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Abstract

The integration of European financial markets of the 1980s created an environment of near-perfect capital mobility across countries that had harmonized indirect taxes but maintained large differences in factor taxes. The years that followed witnessed several rounds of competition in capital taxes with puzzling results. Instead of the dreaded "race to the bottom" in capital taxes, the U.K. lowered its capital tax to a rate closer to those of France, Germany and Italy, while capital taxes changed slightly in these countries. The U.K. increased its labor tax marginally, but the other countries increased theirs sharply. This paper shows that these results are consistent with the quantitative predictions of a dynamic, Neoclassical general equilibrium model of tax competition that incorporates the key international externalities of tax policy operating via relative prices, wealth distribution and fiscal solvency. Tax competition is modeled as a one-shot game over time-invariant capital taxes with dynamic payoffs relative to a status quo calibrated to European data. The calibration is preceded by an empirical analysis that shows that the relationships linking taxes to labor supply and the investment rate in the model are in line with empirical evidence and that domestic taxes seem to respond to foreign taxes. The solutions of the games show that when countries compete over capital taxes adjusting labor taxes to maintain fiscal solvency, there is no race to the bottom and the Nash equilibrium is close to observed taxes. In contrast, if consumption taxes adjust to maintain fiscal solvency, competition over capital taxes triggers a "race to the bottom," but this outcome entails large welfare gains. Surprisingly, the gains from coordination are small in all of these experiments.

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1. Introduction.

The creation of the unified financial market in Europe at the beginning of the 1980s created a region with a very high degree of international capital mobility across countries with uneven tax structures. The agreements on indirect tax harmonization of the 1960s and 70s pegged the countries to nearly uniform rates of indirect taxation, but large differences in factor income taxation remained. As the macroeconomic estimates of effective tax rates shown in Figures 1-3 indicate, the United Kingdom had a higher capital income tax and a lower labor tax than France, Germany and Italy (Continental Europe, or CE). Financial integration thus created ripe conditions for competition in the taxation of capital income to take place.

The views on the effects of this tax competition and on the policies needed to address them varied widely across countries and over time. In 1997, the official European position was that tax competition was harmful and needed to be contained:

> "There is clearly a pressing need to … ensure a more effective co-ordination of taxation policies… Tackling the issue of harmful tax competition, which threatens both to reduce revenues and to distort taxation structures, should be central to this process." (*The Package to Tackle Harmful Tax Competition*, ECOFIN Ministers of the European Community, 1997)

By 2001 the view of the EU commissioner for the internal market was the opposite. The tax burden was seen as excessive and competition was seen as a healthy way to reduce it:

> "The priority is to reduce the tax burden EU wide. And don't even attempt to harmonize national tax systems across the board….the EU is already pledged to eliminate harmful tax competition, but a reasonable degree of tax competition would not be harmful at all: it would lead to a market-driven convergence towards lower tax rates..." (*The Economist*, Feb. 10, 2001, p. 52, citing Frits Bolkenstein, EU Commissioner for the Internal Market)

However, several key EU politicians still maintain that tax competition is harmful and needs to be addressed:

> "Plans to scrap the national veto on tax to eliminate "unfair" tax competition will be proposed by Valéry Giscard d'Estaing...He believes that without reform, the EU's single market will be distorted as countries embark on a damaging race to undercut one another's company tax rates…Britain was a pioneer in the 1980s, cutting corporation tax from 52% to 35%, but Ireland today is the pace-setter with a rate of just 12.5%…. Both countries believe such competition is healthy…However, France and Germany are among those pushing for more tax harmonisation…" (*Financial Times*, May 5, 2003).

Interestingly, France and Germany appear to side with the view that competition is harmful, while Britain and Ireland, which have made major cuts to their corporate tax rates, are among the countries pushing in favor of more tax competition.

The tax rates plotted in Figures 1-3 confirm that tax competition did not result in a fierce race to the bottom in capital taxes (Figure 1). Instead, the UK lowered its capital income tax while countries in CE changed their capital taxes slightly. The UK increased its labor tax somewhat, but labor taxes increased sharply in the CE countries (Figure 2). The indirect tax harmonization agreements led to fairly similar and stable rates of indirect taxation across the UK and CE.

Why did tax competition produce these puzzling dynamics instead of the dreaded race to the bottom? Why are some European countries seeking to prevent and reverse capital tax competition while others are trying to foster it? This paper answers these questions by examining the quantitative predictions of capital income tax competition in a two-country dynamic, Neoclassical general equilibrium model with perfect international capital mobility. We use this model to compare the cooperative and non-cooperative equilibria of one-shot games played by two national fiscal authorities that set taxes on factor incomes and consumption and have access to domestic debt markets. The authorities are benevolent in that they assess the payoffs of tax strategies by computing the impact on households' lifetime utility, taking into account the economies' transitional dynamics along the intertemporal competitive equilibrium path.

