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

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Abstract

This paper studies the macroeconomic implications of tax adjustments in response to large public debt shocks using a two-country dynamic general equilibrium model. Endogenous capital utilization and a limited tax allowance for depreciation are introduced to produce a realistic elasticity of capital tax revenue. 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 capital tax increases 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 do it, but still have negative effects on the GIIPS and positive effects on their trading partners (the "EU10"). Moreover, unilateral tax hikes are less costly for GIIPS under autarky than under free trade. Allowing for strategic interaction, one-shot Nash tax competition in which both regions adjust taxes to offset observed debt shocks produces a "race to the bottom" in capital taxes and higher labor taxes. The regions do better in Cooperative equilibria, but capital (labor) taxes are still lower (higher) than at present, and the welfare loss is smaller under either Nash or Cooperative equilibria than with unilateral tax hikes.

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1 Introduction

The world's advanced economies face a severe public debt crisis. Even before the onset of the Great Recession in 2008, countries in the eurozone exceeded the public debt ceiling of 60 percent of GDP, a condition set by the Maastricht Treaty. The slowing of economic activity combined with increased transfer payments, financial system bailouts, and fiscal stimulus programs resulted in a ballooning of public debt, as illustrated in Figure 1. In the countries that are now at the center of the European debt crisis (Greece, Ireland, Italy, Spain, and Portugal, or GIIPS) gross public debt as a share of GDP rose 30 percentage points between 2008-2011, to a staggering 105 percent of GDP by 2011. The ten largest remaining eurozone members (EU10) also experienced large debt increases, albeit not as larges as in the GIIPS. Their debt levels increased by nearly 18 percentage points of GDP, reaching a ratio of 0.79 in 2011, well in excess of the Maastricht condition. Increases in debt ratios of this magnitude and on such a global scale are rare, and over the previous century occurred only in times of major wars and during the Great Depression.[1]

The European debt crisis changed the nature of fiscal policy discussions in Europe. Until recently, tax policy was the dominant issue and discussions centered on the harmonization of national tax rates and measures to contain or avoid tax competition (Sorensen, 2001; Kellerman and Kammer, 2009).[2] Once the debt crisis started, however, the focus shifted toward the implementation of country-specific fiscal austerity programs to address fiscal imbalances and bring the debt under control. A number of countries, including Portugal, Greece, Italy, Ireland and Spain, and to a lesser extent France and the Netherlands, adopted austerity packages that commit to public expenditure reductions and increases in tax rates.

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 debt crisis, there has been surprisingly little discussion of

[1]Japan, the United Kingdom and the United States have also seen their debts reach very high levels. Over the entire history of public debt in the United States, the data constructed by Bohn (2007) show that the surge in U.S. public debt during the Great Recession ranks below only the two World Wars, and is above the Civil War and the Great Depression.

[2]Since the 1970s, EU member states have worked to bring value-added taxes into alignment, to remove barriers to capital and labor movements across borders and to form a common European trade policy. The European Commission initiated steps to create a common playing field for corporate taxation (the Common Consolidated Corporate Tax Base), though the policy has not yet been adopted by eurozone Member States.

the constraints imposed on fiscal policy by the fact the eurozone countries are highly integrated. Estimates of the sustainability of public debt (Abiad and Ostry, 2005) and Mendoza and Ostry (2008), fiscal space (Ostry, Ghosh, Habermeier, Chamon et al., 2010), and the scope for raising revenue (Trabandt and Uhlig, 2009, 2012) tend to treat countries as isolated economic units, setting aside the 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.[3] Taking these effects into consideration is critical because, although the implications of fiscal austerity for macroeconomic aggregates and social welfare depend on the particular fiscal policy that countries decide to follow, they also depend on the degree of integration of capital and goods markets, since these markets provide a vehicle for international externalities of domestic fiscal adjustment.

This paper develops an open-economy macroeconomic framework for studying the international dimensions of fiscal adjustment, and uses it to examine the positive and normative effects of tax policies aimed at offsetting shocks to initial public debt.[4] The model captures the classic dynamic efficiency (or supply-side) effects of distortionary taxes on factor incomes and consumption, as well as the international externalities of domestic fiscal adjustment that result from cross-country mobility of goods and assets.

The framework we study is similar to the Neoclassical model used in Mendoza and Tesar (1998) and Mendoza and Tesar (2005) to study the international implications of domestic tax reforms that produce dynamic efficiency gains. We deviate from the Neoclassical model, however, because in that model the capital tax revenue is highly inelastic to changes in tax rates, which is contrary to empirical evidence and leads the model to underestimate the distortionary effects of capital taxes and overestimate the ability of the government to raise tax revenue as it aims to offset debt shocks. In contrast, we propose a model that differs from the Neoclassical setup in that it introduces endogenous capital utilization and a limited tax allowance for capital depreciation. Endogenous

[3]Externalities of fiscal policy have 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, Razin, and Sadka (1991) and Turnovsky (1997), and the quantitative studies by Klein, Quadrini, and Rios-Rull (2005), Sorensen (1999), Sorensen (2003) and Eggert (2000)).

[4]In this paper we limit the analysis to changes in tax rates, leaving the analysis of adjustments in expenditure policy to future work.

utilization allows agents to make short run adjustments in the use of installed capital, and hence capital income, in response to a change in capital tax rates. This weakens the capacity to raise tax revenue from capital taxes and makes capital taxes less distorting. On the other hand, a limited depreciation allowance widens the base of the capital tax and makes capital taxes more distorting by increasing the marginal cost of capital utilization. The two mechanisms together result in a dynamic (e.g. present value) Laffer curve with a standard bell shape and a realistic elasticity of capital tax revenue.

In the model, national tax policies induce global externalities that are driven by three transmission 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.

We conduct a quantitative analysis calibrated to eurozone data to derive the model's predictions about the positive and normative effects of alternative tax strategies to respond to debt shocks. This analysis feeds the debt shocks observed in the data to the model and computes the short- and long-run effects on equilibrium allocations, prices and welfare that result from responding to the shocks with capital or labor taxes. These computations allow us to compute dynamic 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. Restoring fiscal solvency requires changing taxes so 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.[5] This is done under relatively "conservative" assumptions, in particular because the model assumes that there is no adverse impact of tax increases on long-run growth, and that debt is priced at the world risk-free rate (i.e. there is no

[5] Hence, to conduct these experiments we solve for the equilibrium transitional dynamics and new steady state that result from a given set of tax changes, and evaluate the equilibrium present discounted value of primary balances. We assume that European countries maintain their VAT harmonization treaties, and therefore rely on adjustments in factor income taxes.

default risk). Even under these highly favorable conditions, we find that tax adjustments to restore fiscal solvency at the observed debt shocks are painful and yield large cross-country spillovers.

The quantitative results produce important insights into the potential effects of fiscal austerity options facing Europe. We begin with an experiment calibrated to an average European country and compute dynamic Laffer curves for a unilateral tax increase on factor incomes. As a consequence of the international externalities of domestic taxes, we find that the open-economy dynamic Laffer curves are shifted down and to the left relative to the corresponding closed-economy curves and closed-economy estimates of steady-state Laffer curves (e.g. Trabandt and Uhlig, 2010). In the case of a unilateral adjustment in the capital income tax rate, we find that the downward shift in the open-economy Laffer curve is so sizable that it is infeasible to raise the revenue needed to respond to the observed debt shocks (and this again assuming that countries continue to have full access to debt markets). A unilateral labor tax hike can meet the revenue requirement, but with negative effects on home allocations and welfare, and nontrivial improvements for the rest of Europe.

The results based on unilateral tax adjustments suggest that strategic incentives are strong. This led us to examine Nash solutions to one-shot tax competition games, in which both regions adjust taxes strategically to offset their observed debt shocks. The Nash game produces a highly distorting race to the bottom in capital taxes from 0.20 to 0.15. Labor taxes increase from 0.35 to 0.42 and welfare declines relative to the pre-crisis equilibrium by 3.28 percent of trend consumption. In the absence of a cooperative solution or a redistribution of the debt burden (i.e. debt haircuts), each country attains higher welfare by moving to autarky.

