (Greece, Ireland, Italy, Spain, and Portugal, or GIIPS). Public debt increased 18 percentage points in the other 10 Eurozone members (EU10). Debt shocks of this magnitude and on such a global scale are rare, and over the previous century they were observed only in times of major wars and during the Great Depression.[1]

Much of the current focus of academic research and policy discussions related to this fiscal crises is rightly placed on the turbulence in debt markets and the high risk of default of the GIIPS region. But clearly, even if these factors were not at play and after the current volatility eventually subsides, substantial fiscal adjustment must follow worldwide, and its effects on macroeconomic aggregates and social welfare will be significant. The magnitude of these effects will depend in part on the efficiency and distributional implications of the particular fiscal policy arrangements that countries decide to follow. It will also be influenced by the high degree of integration of capital and goods markets, which provides a vehicle for international externalities of domestic fiscal adjustment, particularly in the case of the European Union. Thus, understanding and quantifying the tradeoffs implied by alternative fiscal policy strategies in response to large debt shocks has become one of the central questions facing policymakers and the academicians who advise them.

This paper undertakes a quantitative investigation of the positive and normative effects of fiscal adjustment in response to large public debt shocks using a two-country variant of the workhorse Neoclassical model calibrated to European data, with one country representing the GIIPS region and the other EU10. The model captures the classic dynamic efficiency (or supply-side) effects of

[1] Over the entire history of public debt in the United States, the data constructed by Bohn (2007) shows that the surge in public debt during the Great Recession ranks below only the two World Wars, and is above the Civil War and the Great Depression.

distortionary taxes on factor incomes and consumption, as well as the cross-country externalities of domestic fiscal adjustment that result from the perfect cross-country mobility of goods and assets. The model is "conservative" in the sense that it assumes that there is no impact of fiscal consolidation on long-run economic growth, and that debt is priced at the world risk-free rate (i.e. there is no default risk). Even under these highly favorable conditions, fiscal consolidation in the face of actual debt levels is painful. We feed the debt shocks observed in the data to the model and compute the short- and long-run effects on equilibrium allocations, prices and welfare that result from responding to the shocks with capital or labor taxes, and with redistributions of the debt shocks across GIIPS and EU10 that are akin to debt haircuts. These computations allow us to compute dynamic (i.e. present value) Laffer curves for the revenue raised from labor, capital, and consumption taxes, and for total tax revenue, which summarize the governments' ability to restore fiscal solvency by raising taxes. We also quantify the cross-country externalities on macro aggregates, fiscal revenue and welfare that result from factor income tax policies, and compare the outcomes of one-shot cooperative and noncooperative games that result from the strategic interaction between national fiscal authorities induced by the externalities.

The framework adopted in this paper is similar to the one utilized by Mendoza and Tesar (1998) and Mendoza and Tesar (2005) to study the international implications of domestic tax reforms that produce dynamic efficiency gains. The model we propose here differs in one important respect by introducing an endogenous capital utilization decision in conjunction with a limit on the depreciation tax allowance. Endogenous utilization allows firms to make short run adjustments in capital services in response to a change in capital tax rates. This will limit the government's ability to collect tax revenues in the short run and change the shape of the dynamic Laffer curve. Since the Neoclassical model assumes that debt markets work smoothly and sovereigns are committed to repay, reattaining fiscal solvency after debt shocks requires changes in fiscal policy such that the net present discounted value of primary fiscal balances, discounted at equilibrium public debt prices and considering the equilibrium dynamics of allocations and prices, rises by the same amount as the debt shock. Thus, in order to assess whether this is the case, we need to solve for the equilibrium transitional dynamics and new steady state that result from changes tax changes, and evaluate the equilibrium present discounted value of primary balances that they produce. We assume that European countries maintain their VAT harmonization treaties, and therefore rely on adjustments in factor income taxes.

Our quantitative analysis based on a calibration to European data yields a number of new insights on the effects of fiscal consolidation options facing Europe. We begin with unilateral tax increases on factor incomes in the GIIPS region. To the extent externalities result in increased revenue in the rest of the EU through an increase in the tax base, the additional revenue is rebated to households leaving the fiscal constraint unchanged. In general, countries with large debt burdens become relatively less "tax efficient" and their tax adjustments provide significant gains for their trading partners. In the case of an adjustment in GIIPS capital income taxes, there is no unilateral increase in capital taxes that can restore fiscal solvency because their dynamic Laffer curve peaks below the required revenue increase. A unilateral labor tax hike can restore solvency, but with negative effects on the GIIPS equilibrium allocations and welfare, and nontrivial improvements in their trading partners (EU10).

The results based on unilateral tax adjustments suggest that strategic incentives are strong. We then analyze Nash solutions to one-shot tax competition games, in which both regions adjust taxes to offset their observed debt shocks. The noncooperative game produces a highly distorting race to the bottom in capital taxes. In the absence of a cooperative solution or a redistribution of the debt burden (i.e. debt haircuts), the GIIPS region attains higher welfare by moving to autarky.

Finally, we examine Laffer curves for individual GIIPS countries. The previous analysis assumed that the countries in the GIIPS region acted in concert, potentially overstating the impact individual country tax adjustments would have on world prices. In the case where each GIIPS country adjusts taxes alone, Laffer curves peak at significantly lower tax rates, suggesting that their ability to undertake successful fiscal reforms without the cooperation of other GIIPS and EU10 support is extremely limited.

In the model, the global externalities of national tax policies are driven by international transmission effects operating through three channels: (1) relative prices, because national tax changes alter the prices of financial assets (including internationally traded assets and public debt instruments) as well as factor prices at home and abroad; (2) the world distribution of wealth, because efficiency effects of national tax changes affect the allocations of capital and net foreign assets across countries; and (3) the erosion of tax revenues, because via the first two channels national tax policies affect the ability of foreign governments to raise tax revenue.

These channels are essential for evaluating fiscal adjustment efforts in economies that are highly open to trade in goods and assets, as is the case in Europe, and play a central role in answering the four questions that we posed. Their relevance is reflected in numerous media reports of capital flight from the periphery countries of Europe, much of it to the perceived safety of Germany. Some of this flight is triggered by concerns about bank solvency and the potential collapse of the euro, issues that are beyond the scope of this paper. However, businesses also cite rising taxes on capital as an impetus to relocation. (See for example, "EuroCrisis: Big Business Leaving Greece," International Business Times, October 12, 2012 by Paul A. Ebeling, Jr., and "Euroview: Capital Fleeing Entire Periphery, not just Greece," EFX News, May 25, 2012, by Jack Duffy.)

The quantitative results show that indeed the implications of fiscal adjustment for macroeconomic aggregates and welfare are substantial, and that there are significant cross-country externalities at play. The dynamic Laffer curves suggest that re-attaining fiscal solvency is feasible (i.e. the required revenue needed to balance the intertemporal government budget constraint after the debt shock is below the maximum of the dynamic Laffer curve). In addition, as an implication of the cross-country externalities of domestic tax policies, we find that our open-economy dynamic Laffer curves are shifted down and to the left, relative to the comparable closed-economy curves and existing closed-economy estimates of steady-state Laffer curves (e.g. Trabandt and Uhlig, 2010). Furthermore, sensitivity analysis suggests that these shifts can be so sizable as to make raising the revenue needed to respond to the observed debt shocks infeasible (and this assuming that countries continue to have access to debt markets, as implicit in the Neoclassical framework we are using).

The results also show that, even if raising the additional fiscal revenue to offset the debt shocks is feasible, there are significant adverse effects on allocations and welfare for the region that becomes relatively less tax-efficient (i.e. the region where taxes increase relatively more), particularly when capital income taxation is the chosen policy. Moreover, when fiscal adjustment is non-cooperative, so that tax policies are the outcome of Nash competition subject to the constraint that revenues must rise to match the observed debt shocks, the region that becomes relatively more tax efficient receives a nontrivial windfall at the expense of the other region in terms of efficiency gains, fiscal revenue and welfare. Because of these revenue externalities, an increase in one region's tax rate implies that the other region can meet its revenue target with a lower tax rate. Hence, the tax rates that emerge from a cooperative equilibrium in which a global planner internalizes the externalities are higher than the tax rates in the Nash equilibrium.

These results, taken together, suggest that there are likely to be large externalities from tax policy changes in Europe, and that there may be room for gains from policy coordination. Moreover, this coordination could take the form of debt haircuts, which would redistribute the burden of the initial debt shocks across region and thereby change the incentives of non-cooperative fiscal authorities to produce outcomes closer to the cooperative equilibrium.

The rest of the paper is organized as follows: The next Section discusses further the policy background motivating our work, particularly in the context of the European Union, and provides a literature review. Section III describes the model. Section IV discusses the baseline calibration for the quantitative analysis, which is set to match key features of the Eurozone countries before the recent debt shocks. Section V examines the quantitative findings. Section VI concludes.

2 Background and Literature Review

The ongoing European debt crisis radically changed the nature of fiscal policy discussions in Europe. Until recently, discussions of tax policy were largely centered on the harmonization of national tax rates, particularly VAT rates, and measures to mitigate the ostensibly negative effects of tax competition (Sorensen, 2001; Kellerman and Kammer, 2009). Since the 1970s, EU member states have worked to bring value-added taxation into alignment and to remove barriers to capital and labor movements across borders. Steps to create a common playing field for corporate taxation (the Common Consolidated Corporate Tax Base) have met with less success. The debt crisis changed the focus away from these issues and put the emphasis instead on the need to tighten fiscal rules within the Eurozone, and the need to implement far reaching country-specific fiscal austerity programs to address fiscal imbalances. Even before the 2008 global financial crisis, many countries in the Eurozone were pushing up against the public debt ceiling of 60 percent of GDP, a condition of the Maastricht Treaty. The slowing of economic activity combined with increased transfer payments, financial system bailouts, and fiscal stimulus programs in the aftermath of the 2008 crisis resulted in a ballooning of debt ratios, in some cases well above 100 percent of GDP. A number of countries, including Portugal, Greece, Italy, Ireland and Spain, and to a lesser extent France and the Netherlands, have adopted austerity measures that involve expenditure reductions and increases in tax rates in an attempt to stem the growth of budget deficits and the accumulation of debt.

While much ink has been spilled in both the financial and academic press on the pros and cons of austerity measures in response to the European debt crisis, there has been surprisingly little discussion of the constraints imposed on fiscal policy by being part of a region that is economically integrated. Estimates of the sustainability of public debt (Abiad and Ostry, 2005) and Mendoza and Ostry (2008), fiscal space (Ostry et al., 2010), and the scope for raising revenue (Trabandt and Uhlig, 2009, 2012) tend to treat countries in Europe as isolated economic units, which sets aside the nontrivial potential for significant erosion of tax bases across countries due to factor mobility or for spillover effects on the budgets and welfare of other member countries. This is paradoxical, because externalities of fiscal policy have otherwise been widely discussed in the theoretical literature on international tax competition, much of which has focused on the EU, and in broader EU policy studies on tax harmonization and capital income tax competition (see, for example, the survey by Persson and Tabellini (1995), the books by Frenkel et al. (1991) and Turnovsky (1997), and the quantitative studies by Klein et al. (2005), Sorensen (1999), Sorensen (2003) and Eggert (2000)).

The previous research by Mendoza and Tesar (1998) and Mendoza and Tesar (2005) does take into account cross-country externalities of domestic tax policy changes. As mentioned earlier, they developed a two-country Neoclassical model for studying the quantitative implications of efficiency-oriented domestic tax reforms. Mendoza and Tesar (1998) studied the global effects of unilateral refoms that eliminate capital or labor taxes and are rendered neutral for the present value of total tax revenue through the adjustment of consumption taxes. By focusing on revenue neutrality in present value, their setup allows the government to make efficient use of debt markets to smooth the tax burden over time. They found that the efficiency gains of removing factor income taxation are large, but the global externalities are also significant. Given these findings, Mendoza and Tesar (2005) focused on solving for the equilibrium tax structures that result from strategic interaction of national tax authorities in one-shot games under Nash competition and under global cooperation. They found that the outcome of Nash competition in factor income taxes with harmonized indirect taxes calibrated to actual consumption taxes produces tax rates on incomes similar to those observed in the EU before the debt crisis.