The model incorporates the three key international externalities of tax policy via relative prices, wealth distribution and fiscal solvency that have been widely studied in the macroeconomics literature on tax competition since the 1980s. Much of this literature is based on the premise that tax competition is harmful and that coordination of tax policy between national authorities is therefore welfare-improving (see the survey by Persson and Tabellini (1995) and the books by Frankel, Razin and Sadka (1991) and Turnovsky (1997)). Paradoxically, there have been few attempts to quantify the outcomes of tax competition and the gains of tax coordination to assess the robustness of this premise.[2]

The mechanisms that drive the three global externalities of national tax policy are well known. The relative price externality is a variant of the traditional market-power or beggar-thy-neighbor effect on relative prices: countries engaged in tax competition attempt to use tax policy to influence the terms of trade or the world real interest rate in their favor. The argument is often formulated in endowment economy models that isolate this externality from the other two global externalities. Theoretical work shows that the magnitude of this relative-price externality depends on factors such as a country's relative size, or the degree of market concentration (see for example Chari and Kehoe (1990) and Kanbur and Keen (1993)).

[2] A recent quantitative study by Klein, Quadrini and Rios-Rull (2001) studies optimal, time-consistent policies in a setting with dynamic strategic interaction to explain why the tax on capital income is higher in the United States than in Europe. Sorensen (1999, 2003) and Eggert (1998) quantify the gains from tax coordination using static models that emphasize strategic effects on international prices.

The wealth-redistribution externality emerges in environments in which taxation affects the accumulation of factors of production, and as a result strategic cuts in taxes can be used to attract internationally mobile factors. The payoffs assigned to strategic tax cuts reflect the welfare effects induced by the cross-country relocation of mobile factors and its impact on the present discounted value of national income and the long-run stocks of physical capital and foreign financial assets. Mendoza and Tesar (1998) and Mendoza (2002) show that this wealth-redistribution externality is large and has significant welfare effects in quantitative experiments of unilateral capital income tax cuts.

The fiscal solvency externality is triggered by the adverse effect of tax competition on tax revenue, and is a byproduct of the relative-price and wealth-redistribution externalities discussed above. For example, if tax competition did trigger a "race to the bottom" reducing taxes on mobile factors of production, this would erode tax revenues because (a) revenues from taxes on mobile factors decline on account of lower tax rates (assuming these tax rates are in the upward-slopping region of their Laffer curves), (b) the flow of mobile factors of production from a high-tax country to a low-tax country directly reduces the tax base in the high tax country, and (c), in general equilibrium, the relocation of mobile factors can also lower factor payments to immobile factors and overall factor income in the high tax country, thus further eroding its tax base. As tax revenue falls, governments are forced either to reduce expenditures or to raise other taxes. If government outlays have utility or production benefits, or if the alternative taxes are distortionary, this fiscal solvency externality reduces welfare (see Huber (1999), Keen and Marchand (1997) and Rodrik and van Ypersele (1999)).

The existing literature on international tax competition often treats these three externalities separately and deals with them in simplified dynamic environments under partial equilibrium and with governments running balanced budgets in every period. In contrast, the quantitative analysis we conduct in this paper captures the three international externalities of national tax policy simultaneously in a fully dynamic general equilibrium framework. Each country taxes a mobile factor of production (physical capital), an immobile factor (labor) and consumption using time-invariant tax rates. Countries trade one-period bonds under perfect mobility of *financial* capital. This allows physical capital to relocate across countries even though ownership shares of each country's capital stock are not directly traded. The international mobility of *physical* capital is less than perfect, however, because capital-adjustment costs limit the pace at which capital migrates across countries. The model also features domestic public debt markets so that the fiscal authorities do not need to balance the primary deficit each period, but instead equate the present value of tax revenue with the present value of a pre-determined, time-invariant amount of government outlays (i.e., current government purchases

plus transfer payments). Thus, the fiscal solvency externality imposes endogenous tax adjustments but with the flexibility to use public debt as a means to smooth the tax burden over time.

In Mendoza and Tesar (1998) we used a similar model to quantify the international spillovers of tax policy caused by a unilateral tax reform replacing a country's tax on capital income with a consumption tax. In simulations calibrated to data for the United States and Europe, we found that these spillovers are large and lead to important deviations from what similar experiments predict in closed-economy models. In a closed economy, agents face the prospect of a large and costly transition period as the cut in the capital tax triggers an investment boom that is financed at the expense of reduced consumption and increased labor effort. The economy faces a tradeoff between the short-run pain of postponing consumption and the long-run benefit of higher output and higher consumption that results from more efficient taxation (see Chamley (1981) and Lucas (1990)). In a world with open capital markets, however, the ability to borrow from abroad reduces the transition costs and shifts some of the burden of adjustment onto the rest of the world. Indeed, we found that eliminating the U.S. capital income tax leads to an increase in welfare for U.S. households equivalent to a 2.9 percent rise in trend consumption and a fall in European welfare equivalent to a –1.7 percent adjustment in trend consumption. The negative impact on Europe is due to a temporary increase in the world interest rate, a large outflow of capital from high-tax Europe to the low-tax United States, and an undesired increase in the European consumption tax needed to preserve fiscal solvency (Europe's consumption tax must increase nearly 10 percentage points).