We also consider the outcome of tax competition games when countries are asymmetric in ways that reflect the differences between the GIIPS countries and the EU10. Two key findings emerge. First, initial conditions prior to the tax competition game matter. Small countries have an advantage in competition (that is they can raise an additional euro of revenue at lower utility cost, relative to large countries), and countries with current account deficits, higher initial taxes and bigger revenue needs are at a disadvantage. When these asymmetries are incorporated into the EU10-GIIPS tax competition game, the balance swings in favor of EU10 with a welfare loss of -2.93 percent from tax competition, compared to -3.5 percent for GIIPS.

Second, in all of the experiments we consider the capital income tax rate that is implied by the cooperative solution is nearly identical to the initial, pre-crisis capital income tax. Adjustment in labor taxes both raises enough revenue to meet the debt target and produces the lowest welfare cost relative to other tax strategies. This suggests that a simple commitment to keep capital tax rates fixed and use labor taxes to restore fiscal solvency would produce the lowest welfare losses from austerity. While a policy suggestion that countries should tax the immobile factor seems obvious, many countries in Europe are taking advantage of the international externalities that are currently tilting to their benefit considering tax reforms that involve lowering capital income tax rates. (See Pohjanpalo, 2013, for details.) Spillovers–both positive and negative–from unilateral tax policy changes should be acknowledged in fiscal policy discussions in Europe.

The rest of the paper is organized as follows. Section 2 describes the model, examines the optimality conditions of households and firms, and defines the competitive equilibrium. Section 3 calibrates the model to eurozone data from before the 2008 crisis. Section 4 discusses the results of the quantitative analysis, starting with the implications of unilateral tax adjustments and the construction of dynamic Laffer curves, followed by the analysis of the solutions to Nash and Cooperative tax competition games. Section 5 provides conclusions.

2 A Two-Country Model with Global Tax Externalities

We study the fiscal adjustment in response to debt shocks using a two-country dynamic general equilibrium model. The model shares several of the features of the widely used two-country Neoclassical model with exogenous long-run balanced growth driven by labor-augmenting technological change, except for two important differences: endogenous capacity utilization of the installed capital stock and a limited tax allowance for capital depreciation expenses. The model abstracts from stochastic elements because the focus of the analysis is on the transitional dynamics and long-run implications of fiscal adjustment, rather than on business cycle effects.

The world consists of two countries: home (H) and foreign (F). 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. We assume that households make investment and capital utilization decisions, so that they rent out to firms labor services and effective capital services. The representative firm in each country produces a single tradable good using capital and labor as inputs. Physical capital and labor are immobile factors, but trade in bonds is sufficient for international transmission of national tax policies, affecting the global distribution of wealth, the size of the global capital stock and its distribution across countries. In addition to this wealth reallocation mechanism, national tax policies also trigger global externalities via relative prices and revenue spillover.

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

Households

The representative household has standard preferences, which in the case of the home country are given by:

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

The period utility function is the standard CRRA function with CES argument in terms of consumption, c_t, and leisure. Since we assume a unit time endowment, the latter is defined as $1-l_t$, where l_t is the supply of labor. 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.

Following King, Plosser, and Rebelo (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[6]. 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 $1+\gamma$.

[6]The assumption that growth is exogenous implies that tax policies do not affect long-run economic growth. This is in line with the empirical and quantitative findings of Mendoza, Milesi-Ferretti, and Asea (1997).

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 also takes as given the rental rates of labor w_t and capital services r_t, and the prices of domestic government bonds and international-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 household makes rents out inputs to firms but it makes the capital accumulation decision. The price of capital and the price of consumer goods differ because investment incurs quadratic adjustment costs:

$$\phi(k_{t+1}, k_t, m_t) = \frac{\eta}{2}\left(\frac{(1+\gamma)k_{t+1} - (1-\delta(m_t))k_t}{k_t} - z\right)^2 k_t, \tag{2}$$

where the coefficient η determines the speed of adjustment of the capital stock k, and m denotes the rate of capital utilization, while z is set to the long-run investment-capital ratio so that at steady state the capital adjustment cost is zero.[7]

The household chooses intertemporal sequences of consumption, leisure, investment inclusive of adjustment costs x, international bonds b, domestic government bonds d, and capital utilization rates m to maximize utility in (1) subject to a sequence of period budget constraints given by:

$$(1+\tau_c)c_t + x_t + q_t b_{t+1} + q_t^g d_{t+1} = (1-\tau_L)w_t l_t + (1-\tau_K)r_t m_t k_t + \theta\tau_K\delta(m_t)k_t + b_t + d_t + e_t, \tag{3}$$

and the following law of motion for the capital stock:

$$x_t = (1+\gamma)k_{t+1} - (1-\delta(m_t))k_t + \phi(k_{t+1}, k_t, m_t), \tag{4}$$

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

The left-hand-side of equation (3) measures household expenditures, which include purchases

[7] It is well known that open-economy models with frictionless goods and asset markets require some sort of capital adjustment costs in order to reduce the cyclical volatility of investment to observed levels and to reduce the speed of adjustment of physical assets v. financial assets.

of consumption goods inclusive of the indirect tax, investment inclusive of capital adjustment costs, international bonds, and domestic government bonds. The right-hand side of equation (3) shows household after-tax income. This includes net-of-tax income from labor and effective capital services, $\tilde{k} = mk$, rented out to firms, a tax allowance for a fraction θ of capital depreciation costs, payments on holdings of public and international bonds, and lump-sum entitlement payments from the government.

As in the literature on DSGE models with endogenous capacity utilization initiated by the work of Greenwood, Hercowitz, and Huffman (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 $0 \leq \delta(m) \leq 1$. The partial depreciation tax allowance reflects the fact that these allowances generally apply only to capital income taxed from business, not from individuals, and also do not apply to residential capital[8].

In line with the environment in the European Union, the two regions in the model have perfectly integrated 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 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, Razin, and Sadka, 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 would make the model less tractable.[9]

[8]The standard assumption of a 100 percent depreciation allowance has the unrealistic implications that it renders m 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 the partial depreciation allowance to maintain the traditional setup of capacity utilization.

[9]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,

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

Firms

The assumptions that the household makes the investment and capital utilization decisions and rents out effective capital services $\tilde{k}$ allow us to characterize the firm's problem as a static plan for production. Firms employ labor and effective capital services to maximize profits, given by $y_t - w_t l_t - r_t \tilde{k}_t$, taking factor prices as given. The production function is assumed to be Cobb-Douglas:

$$y_t = F(\tilde{k}_t, l_t) = \tilde{k}_t^{1-\alpha} l_t^{\alpha} \tag{5}$$

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

$$\begin{aligned} (1-\alpha)\tilde{k}_t^{-\alpha} l_t^{\alpha} &= r_t, && (6) \\ \alpha \tilde{k}_t l_t^{\alpha-1} &= w_t. && (7) \end{aligned}$$

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

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 $t = 0, ..., \infty$. 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

most industrial countries have bilateral tax treaties that render tax systems largely residence-based (see Frenkel, Razin, and Sadka, 1991).

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 of eliminating transfer payments in response to debt shocks 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, 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:

$$d_t - (1+\gamma)q_t^g d_{t+1} = \tau_C c_t + \tau_L w_t l_t + \tau_K (r_t m_t - \theta\delta(m_t))k_t - (g_t + e_t). \tag{8}$$

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.[10] 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

[10] 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.

are large inefficiencies, welfare effects, and cross-country externalities involved in fiscal adjustment.