Our work is also related to the large literature on debt sustainability that studies whether observed public debt ratios are consistent with the intertemporal government budget constraint (IGBC). The seminal contributions by Bohn (1998) and Bohn (2007) have shown, however, that this is an uninteresting endeavor, because all that is required is for either public debt or primary fiscal balances to be stationary of *any* finite order. Moreover, a fiscal reaction function with a positive response of the primary balance to debt is sufficient for the IGBC to hold. The implied debt dynamics are stationary if the response is larger than the real interest rate, but small changes in the response coefficient imply large differences in long-run debt ratios, with all of them being consistent with the same initial debt. Further, a positive response coefficient smaller than the interest rate implies explosive debt dynamics that are also consistent with solvency. Thus, from this perspective, countries which pass the reaction-function test for debt sustainability can be expected to re-attain fiscal solvency after the recent large debt shocks either under the estimated response coefficient, which will eventually require large surpluses to slowly return the debt to their pre-2008 average, or with small reductions in the response coefficient, which would allow the debt to converge to new much higher long-run averages. Unfortunately, none of this is informative about which adjustment is more desirable in terms of tax distortions, welfare and global externalities. Neither can this approach answer the question of whether necessary revenue increases are feasible in terms of the tax-revenue-generating capacity of governments. These questions are the focus of this paper.

3 A Two-Country Model with Global Tax Externalities

We study the fiscal adjustment in response to debt shocks using an extension of the standard two-country Neoclassical balanced-growth model that includes endogenous capacity utilization and a fully specified tax system, including limited allowance for capital depreciation expenses. Since our focus is on the transitional dynamics and long-run implications of fiscal adjustment, rather than on business cycle effects, the model is set without uncertainty.

The two countries, with the home country (H) intended to represent the GIIPS region and the foreign country (F) intended to represent the EU10 region. We denote the relative country size by ϕ. The countries are perfectly integrated in goods and asset markets. The latter are modeled as one-period discount bonds, without loss of generality given the absence of uncertainty. Each country is inhabited by an infinitely-lived representative household. For tractability, we also assume that they make investment and capital utilization decisions, so that they rent out to firms labor services and effective capital services. Firms in each country are also representative, and they produce a single tradable good using capital and labor as input.

Preferences and technology are assumed to be identical across countries. As is the case in the Eurozone, however, the countries differ in that they have fully independent national fiscal authorities that can set different policies for taxation and government outlays, specified in detail below. Physical capital and labor are immobile factors, but trade in bonds is sufficient to create important global spillovers of national tax policies that affect the global distribution of wealth, including the size of the global capital stock and its distribution across countries. In addition to this wealth reallocation mechanism, national tax policies trigger also the other two mechanisms driving global externalities via relative prices and revenue erosion noted in the introduction.

We present below the structure of preferences, technology and the government sector of the H country. The same structure applies to the F country, and when is relevant to distinguish variables or decisions across the two we use asterisks to identify the F country.

Households

The representative household in H maximizes lifetime utility over consumption, c_t, and leisure, which assuming a unit time endowment we define as $1-l_t$, where l_t is the labor supply. The utility function has the standard form of Neoclassical models:

$$\sum_{t=0}^{\infty}\left[\beta(1+\gamma)^{1-\sigma}\right]^t \frac{(c_t(1-l_t)^a)^{1-\sigma}}{1-\sigma}, \quad \sigma>1,\ a>0,\ \text{and } 0<\beta<1. \tag{1}$$

β is the household's subjective discount factor, $\frac{1}{\sigma}$ is the intertemporal elasticity of substitution in consumption, and a governs the intertemporal elasticity of labor supply for a given value of σ.

As in the standard neoclassical framework of King et al. (1988), growth is driven by labor-augmenting technological change that occurs at exogenous rate γ. Accordingly, all variables (except labor and leisure) are rendered stationary by dividing by the level of this technological factor.[2] In addition, the stationarity-inducing transformation requires changing the discount factor to $\beta(1+\gamma)^{1-\sigma}$ and adjusting the laws of motion of accumulable assets so that date-$t+1$ stocks grow by the balanced-growth factor $1+\gamma$.

The household maximizes (1) subject to a sequence of period budget constraints:

$$\begin{aligned}(1+\tau_c)c_t+(1+\gamma)k_{t+1}-k_t+(q_tb_{t+1}+q_t^g d_{t+1})+\tfrac{\eta}{2}\left[\tfrac{x_t}{k_t}-z\right]^2 k_t\\ =(1-\tau_L)w_tl_t+(1-\tau_K)r_tm_tk_t-(1-\theta\tau_K)\delta(m_t)k_t+b_t+d_t+e_t,\end{aligned} \tag{2}$$

for $t=0,...,\infty$, given the initial conditions $k_0>0$, b_0, and d_0.

The household takes as given government-determined proportional tax rates on consumption, labor income and capital income, denoted τ_C , τ_L , and τ_K, respectively, and lump-sum government transfer or entitlement payments, denoted by e_t. The household takes as given the returns to labor w_t and capital r_t, and the prices of government bonds and internationally traded bonds, q_t^g and q_t (the gross real rates of return on these bonds are $R_t^g=\frac{1}{q_t^g}$ and $R_t=\frac{1}{q_t}$, respectively).

The left-hand-side of equation (2) measures household expenditures, which include purchases of consumption goods inclusive of the indirect tax, new capital goods, k_{t+1}, international bonds, b_{t+1},

[2]The assumption that growth is exogenous implies that in this model tax policies do not affect long-run economic growth. This is in line with the empirical and quantitative findings of Mendoza et al. (1997).

and domestic government bonds d_{t+1}. The price of capital and the price of consumer goods differ because investment incurs quadratic adjustment costs as a function of the ratio of net investment x_t to existing capital k_t. The coefficient η determines the speed of adjustment of the capital stock, while z is set equal to the long-run investment-capital ratio to ensure that at steady state the capital adjustment cost is zero.

The right-hand side of equation (2) shows household after-tax income. This includes net-of-tax income from wages and effective capital services rented out to firms, payments on holdings of public and international bonds, and lump-sum entitlement payments from the government. Effective capital services are given by mk, where m is the rate of utilization of the capital stock defined as a percent in the 0-1 interval. As in the literature on DSGE models with endogenous capacity utilization initiated by the work of Greenwood et al. (1988), the cost of utilization is faster depreciation, with the depreciation rate given by a convex function $\delta(m) = \chi_0 m^{\chi_1}/\chi_1$, with $\chi_1 > 1$ and $\chi_0 > 0$ so that $0 \leq \delta(m) \leq 1$. Given that the depreciation rate depends on utilization, net investment adjusted for exogenous technological progress is defined as $x_t = (1+\gamma)k_{t+1} - (1-\delta(m_t))k_t$.

We assume that households choose m and rent out effective capital services (i.e. $\tilde{k} \equiv mk$) in order to keep the decentralization between households and firms as in usual representations of the Neoclassical model, in which firms make static plans for production and factor demands facing factor rental rates. To be consistent with the facts that tax allowances for depreciation generally apply only to capital income taxed from business, not from individuals, and also do not apply to residential capital, we assume that the depreciation allowance applies to a fraction θ of actual depreciation.[3]

In line with the environment in the European Union, the two regions in the model are perfectly integrated in terms of goods and asset markets. The latter implies that international bond payments are not taxed. Also in line with other features of European tax systems, capital income is taxed

[3]Full depreciation allowance has the unrealistic implications that it renders the utilization rate independent of the capital income tax in the long run, and in the short run the capital tax affects the utilization decision margin only to the extent that it reduces the marginal benefit of utilization when traded off against the marginal cost due to changes in the marginal cost of investment. Alternatively, we could assume that there is a full depreciation allowance but that there are costs other than depreciation associated with capital utilization for which there is no tax allowance. These two formulations are isomorphic, but we opted for partial depreciation allowance to maintain the traditional setup of capacity utilization.

according to the residence principle, and countries are allowed to tax capital income at different tax rates. Under these assumptions, we must also assume that physical capital is owned entirely by domestic residents, in order to support a competitive equilibrium with different capital taxes (see Mendoza and Tesar, 1998; Frenkel et al., 1991). Without this assumption, cross-country arbitrage of returns across capital and bonds at common world prices implies equalization of pre- and post-tax returns on capital, which therefore requires identical capital income taxes across countries. Other forms of financial-market segmentation, such as trading costs or short-selling constraints, could be introduced for the same purpose, but they make the model less tractable.[4]

The model also imposes a no-Ponzi condition on households. This restriction, along with the budget constraint in (2) imply that the present value of total household expenditures equals the present value of after-tax income plus initial asset holdings.

Firms

Firms employ labor and effective capital services to maximize profits $(y_t - w_t l_t - r_t \tilde{k}_t)$ taking factor prices as given. The production function is assumed to be Cobb-Douglas:

$$y_t = F(\tilde{k}_t, l_t) = \tilde{k}_t^{1-\alpha} l_t^{\alpha} \tag{3}$$

where α is labor's share of income and $0 < \alpha < 1$. Firms behave competitively and thus chose $\tilde{k}_t, l_t$ so as to equate their marginal products with their corresponding rental rates:

$$(1-\alpha)\tilde{k}_t^{-\alpha} l_t^{\alpha} = r_t \tag{4}$$

$$\alpha \tilde{k}_t l_t^{\alpha-1} = w_t \tag{5}$$

Because of the linear homogeneity of the technology, these factor demand conditions imply that the value of output equals total factor payments $(y_t = w_t l_t + r_t \tilde{k}_t)$.

[4]The assumptions of immobile capital and residence-based taxation could be replaced with source-based taxation and this would result in similar saving and investment optimality conditions that would support competitive equilibria with different capital income tax rates across countries. While actual tax codes tend to be source-based, however, most industrial countries have bilateral tax treaties that render tax systems largely residence-based (see Frenkel et al., 1991).

Public Sector

Fiscal policy in this economy has three components. The first component is government outlays, and is composed of pre-determined sequences of government purchases on goods and services, g_t, and transfer/entitlement payments to households, e_t, for $t = 0, ..., \infty$. As is standard in Neoclassical models with government outlays, government purchases are unproductive in the sense that they do not enter in household utility or the production function. Under this assumption, it would follow trivially that the optimal response to a debt shock should include setting $g_t = 0$. We rule out this possibility because it is unrealistic, and also because if the model is modified to allow government purchases to provide utility or production benefits, cuts in these purchases would be distortionary in a way analogous to the taxes we are considering. Hence, our quantitative analysis is calibrated assuming that $g_t = \bar{g}$, where $\bar{g}$ is the steady state level of government purchases that prevailed before the debt shocks. Entitlement payments are treated in the same way (with $\bar{e}$ denoting the steady state level of entitlements before the debt shocks). Note, however, that since entitlements represent a form of lump-sum transfer payments, they are always non-distortionary in this representative agent setup. Still, they do impose on the government the need to raise distorting tax revenue, since we do not allow for lump sum taxation, and hence again the (trivial) optimal policy in response to debt shocks would include eliminating transfer payments is ruled out.

The second component of fiscal policy is the tax structure. This includes the set of time invariant tax rates on consumption τ_C, labor income τ_L and capital income τ_K, and the depreciation allowance limited to a fraction θ of depreciation expenses.

The third component is government debt, d_t. The government must satisfy the following sequence of budget constraints:

$$d_t - (1+\gamma)q_t^g d_{t+1} = \tau_C c_t + \tau_L w_t l_t + \tau_K (r_t m_t - \theta\delta(m_t))k_t - (g_t + e_t). \qquad (6)$$

The right-hand-side of this equation shows the primary fiscal balance (tax revenues net of total government outlays). The primary balance is financed with the change in debt including debt service in the left-hand-side of the constraint.

We impose a no-Ponzi-game condition on the government. This condition ensures that the present value of government revenues net of expenditures equals the initial public debt d_0.[5] This is not an innocuous assumption in the analysis of fiscal adjustment in response to debt shocks, because it implies both that governments are committed to repay and that sovereign debt markets are working smoothly at all times. Our findings will show that even under these ideal conditions, there are large inefficiencies, welfare effects, and cross-country externalities involved in fiscal adjustment.