Our previous work did not consider the strategic interaction implied by the international externalities of unilateral tax reforms that we quantified. We did show that an arbitrary world-wide elimination of the capital income tax could lead to significant welfare gains for all countries. Hence, our previous results suggest that strategic interaction is likely to play a central role in the analysis of international taxation. This paper follows up on this suggestion by undertaking a quantitative analysis of the effects of tax competition. Our previous analysis also did not explore the possibility of trade offs across highly-distortionary taxes. We assumed that losses in the present value of tax revenues resulting from unilateral cuts in capital taxes were made up by increases in consumption taxes, which in our Neoclassical setup result in weak distortions. Hence, in this paper we alter this assumption and explore tax competition games in which fiscal solvency effects due to strategic cuts in capital taxes result in either consumption tax adjustments or labor tax adjustments. Mendoza (2002) showed that in the latter case the trade off between the two highly-distorting factor income taxes can be complex because of dynamic Laffer curve considerations. In our game-theoretic analysis, these considerations imply that reaction curves are only well-defined in the region of the strategy space of capital tax rates

in which the Laffer curves generate enough tax revenue to cover the present value of government outlays.

The numerical solutions of the tax competition games start from a status quo calibrated to European data. The calibration is preceded by an empirical analysis of the co-movements between macroeconomic aggregates and our estimates of effective tax rates. We find evidence suggesting that investment rates and the supply of labor respond to changes in tax rates in a manner consistent with the predictions of the Neoclassical model that anchors the tax competition analysis. In particular, the investment rate is found to be negatively related to the capital income tax in a low-frequency, cross-section analysis (as predicted by the model's stationary equilibrium conditions) and the supply of labor is found to respond negatively to increases in the effective tax on labor and in the consumption-output ratio in time-series regressions of individual countries (as predicted by the model's optimality condition for labor supply). In addition, the data provide evidence suggesting that financial integration led to stronger strategic interaction in tax policies. In particular, we found that cross-country correlations in tax rates increased significantly in the 1980s relative to the 1970s and there is some evidence at the annual frequency showing that domestic investment rates respond to foreign tax rates.

The quantitative analysis of tax competition starts with a game between two perfectly symmetric countries calibrated to an "average" CE country with a relatively high labor tax and a relatively low capital tax. The aim is to start with a scenario in which the externalities driving strategic tax choices are unaffected by country-specific differences in initial tax structures, government outlays, or initial holdings of physical capital and foreign financial assets. We examine two variations on the tax competition game. In the first case, the fiscal solvency externality forces endogenous adjustments in labor income tax rates so as to ensure that the present value of tax revenue in each country matches the present value of their unchanged government outlays. The second case preserves fiscal solvency by requiring instead adjustments in consumption tax rates.

The results of these symmetric games are striking. In the experiment with labor taxes adjusting to maintain fiscal solvency, the Nash equilibrium yields capital and labor tax rates that are close to observed tax rates. Thus, the model can account for the tax rates observed in Europe in the 1980s as the outcome of tax competition over capital income taxes in a game in which the tax revenue externality triggered changes in tax rates on the immobile factor, labor. This is also consistent with the fact that there was little room for changes in indirect taxes in Europe because of VAT harmonization treaties. When countries coordinate, we obtain the standard result that they choose higher tax rates on capital income relative to the Nash outcome, and these higher taxes in turn support slightly lower labor tax rates. However, despite differences in tax rates and in allocations under tax

competition and coordination, the welfare gain of coordination is under 0.26 percent in terms of a compensating variation in lifetime consumption.

In the symmetric game with consumption taxes adjusting to maintain fiscal solvency, the results are markedly different. Tax competition triggers a race to the bottom in capital tax rates, and the consumption taxes increase by 8 percent in each country to maintain fiscal solvency. However, as the quote from Frits Bolkenstein suggested, both countries *gain* from tax competition (relative to the status quo) as the more distortionary capital income tax is replaced by higher consumption taxes. The gains from coordination are even smaller than in the previous game as the gain in welfare relative to the Nash outcome is about 0.04 a percentage point.

We then move on to an asymmetric game calibrated to capture tax competition between the United Kingdom and CE (which incorporates only the asymmetry of observed differences in initial tax rates and transfer payments). In the case that labor taxes are used to maintain fiscal solvency, tax competition is immiserizing for CE and welfare-improving for the UK. The UK starts with a lower labor tax and a higher capital tax. Tax competition results in a lower capital income tax in the UK and capital relocates from CE to the UK. The tax base in CE erodes and therefore CEe must increase *both* capital and labor income tax rates to maintain fiscal solvency. The gains from coordination are small for both the UK and CE, and do not allow CE to recoup its losses from tax competition. These results help explain the opposing views of the UK, on one side, and France and Germany, on the other side, about whether to counter or foster tax competition. In the game with adjustment in consumption taxes, we again observe the race-to-the-bottom in capital income taxes of the symmetric game, and both parties gain from competition. Coordination again yields only tiny welfare gains over the Nash outcome.