Because 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:

$$\frac{d_0}{y_0} = \frac{pb_0}{y_0} + \sum_{t=1}^{\infty}\left(\left[\prod_{i=1}^{t} \upsilon_i\right]\frac{pb_t}{y_t}\right) \tag{9}$$

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

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

$$\frac{d_0}{y_{-1}} = \psi_0\left[\frac{pb_0}{y_0} + \sum_{t=1}^{\infty}\left(\left[\prod_{i=1}^{t} \upsilon_i\right]\frac{pb_t}{y_t}\right)\right]. \tag{10}$$

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.[11] The left-hand-side is an exogenous constant taken from the data, and 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:

$$F(m_t k_t, l_t) - c_t - g_t - x_t = (1+\gamma)q_t b_{t+1} - b_t. \tag{11}$$

[11] In detrended levels (which are ratios relative to the state of labor augmenting technology), we would have $d_0 = pb_0 + \sum_{t=1}^{\infty}\left(\left[\prod_{i=1}^{t} q_i^s\right]\Gamma^t pb_t\right)$.

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:

$$\omega\left(y_t - c_t - x_t - g_t\right) + \left(y_t^* - c_t^* - x_t^* - g_t^*\right) = 0, \tag{12}$$

$$\omega b_t + b_t^* = 0, \tag{13}$$

where ω denotes the initial relative country size measured by output y. In response to debt shocks, different tax policies across countries might induce endogenous changes in relative country size.

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 government bonds imply that the following arbitrage conditions hold:

$$\frac{(1+\gamma)u_1(c_t, 1-l_t)}{\beta u_1(c_{t+1}, 1-l_{t+1})} = (1-\tau_K)F_1(m_{t+1}k_{t+1}, l_{t+1})m_{t+1} + 1 - (1-\tau_K\theta)\delta(m_{t+1}) = R_t = R_t^g, \tag{14}$$

$$\frac{(1+\gamma)u_1(c_t^*, 1-l_t^*)}{\beta u_1(c_{t+1}^*, 1-l_{t+1}^*)} = (1-\tau_K^*)F_1(m_{t+1}^*k_{t+1}^*, l_{t+1}^*)m_{t+1}^* + 1 - (1-\tau_K^*\theta^*)\delta(m_{t+1}^*) = R_t = R_t^{g*}. \tag{15}$$

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. Thus, 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 differ across regions due to differences in capital taxation.[12] 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 though physical capital is not mobile across countries directly, perfect mobility of financial capital and arbitrage of returns induces 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:

$$\frac{1}{q} = \frac{(1+\gamma)^{\sigma}}{\beta}, \tag{16}$$

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 consumption taxes:

$$\frac{u_2(c_t, 1-l_t)}{u_1(c_t, 1-l_t)} = \frac{1-\tau_L}{1+\tau_C} F_2(k_t, l_t) \tag{17}$$

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

[12] 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.

internationally, changes in the labor tax rate 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:

$$F_1(m_t k_t, l_t) = \frac{1 - \theta\tau_K + \Phi_t}{1 - \tau_K}\delta'(m_t), \tag{18}$$

where $\Phi_t = \eta\left(\frac{(1+\gamma)k_{t+1} - (1-\delta(m_t))k_t}{k_t} - z\right)$. The capital tax generates a wedge between the marginal benefit of utilization on the left-hand-side with the marginal cost of utilization on the right-hand-side. The sign of the marginal adjustment cost of investment Φ_t depends on Tobin's Q (in this model, $Q_t = 1 + \Phi_t$). If Q_t is greater than 1, i.e. $\Phi_t > 0$, so that the desired investment rate is higher than the steady state one, the higher-than-unity 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. $\Phi_t < 0$. 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 ($\theta = 1$), the capital income tax does not introduce a first-order wedge between marginal costs and benefits of utilization around the steady state ($\Phi_t = 0$). 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 increases the wedge and reduces the rate of utilization. Moreover, for a given τ_K, a smaller θ increases the wedge, inducing a lower rate of utilization.

Outside the steady state, the distortion term that would remain if $\theta = 1$ would be $1 + \frac{\Phi_t}{1-\tau_k}$ via adjustment costs. The size of the distortion will again depend 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 $\Phi_t < 0$, 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 weakens the capacity to raise tax revenue from capital taxes and makes capital taxes less distorting. On the other hand, a limited depreciation allowance widens the base of the capital tax and makes capital taxes more distorting by increasing the marginal cost of capital utilization. We will show in the quantitative section that the two mechanisms together result in a dynamic Laffer curve with a standard bell shape and in line with the observed elasticity of capital tax revenue.

3 Calibration and Pre-Crisis Fiscal Policy

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

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, Razin, and Tesar (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, Razin, and Tesar (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.[13]

Table 1 shows that 2008 tax rates were not very different across EU10 and GIIPS, which reflects the tax harmonization treaties and directives adopted by the European Union, as well as the 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, Razin, and Tesar (1994) and

[13]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.

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 shares of GDP 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 by 2008 had dropped to -3 percent. The latter would grossly over-estimate the long-run net foreign asset position if we were to 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 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, GIIPS GDP is about half the size of the EU10 GDP in 2008 (a ratio of 0.54). Hence, GIIPS share in the two regions aggregate output is 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 to GDP ratios (henceforth "debt ratio") and their change between end–2007 (beginning of 2008) and 2011. 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 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 ratios 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 (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)[14].

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 $\delta(\bar{m}) = 0.0164$ quarterly.[15]

[14] It is true that GDP fell during this interval, contributing to the increase in the debt to GDP ratio. However, the decline in GDP is swamped by the increase in debt, particularly in GIIPS.

[15] 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

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 $\chi_0 = (1-\alpha)/(k/y) = 0.03$. Given this, the value of χ_1 follows from the definition of the depreciation rate function ($\chi_0 \bar{m}^{\chi_1}/\chi_1 = 0.0164$), which implies $\chi_1 = 1.66$. Finally, the relative size of the two regions is set to $\phi = 0.50$ to capture the symmetric countries in the benchmark. We also experiment with the observed relative initial country size in the asymmetric case.

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 $\beta = 0.992$. The values of β, γ and σ pin down the steady-state real interest rate, $R = \beta^{-1} - \gamma\sigma = 1.0036$, which is about 1.4 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 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. In the benchmark of the symmetric countries, we take the EU average tax rates, and for the

and EU10 is x/y =0.222, and the 2007 average capital-output ratio is k/y =2.97 (which is also the average over the 2000-2008 period).

asymmetric case, we take the group average tax rates.

Table 3 compares 2008 GDP ratios of key macro-aggregates in the data with the model's balanced-growth, steady-state allocations for all EU symmetric calibration and the GIIPS-EU10 asymmetric calibration. Effectively, 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 are 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.

4 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 either capital or labor 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. We consider the benchmark case with two symmetric countries calibrated to the EU 15-country averages.

Second, in light of the externalities implied by unilateral tax changes, we study the solutions of cooperative and non-cooperative tax competition games. To illustrate the intuition, we start with the symmetric country case with symmetric debt shocks. We then study the asymmetric case which captures GIIPS and EU10. 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 give a specific example, in the asymmetric case 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 10) for GIIPS. 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.

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, because the new steady state is independent 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 new 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).

4.1 Unilateral Tax Increases and Net Revenue Laffer Curves

Before introducing the debt shocks, we start by examining the overall capacity of the home capital and labor taxes to raise revenue and increase the present value of its primary fiscal balance in the symmetric benchmark. 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}). Thus, the net revenue ratio corresponds exactly to the right-hand-side of the intertemporal government budget constraint (10), which shows the amount of initial debt that particular values of τ_K or τ_L can support in a world competitive equilibrium when the home taxes vary unilaterally.[16] Since the foreign country is

[16]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.

affected by positive revenue externalities of the home tax hikes and the home Laffer curves consider only the home debt shock, we need to make an adjustment in the foreign country so as to keep the present value of its primary balance unchanged. This can be done by increasing transfers or reducing distortionary taxes. We assume that the foreign country maintains primary-balance neutrality by lowering τ_L^*.

Net Laffer Curves of Capital Tax Rates

Figure 2 illustrates home net revenue Laffer curves for τ_K in autarky (the closed-economy dotted line) and in the open-economy case (the solid line). The y-axis plots the increase in the net revenue ratio relative to the pre-crisis ratio. Thus, at the pre-crisis home capital tax rate of 20 percent, the corresponding y-axis value is normalized to zero. To restore fiscal solvency, the home country needs a capital tax rate that increases the ratio of the present value of the primary balance to GDP by 0.22, so as to support the debt ratio 0.88 after the debt shock. This debt shock is indicated by a horizontal line crossing the y-axis at 0.22 in the figure.