Since we calibrate the model using fiscal data in shares of GDP, it is useful to write the intertemporal government budget constrain also in shares of GDP. Defining the primary balance as $pb_t \equiv \tau_c c_t + \tau_L w_t L_t + \tau_K (r_t m_t - \theta\delta(m_t))k_t - (g_t + e_t)$, the constraint in shares of GDP is:

$$\frac{d_0}{y_0} = \frac{pb_0}{y_0} + \sum_{t=1}^{\infty}\left(\left[\prod_{i=1}^{t} \upsilon_i\right]\frac{pb_t}{y_t}\right) \tag{7}$$

$$\upsilon_i \equiv (1+\gamma)\psi_i q_i^g \ , \quad \psi_i \equiv y_{i+1}/y_i$$

In this expression, the stream of future primary balances is discounted to account for long-run growth at rate γ, transitional growth ψ_i as the economy converges to the long-run, and the equilibrium price of public debt q_i^g. Since y_0 is endogenous (i.e. it responds to debt shocks and required tax adjustments), it is useful to rewrite the above solvency condition so that the debt ratio in the left-hand-side is an exogenous initial condition. Multiplying both sides of the above condition times $\psi_0 = (y_0/y_{-1})$ we obtain:

$$\frac{d_0}{y_{-1}} = \psi_0\left[\frac{pb_0}{y_0} + \sum_{t=1}^{\infty}\left(\left[\prod_{i=1}^{t} \upsilon_i\right]\frac{pb_t}{y_t}\right)\right] \tag{8}$$

The exogenous debt shock we will examine is reflected in the magnitude by which d_0/y_{-1} (the debt ratio at the end of $t-1$, since d_0 is chosen on that date) changed. Hence, the solvency condition represents a constraint that the new regimes with altered tax policy in response to a debt shock must satisfy.[6] The left-hand-side is an exogenous constant taken from the data, and

[5] Note that, as explained in Mendoza and Tesar (1998), public debt in this model is Ricardian in the sense that the equilibrium dynamics of government debt can be equivalently characterized as a sequence of lump-sum transfers between government and households (separate from the "explicit" entitlement payments e_t), with these transfers set equal to the primary fiscal balance. We use this to simplify the numerical solution of the model. Once we have the equilibrium sequence of debt-equivalent transfers, the implied equilibrium dynamics for public debt follows from an initial condition calibrated to actual debt data and the government budget constraint.

[6] In detrended levels (which are ratios relative to the state of labor augmenting technology), we would have

the right-hand-side is the present discounted value of the primary balance-GDP ratios (where both pb_t and y_t are equilibrium outcomes), discounted taking into account exogenous long-run growth, endogenous transitional growth, and endogenous debt prices.

Consolidation of the government's constraint with the household's constraint in (2) and the firm's zero profit condition in (4) yields the economy-wide resource constraint for the home region:

$$F(k_t, l_t) - c_t - g_t - x_t - \left(\frac{\eta}{2}\left(\frac{x_t}{k_t} - z\right)^2 - 1\right) k_t = (1+\gamma) q_t b_{t+1} - b_t. \tag{9}$$

Competitive Equilibrium

A competitive equilibrium for this two-region economy is a sequence of prices $\{r_t$, r_t^*, q_t, q_t^g, q_t^{g*}, w_t, $w_t^*\}$ and allocations $\{k_{t+1}$, k_{t+1}^*,m_{t+1},m_{t+1}^*,b_{t+1}, b_{t+1}^*, x_t, x_t^*, l_t, l_t^*, c_t, c_t^*, d_{t+1}, $d_{t+1}^*\}$ for $t = 0, ..., \infty$ such that: (a) households in each region maximize utility subject to their corresponding budget constraints and no-Ponzi game constraints, taking as given all fiscal policy variables as well as pre-tax prices and factor rental rates, (b) firms maximize profits subject to the Cobb-Douglas technology taking as given pre-tax factor prices, (c) the government budget constraints hold for given tax rates and exogenous sequences of government purchases and entitlements, and (d) the following market-clearing conditions hold in the global markets of goods and bonds

$$\phi\left(y_t - c_t - x_t - \frac{\eta}{2}\left[\frac{x_t}{k_t} - z\right]^2 k_t - g_t\right) + \left(y_t^* - c_t^* - x_t^* - \frac{\eta^*}{2}\left[\frac{x_t^*}{k_t^*} - z^*\right]^2 k_t^* - g_t^*\right) = 0, \tag{10}$$

$$\phi b_t + b_t^* = 0. \tag{11}$$

Optimality Conditions, Tax Distortions and International Externalities

The model yields four key optimality conditions that are helpful for characterizing the distortions induced by the taxes present in the model and their international externalities. The Euler equations for capital (excluding adjustment costs for simplicity), international bonds and domestic

$d_0 = pb_0 + \sum_{t=1}^{\infty}\left(\left[\prod_{i=1}^{t} q_i^s\right]\Gamma^t pb_t\right)$.

government bonds imply that the following arbitrage conditions hold:

$$\frac{(1+\gamma)u_1(c_t, 1-l_t)}{\beta u_1(c_{t+1}, 1-l_{t+1})} = (1-\tau_K)F_1(m_{t+1}k_{t+1}, l_{t+1})m_{t+1} + 1 - (1-\tau_K\theta)\delta(m_{t+1}) = R_t = R_t^g, \quad (12)$$

$$\frac{(1+\gamma)u_1(c_t^*, 1-l_t^*)}{\beta u_1(c_{t+1}^*, 1-l_{t+1}^*)} = (1-\tau_K^*)F_1(m_{t+1}^*k_{t+1}^*, l_{t+1}^*)m_{t+1}^* + 1 - (1-\tau_K^*\theta^*)\delta(m_{t+1}^*) = R_t = R_t^{g*}. \quad (13)$$

Because households in each region have access to the global market for bonds, the intertemporal marginal rate of substitution will be equalized across regions and will be equal to the rate of return on the international bond. Households in each region face a distortionary tax on the return to capital investment. Therefore, while the after-tax rate of return on capital is equalized across regions, the pre-tax return is not, and hence the capital stock and output differs across regions due to differences in capital taxation.[7] Arbitrage in asset markets implies that the price of external bonds and domestic public bonds are equalized. Hence, at equilibrium: $q_t = q_t^g = q_t^{g*}$.

As shown in Mendoza and Tesar (1995), unilateral changes in the capital income tax result in a permanent reallocation of physical capital, and ultimately a permanent shift in wealth, from the high-tax to the low-tax region. Thus, even tough physical capital is not mobile across countries directly, perfect mobility of financial capital and arbitrage of returns ends up inducing international mobility of physical capital. Note that in the long run, the global interest rate (the inverse of the bond price) is a function of β, γ and σ:

$$\frac{1}{q} = \frac{(1+\gamma)^\sigma}{\beta}, \quad (14)$$

and thus is invariant to tax rates. However, Mendoza and Tesar also showed that the interest rate does change along the transition path and alters the paths of consumption, output and international asset holdings. These dynamics will turn out to be important here as regions alter tax rates in an effort to reduce overall debt burdens.

The optimality condition for labor supply reflects the distortionary effects of the labor and

[7]As explained earlier, the equilibrium difference in pre-tax marginal product of capital is because we assume physical capital is immobile and all domestic capital is owned only by domestic agents. With cross-region ownership of capital, pre-tax marginal products would be equalized as well, and arbitrage would imply that at equilibrium with residence-based taxation the capital tax rates need to be the same.

consumption taxes:

$$\frac{u_2(c_t, 1-l_t)}{u_1(c_t, 1-l_t)} = \frac{(1-\tau_L)}{(1+\tau_C)} F_2(k_t, l_t) \tag{15}$$

A symmetric condition holds in the other region. Taxes on labor and consumption together drive a wedge between the marginal rate of substitution between leisure and consumption and the pre-tax real wage (which is equal to the marginal product of labor). In the full general equilibrium, however, the distortionary effect on allocations is larger for the labor tax than the consumption tax. Because the labor tax affects both the return to labor, which reduces an input into production, in addition to distorting the household's leisure-consumption trade-off. Despite the fact that labor is immobile internationally, changes in the labor tax rate potentially could have large spillover effects. An increase in the labor tax rate reduces the return to capital, changing the world interest rate and the allocation of capital, consumption and bond holdings across regions.

Finally, in this setup the elasticity of the capital tax base also depends on how taxes affect incentives for capacity utilization. In particular, the optimal choice for capacity utilization implies:

$$(1-\tau_K)F_1(m_t k_t, l_t) = \left[(1-\theta\tau_K) + \eta\left(\frac{x_t}{k_t} - z\right)\right]\delta'(m_t) \tag{16}$$

This condition equates the after tax marginal benefit of utilization in the left-hand-side with the after tax marginal cost of utilization in the right-hand-side.

The after-tax marginal cost of utilization depends on the rate of utilization $\delta'(m_t)$ and the two terms in the brackets (a) the depreciation tax allowance and (b) the marginal cost of investment. The second effect has a sign that depends on Tobin's Q (in this model, $Q = 1 + \eta\left(\frac{x_t}{k_t} - z\right)$). If Q is greater than 1, i.e. $\eta\left(\frac{x_t}{k_t} - z\right) > 0$, so that the desired capital stock is higher than the actual one and investment needs to rise, the higher-than-one Tobin Q increases the marginal cost of utilization (because higher utilization means higher depreciation, which makes it even harder to attain the higher target capital stock). The opposite happens when Q is lower than 1, i.e. $\eta\left(\frac{x_t}{k_t} - z\right) < 0$, because in this case the faster depreciation at higher utilization rates makes it easier to run down the capital stock and reach its lower target level.

Notice that with a full depreciation allowance (plus the implicit assumption that capital utilization does not incur any additional costs that do not have a full tax allowance), the capital income tax does not distort the decision on capacity utilization (i.e. it does not introduce a first-order wedge between marginal costs and benefits of utilization) around the steady state ($\eta\left(\frac{x_t}{k_t} - z\right) = 0$). The level of utilization will differ for different tax rates because the marginal product of capital (i.e. the marginal benefit of utilization) will differ, but this is a second order effect, not a distortion on the utilization decision margin. With less than full allowance (or with other utilization costs that are not tax-advantaged) this is not true. In our setup, in particular, the fact that the depreciation rate is increasing and convex in m_t and the concavity of the production function imply that for $0 \leq \theta < 1$, an increase in the capital income tax rate reduces the rate of utilization. Moreover, this is also approximately true outside the steady state, where the distortion term that would remain if $\theta = 1$ would be $\eta\left(\frac{x_t}{k_t} - z\right)/(1 - \tau_k)$. The full depreciation allowance would neutralize completely the distortion on the utilization decision margin via the depreciation allowance, but not via adjustment costs. The size of the distortion will depend again on whether the Tobin Q is higher or lower than 1, but higher capital tax will always distort more the utilization choice (e.g. if Q is below 1 by a given magnitude, so $\eta\left(\frac{x_t}{k_t} - z\right) < 0$, the marginal cost of utilization is lower at higher capital tax rates, making utilization increase more to induce faster depreciation).

Changes in utilization are an important feature of the model, because they imply that the government cannot treat the initial capital stock as a fully inelastic source of taxation. If the effective capital services employed in production decline with the capital tax, then even when the capital stock is pre-determined, the base of the capital income tax contracts. This strengthens the mechanisms by which capital income taxes induce efficiency losses in this model. But incentives for utilization resulting from changes in taxes can also work in the opposite direction (as is the case for example when the capital stock is outside steady state), so it is necessary to study further the utilization decision and its effects on tax revenues.

4 Calibration and Pre-Crisis Fiscal Policy

We set 2008 as the year in which the fiscal crisis started, and calibrate the model using Eurozone data from that year for the 15 largest countries (Cyprus and Malta are excluded). Table 1 shows key statistics for expenditures and fiscal variables as shares of GDP for each country in the sample. The last two columns show regional GDP-weighted ratios for the two regions that are the focus of our analysis: the GIIPS region (Greece, Ireland, Italy, Portugal and Spain) and the EU10 region, for the remaining ten countries. The GIIPS group accounts for roughly one-third of the combined GDP of the 15 countries.