We conduct sensitivity analysis to study how the results vary with changes in initial debt levels, labor supply elasticity, and capital adjustment costs. This analysis shows that the elasticity of labor supply plays a central role in the results. As this elasticity falls, the game with labor tax adjustments delivers results similar to those of the game with consumption tax adjustments (e.g., a race to the bottom in capital taxes), since the effects of the labor tax become similar to those of the consumption tax as labor supply becomes less elastic. In this context, the empirical evidence lending support to the labor elasticity used to calibrate model is an important factor that suggests that the model's explanation for the absence of a race to the bottom in capital taxes in the EU is empirically plausible. A second important result of the sensitivity analysis is the finding that the gains from tax coordination are generally, ranging from 0.01 to 0.5 percent of trend consumption. These findings suggest that the structure of tax rates observed in Europe is consistent with the pressures induced by

tax competition, and that, given the small incremental gains from tax competition, it is not surprising that tax coordination has proven to be an elusive goal.

The paper proceeds as follows. Section 2 presents the structure of the model, defines the model's competitive equilibrium, and develops the intuition behind the three international externalities of unilateral tax policy. Section 3 defines the tax competition environment by providing explicit definitions for the pre-tax-competition equilibrium, the tax strategy space, the Nash equilibrium of tax competition, and the cooperative equilibrium. Section 4 conducts the empirical analysis of the co-movements of macroeconomic aggregates and effective tax rates. Section 5 calibrates the model to European data and reports the results of the tax competition experiments. Section 6 concludes.

2. A Dynamic, Neoclassical General Equilibrium Model with Distortionary Taxes

We study international tax competition using a standard two-country, Neoclassical balanced-growth model. The model is a deterministic version of the typical two-country real-business-cycle model to which we introduce fiscal policy following the setup developed by Mendoza and Tesar (1998). Each country is inhabited by identical, infinitely-lived individuals. Both countries produce a single tradable commodity using capital and labor, and trade this good and real one-period bonds issued by the private sector. All markets for goods, factors of production and financial assets are perfectly competitive. To help isolate the effects of the international externalities of tax policy and their impact on tax competition, we assume that countries are fully symmetric in technology and preferences. Therefore, the model will be characterized using home-country equations. Later, foreign variables will be denoted with an asterisk (*).

The specification of preferences and technology is consistent with the well-known conditions required to support exogenous balanced growth driven by labor-augmenting technological change. Accordingly, we assume that the state of labor-augmenting technology grows at the exogenous long-run growth rate γ. All variables, except leisure and labor, are rendered stationary by dividing through by the state of technology and the stationary variables are written in lower case. We focus on the competitive equilibrium of the detrended model without loss of generality.

The assumption that long-run growth is exogenous implies that the externalities of tax policy and tax competition do not affect long-run growth. This may seem at odds with *qualitative* predictions of a large class of endogenous growth models, but it is in line with their *quantitative* predictions and with the evidence indicating that long-run growth seems largely independent of the variations of tax rates observed in the data (see Lucas (1990) and Mendoza, Milesi-Ferretti and Asea (1997)). Note in addition that even without growth effects, the welfare implications of tax policies that result from efficiency gains or losses in exogenous-growth models are generally large (see Lucas (1990), Cooley and Hansen (1992) and Mendoza and Tesar (1998)).

Households

The representative household in the home country maximizes an isoelastic lifetime utility function over consumption, c_t, and leisure, ℓ_t:

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

In this expression, β is the household's subjective discount factor, $1/\sigma$ is the intertemporal elasticity of substitution in consumption, and a is a coefficient that governs the intertemporal elasticity of labor supply for a given value of σ. Note that the stationary transformation of the model implies an effective discount factor given by $\beta(1+\gamma)^{1-\sigma}$ instead of β.

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

$$(1+\tau_C)c_t+(1+\gamma)\left(k_{t+1}+q_t b_{t+1}+q_t^g d_{t+1}\right)+\left(\frac{\eta}{2}\left(\frac{x_t}{k_t}-z\right)^2-1\right)k_t = (1-\tau_L)w_t L_t+(1-\tau_K)(r_t-\delta)k_t+b_t+d_t+e_t \tag{2}$$

for $t = 0,\ldots,\infty$, given the initial conditions $k_0>0$, b_0, and d_0. The household takes as given government-determined 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 the factor payment rates to labor, w_t and capital, r_t, and the prices of government bonds and foreign bonds, q_t^g and q_t as given (for simplicity, international and government bonds are represented as discount bonds, so the gross real rates of return on these bonds are $R_t/(1/q_t)$ and $R_t^g/(1/q_t^g)$ respectively).

The left-hand-side of (2) measures household expenditures. These include purchases of consumption goods inclusive of the indirect tax, new capital goods, k_{t+1}, private international bonds, b_{t+1}, and domestic government bonds d_{t+1}. The price of capital and the price of consumer goods differ because investment incurs quadratic capital-adjustment costs as a function of the ratio of net investment (x_t) to existing capital (k_t). The coefficient η determines the speed of adjustment of the capital stock, while z is set equal to the long-run investment-capital ratio to ensure that at steady state the capital adjustment cost is zero. Net investment adjusted for exogenous technological progress is defined as $x_t/(1+\gamma)k_{t+1}-(1-\delta)k_t$, where δ is the rate of depreciation of the capital stock.