Figure 2 shows that 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 increase in the ratio of the present value of the primary balance to GDP of about 14 percentage points, well below the required 22. The reason is that international tax externalities move sharply against the home country when it increases τ_K. As we show below in reviewing the transitional dynamics of raising τ_K to the maximum point of the Laffer curve, the widening of the capital tax differential between the home and the foreign country induces a reduction in the capital stock in the home country and an expansion in the foreign country. Returns to labor are also affected, and so the tax bases of both the labor and the capital tax expand in the foreign country and shrink at home.

The home net revenue Laffer curve for τ_K under autarky is steeper than the open-economy curve at the pre-crisis tax rate, and it peaks at a higher tax rate than when the home county is open (i.e. the closed-economy curve sits higher than in the open-economy case). Thus, in autarky, the home country 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 home Laffer curve under autarky provides extra present value of primary balance of around 0.30. At the same 34 percent capital tax rate at which the open-economy home Laffer curve yields the maximum revenue (but far below the required target to support the increased debt), the autarky economy can generate more than enough revenue to support the 0.88 post-shock debt ratio.

The fact that the home country 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, 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 home τ_K to the maximum point on the open-economy net revenue Laffer curve (34 percent). In this scenario, the foreign country maintains primary-balance neutrality in the presence of the positive revenue externality from the tax hike at home by lowering τ_L^* from 0.35 to 0.32. Since the home capital tax rate increases by 14 percentage points, and this tax is highly distorting, the home country experiences a very large welfare cost of 6.74 percent, while the foreign country obtains a non-trivial welfare gain of 1.27 percent.[17]

Comparing home outcomes as an open economy (first two columns of Table 4) v. closed economy (last two columns) with the same 34 percent capital tax rate, we find that the home country as a closed economy experiences an increase in the present value of its primary balance of 28 percentage points, about twice as large as in the open-economy case and 6 percentage points above what is needed to offset the debt shock. The welfare loss is nearly the same (6.65 percent), but normalizing by the amount of revenue generated, the home country is much better off in autarky. This result can also be illustrated in a slightly different experiment by computing the value of τ_K at home as a closed economy that yields the same 14 extra percentage points of present value of the primary

[17] 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 exclusive of transitional dynamics.

balance that the home country attained as an open economy with τ_K set to 34 percent. As Figure 2 shows, the home country 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 the home country as an open economy. Again, if fiscal austerity focuses on capital taxes, the home country would be much better off under autarky, and hence the country has strong incentives to move in that direction.

The impact and long-run effects on key macro-aggregates in both countries 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 3. The increase in τ_K at home causes a steady drop in k over time to a 28.45 percent fall relative to the pre-crisis level, while k^* rises gradually to converge to a level 4.47 percent higher than in the pre-crisis equilibrium. Capacity utilization falls sharply initially at home, 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 at home and decreases in the foreign country, but this pattern reverses as the economy transitions to steady state because of the lower (higher) capital stock in the home (foreign) country in the new steady state. The home country increases its NFA position by running substantial trade surpluses in the early stages of transition, while the foreign country decreases its NFA position by running deficits.

The foreign 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 the foreign country kept its tax rates unchanged, it would see its present value of primary balances over pre-crisis GDP increase by 9 percentage points, halfway to its revenue target with only a slight utility fall of 0.06 percent. The 1.27 percent welfare gain that the foreign country obtains because of the positive externalities from the home capital tax hike is largely overlooked in current discussions of fiscal adjustment in Europe. The home country 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 foreign country and provides it with an unintended welfare gain.

Roles of Endogenous Utilization and Limited Depreciation Allowances

Our model features three key features: open economy, endogenous utilization and limited depreciation allowance. We have focused on the impact of the open economy aspect on the dynamic laffer curves of the capital tax rates above. We now hightlight the important role of the other two features of the model. To do so, we compare the dynamic net laffer curves under the following four senarios: (i) the neoclassical case with exogenous utilization and a full depreciation allowance (i.e. $\theta = 1$); (ii) the case with endogenous utilization and a full depreciation allowance; (iii) the case wtih exogenous utilization and a limited depreciation allowance ($\theta = 0.22$); (iv) the benchmark case above with both endogenous utilization and a limited depreciation allowance ($\theta = 0.22$). All other parameter values are kept the same across all these cases.

The neoclassical dynamic net laffer curve, plotted as the red line in Figure 4, does not display a bell shape (even when we extend the capital tax rate beyond 0.9). The neoclassical steady state net laffer curve over the capital tax rate is bell-shaped. However, given that the capital stock is predetermined and slow to adjust over time, the government can raise substantial revenue over the transition period when increasing the capital tax rate. The additional tax revenue from the transition phase dominates the decline in the steady state tax revenue, leading to increasing dynamic net laffer curves.

When endogenous utilization is introduced in the neoclassical case, it allows the agents to adjust capital services in the short run, even though capital is predetermined, in response to increases in capital tax rates. Consequently, the government's ability to raise tax revenues declines with endogenous capacity utilization. The dynamic net laffer curve (plotted as the black dashed line) is below the neoclassical one. When a limited depreciation allowance is introduced in the neoclassical case, it decreases the incentive to accumulate capital and lowers the steady capital output ratio and tax bases. At the same time, it increases the government revenue given that a small fraction of the capital tax revenue is rebated back to the households. The latter effect dominates the first effect when the capital tax rate is small, while the opposite results holds when the capital tax rate is high. In both these cases, the dynamic net laffer curve does not display a bell shape.

When both endogenous utilization and a limited depreciation allowance are introduced, the limited depreciation allowance amplifies the responses of utilization to capital tax hikes both in the short run and in the steady state by generating the static inefficiency as illustrated in equation (18). The short run revenue increases are substantially limited, and the long run revenue loss is amplified, as the capital tax rate increases. This leads to a bell-shaped dynamic net laffer curve plotted by the green solid line in Figure 4. Comparing to the other dynamic laffer curves in the figure, it shows that the features of endogenous utilization and a limited depreciation allowance are important for guaging the revenue capacity of the capital tax rate.

Net Laffer Curves of Labor Tax Rates

Figures 5 and 6 and Table 5 show the results now for an increase in the home labor tax rate. The results are more optimistic in terms of the ability of the home country to raise revenue and restore fiscal solvency in response to the debt shock. The open-economy Laffer curve for τ_L (Figure 5) is considerably steeper than for the capital tax rate. Starting from a pre-crisis tax rate of 0.35 on labor, the open-economy Laffer curve peaks at a tax rate of 0.49 with an increase in the ratio of the present value of net revenue to GDP above 0.4, well above the 0.22 needed to match the post-crisis debt ratio. The exact tax rate that the open economy would need to support the 0.88 debt ratio is about 39 percent, and just a little less for the home country 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 so as to make the results in Tables 4 and 5 comparable. The required increase in τ_L is only 2 percentage points, from 35 to 37 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 1.8 percent. The gap in the increase of the present value of the primary balance in the results in the home closed v. open economy is almost negligible, 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 the home capital and labor taxes that attempt to yield the required extra 22 percentage points of present value of the primary balance to offset the debt shock would lead the home region to prefer autarky. With capital taxes, the home country 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 6.74 percent. With labor taxes, the home country needs about a 39 percent labor tax either as an open economy or under autarky to offset the fiscal shock, with a welfare cost of 3.21 percent, and in the open economy scenario it would also produce a 0.22 percent welfare gain for the foreign country.

So far, we considered the symmetric country experiments. Table 6 examines the implications of tax policy adjustments for each country in the GIIPS region if they were to act 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. Intuitively, each country in GIIPS treated in this way becomes much smaller, 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.