The first three rows of Table 1 show estimates of effective tax rates on consumption, labor and capital calculated from revenue and national income accounts statistics following the methodology introduced by Mendoza et al. (1994) (MRT). These tax rates have been widely used in a number of studies including Carey and Tchilinguirian (2000), Sorensen (2001) and recently by Trabandt and Uhlig (2009) and Trabandt and Uhlig (2012). The MRT methodology uses the wedge between reported pre-tax and post-tax macro estimates of consumption, labor income and capital income to infer the effective tax rate levied on each of the three tax bases. There are several advantages to using this methodology to construct macro estimates of effectives tax rates. First, this methodology provides a fairly simple approach to estimating effective tax rates at the macro level, despite the complexity of the various credits and deductions of national tax systems. Second, the taxes computed here correspond directly to the tax distortions in the model, which is a representative-agent model with taxes on consumption and factor incomes. Finally, the taxes are reasonably close to estimates produced by the OECD and other sources that use more details from the tax code than our method. The main disadvantage of the MRT tax rates is that they are average tax rates, not marginal tax rates, but because we study a representative-agent economy, this disadvantage is less severe than it would be in a model with heterogeneous agents and firms. Moreover Mendoza et al. (1994) show that existing estimates of aggregate marginal tax rates have a high time-series correlation with the MRT effective tax rates, and that both have similar cross-country rankings.

Following Trabandt and Uhlig (2009), we modify the MRT methodology for computing labor and capital taxes by adding supplemental wages (i.e. employers' contributions to social security and private pension plans) to the tax base for personal income taxes. These data were not available at the time of the MRT 1994 calculations and, because this adjustment affects the calculation of the personal tax rate, it alters the estimates of both the labor and capital income taxes. In general, this adjustment makes the labor tax base bigger and therefore the labor tax rate smaller than our previous estimates.[8]

Table 1 shows that 2008 tax rates were not very different across EU10 and GIIPS, which reflects the effects of the series of tax harmonization treaties and directives that the European Union has adopted since the 1960s, and also the potential effects of competition in corporate income taxation. Consumption and labor tax rates are slightly higher in EU10 than in GIIPS (0.18 v. 0.14 for consumption and 0.36 v. 0.33 for labor), and capital taxes are just a notch higher in GIIPS than in EU10 (0.21 v. 0.20). In contrast, these tax structures differ sharply from those of non-European industrial countries (see Mendoza et al. (1994) and Mendoza, Milesi and Asea (1997) for detailed international comparisons of tax systems across all OECD industrial countries). This relative homogeneity of the pre-fiscal-crisis tax systems is worth noting, because the relative size of debt shocks differs sharply across GIIPS and EU10 (see below), and hence the numerical experiments conducted in the next Section focus on tax adjustments in response to heterogeneous public debt shocks across countries starting from relatively homogeneous tax systems.

The GIIPS region has higher consumption and investment GDP shares than EU10 by 4 and 3 percentage points respectively. Their government expenditure shares (purchases of goods and services, excluding transfers) are about the same, at one-fifth of GDP. These three ratios of demand components of GDP are fairly stable over time, so using 2008 or time-series averages for the calibration makes little difference. This is not true, however, for net exports, which on average over 1995-2011 were -0.1 percent for GIIPS but as of 2008 were -3 percent. The latter would grossly over-estimate the long-run net foreign asset position if we calibrate the model to a pre-crisis steady state trade deficit of that magnitude. Hence, for net exports we use the 1995-2011 average ratio and set it to zero for simplicity, so there is balanced trade within the Eurozone members at the pre-crisis stationary equilibrium. Examining the countries individually, GIIPS countries tend to have trade deficits with the exception of Ireland, and in EU10 Germany and the Netherlands have

[8]Trabandt and Uhlig make a further adjustment to the original Mendoza, Razin and Tesar formulas by attributing some of the operating surplus of corporations and non-incorporated private enterprises to labor, with the argument that this is the return to entrepreneurs rather than to capital. While in principle this could be true, it is not obvious how much of the operating surplus should be allocated to labor. In the absence of additional information about the source of the operating surplus, we chose not to make this particular adjustment.

large trade surpluses that influence signficantly the GDP weighted average for EU10. Note, however, that these trade balances include all external trade of the Eurozone countries, not just within the Eurozone.

In terms of fiscal flows, Eurostat data on total tax revenues and total government outlays (including both expenditures and transfer payments) shows that both revenues and outlays are slightly higher in EU10 than GIIPS, by 3 and 2 percentage points respectively. The gap between revenues and expenditures, however, is about the same in both regions.

In short, looking at all the national account expenditure ratios and fiscal flow ratios we see that, as was the case with the tax rates, the two regions are fairly homogeneous. The two key elements of heterogeneity that are present in this exercise are the size of the debt shocks each region experienced and the relative size of the two regions. In terms of relative size, the GIIPS GDP was about half the size of the EU10 GDP in 2008 (the ratio was 0.544). Hence, the GIIPS share in the two regions aggregate output was about a third. This difference in country size will play an important role in driving the size of the cross-country externalities of tax policy, as shown in the next section.

The bottom panel of Table 1 reports government debt-GDP ratios and their change between end-2007 (beginning of 2008) and 2011. As described in the Introduction, we define these differences as the "debt shocks" that each region experienced, and hence they are a key statistic for the quantitative experiments. Government debt-GDP ratios correspond to general government, consolidated gross debt as reported by Eurostat. These are the debt ratios used to measure compliance with the Maastricht Treaty. Under the Treaty, Eurozone governments are to keep this ratio below 60 percent of GDP. As the table shows, debt levels between end-2007 and 2011 rose sharply. Only five countries were in compliance with the Maastricht limit, and all of the large European economies in both EU10 and GIIPS had debt ratios significantly higher than 0.6. The debt shock in EU10 amounts to an increase of 18 percentage points in the debt ratio (reaching a 79 percent debt ratio by 2011), while in GIIPS the ratio increased by 30 percentage points. (reaching a 105 percent debt ratio in 2011).

Table 2 lists all the calibrated parameter values and corresponding sources or targets. The parameter values that must be set include preference and technology parameters, and fiscal policy parameters. The model is calibrated to a quarterly frequency, and the calibration strategy proceeds as follows. For technology parameters, the labor share of income is set to 0.61. The quarterly rate of labor-augmenting technical change, γ, is 0.002, which corresponds to the 0.9 percent annual average growth rate in real GDP per capita observed in the Euro area between 2000 and 2011 based on Eurostat data. The investment-adjustment cost parameter, η, is set to 2, which is consistent with estimates of the elasticity of investment in response to changes in the capital tax rate in House and Shapiro (2008). The long-run capacity utilization rate is normalized to $\bar{m} = 1$. Given $\gamma = 0.002$ and the observed investment- and capital-output ratios from the data, the steady-state law of motion of the capital stock ($x/y = (\gamma - \delta(\bar{m}))k/y$) implies a depreciation rate of $\delta(\bar{m}) = 0.0175$ quarterly.[9] The value of χ_0 follows from the optimality condition for utilization at steady state, together with the capital share and the capital-output ratio, which yields $\chi_0 = (1-\alpha)/(k/y) = 0.027$. Given this, the value of χ_1 follows from the definition of the depreciation rate function ($\chi_0 \bar{m}^{\chi_1}/\chi_1 = 0.0175$), which implies $\chi_1 = \chi_0/0.0175$ =1.62. Finally, the relative size of the two regions is set to $\phi = 0.54$ which is the ratio of GIIPS GDP to EU10 GDP in 2008 (i.e. the region weights are 0.35 for GIIPS and .65 for EU10).

For preference parameters, the coefficient of relative risk aversion, σ, is set equal to 2, the standard parameter in DSGE models. The Frisch elasticity of labor supply $a = 2.675$ is from Mendoza and Tesar (1998). This supports a labor allocation of 18.2 hours, which is in the range of the 1993-1996 averages of hours worked per person aged 15 to 64 in France (17.5), Germany (19.3) and Italy (16.5) reported by Prescott (2004). Given the rest of the parameters and the capital-output ratio, the value of β is determined by solving the steady-state Euler equation, which reduces to $(k/y) = \frac{\beta(1-\tau_k)(1-\alpha)(\chi_1-1)}{\chi_1(1+\gamma-\beta)}$. This yields $\beta = 0.991$. The values of β, γ and σ pin down the steady-state real interest rate, $R = \beta^{-1} - \gamma\sigma = 1.0051$, which is about 2 percent per annum.

The fiscal policy parameters include each region's capital, labor and consumption tax rates and the share of government expenditures in GDP (all of which are taken from Table 1) and the

[9] Investment rate data are from the OECD National Income Accounts and capital-output ratio data are from the AMECO database of the European Commission.The 2008 GDP-weighted average investment rate across the GIIPS and EU10 is x/y =0.225, and the 2007 average capital-output ratio is k/y =2.97 (which is also the average over the 2000-2008 period).

limit on the depreciation tax allowance θ. As explained in the previous section, this limit reflects the fact that tax allowances for depreciation costs apply only to capital income taxation levied on businesses, not individuals, and do not apply to residential capital (which is included in k). Hence, the value of θ can be approximated as $\theta = (REV_K^{corp}/REV_K)(K^{NR}/K)$, where (REV_K^{corp}/REV_K) is the ratio of revenue from corporate capital income taxes on total capital income tax revenue and (K^{NR}/K) is the ratio of non-residential fixed capital on total fixed capital. Using 2007 data from OECD *Revenue Statistics* for revenues and from the European Union's *EU KLEMS* database for capital stocks for the six countries with enough data coverage (Austria, Finland, Germany, Italy, Netherlands and Spain), these ratios range from 0.39 to 0.48 for (REV_K^{corp}/REV_K) and from 37 to 46 percent for (K^{NR}/K). Weighting by GDP, the average limit on the depreciation allowance θ is 0.22.

Table 3 compares 2008 GDP ratios of key macro-aggregates in the data with the model's balanced-growth, steady-state allocations for the GIIPS and EU10 regions. Effectively, in this comparison we treat the 2008 data observations as if they corresponded to the model's pre-crisis long-run equilibrium. As we explained earlier, we could use time-series averages from the data, but the expenditure shares of consumption, investment and government purchases have been relatively stable in the data, while fiscal flows have been trending upward, and for this reason we opted for using the 2008 observations. The ratios marked with an asterisk are identical in the data and the model by design, because they were used as calibration targets. The small differences in the other ratios across model and data suggest that the model is doing a good job at capturing the pre-fiscal-crisis scenario as the initial balanced-growth stationary state.

5 Quantitative Analysis

The quantitative experiments in this section illustrate the effects of alternative tax policy responses to observed debt shocks. We conduct two sets of experiments. First, we examine the effects of unilateral increases in GIIPS tax rates, looking at the effects on equilibrium allocations and prices as well as social welfare in both regions, and comparing with the autarky case.[10] Second, in light of the externalities implied by unilateral tax changes and the fact that both regions experienced debt shocks, we study the solutions of cooperative and non-cooperative tax competition games in which both GIIPS and EU10 are required to increase the present value of their primary balances to offset the observed debt shocks. In all of the experiments, we perturb the pre-crisis stationary equilibrium used for the baseline calibration by increasing the initial outstanding debt of one or both regions by the amount of the observed debt shocks in a once-and-for-all, unanticipated fashion. To be precise, in the case of GIIPS, the debt shock is introduced as an increase of 30 percentage points in the initial condition d_0/y_{-1} in the intertemporal government budget constraint (equation 8). The levels of g_t and e_t remain constant at their pre-crisis levels, but note that their present values in terms of GDP ratios change because of changes in equilibrium interest rates and transitional GDP growth.