The right-hand side of (2) shows the household's after-tax income, which includes payments on labor and capital rented out to firms, the payoffs on domestic public bonds and foreign bonds, and government transfers. Implicit in this expression are the assumptions that the capital income tax is based on the residence principle and the tax code provides for a depreciation allowance. Also implicit

is the assumption that bond payments are tax-free (Mendoza and Tesar (1998) examined the implications of relaxing this assumption and found that it can have important effects on the quantitative predictions of the model).

According to equation (2), domestic physical capital and public debt are owned entirely by domestic households. This assumption of "extreme home bias" in the holdings of these assets is required for the model to support competitive equilibria in which international trade in private bonds and residence-based taxation co-exist with different country-specific tax rates on domestic capital income. As we show in Mendoza and Tesar (1998), this is not possible if shares on physical capital and/or government bonds are freely traded across countries (see also Frenkel et al. (1991)). Other forms of financial-market segmentation, such as trading costs or short-selling constraints, could be introduced for the same purpose, but so far they have proven inadequate to solve the high degree of home bias observed in the data and they would complicate the model significantly. [3]

Households also face a standard no-Ponzi-game restriction. This restriction, together with (2) implies that the present value of household income must equal that of expenditures plus any initial asset holdings.

Households allocate their time between labor and leisure subject to the time constraint:

$$\ell_t + L_t = 1 \tag{3}$$

where we normalize the total number of hours to unity. Labor is immobile across countries.

Firms

Firms maximize profits taking factor prices as given. The production function is Cobb-Douglas:

$$F(k_t, L_t) = k_t^{1-\alpha} L_t^{\alpha}, \qquad 0 < \alpha < 1. \tag{4}$$

where α is the labor income share. Since firms operate under perfect competition, they earn zero profits in equilibrium and factor demands are given by standard marginal productivity conditions. Without loss of generality, all corporate taxes are viewed as included in the capital income tax levied on households.

The Public Sector

Fiscal policy in each country has three components: first, a predetermined sequence of government outlays made up of unproductive expenditures and entitlement payments, (g_t+e_t) for

[3]The assumptions of extreme home bias 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. However, actual tax systems are a mixture of residence- and source-based systems. Frenkel et al. (1991) show that personal income taxes across

$t=0,\ldots,\infty$; second, a set of time-invariant tax rates $\tau=(\tau_C, \tau_L, \tau_K)$; and third, a sequence of public bond issues, d_t, for $t=0,\ldots,\infty$. The period government budget constraint is given by:

$$(g_t + e_t) + d_t = \tau_c c_t + \tau_L w_t L_t + \tau_K (r_t - \delta) k_t + (1+\gamma) q_t^g d_{t+1} \tag{5}$$

The left-hand-side of equation (5) measures uses of government income (i.e. goods purchases, entitlement payments, and debt payments). The right-hand-side measures sources of government income: tax revenue and the proceedings from sales of newly-issued bonds (adjusted to conform with the stationary transformation of the model). Government purchases, entitlement payments, and tax rates are the instruments of fiscal policy. Thus, a primary fiscal deficit or surplus at date t (i.e., a gap between goods purchases, entitlement payments and tax revenue) is offset by an endogenous change in public debt (net of interest and principal on existing debt). However, since the government also faces a no-Ponzi-game constraint, the intertemporal government budget constraint requires that the present value of government expenditures plus entitlement payments must equal the present value of tax revenue net of payments on initial public debt.[4] Hence, given its tax and expenditure policies and its initial bond position, the government is constrained to choosing a time path of public bond issues that satisfies its intertemporal budget constraint.

Public debt is "Ricardian" in the sense that, given d_0 and the policy choices on government purchases, entitlement payments, and tax rates, the competitive equilibrium can be represented either with the path of public bonds dictated by (5) or with a hypothetical sequence of lump-sum taxes (subsidies), T_t, set to an amount equal to the primary fiscal deficit (surplus):

$$T_t = \tau_C c_t + \tau_L w_t L_t + \tau_K (r_t - \delta) k_t - (g_t + e_t) \tag{6}$$

For simplicity, the numerical analysis is conducted using this Ricardian representation of the government budget constraint. With this change, the budget constraint for households becomes:

$$(1+\tau_C) c_t + (1+\gamma)(k_{t+1} + q_t b_{t+1}) + \left(\frac{\eta}{2}\left(\frac{x_t}{k_t} - z\right)^2 - 1\right) k_t = (1-\tau_L) w_t L_t + (1-\tau_K)(r_t - \delta) k_t + b_t + e_t + T_t \tag{7}$$

Competitive Equilibrium

A *competitive equilibrium* for this two-country world economy is defined by sequences of prices $[r_t, r_t^*, q_t, w_t, w_t^*]$ and allocations $[k_{t+1}, k_{t+1}^*, b_{t+1}, b_{t+1}^*, x_t, x_t^*, L_t, L_t^*, \ell_t, \ell_t^*, c_t, c_t^*, T_t, T_t^*]$ for

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OECD countries are mainly residence based, while corporate income taxes are source based in principle but supplemented by treaties that allow for credits or deductions so as to approximate residence-based taxation.

[4] Note that (2), (5), and the no-Ponzi-game constraints on households and government imply that the present value of the trade balance equals b_0.