4.2 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 an incentive 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 — 22 percentage points for both in the symmetric benchmark case, and 30 for GIIPS and 18 for EU10 in the asymmetric case.[18] 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: (i) the implied allocations and prices for an European-wide tax structure given by the pairs (τ_K, τ_L), (τ_K^*, τ_L^*) with unchanged consumption taxes are a competitive equilibrium; and (ii) labor taxes in each region adjust so that intertemporal government budget constraints (equation 10) support increases in the present value of the primary fiscal balances equal to each region's debt shock.

Each region chooses its capital tax rate from values in discrete grids with M and N nodes for the

[18]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.

home and foreign country respectively: $T_K = \{\tau_{K1}, \tau_{K2}, ..., \tau_{KM}\}$ and $T_K^* = \{\tau_{K1}^*, \tau_{K2}^*, ..., \tau_{KN}^*\}$. 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 the home's strategic choice of τ_K given τ_K^* is denoted $V(\tau_K|\tau_K^*)$. The corresponding foreign payoff function is denoted by $V^*(\tau_K^*|\tau_K)$. Given these definitions, the home 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 foreign country 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 $\tau_K^{N*} = \tau_K^*(\tau_K^N)$.

Figure 8 shows the reaction functions in (τ_K, τ_K^*) space and identifies the Nash and pre-crisis equilibria in the symmetric country case. The "Nash" column in 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 because of the positive externalities through the reallocation of capital and the adjustment in labor supplies. The positive externalities 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 identical tax rates on capital of 0.20 pre-crisis, Nash competition results in the familiar "race to the bottom" in capital taxes, to 0.15. Labor taxes increase from 0.35 to 0.42 and welfare declines relative to the pre-crisis equilibrium by 3.28 percent of trend consumption[19].

Consider next a cooperative equilibrium. A cooperative equilibrium is defined as a pair (τ_K^C, τ_K^{C*}) such that: (1) it satisfies properties (i) and (ii), 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 an arbitrary weight 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

[19]Note that the gains or losses from tax competition involve two competing effects. The first is that countries must raise revenue in response to the debt shock. The second is that the game as we have structured it allows countries to reform their tax systems; i.e. relative to pre-crisis tax rates, countries may optimally choose labor and capital taxes to raise the most revenue at the lowest efficiency cost. It is possible that the gains from tax reform could outweigh the costs of raising the additional revenue. In the symmetric case, the gains from a revenue-neutral tax reform do result in slightly lower capital taxes in exchange for higher labor taxes relative to the pre-crisis rates. However, the welfare gains are relatively small (0.18). The race-to-the-bottom results are primarily driven by the international externalities that we discuss in the text, and not the benefits of tax reform.

$\lambda' s$, 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.

Because of symmetry, we can focus on the cooperative outcomes for equal country weights (see column Cooperative in Table 7). In the cooperative equilibrium, the capital tax rate is higher than under Nash: 0.20 versus 0.15, and the labor tax rate is lower: 0.39 versus 0.42. Cooperation allows countries to commit to higher capital taxes relative to Nash and avoid painful increases in labor taxes, with welfare gains relative to the Nash outcome of 0.45.

While tax coordination helps prevents welfare-reducing strategic interaction, 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 rates, capital taxes are lower and labor taxes are higher in the Nash equilibrium after the debt shocks for two reasons. First, capital tax rates are lower because governments wish to reduce the tax that is most distorting in terms of welfare cost per unit of revenue (i.e. the capital tax). Second, in an open economy governments have an incentive to undercut other countries tax rates in an effort to attract foreign capital and thereby increase the tax base. Of course, since both countries are attempting the same strategy, the outcome is lower capital tax rates and higher labor tax rates than is optimal under cooperation.

It is also worth comparing the outcome of Nash and cooperative equilibria with the outcome that each region could attain under autarky. We can interpret the autarky outcome as the value of the exit option for each country. Note that under symmetry, the autarky outcome is identical to the cooperative outcome given equal country weights. In the asymmetric experiment below, we show that autarky might be preferred by one country but is generally not preferred by both.

To highlight the impact of strategic reaction by the foreign country on the home country, we conduct two additional experiments. The results in the "Unilateral" column of Table 7 correspond to the unilateral Laffer curve experiment illustrated in Figure 1. We assume that only the home country experiences the debt shock, and the foreign country adjusts its labor tax rate to maintain revenue neutrality but does not behave strategically. The home country chooses a capital (labor) tax rate higher (lower) than the one in the Nash equilibrium. Consequently, the welfare cost of the debt shock for the home country is smaller in the unilateral case than in the Nash case: 2.87 versus 3.28. In the second experiment, shown in the "Nash 1" column of Table 7, the foreign country responds strategically to changes in home tax rates while maintaining revenue neutrality. In this case, the foreign country substantially undercuts the home capital tax rate by lowering its capital tax rate to 0.10, and the welfare cost of the debt shock at home is much larger: 5.5 percent. One interpretation of the one percent welfare gain for foreign country is that it is the benefits of having ones neighbors undergo an austerity program.

We next move to the asymmetric case of the GIIPS region and the EU10 region. These two regions differ a number of dimensions including their relative sizes, initial net foreign asset positions (NFA), initial tax rates and the size of debt shocks. To highlight the role of these differences in the Nash game, we introduce each difference one-by-one into the symmetric benchmark case. The results are reported in Table 8.

Starting with country size (the second column of Table 8), tax competition benefits small countries in two ways. One is that by having a smaller impact on world prices, the small country can play off of the large country without offsetting price adjustments. Second, the smaller country faces a bigger supply of foreign capital from which the home country can steal by undercutting the capital tax rate. Indeed, the benefit of being small leads to an approximate 0.75 relative welfare benefit to the smaller home country. A positive current account position (negative capital account position) is an advantage for EU10. The initial drop in interest rates along the transition path reduces the cost of servicing external debt. This has a sizable welfare effect, with a relative gain for EU10 of nearly four percent. Asymmetries in initial tax rates also matter in the Nash game. Having a higher capital tax rate but lower labor and consumption taxes benefits GIIPS at the expense of the EU10 in the Nash game (the higher the capital tax rate initially, the more to gain from the race to the bottom). Finally, facing a larger debt shock places GIIPS at a disadvantage in the Nash game. The impact of the differential debt shock is large: the GIIPS region suffers a welfare loss of 6.81 percent while the EU10 suffers only 1.4 percent.

The last column of Table 8 reports the outcome of putting all of these differential factors altogether. We find that GIIPS undercuts EU10 in capital tax rates: 0.13 versus 0.16, but given its larger debt shock, GIIPS still experiences a substantial welfare loss of 3.5 percent, and EU10 experiences a welfare loss of 2.93 percent, relative to their pre-crisis levels.

Table 9 reports Nash, cooperative and autarky outcomes for the symmetric game. The Nash column repeats the results from the final column of Table 8. The important message of Table 9 is the comparison of the Nash equilibrium with the cooperative equilibrium and the autarky exit option in the right-most column. Two points are worth noting. First, both regions are hurt by tax competition and would prefer the exit option over playing Nash. Second, the capital tax rates implied by cooperative solution are not very different from the pre-crisis tax rates. That is, both regions can meet the revenue requirements of the debt shock through an adjustment in labor tax rates and thereby minimize the negative externalities for the other region.