It is important to note that, because the two regions are fully integrated in goods and asset markets, we need to solve jointly for the equilibrium transition paths of allocations and prices in each economy and for the new, post-tax-change steady-state equilibrium. In a closed economy, the new steady state is a relatively straightforward solution of steady-state conditions under the new tax policy that can be solved independently of transitional dynamics. In an open economy, however, adjustments along the transition involve international borrowing and lending that in turn affect the long-run net foreign asset positions of each region and induce changes in all other macro-aggregates, and hence affect steady-state equilibrium allocations and prices. For this reason, we use the solution method proposed by Mendoza and Tesar (1998) that employs a standard perturbation algorithm nested within a shooting algorithm. The shooting algorithm iterates on the long-run net foreign asset position until the asset positions conjectured as candidates for the new long-run equilibrium match those to which the model converges when simulated forward to its steady state (see Mendoza and Tesar, 1998, for details).

[10] We could also perform the symmetric analysis and study unilateral changes in EU10 tax rates, but since we showed that in the baseline calibration the two regions have similar parameters, the results would be qualitatively similar (but quantitatively different because of the smaller debt shock and larger size of the EU10 region).

5.1 Unilateral Tax Increases and Net Revenue Laffer Curves

Before introducing the debt shocks, we start by examining the overall capacity of the GIIPS capital and labor taxes to raise revenue and increase the present value of its primary fiscal balance. We construct "Net Revenue Laffer Curves" that map values of τ_K or τ_L into the associated equilibrium present discounted value of *total* tax revenue, net of the present value of the unchanged government purchases and outlays (i.e. net revenue is also the primary fiscal balance), all expressed as a ratio of pre-crisis output (y_{-1}). This is done so that the vertical axis of the Laffer curves corresponds exactly to the right-hand-side of the intertemporal government budget constraint (8), and thus shows the amount of initial debt that particular values of τ_K or τ_L can support in a world competitive equilibrium when GIIPS taxes vary unilaterally.[11] Since EU10 is affected by positive revenue externalities of GIIPS tax hikes and the GIIPS Laffer curves consider only the GIIPS debt shock, we need to make an adjustment in EU10 so as to keep the present value of its primary balance unchanged. This can be done by increasing transfers or reducing distortionary taxes, since the latter yields higher welfare, we assume that EU10 maintains primary-balance neutrality by lowering τ_L^*.

Figure 1 illustrates the net revenue Laffer curves for τ_K in GIIPS in autarky (the closed-economy dotted line) and in the open-economy case (the solid line). The vertical line shows the pre-crisis GIIPS capital tax rate of 21 percent, which supports the initial observed debt ratio of 75 percent (see Table 1). To restore fiscal solvency, GIIPS needs a capital tax rate that increases the ratio of the present value of the primary balance to GDP by 0.3, so as to support the debt ratio after the debt shock (1.05).

Figure 1 shows that for GIIPS as an open economy there is no value of τ_K that can restore fiscal solvency. The maximum point of the net revenue Laffer curve is attained with a tax rate of 0.34, with a maximum present value of net revenue as a share of output of about 0.89. Thus, the largest increase in the ratio of the present value of the primary balance to GDP that can be produced is about 14 percentage points, well below the required 30. The reason is that the international tax externalities move sharply against the GIIPS region when it increases τ_K. As we show below in

[11]Since we maintained $g_t + e_t$ constant at the pre-crisis levels and equilibrium interest rates display relatively small movements, these Laffer Curves display the same shape as standard dynamic Laffer curves that map taxes into the present value of total revenue.

reviewing the transitional dynamics of raising τ_K to the maximum point of the Laffer curve, the widening of the tax differential on capital between EU10 and GIIPS induces a reduction in the capital stock in GIIPS and an expansion in EU10. Returns to labor are also affected, and so the tax bases of both the labor and the capital tax expand in EU10 and shrink in GIIPS.

The GIIPS net revenue Laffer curve for τ_K under autarky is steeper than the open-economy one at the pre-crisis tax rate, and it peaks at a higher tax rate than when GIIPS is an open economy (i.e. the closed-economy curve sits higher than in the open-economy case). Thus, in autarky, GIIPS can obtain significantly higher present value of net revenue at tax rates around the maximum point of the open-economy Laffer curve. The peak of the GIIPS Laffer curve under autarky is slightly above the required extra present value of primary balance of 0.30. Interestingly, at about the same 34 percent capital tax rate at which the open-economy GIIPS Laffer curve yields the most revenue (but far below the required target to support the increased debt) the autarky economy can generat just enough revenue support the 1.05 post-shock debt ratio.

The fact that the GIIPS region can generate more revenue per percent increase in τ_K if the economy is closed than open shows that evaluating "fiscal space," or the capacity to raise revenue, without taking into account factor mobility and international tax externalities leads to substantial overestimates of the effectiveness of tax hikes as a tool to restore fiscal solvency. It also suggests that, by focusing on unilateral tax austerity alone, the countries that have heavier outstanding debt burdens will have non-trivial incentives to consider moving to autarky, imposing capital controls and/or trade barriers, or repudiating their debt.

Table 4 summarizes the effects that result from an unilateral increase in the GIIPS τ_K to the maximum point on the open-economy net revenue Laffer curve (34 percent). In this scenario, the EU10 maintains primary-balance neutrality in the presence of the positive revenue externality from the tax hike in GIIPS by lowering τ_L^* from 0.36 to 0.34. Since the GIIPS capital tax rate increases by 13 percentage points, and this tax is highly distorting, GIIPS experiences a very large welfare cost of 6.63 percent, while EU10 obtains a non-trivial gain of 1.01 percent.[12]

[12]Welfare effects are computed as in Lucas (1987), in terms of a percent change in consumption constant across all periods that equates lifetime utility under a given tax policy change with that attained in the pre-fiscal-crisis steady state. We report the overall effect, which includes transitional dynamics across the pre- and post-crisis steady states, as well as a comparison across steady states only.

Comparing GIIPS outcomes as open (first two columns of Table 4) v. closed economy (last two columns) with the same 34 percent capital tax rate, we find that GIIPS as a closed economy increases the present value of its primary balance by 31 percentage points, more than twice as in the open-economy case and 1 percentage point above what is needed to offset the debt shock. The welfare loss is nearly the same (6.6 percent), but normalizing by the amount of revenue generated, the GIIPS region is much better off in autarky. This result can also be illustrated in a slightly different experiment by computing the value of τ_K in GIIPS as a closed economy that yields the same 14 extra percentage points of present value of the primary balance that GIIPS attained as an open economy with τ_K set to 34 percent. As Figure 1 shows, GIIPS as a closed economy can do this with a 24 percent tax rate, which carries a much smaller welfare cost than the 6.66 percent for GIIPS as an open economy. Again, if fiscal austerity focuses on capital taxes, GIIPS would be much better off under autarky, and hence the region has strong incentives to move in that direction.

The impact and long-run effects on key macro-aggregates in both GIIPS and EU10 are shown in the bottom of Table 4. The corresponding transition paths as the economies move from the pre-crisis steady state to the new steady state are illustrated in Figure 2. The increase in τ_K in GIIPS causes a steady drop in k over time, which results in decline of 28.5 percent relative to the pre-crisis level, while k^* in EU10 rises gradually to converge to a level 3.1 percent higher than in the pre-crisis equilibrium. Capacity utilization falls sharply initially in GIIPS, which drives the higher elasticity of the base of capital income taxation due to the combination of endogenous utilization and partial depreciation tax allowance. Initially, labor increases in GIIPS and decreases in EU10, but this pattern reverses as the economy transitions to steady state, because of the lower (higher) capital stock in GIIPS (EU10) in the new steady state. GIIPS reduces its NFA position by running substrantial trade surpluses in the early stages of transition, while EU10 increases its NFA position by running deficits (which are smaller in absolute value because of the larger relative size of EU10 v. GIIPS).

Most of the additional tax revenue in GIIPS is generated in the initial phase of the transition, before its tax bases are eroded by the adverse effects of the higher distortion on capital accumulation and the international externalities. The more elastic the response of capital, the less revenue can be generated from the hike in tax rates, because the tax bases are eroded faster. Hence, the capital adjustment cost and the endogenous utilization rate also play an important role in these results. The EU10 region enjoys an increase in its revenue bases, which allows it to cut its labor tax and still generate the same present value of primary balance as in the pre-crisis steady state. If EU10 kept its tax rates unchanged, it would see its primary balance increase by 0.09, halfway to its revenue target with only a slight utility fall of 0.06 percent.

The 1 percent welfare gain that the EU10 obtains because of the positive externalities from the capital tax hike in GIIPS is largely overlooked in current discussions of fiscal adjustment in Europe. GIIPS can raise more revenue by increasing τ_K along the upward-sloping region of its net revenue Laffer curve, but its ability to do so is significantly hampered by the adverse externality they face through the erosion of its tax bases. The same externality indirectly improves government finances, or reduces the distortions associated with tax collection, in the EU10 region and provides it with an unintended welfare gain.

Figures 3 and 4 and Table 5 show the results now for an increase in the GIIPS labor tax rate. The results are more positive in terms of the ability of GIIPS to raise revenue and restore fiscal solvency in response to the debt shock. The open-economy Laffer curve for τ_L (Figure 3) is considerably steeper than for the capital tax rate. Starting from a pre-crisis tax rate of 0.33 on labor, the open-economy Laffer curve peaks at a tax rate of 0.51 with a present value of net revenue above 1.3, well above the 1.05 needed to match the post-crisis initial debt. The exact tax rate that the open-economy GIIPS would need to support the 1.05 debt ratio is about 38 percent, and just a little less for GIIPS as a closed economy. This is because the open- and closed-economy Laffer curves are much closer to each other than in the case of the capital tax experiment, even though again the close-economy curve is higher and shifted to the right.

Table 5 shows results for an increase in the labor tax that raises the present value of the primary fiscal balance by the same magnitude as in the capital tax experiment of Table 4 (0.14). This is done, instead of considering the labor tax at the maximum point of the open-economy GIIPS Laffer curve, or the labor tax that would offset exactly the debt shock, so as to make the results in Tables 4 and 5 comparable. The required increase τ_L is only 2 percentage points, from 33 to 35 percent.

This yields much smaller declines in steady state output, consumption, capital and the investment rate than in the capital tax case. The welfare cost is also much smaller, although still sizable, at 1.3 percent. The gap in the increase of the present value of the primary balance in the results in GIIPS closed v. open economy is almost neglible, in contrast with the wide gap obtained for the capital tax.

Taken together these findings are consistent with two familiar results from tax analysis in representative-agent models that emphasize the efficiency costs of tax distortions. First, the capital tax rate is the most distorting tax. Second, in open-economy models, taxation of a mobile factor (i.e. capital) yields less revenue at greater welfare loss than taxation of the immobile factor (i.e. labor). But the more important finding is that unilateral increases in GIIPS capital and labor taxes that attempt to yield the required extra 30 percentage points of present value of the primary balance to offset the debt shock would lead the GIIPS region to prefer autarky, or be nearly indifferent. With capital taxes, GIIPS as an open economy cannot restore fiscal solvency, while under autarky it can, but with a capital tax of about 34 percent at a welfare cost of 6.6 percent. With labor taxes, GIIPS needs about a 38 percent labor tax either as an open economy or under autarky to offset the fiscal shock, with a welfare cost of 4 percent, and in the open economy scenario it would also produce a 0.2 percent welfare gain for EU10.

One could repeat the tax experiments conducted here for the case when EU10 increases its tax rates while GIIPS remains passive. These results are not reported here as the basic message of the analysis is similar, and there is little heterogeneity in the pre-crisis baseline calibration parameters. In EU10 unilateral tax experiments, the tax hikes are costly in terms of efficiency and welfare for EU10 and there are gains for GIIPS with unchanged taxes and ignoring its debt shock. Further, the revenue gains for GIIPS would be sizable. Finally, the revenue increases are always larger in the closed economy than in the open economy, particularly in the case of capital taxation. The differences are only that EU10 has a smaller debt shock to offset, which would weaken the effects documented in the unilateral GIIPS tax change experiments, and that the EU10 is about twice the size of the GIIPS, which affects the size of the tax externalities.