$t=0,\ldots,\infty$ such that: (a) households in each country maximize utility subject to their corresponding budget constraints, time constraints and no-Ponzi-game constraints, taking as given pre-tax prices and factor rental rates, the values of all fiscal policy variables, and date-0 holdings of capital and foreign bonds, (b) firms maximize profits subject to the Cobb-Douglas technologies 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 for the global markets of goods and bonds hold:

$$k_t^{1-\alpha} L_t^{\alpha} + \left(k_t^*\right)^{1-\alpha^*} \left(L_t^*\right)^{\alpha^*} = c_t + c_t^* + x_t + \frac{\eta}{2}\left(\frac{x_t}{k_t} - z\right)^2 k_t + x_t^* + \frac{\eta^*}{2}\left(\frac{x_t^*}{k_t^*} - z^*\right)^2 k_t^* + g_t + g_t^*, \tag{8}$$

$$b_t + b_t^* = 0 \tag{9}$$

The Three International Externalities of National Tax Policy

The international externalities of tax policy operating in the model can be characterized by studying the implications of the tax distortions on saving, investment and labor supply. This issue is covered in detail in Mendoza and Tesar (1998). We provide here a condensed description to make more room for the analysis of tax competition.

One of the main driving forces of international tax policy externalities in the model is the arbitrage of after-tax real returns to physical capital that is obtained through cross-country trade in one-period private bonds. The Euler conditions for capital and bonds in the two countries (simplified here to ignore capital-adjustment costs) imply:

$$\frac{(1+\gamma)u_1(c_t, L_t)}{\beta u_1(c_{t+1}, L_{t+1})} = (1-\tau_k)[F_1(K_{t+1}, N_{t+1}) - \delta] + 1 = R_t \tag{10}$$

$$\frac{(1+\gamma)u_1(c^*_t, L^*_t)}{\beta u_1(c^*_{t+1}, L^*_{t+1})} = (1-\tau^*_k)[F_1(K^*_{t+1}, N^*_{t+1}) - \delta] + 1 = R_t \tag{11}$$

Bond trading ensures that the intertemporal marginal rate of substitution in consumption in each country equals the common real rate of return on bonds. In turn, households in each country set optimal investment in their country's capital so that the after-tax net return on capital equals the return on international bonds. Thus, after-tax returns on capital are equalized across countries.

Consider a unilateral cut in the home capital income tax rate. The home country after-tax return on capital increases relative to the foreign country. This efficiency gain leads home agents to borrow from abroad to spread the resulting increase in wealth across consumption in all periods and to offset the short-run burden of increased investment as the economy evolves toward a higher capital

stock. This short-run accumulation of debt leads them to service a larger stock of foreign debt in the new long-run equilibrium. In Mendoza and Tesar (1998) we labeled the initial inflow of foreign goods to the home country implied by the debt build-up the "smoothing effect," and the long-run outflow implied by the increased long-run debt service the "income-redistribution effect."

The increased borrowing by the domestic economy puts pressure on the world interest rate to increase, but the increase can only be temporary because in the long run the model's balanced growth restrictions pin down the long-run real interest rate independently of the tax structure. In particular, the gross long-run real interest rate is given by $R=\beta^{-1}-\gamma\sigma$. However, we show in Mendoza and Tesar (1998) that even though the interest rate hike is only temporary and quantitatively small, it can trigger large reallocations of capital across countries and large adjustments in consumption (which in turn can have sizable welfare effects).

In this example of a unilateral home capital income tax cut, the international externality operating via the intertemporal relative price of consumption is reflected in the transitory interest rate hike discussed above. Moreover, since equilibrium factor prices depend on labor and capital allocations, which are altered by the tax cut, there are also price externalities working through changes in wages and the rental rate of capital in each country. The wealth redistribution effect results from changes in the present value of factor income induced by the reallocation of capital across countries and the changes in the dynamics of capital and labor allocated to production.

Changes in prices, factor incomes and the distribution of wealth in turn have an impact on the tax base in the two countries. Since government outlays are kept constant, the decline in the foreign country's present value of tax revenue induced by the price and wealth externalities means that the foreign labor income and/or consumption taxes must increase to bring the present value of tax revenue back into balance with the present value of government outlays. These changes in consumption or labor taxes abroad are distortionary because these taxes affect the traditional wedge between the marginal rate of substitution in consumption and leisure and the pre-tax real wage that determines the supply of labor:

$$\frac{u_2(c_t, \ell_t)}{u_1(c_t, \ell_t)} = \frac{(1-\tau_L)}{(1+\tau_c)} F_2(k_t, L_t) \qquad (12)$$

Labor and consumption taxes have symmetric distortionary effects on account of the above tax wedge, but they are not equivalent because labor is not the sole source of factor income, capital and labor income are not taxed at the same rates, and the price elasticities of labor supply and consumption

differ.[5] Around the calibrated values of the tax rates we work with later, labor and consumption taxes have very different effects on tax revenue, welfare and household income. In particular, the increase in the labor tax needed to replace the loss in the present value of tax revenue due to a reduction in the capital income tax involves greater distortions than those caused by the consumption tax.