5 Conclusions

Public debt ratios surged between 2008 and 2011 across many key industrial countries, particularly in those in the eurozone. Public debt increased by a GDP-weighted average of 30 percentage points in the GIIPS region and in the EU10 by 18 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 such 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, dynamic general equilibrium model with fully specified tax systems. The workhorse Neoclassical model widely used for quantifying the macro effects of tax policies 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: Debt Shocks in the Eurozone

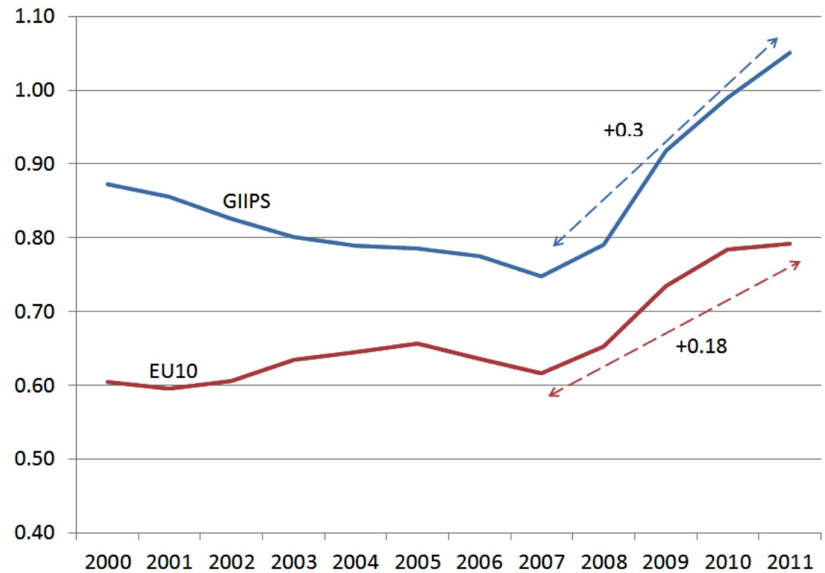
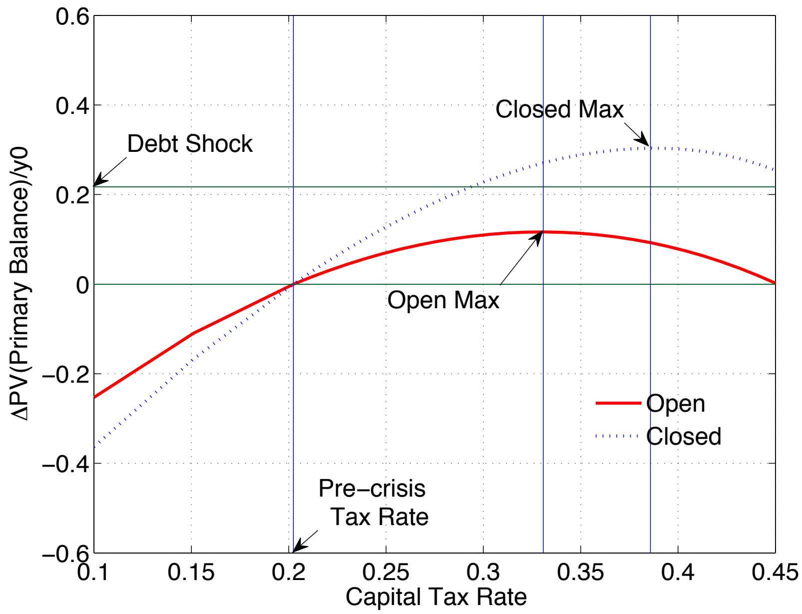
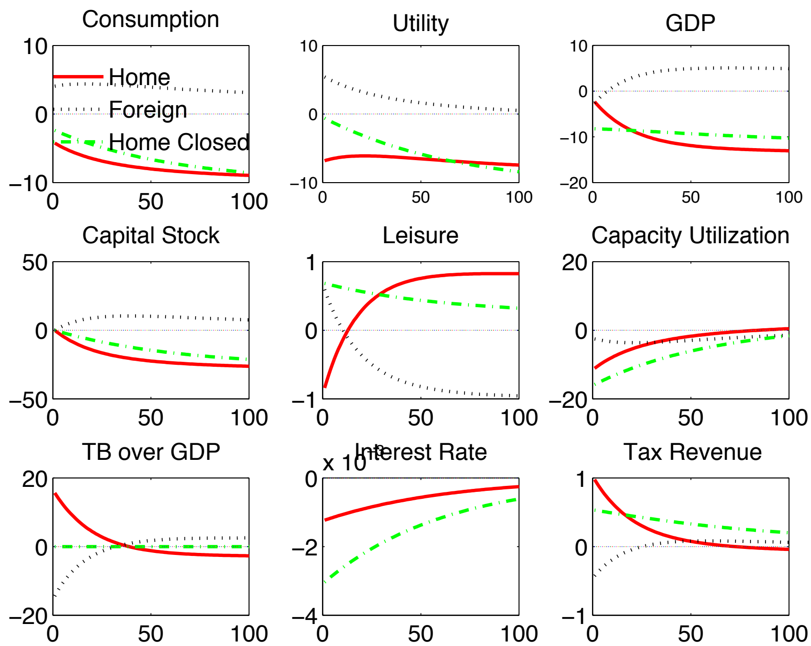


Figure 2: Net Laffer Curves for the Capital Tax Rate



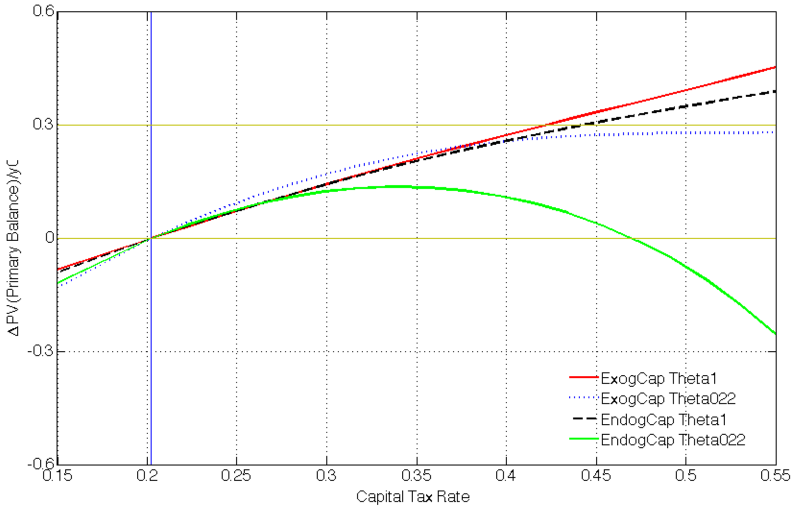
Notes: Net Laffer curves plot the equilibrium present value of total tax revenue net of the equilibrium present value of government spending and transfers as the capital tax rate changes.

Figure 3: Macro Responses to a Capital Tax Rate Increase



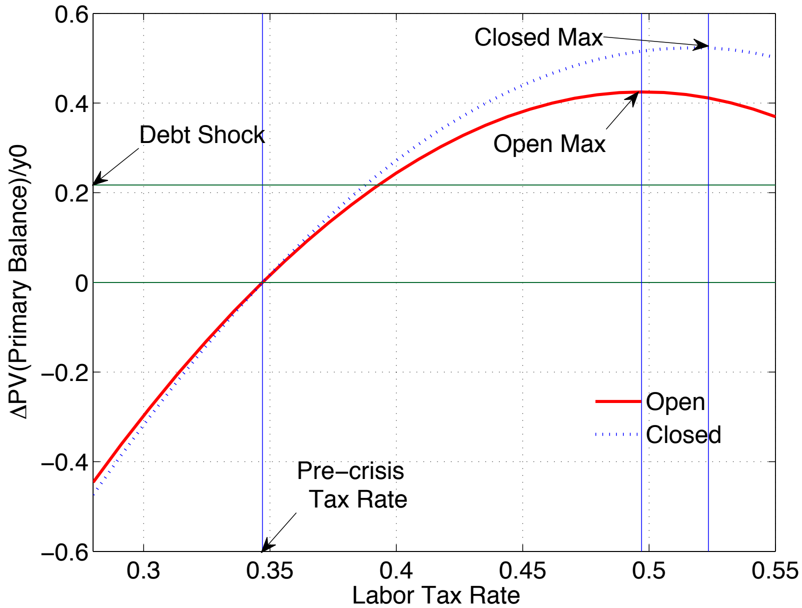
Notes: In this experiment, the foreign labor tax rate is adjusted from 0.35 to 0.32 to reserve its revenue neutrality. All variables are reported as percent changes from pre-crisis steady state except the lower panel, which are in percentage point differences from pre-crisis steady state.