In the experiments considered thus far, the countries in the GIIPS region are assumed to change tax policy in concert. Table 6 examines the implications of tax policy adjustments for each country in the GIIPS region acting unilaterally. In each scenario, we solve the model resetting the parameter controlling the relative size of the two economies in the model so that the home country has the size of a particular GIIPS country and the foreign remains the EU10. Intuitively, each country in GIIPS treated in this way becomes much smaller than when grouped into the GIIPS region, and the effect of a domestic tax policy change on international prices will be correspondingly smaller. This in turn means that the impact on domestic capital outflow is greater, and thus the ability to raise revenue weakens considerably. This is reflected in the peaks of the Laffer curves listed in Table 6, which show the maximum increase in the present discounted value of the primary balance that can be raised by each GIIPS country individually using capital or labor taxes. None of the countries can restore fiscal solvency with a capital income tax hike (i.e. the peaks of the Laffer curves are smaller than the debt shocks), and two of the five countries are unable to do it even with the labor tax. Note also that Greece and Ireland experienced debt shocks that are much higher than the GDP-weighted GIIPS regional average of 0.3.

5.2 Strategic Tax Responses to Debt Shocks

The findings from the analysis of unilateral tax changes suggest that there is scope for strategic interaction and potential gains from coordination. The results show that a region that lowers its capital tax rate relative to the other moves tax externalities in its favor, thus lowering the burden of fiscal adjustment in response to debt shocks. But the governments of both regions are aware of this externality, and thus have the incentives to engage in tax competition.

To analyze strategic interaction, we study one-shot cooperative and non-cooperative games in which each region uses both capital and labor tax instruments to respond to their corresponding debt shocks. The strategy space is defined in terms of vectors of possible capital tax rates of each region. For each given pair of capital tax rates (τ_K, τ_K^*) in this strategy space, we solve for the pair of labor tax rates (τ_L, τ_L^*) that allows each region to increase revenues so that its present value of the primary balance at the corresponding competitive equilibrium increases as needed to restore solvency after the debt shocks — 30 percentage points for GIIPS, 18 for EU10.[13] The games are played once, but the payoffs are dynamic, because they take into account the full transitional dynamics from the pre-crisis competitive equilibrium to the new stationary equilibrium of a particular set of capital and labor taxes.

The technical characterization of the strategy space and the game we solve is as follows: Each region chooses its capital tax rate so as to maximize the payoff to its residents taking as given the other region's taxes and subject to the constraints that:

(a) The implied allocations and prices for an European-wide tax structure given by the pairs $(\tau_K, \tau_L), (\tau_K^*, \tau_L^*)$ with unchanged consumption taxes are a competitive equilibrium.

(b) Labor taxes in each region adjust so that intertemporal government budget constraints (equation 8) support increases in the present value of the primary fiscal balances equal to each region's debt shock (30 percentage points for GIIPS and 18 for EU10).

Each region chooses its capital tax rate from values in discrete grids with M and N nodes for GIIPS and EU10 respectively: $T_K = [\tau_{K1} < \tau_{K2} < ... < \tau_{KM}]$, $T_K^* = [\tau_{K1}^* < \tau_{K2}^* < ... < \tau_{KN}^*]$. Hence, the strategy space is the set of $M \times N$ capital tax rate pairs. For each pair, we compute prices and allocations that satisfy conditions (a) and (b) and the associated welfare payoffs. The payoff function for GIIPS's strategic choice of τ_K given τ_K^* is denoted $V(\tau_K|\tau_K^*)$.The corresponding EU10 payoff function is denoted by $V^*(\tau_K^*|\tau_K)$. Given these definitions, the GIIPS reaction curve is defined by the mapping $\tau_K(\tau_K^*) = \arg\max_{\tau_K} [V(\tau_K|\tau_K^*)]$ and the one for the EU10 is $\tau_K^*(\tau_K) = \arg\max_{\tau_K^*} [V^*(\tau_K^*|\tau_K)]$ .The Nash non-cooperative equilibrium is given by the tax rate pair (τ_K^N, τ_K^{N*}) at which these reaction functions intersect (that is $\tau_K^N{=}\tau_K(\tau_K^{N*})$ and $\tau_K^{N*}{=}\tau_K^*(\tau_K^N)$). Thus, the Nash equilibrium represents the capital tax pair at which the capital tax GIIPS (EU10) takes as given from EU10 (GIIPS) when choosing its own optimal capital tax is also the tax that EU10 (GIIPS) finds optimal to choose.

Figure 6 shows the reaction functions in (τ_K, τ_K^*) space and identifies the Nash and pre-crisis

[13] The regions could also use the consumption tax or both labor and consumption taxes to restore fiscal solvency, but for tractability we consider only labor taxes. In the sensitivity analysis we conduct later we examine the alternative in which the consumption tax is used instead. The case using the labor tax is perhaps more relevant, because of the VAT harmonization treaties that limit the Eurozone member countries from unilaterally changing consumption taxes.

equilibria. Table 7 shows the corresponding tax rates, welfare outcomes, and changes in the present value of primary balance. Both reaction functions have a negative slope. This is because of the positive externalities through the reallocation of capital and the adjustment in labor supplies, which imply that the higher the foreign capital tax, the lower the optimal home tax choice, because it allows the home country to reduce tax distortions while still maintaining fiscal solvency. Starting from nearly identical tax rates on capital of 0.21 (GIIPS) and 0.2 (EU10) in the pre-crisis baseline calibration, Nash competition results in the familiar "race to the bottom" in capital taxes, to τ_K^N =0.104 in GIIPS and τ_K^{N*} =0.176 in EU10. Labor taxes increase from 0.33 to 0.442 in GIIPS and welfare declines relative to the pre-crisis equilibrium by 2.3 percent of trend consumption. Labor taxes increase in EU10 as well, from 0.36 to 0.426, and welfare falls by 3.8 percent.

Consider next a cooperative equilibrium in capital taxes. A cooperative equilibrium is defined as a pair (τ_K^C, τ_K^{C*}) such that: (1) it satisfies properties (a) and (b), and (2) the pair maximizes the payoff of a utilitarian European-wide social planner given by the weighted sum of the two regions' payoffs ($\lambda V(\tau_K|\tau_K^*) + (1-\lambda)V^*(\tau_K^*|\tau_K)$ for arbitrary weights λ and (1-λ)) subject to participation constraints that require each region to be at least as well off as under the Nash equilibrium: $V(\tau_K^C|\tau_K^{C*}) \geq V(\tau_K^N|\tau_K^{N*})$ and $V^*(\tau_K^{C*}|\tau_K^C) \geq V^*(\tau_K^{N*}|\tau_K^N)$. There can be several cooperative equilibria supported by different $\lambda's$, and the set of all cooperative equilibria determines the core of the players' contract curve. Note that these cooperative equilibria are still tax-distorted competitive equilibria, because cooperation internalizes the effects of the international tax externalities but does not remove domestic tax distortions.

Table 7 shows the ranges of welfare weights that support cooperative equilibria, along with the associated ranges of tax rates and welfare outcomes. In these cooperative equilibria, capital tax rates are higher than under Nash (about 0.16 for GIIPS in the average of the τ_K^C range and 0.22 in EU10), and labor taxes are lower and similar for the two regions at about 39-40 percent. By avoiding cutting capital taxes and raising labor taxes "too much," both regions benefit from cooperation, with welfare gains relative to the Nash outcome that range from 0.1 to 0.6 percentage points for both GIIPS and EU10.

While tax coordination prevents strategic interaction from inducing extra welfare costs, the welfare costs of adjusting taxes to offset debt shocks are still quite large in both Nash and cooperative outcomes. Relative to the pre-crisis tax structures, capital taxes are lower and labor taxes are higher in Nash equilibria after the debts shocks, because the governments are aiming to reduce the tax that is most distorting in terms of welfare cost per unit of revenue and also trying to undercut each other. The welfare costs of fiscal adjustment in the Nash equilibrium are 2.3 and 3.8 percent for the GIIPS and EU10 respectively. Under cooperation, the GIIPS capital tax is still lower than before the crisis, but the EU10 capital tax is higher, and the welfare costs in the cooperative equilibria range from 2.21 to 1.71 percent for GIIPS and from 3.66 to 3.15 for the EU10.

It is also worth comparing the outcome of Nash and Cooperative equilibria with the ouctome that each region could attain under autarky. The autarky scenarios show the choice of capital tax rate that yields the required extra revenue at the lowest welfare cost, using the labor tax as needed to satisfy the post-debt-schock intertemporal government budget constraint. Hence, these scenarios provide the value of the exit option for GIIPS and EU10. The results show that the value of tax adjustment to the debt schok under autarky is inferior to both the Nash and Cooperative outcomes for GIIPS but the opposite is true for the EU10. This finding suggests that a supply-side oriented re-structuring of tax systems to restore fiscal solvency by of lowering (increasing) capital (labor) income taxes across the Eurozone would strengthen the incentives of GIIPS countries to remain in the Eurozone but would weaken those of the EU10 countries. We have also seen, however, that the incentives could go in the opposite direction if tax changes go in favor of hiking (cutting) capital (labor) taxes and doing so more in the GIIPS region.

6 Conclusions

Public debt ratios surged between 2008 and 2011 across many key industrial countries, particularly in Europe and the United States. Public debt increased by a GDP-weighted average of 30 percentage points in the GIIPS region and in the EU10 by 10 percentage points. Assuming that defaults are to be averted (i.e. that fiscal solvency conditions will be maintained), and taking into account that these economies are highly integrated into world markets of goods and financial assets, raises two key questions for the analysis of the fiscal policy response to large debt shocks: First, is tax-driven adjustment feasible (i.e. are the required adjustments in the present value of the primary fiscal balance to match the higher debt ratios within the range of what Laffer curves can support)? Second, what would be the costs of non-cooperative tax competition trying to exploit the externalities to facilitate fiscal adjustment and what are the benefits of coordinating adjustment instead?

In this paper we provide answers to these questions using a two-country, Neoclassical model with fully specified tax systems. The workhorse model of this class has the unappealing feature that capital tax revenue is relatively inelastic, because of the ability to tax income generated from pre-determined initial capital and because the standard assumption of a 100 percent depreciation allowance. This results in unrealistic capital tax elasticities, which blur the picture of the potential difficulties faced when responding to large debt shocks with tax hikes and their cross-country externalities. Hence, we modify the workhorse model by introducing endogenous utilization of capital and a limited depreciation tax allowance, which is in line with the facts that these allowances in actual tax codes apply to taxes levied to business incomes, not capital income accruing to individuals (e.g. dividends, capital gains), and do not apply to residential capital.

We calibrate the model to detailed data for Eurozone countries, and find striking results. In particular, raising capital taxes unilaterally in GIIPS countries cannot produce enough revenue to offset their observed debt shock. Labor taxes can do it, but in both cases the adjustment entails large welfare costs and non-trivial externalities that favor the EU10. Moreover, in both scenarios GIIPS can offset the observed debt shocks at lower tax rates and welfare costs under autarky, which in the model provides them with a strong incentive to move in that direction or default in their debt obligations.

Non-cooperative Nash competition over capital taxes yields the well-known race to the bottom in capital tax rates, but because of the need to offset the debt shocks, the race ends with finite capital taxes (lower than pre-crisis taxes) and higher labor taxes. Cooperation reduces the size of the cut in capital taxes and hike in labor taxes, and makes adjustment slightly less costly, but still even in these scenarios, in both of which the cost of fiscal adjustment to large debt shocks is smaller than with unilateral policy changes, the cost of adjusment remains sizable.

The costs of adjusting to the large debt shocks are not only lower with either non-cooperative or cooperative tax adjustments than with unilateral changes, they are also lower than when GIIPS undertakes the adjustments under autarky. This is because the tax structure shifts sharply toward lower capital and higher labor taxation across Europe, and in models of the class we study this induces significant efficiency gains, and thus large welfare gains. This finding suggests that a supply-side oriented reform of tax systems in the Eurozone would have the unintended benefit of strengthening the sustainability of the currency union by offering member countries a less costly path to restoring fiscal solvency than the threat of reverting to autarky.