3. Pre-Tax Competition Stationary Equilibrium and Tax Competition Framework

Pre-Tax-Competition Stationary Equilibrium

The strategic interaction between the two countries' fiscal authorities takes place starting from a pre-tax-competition stationary equilibrium. This pre-tax-competition equilibrium is determined by assigning values to the model's preference, technology and fiscal policy parameters and solving for steady-state allocations along the long-run balanced-growth path. The equations that describe the balanced-growth stationary equilibrium of the home country are:

$$\frac{k}{y}=\frac{\beta\left(1+\gamma\right)^{1-\sigma}\left(1-\alpha\right)\left(1-\tau_K\right)}{\left(1+\gamma\right)-\beta\left(1+\gamma\right)^{1-\sigma}\left[1-\delta\left(1-\tau_K\right)\right]} \tag{13}$$

$$\frac{x}{y}=\left(\gamma+\delta\right)\frac{k}{y} \tag{14}$$

$$\frac{c}{y}=1-\frac{x}{y}-\frac{g}{y}-\frac{nx}{y} \tag{15}$$

$$\frac{nx}{y}=\left[\beta\left(1+\gamma\right)^{1-\sigma}-1\right]\frac{b}{y} \tag{16}$$

$$L=\frac{\left(\frac{1-\tau_L}{1+\tau_C}\right)\alpha}{a\frac{c}{y}+\left(\frac{1-\tau_L}{1+\tau_C}\right)\alpha} \tag{17}$$

Equation (13) follows from the steady-state Euler equation for physical capital. It expresses the capital-output ratio at steady state, *k/y*, as a function of preference and technology parameters, and the tax on capital income. Equation (14) is the law of motion for capital accumulation evaluated at steady state, which determines the steady-state investment rate, *x/y*. Notice that at steady state both the capital-output ratio and the investment rate are not *directly* affected by foreign tax policy. These ratios

[5] See Frenkel et al. (1991) for details on direct versus indirect taxation equivalences. The equivalence in our model would also require an inelastic capital stock because otherwise the common labor-capital tax that could yield a leisure-consumption distortion identical to that of a given consumption tax would imply a different distortion on the investment margin.

are affected by foreign taxes only *indirectly* through the effects of tax competition on the domestic capital income tax.

Equation (15) is the resource constraint of the economy, which follows from consolidating the budget constraints of households and government. This equation determines the steady-state consumption-output ratio, c/y, as a function of the investment rate, the GDP share of government purchases, g/y, and the net exports-output ratio, nx/y. Equation (16) is the foreign-asset evolution equation along a balanced-growth path. Since the parameter restrictions set in equation (1) imply $\beta(1+\gamma)^{1-\sigma}<1$, equation (16) implies that a long-run positive (negative) foreign asset position finances a long-run trade deficit (surplus).

Equation (17) represents long-run equilibrium in the labor market as given by the equality between the marginal rate of substitution between consumption and leisure and the post-tax marginal product of labor. The steady state supply of labor does not depend *directly* on foreign taxes, but it does depend on them *indirectly* through the effects of the three international externalities of tax policy on c/y and through endogenous adjustments of the labor or consumption tax rates forced by the fiscal solvency externality. Note that (17) applies not only at steady state but also at any date along the equilibrium path, replacing the steady-state consumption-output ratio in the right-hand-side with the corresponding c_t/y_t ratio.

The above results illustrate important differences in the long-run incidence of domestic taxes. The capital income tax affects k/y, x/y and, through the effect of changes in x/y on c/y, the steady-state allocation of labor, while consumption and labor taxes affect equilibrium labor but not the investment rate or the capital output ratio.

As explained in Mendoza and Tesar (1998), given all preference, technology and fiscal policy parameters, the system (13)-(17) is an underidentified system of five equations in six unknown steady-state variables [$k/y,x/y,L,c/y,tb/y,b/y$]. The system is underidentified because the model displays dependency of the stationary state of bond holdings on initial conditions. For purposes of the pre-tax competition calibration, we use European data to set the values for the variables [$k/y,x/y,L,nx/y$], assign values to the parameters $[\alpha,\gamma,\sigma,g/y,\tau_K,\tau_L,\tau_C]$ as described later, and then solve the system (13)-(17) as a system of five simultaneous equations in the five unknowns [$\beta,\delta,a,c/y,b/y$]. For solving the competitive equilibria of alternative tax strategies, we use the solution method developed in Mendoza and Tesar (1998) to address the problem of dependency of the long-run equilibrium on initial conditions. This method iterates over conjectured long-run bond positions under a new set of tax rates until we find the steady-state bond positions consistent with the initial conditions set by the pre-tax competition equilibrium.

The solution of the pre-tax-competition stationary equilibrium for a pair of initial tax vectors, $\tau = [\tau_c, \tau_L, \tau_k]$ and $\tau^* = [\tau_c^*, \tau_L^*, \tau_k^*]$, and pairs of time-invariant levels of transfer payments and government purchases, [g,e] and [g*,e*], also yields solutions for the steady-state primary fiscal balances T and T*. These solutions represent the debt service of the steady-state stocks of public debt in each country.