Figure 4: Comparisons of Net Laffer Curves for the Capital Tax Rate



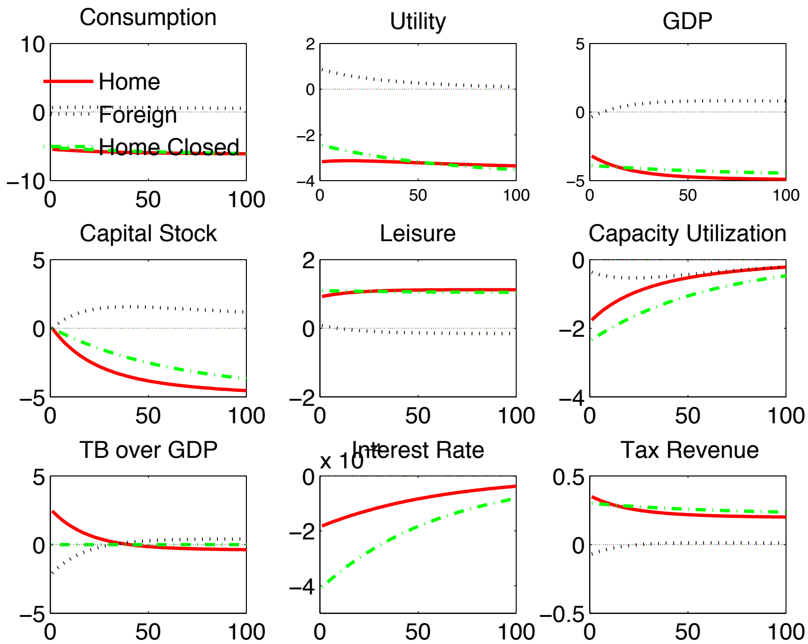
Notes: Net Laffer curves plot the equilibrium present value of total tax revenue net of the equilibrium present value of government spending and transfers as the capital tax rate changes.

Figure 5: Net Laffer Curves for the Labor Tax Rate



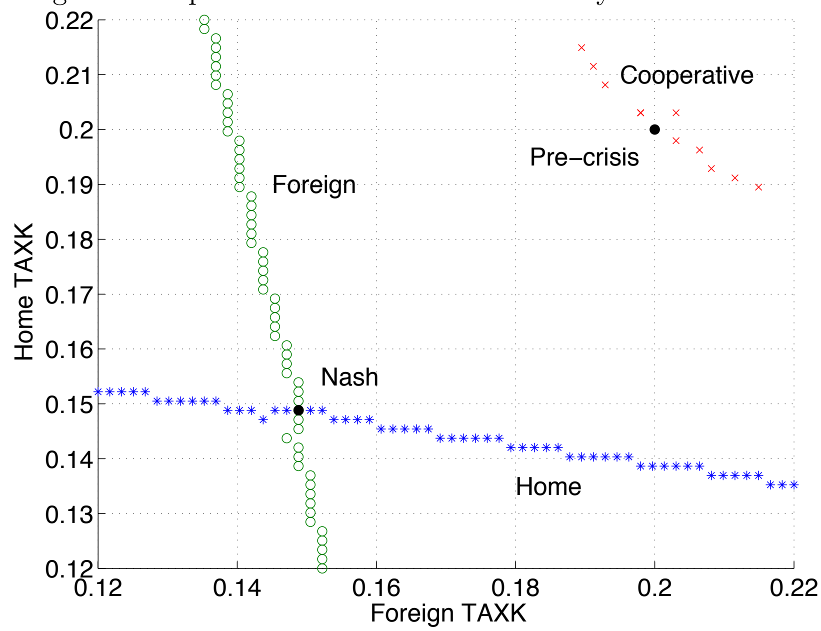
Notes: Net Laffer curves plot the equilibrium present value of total tax revenue net of the equilibrium present value of government spending and transfers as the labor tax rate changes.

Figure 6: Macro Responses to a Labor Tax Rate Increase in GIIPS



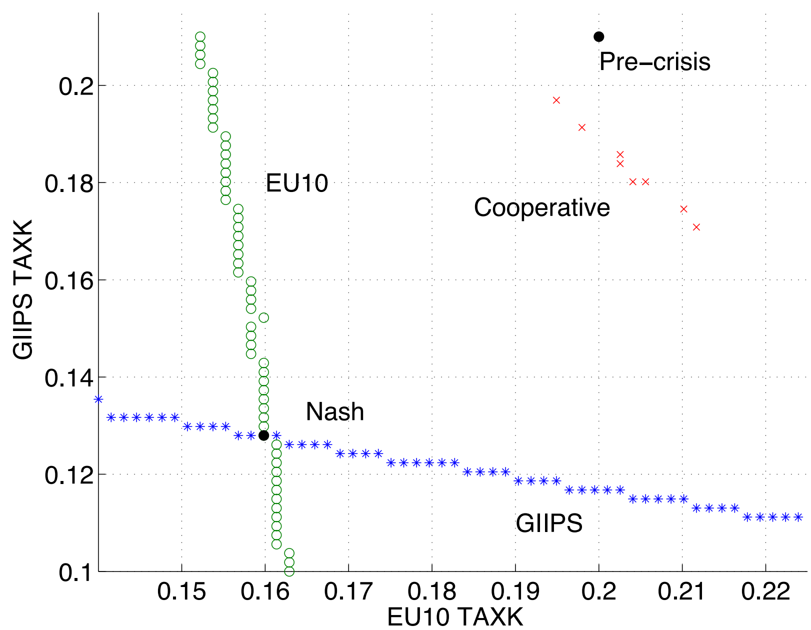
Notes: In this experiment, foreign labor tax rate is adjusted from 0.35 to 0.34 to reserve its revenue neutrality. All variables are reported as percent changes from pre-crisis steady state except the lower panel, which are in percentage point differences from pre-crisis steady state.

Figure 7: Capital Tax Reaction Functions: Symmetric Game



Notes: Labor taxes are used to preserve solvency.

Figure 8: Capital Tax Reaction Functions: Asymmetric Game



Notes: Labor taxes are used to preserve solvency.

Table 1: MACROECONOMIC STANCE AS OF 2008

	EU10							GIIPS					GDP-weighted ave.		
	AUT	BEL	FIN	FRA	GER	NET	Other	GRE	IRE	ITA	POR	SPA	EU10	GIIPS	All EU
(a) Macro Aggregates															
τ_C	0.19	0.17	0.24	0.17	0.17	0.20	0.23	0.15	0.21	0.13	0.18	0.12	0.18	0.14	0.16
τ_L	0.42	0.37	0.37	0.36	0.34	0.36	0.32	0.33	0.23	0.38	0.23	0.29	0.36	0.33	0.35
τ_K	0.16	0.27	0.21	0.25	0.16	0.19	0.12	0.12	0.17	0.25	0.20	0.17	0.20	0.21	0.20
c/y	0.53	0.52	0.52	0.57	0.56	0.45	0.50	0.72	0.51	0.59	0.67	0.57	0.55	0.59	0.56
x/y	0.23	0.24	0.22	0.22	0.19	0.20	0.22	0.24	0.22	0.22	0.23	0.29	0.21	0.24	0.22
g/y	0.19	0.23	0.22	0.23	0.18	0.26	0.17	0.18	0.19	0.20	0.20	0.19	0.21	0.20	0.21
tb/y	0.06	0.01	0.04	−0.02	0.06	0.08	0.06	−0.14	0.09	−0.01	−0.10	−0.06	0.03	−0.03	0.01
Rev$/y$	0.42	0.43	0.42	0.41	0.36	0.38	0.33	0.31	0.29	0.41	0.41	0.32	0.39	0.36	0.38
Total Exp$/y$	0.49	0.50	0.49	0.53	0.44	0.46	0.39	0.51	0.43	0.49	0.45	0.41	0.48	0.46	0.47
(b) Debt Shocks															
d_{2007}/y_{2007}	0.60	0.84	0.35	0.64	0.65	0.45	0.20	1.07	0.25	1.03	0.68	0.36	0.62	0.75	0.66
d_{2011}/y_{2011}	0.72	0.98	0.49	0.86	0.81	0.65	0.34	1.71	1.08	1.20	1.08	0.69	0.79	1.05	0.88
$\Delta d/y$	0.12	0.14	0.14	0.22	0.15	0.20	0.14	0.63	0.83	0.17	0.40	0.33	0.18	0.30	0.22