The analysis of this paper has clear policy implications that can inform policy debates. In Europe in particular, despite the fact that the European nations have closely integrated goods and financial markets, the policy discussions have proceeded largely without taking into account international ramifications of domestic tax policy adjustments. In the United States, the debt shock has been of similar magnitude as in Europe (about 22 percentage points hike in the debt ratio between 2008 and 2011), and the U.S. is highly integrated to world markets as well, so the lessons for Europe have relevance in pondering policy options in the United States.

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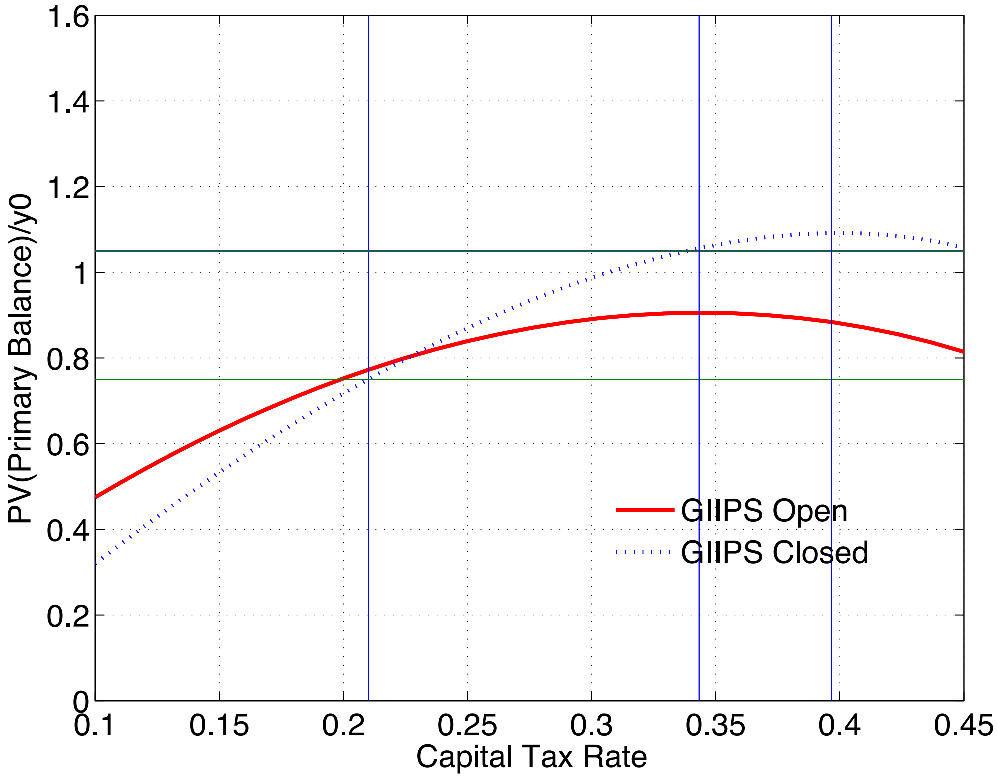
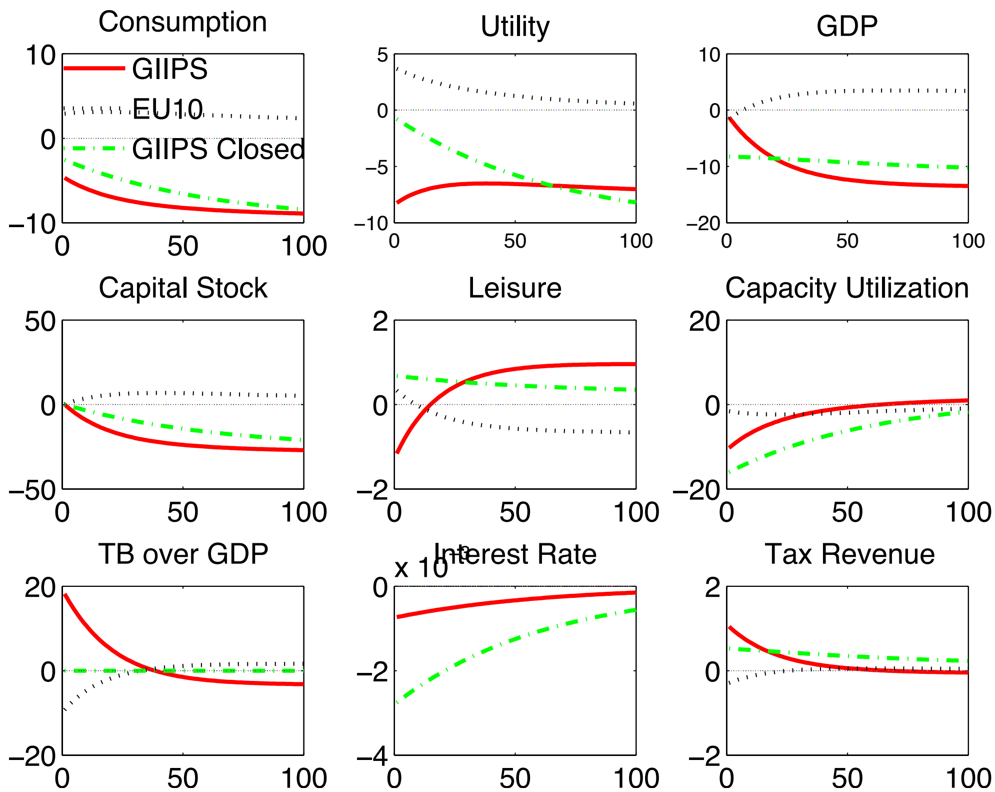
Figure 1: Net Laffer Curves for the GIIPS Capital Tax Rate



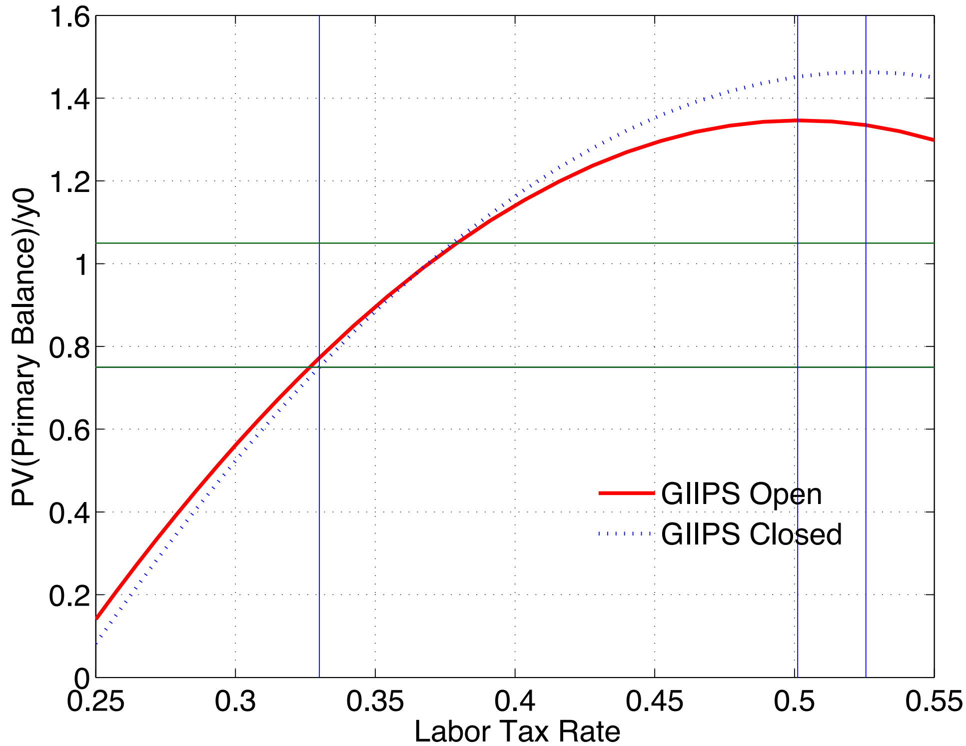
Notes: Net Laffer curves plot the equilibrium present value of total tax revenue net of the equilibrium present value of government spending and transfers as the capital tax rate changes.

Figure 2: Macro Responses to a Capital Tax Rate Increase in GIIPS



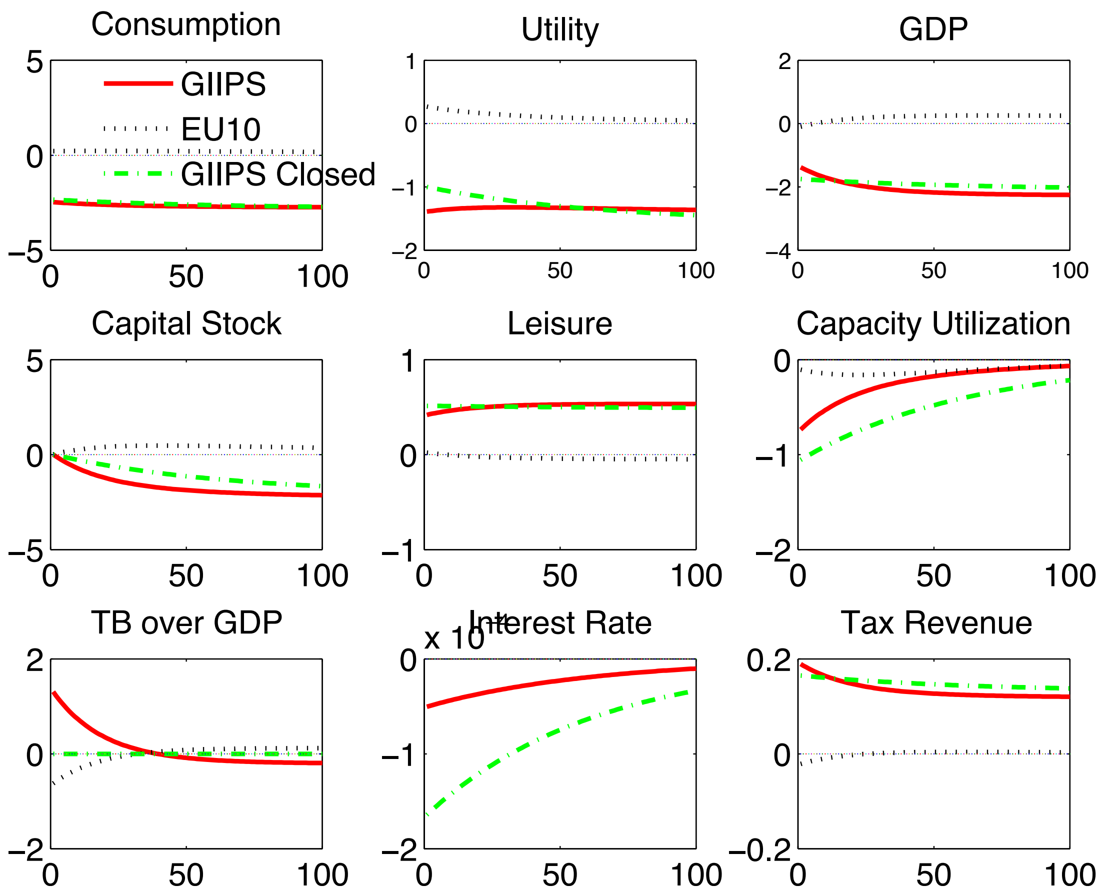
Notes: In this experiment, EU10's labor tax rate is adjusted from 0.36 to 0.346 to reserve its revenue neutrality. All variables are reported as percent changes from pre-crisis steady state except the lower panel, which are in percentage point differences from pre-crisis steady state.

Figure 3: Net Laffer Curves for the GIIPS Labor Tax Rate



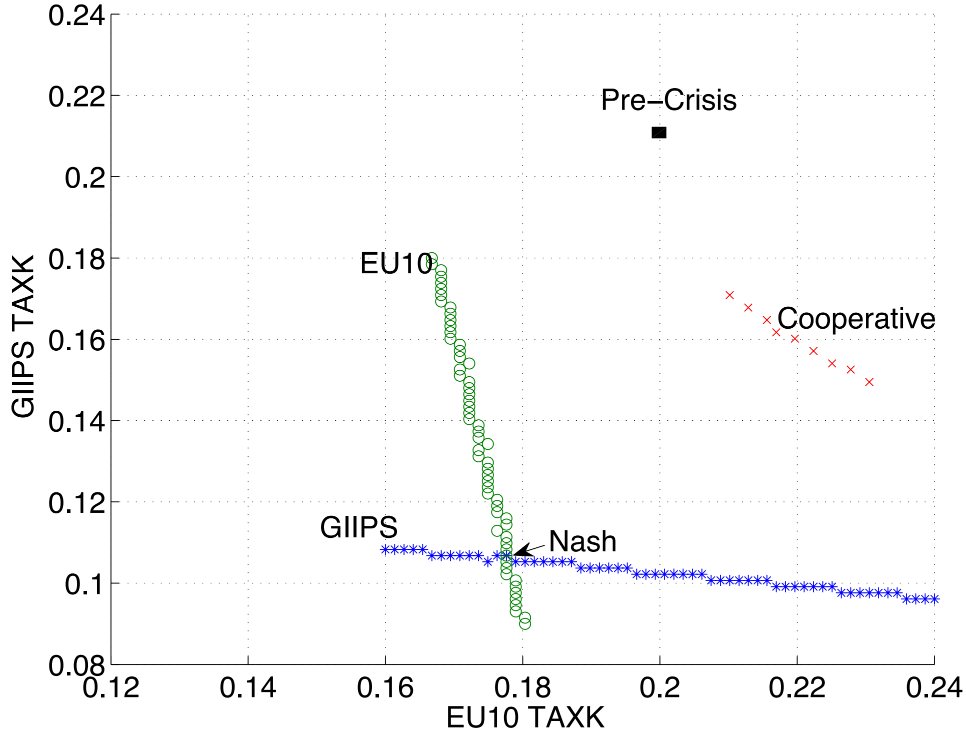
Notes: Net Laffer curves plot the equilibrium present value of total tax revenue net of the equilibrium present value of government spending and transfers as the labor tax rate changes.

Figure 4: Macro Responses to a Labor Tax Rate Increase in GIIPS



Notes: In this experiment, EU10's labor tax rate is adjusted from 0.36 to 0.359 to reserve its revenue neutrality. All variables are reported as percent changes from pre-crisis steady state except the lower panel, which are in percentage point differences from pre-crisis steady state.

Figure 5: Capital Tax Reaction Functions



Notes: Labor taxes are used to preserve solvency.

Table 1: MACROECONOMIC STANCE AS OF 2008 AND DEBT SHOCKS

	EU10										GIIPS					GDP-weighted ave.	
	AUT	BEL	EST	FIN	FRA	GER	LUX	NET	SLK	SLA	GRE	IRE	ITA	POR	SPA	EU10	GIIPS
(a) Macro Aggregates																	
τ_C	0.19	0.17	0.22	0.24	0.17	0.17	0.33	0.20	0.17	0.25	0.15	0.21	0.13	0.18	0.12	0.18	0.14
τ_L	0.42	0.37	0.26	0.37	0.36	0.34	0.33	0.36	0.32	0.34	0.33	0.23	0.38	0.23	0.29	0.36	0.33
τ_K	0.16	0.27	0.09	0.21	0.25	0.16	0.17	0.19	0.09	0.13	0.12	0.17	0.25	0.20	0.17	0.20	0.21
c/y	0.53	0.52	0.55	0.52	0.57	0.56	0.33	0.45	0.57	0.53	0.72	0.51	0.59	0.67	0.57	0.55	0.59
x/y	0.23	0.24	0.30	0.22	0.22	0.19	0.22	0.20	0.28	0.32	0.24	0.22	0.22	0.23	0.29	0.21	0.24
g/y	0.19	0.23	0.19	0.22	0.23	0.18	0.16	0.26	0.17	0.18	0.18	0.19	0.20	0.20	0.19	0.21	0.20
tb/y	0.06	0.01	−0.04	0.04	−0.02	0.06	0.30	0.08	−0.02	−0.03	−0.14	0.09	−0.01	−0.10	−0.06	0.03	−0.03
Rev$/y$	0.42	0.43	0.32	0.42	0.41	0.36	0.35	0.38	0.29	0.37	0.31	0.29	0.41	0.41	0.32	0.39	0.36
Total Exp$/y$	0.49	0.50	0.40	0.49	0.53	0.44	0.59	0.46	0.35	0.44	0.51	0.49	0.49	0.45	0.42	0.48	0.46
(b) Debt Shocks																	
d_{2007}/y_{2007}	0.60	0.84	0.04	0.35	0.64	0.65	0.07	0.45	0.30	0.23	1.07	0.25	1.03	0.68	0.36	0.62	0.75
d_{2011}/y_{2011}	0.72	0.98	0.06	0.49	0.86	0.81	0.18	0.65	0.43	0.47	1.71	1.08	1.20	1.08	0.69	0.79	1.05
$\Delta d/y$	0.12	0.14	0.02	0.14	0.22	0.15	0.12	0.20	0.14	0.24	0.63	0.83	0.17	0.40	0.33	0.18	0.30

Source: OECD Revenue Statistics, OECD National income Accounts, and EuroStat. Tax rates are authors' calculations based on Mendoza, Razin, and Tesar (1994). "Total Exp" is total non-interest government outlays.

Table 2: PARAMETER VALUES

Preferences:				
β	discount factor	0.992		steady state Euler equation
σ	risk aversion	2.000		standard DSGE value
a	labor supply elasticity	2.675		$\bar{l} = 0.18$ (Prescott, 2004)
Technology:				
α	labor income share	0.61		Trabandt and Uhlig (2009)
γ	growth rate	0.0022		real GDP p.c. growth of euro area (Eurostat 2000–2011)
η	capital adjustment cost	2		House and Shapiro (2008)
$\bar{m}$	capacity utilization	1		steady state normalization
$\delta(\bar{m})$	depreciation rate	0.0175		$x/y = 0.225$ and $k/y = 2.97$ (OECD and AMECO)
χ_0	capacity utilization	0.027		set to match $\delta(\bar{m})$ and $\bar{m}$
χ_1	capacity utilization	1.62		set to match $\delta(\bar{m})$ and $\bar{m}$
ϕ	country size	0.544		GIIPS' GDP share in Europe = 0.35
Fiscal Policy:		GIIPS	EU10	
g/y	Gov't exp share in GDP	0.20	0.21	OECD National Income Accounts
τ_C	consumption tax	0.14	0.18	MRT modified
τ_L	labor income tax	0.33	0.36	MRT modified
τ_K	capital income tax	0.21	0.20	MRT modified
θ	depreciation allowance limitation	0.22	0.22	$(REV_K^{corp}/REV_K)(K^{NR}/K)$

Note: REV_K^{corp}/REV_K is the ratio of corporate tax revenue to total capital tax revenue. K^{NR}/K is the ratio of nonresidential fixed capital to total fixed capital.

Table 3: BALANCED GROWTH ALLOCATIONS (GDP RATIOS) OF 2008

	GIIPS		EU10	
	Data	Model	Data	Model
c/y	0.59	0.57	0.55	0.56
x/y	0.24	0.23	0.20	0.23
g/y^*	0.20	0.20	0.21	0.21
tb/y	-0.03	0.00	0.03	0.00
Rev$/y$	0.36	0.35	0.39	0.36
d/y^*	0.75	0.75	0.62	0.62

Table 4: MACROECONOMIC EFFECTS OF AN INCREASE IN THE GIIPS CAPITAL TAX RATE

(EU10 maintains revenue neutrality with labor tax)

	Open Economy				Closed Economy	
	GIIPS		EU10		GIIPS	
Tax rates	Old	New	Old	New	Old	New
τ_C	0.14	0.14	0.18	0.18	0.14	0.14
τ_L	0.33	0.33	0.36	0.34	0.33	0.33
τ_K	0.21	0.35	0.20	0.20	0.21	0.35
Change in PV of primary bal. as a share of initial GDP		0.14		0.00		0.31
Welfare effects (percent)						
steady-state only		−7.02		0.06		−9.30
overall		−6.63		1.01		−6.63
Percentage changes	Impact Effect	Long-Run Effect	Impact Effect	Long-Run Effect	Impact Effect	Long-Run Effect
y	−1.27	−13.81	−1.54	3.11	−8.25	−11.20
c	−4.68	−9.33	2.90	1.92	−2.56	−9.94
k	0.00	−28.54	0.00	3.11	0.00	−26.37
Percentage point changes						
tb/y	18.21	−2.85	−9.26	1.28		
x/y	−18.26	−3.33	6.36	0.00	−8.81	−3.34
r	−0.00	−0.00	−0.00	−0.00	−0.00	0.00
$1-l$	−0.94	0.77	0.27	−0.56	0.55	0.22
m	−10.30	1.97	−1.60	−0.00	−16.03	1.96

Table 5: MACROECONOMIC EFFECTS OF AN INCREASE IN THE GIIPS LABOR TAX RATE

(EU10 maintains revenue neutrality with labor tax)

	Open Economy				Closed Economy	
	GIIPS		EU10		GIIPS	
Tax rates	Old	New	Old	New	Old	New
τ_C	0.14	0.14	0.18	0.18	0.14	0.14
τ_L	0.33	0.35	0.36	0.36	0.33	0.35
τ_K	0.21	0.21	0.20	0.20	0.21	0.21
Change in PV of primary bal. as a share of initial GDP		0.14		0.00		0.15
Welfare effects (percent)						
steady-state only		−1.38		0.01		−1.54
overall		−1.34		0.08		−1.36
Percentage changes	Impact Effect	Long-Run Effect	Impact Effect	Long-Run Effect	Impact Effect	Long-Run Effect
y	−1.38	−2.28	−0.10	0.23	−1.75	−2.09
c	−2.47	−2.77	0.21	0.15	−2.34	−2.81
k	0.00	−2.28	0.00	0.21	0.00	−2.09
Percentage point changes						
tb/y	1.31	−0.18	−0.62	0.09		
x/y	−1.10	0.00	0.43	0.00	−0.35	−0.00
r	−0.00	−0.00	−0.00	−0.00	−0.00	0.00
$1-l$	0.34	0.43	0.02	−0.04	0.42	0.40
m	−0.74	0.00	−0.11	−0.00	−1.06	−0.00

Table 6: PEAK INCREASE IN PRESENT VALUE OF PRIMARY BALANCE IN INDIVIDUAL GIIPS COUNTRIES

			Peak Rev Increase/y2008 of	
	Country Size	ΔDebt/y2008	Capital Tax Net Laffer Curve	Labor Tax Net Laffer Curve
Greece	0.026	0.63	0.05	0.48
Ireland	0.020	0.83	0.03	0.42
Italy	0.211	0.17	0.08	0.42
Portugal	0.019	0.40	0.05	0.42
Spain	0.137	0.33	0.07	0.44

Table 7: GAME OUTCOMES

	Pre-Crisis	Nash	Cooperative	Autarky
GIIPS				
τ_K	0.210	0.107	$[0.149, 0.171]$	0.166
τ_L	0.330	0.423	$[0.390, 0.392]$	0.400
ΔPV(Primary Balance)/Y		0.300	0.300	0.300
ΔWelfare v. pre-crisis		-2.282	$[-2.253, -1.653]$	-2.782
ΔWelfare v. Nash			$[0.028, 0.629]$	-0.500
EU10				
τ_K	0.200	0.178	$[0.231, 0.210]$	0.186
τ_L	0.360	0.424	$[0.398, 0.394]$	0.403
ΔPV(Primary Balance)/Y		0.180	0.180	0.180
ΔWelfare v. pre-crisis		-3.768	$[-3.723, -3.117]$	-2.538
ΔWelfare v. Nash			$[0.045, 0.652]$	1.230
Weights			$[0.32, 0.40]$	

Note: For the cooperative equilibrium, 'Weights' report the range of social weights that the planner assigns to the two countries to obtain Pareto improvements over the Nash outcome. The range of tax rates are reported from lowest to the highest tax rate for the set of cooperative equilibria. However, that the lower the capital tax rate, the higher the labor tax rate must to satisfy budget balance.