Note: EU10 includes Austria, Belgium, Estonia, Finland, France, Germany, Luxembourg, the Netherlands, the Slovak Republic and Slovenia.
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	0.0164	$x/y = 0.222$ and $k/y = 2.97$ (OECD and AMECO)
χ_0	capacity utilization	0.03	set to match $\delta(\bar{m})$ and $\bar{m}$
χ_1	capacity utilization	1.66	set to match $\delta(\bar{m})$ and $\bar{m}$
ϕ	country size	0.50	symmetric countries
Fiscal Policy:			
g/y	Gov't exp share in GDP	0.21	OECD National Income Accounts
τ_C	consumption tax	0.16	MRT modified
τ_L	labor income tax	0.35	MRT modified
τ_K	capital income tax	0.20	MRT modified
θ	depreciation allowance limitation	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

	Symmetric Case		Asymmetric Case			
	All EU		GIIPS		EU10	
	Data	Model	Data	Model	Data	Model
c/y	0.56	0.57	0.59	0.60	0.55	0.53
x/y	0.22	0.22	0.24	0.23	0.20	0.23
g/y^*	0.21	0.21	0.20	0.20	0.21	0.21
tb/y	0.00	0.00	-0.03	-0.03	0.03	0.03
Rev/y	0.38	0.38	0.36	0.36	0.39	0.39
d/y^*	0.66	0.66	0.75	0.75	0.62	0.62

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

(Foreign maintains revenue neutrality with labor tax)

	Open Economy				Closed Economy	
	Home		Foreign		Home	
Tax rates	Old	New	Old	New	Old	New
τ_K	0.20	0.34	0.20	0.20	0.20	0.34
τ_C	0.16	0.16	0.16	0.16	0.16	0.16
τ_L	0.35	0.35	0.35	0.32	0.35	0.35
Change in PV of primary bal. as a share of initial GDP		0.14		0.00		0.28
Welfare effects (percent)						
steady-state only		−7.68		−0.31		−9.55
overall		−6.74		1.27		−6.65
Percentage changes	Impact Effect	Long-Run Effect	Impact Effect	Long-Run Effect	Impact Effect	Long-Run Effect
y	−2.32	−13.50	−2.60	4.47	−8.24	−11.25
c	−4.24	−9.61	4.06	2.41	−2.40	−10.11
k	0.00	−28.45	0.00	4.47	0.00	−26.59
Percentage point changes						
tb/y	15.65	−2.44	−14.44	2.00		
x/y	−16.80	−3.33	9.89	0.00	−8.87	−3.33
r	0.00	0.00	0.00	0.00	0.00	0.00
$1-l$	−0.69	0.65	0.48	−0.82	0.56	0.19
m	−11.11	1.97	−2.52	0.00	−15.80	1.97

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

(Foreign maintains revenue neutrality with labor tax)

	Open Economy				Closed Economy	
	Home		Foreign		Home	
Tax rates	Old	New	Old	New	Old	New
τ_K	0.20	0.20	0.20	0.20	0.20	0.20
τ_C	0.16	0.16	0.16	0.16	0.16	0.16
τ_L	0.35	0.37	0.35	0.34	0.35	0.37
Change in PV of primary bal. as a share of initial GDP		0.14		0.00		0.15
Welfare effects (percent)						
steady-state only		−1.88		−0.10		−2.04
overall		−1.79		0.12		−1.80
Percentage changes	Impact Effect	Long-Run Effect	Impact Effect	Long-Run Effect	Impact Effect	Long-Run Effect
y	−1.83	−2.83	−0.20	0.41	−3.21	−2.63
c	−3.09	−3.53	0.37	0.24	−2.95	−3.57
k	0.00	−2.83	0.00	0.41	0.00	−2.63
Percentage point changes						
tb/y	1.37	−0.19	−1.16	0.18		
x/y	−1.21	0.00	0.78	0.00	−0.44	−0.00
r	−0.00	−0.00	−0.00	0.00	−0.00	−0.00
$1-l$	0.43	0.52	0.04	−0.08	0.51	0.48
m	−0.99	0.00	−0.21	−0.00	−1.31	−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: SYMMETRIC-COUNTRY GAME OUTCOMES

	Pre-Crisis	Nash	Cooperative	Autarky	Unilateral	Nash 1
Home						
τ_K	0.202	0.149	0.203	0.203	0.152	0.174
τ_L	0.347	0.424	0.389	0.389	0.416	0.437
ΔPV(Primary Balance)/Y		0.22	0.22	0.22	0.22	0.22
ΔWelfare v. pre-crisis		-3.28	-2.83	-2.83	-2.87	-5.50
Foreign						
τ_K	0.202	0.149	0.203	0.203	0.202	0.102
τ_L	0.347	0.424	0.389	0.389	0.342	0.389
ΔPV(Primary Balance)/Y		0.22	0.22	0.22	0	0
ΔWelfare v. pre-crisis		-3.28	-2.83	-2.83	-0.18	1.00

Note: In the Nash game, the home and foreign countries both have the debt shock of 0.22. We assign equal weights for the two countries in the cooperative equilibrium. For the unilateral experiment, the foreign country keeps its pre-crisis capital tax rate and adjusts its labor tax rate to maintain revenue neutrality, while the home country chooses its capital and labor tax rate which maximizes its welfare subject to the debt requirement. In the Nash 1 case, the home and foreign countries play the nash game in which the home has to meet its debt shock, while the foreign country has no debt shock.

Table 8: ASYMMETRIC-COUNTRY NASH GAME OUTCOMES

	Symmetric	Asymmetric						
	Bench	Size	NFA	τ_K	τ_L	τ_C	Debt shock	All
GIIPS								
τ_K	0.15	0.12	0.19	0.15	0.12	0.13	0.19	0.13
τ_L	0.42	0.43	0.44	0.43	0.41	0.42	0.45	0.43
ΔPV(Primary Balance)/Y	0.22	0.22	0.22	0.22	0.22	0.22	0.30	0.30
ΔWelfare v. pre-crisis	-3.28	-2.72	-5.79	-3.18	-1.75	-2.30	-6.81	-3.50
EU 10								
τ_K	0.15	0.17	0.12	0.15	0.18	0.17	0.12	0.16
τ_L	0.42	0.42	0.42	0.42	0.45	0.43	0.41	0.42
ΔPV(Primary Balance)/Y	0.22	0.22	0.22	0.22	0.22	0.22	0.18	0.18
ΔWelfare v. pre-crisis	-3.28	-3.46	-1.90	-3.27	-5.63	-4.52	-1.40	-2.93

Table 9: GIIPS-EU10 GAME OUTCOMES

	Pre-Crisis	Unilateral	Nash	Cooperative	Autarky
GIIPS					
τ_K	0.210	0.143	0.128	$[0.171, 0.197]$	0.180
τ_L	0.330	0.419	0.429	$[0.391, 0.394]$	0.395
ΔPV(Primary Balance)/Y		0.30	0.30	0.30	0.30
ΔWelfare v. pre-crisis		-3.30	-3.50	$[-3.43, -2.62]$	-2.95
EU10					
τ_K	0.200	0.200	0.160	$[0.212, 0.195]$	0.204
τ_L	0.360	0.364	0.423	$[0.397, 0.394]$	0.394
ΔPV(Primary Balance)/Y		0	0.18	0.18	0.18
ΔWelfare v. pre-crisis		-0.25	-2.93	$[-2.87, -2.36]$	-2.58
Weights				$[0.23, 0.30]$	

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. For the unilateral experiment, the foreign country keeps its pre-crisis capital tax rate and adjusts its labor tax rate to satisfy the revenue neutrality, while the home country chooses its capital and labor tax rate which maximizes its welfare subject to the debt requirement.