Tax Competition Framework

The fiscal authorities of each country meet once to play game in which they choose a time-invariant tax rate on capital income. The payoff that each country receives for a particular choice of capital tax strategies played by each country correspond to the welfare gain or loss that each country stands to make at the competitive equilibrium supported by the chosen capital tax rates and the endogenous labor *or* consumption taxes needed to satisfy the intertemporal government budget constraints. The payoffs are computed as percent variations in consumption at all dates that render households indifferent between the pre-tax-competition levels of lifetime utility and the lifetime utility derived under the competitive equilibrium of the new tax rates.

The computation of the payoffs takes into account the transitional dynamics that the two countries follow in moving from the pre-tax-competition equilibrium to the new long-run equilibrium implied by the new set of tax rates.[6] Both the transitional dynamics and the new long-run equilibrium need to be solved simultaneously because, as explained earlier, the model display dependency on initial conditions in the long-run allocations of foreign bonds, and because of the endogenous adjustment in either the labor or the consumption tax needed to preserve fiscal solvency. We employ the solution method proposed in Mendoza and Tesar (1998), which takes care of these two issues by ensuring that the tax rates in each country and the dynamics of foreign assets satisfy the present-value constraints of private agents and the government in both countries.

The relationship between the endogenous tax adjustments needed to preserve fiscal solvency and the intertemporal government budget constraints can be characterized as follows. At a competitive equilibrium, the home country's intertemporal government budget constraint can be expressed as:

$$\sum_{t=0}^{\infty}\left[\prod_{\tau=0}^{t} R_\tau\left(\tau,\tau^*\right)\right]^{-1}(g+e) = \sum_{t=0}^{\infty}\left[\prod_{\tau=0}^{t} R_\tau\left(\tau,\tau^*\right)\right]^{-1}\left[\tau_K\left(r_t\left(\tau,\tau^*\right)-\delta\right)k_t\left(\tau,\tau^*\right)+\tau_L w_t\left(\tau,\tau^*\right)N_t\left(\tau,\tau^*\right)+\tau_C c_t\left(\tau,\tau^*\right)\right] \tag{18}$$

8 We consider only time-invariant changes in tax policy. In the closed-economy context, Lucas (1990) and Cooley and Hansen (1992) show that the welfare gains from tax reform with time-invariant tax rates dwarf the additional gains from allowing time-variation in tax rates.

The left-hand-side of (18) is the present value of the constant stream of government outlays $g+e$. In this present value calculation, $\left[R_t(\tau, \tau^*) \right]_0^\infty$ is the intertemporal sequence of *equilibrium* world real interest rates that pertain to a competitive equilibrium for given vectors of tax policy (τ,τ^*). The right-hand-side of (18) is the present value of tax revenues. The sequences of *equilibrium* factor prices and allocations that determine the flow of tax revenues (r_t, k_t,, w_t, N_t, and c_t) are also competitive equilibrium prices and allocation for the same two tax vectors.

In principle, for given capital income taxes (τ_K,τ_K^*), the home-country government could satisfy the above constraint (i.e., maintain intertemporal fiscal solvency) with any combination of τ_C and τ_L that solves equation (18). However, the equation cannot be solved in closed form for these endogenous tax adjustments because the equilibrium prices and allocations in both sides of (18) vary with the tax rates on factor incomes and consumption. For tractability, we narrow the analysis to tax competition experiments that adopt one of these two rules to maintain fiscal solvency: adjust consumption taxes only (keeping labor tax rates constant) or adjust labor taxes only (keeping consumption taxes constant). These fiscal solvency rules are known to both governments and both governments are assumed to be credibly committed to follow them. The fiscal solvency rule that adjusts the labor tax is a better proxy for the current situation in the European Union, where the high degree of VAT harmonization attained by international treaties limits the possibility of adjusting indirect tax rates.

A strategic decision rule for each country's capital income tax rate given the other country's capital tax rate is obtained as follows. The government of each country chooses its capital income tax rate so as to maximize the payoff to that country's residents taking as given the other country's capital income tax and subject to the constraints that:

(a) The implied allocations and prices for a global tax structure $\tau=(\tau_K,\tau_L,\tau_C)$ and $\tau^*=(\tau_K^*,\tau_L^*,\tau_C^*)$ are a competitive equilibrium.

(b) Labor or consumption taxes in both countries adjust so that the intertemporal government budget constraints of the two countries hold.

In the numerical solutions of the tax competition games, each country chooses its capital income tax rate from values in discrete grids: $\tau_K \in \Psi_K = \left\{ \tau_{K,1} < \tau_{K,2} < ... < \tau_{K,M} \right\}$ and $\tau_K^* \in \Psi_K^* = \left\{ \tau_{K,1}^* < \tau_{K,2}^* < ... < \tau_{K,M}^* \right\}$. Hence the tax strategy space is defined by the set of MxN capital income tax rate pairs (τ_K,τ_K^*) in $\Psi_k x \Psi_k^*$. For each of these pairs, we compute prices and allocations that satisfy conditions (a) and (b) and the associated welfare payoffs. Condition (b) implies endogenous adjustments in either (τ_L,τ_L^*) or $(\tau_C,,\tau_C^*)$ so as to ensure that the present value of

government outlays equals the present value of tax revenue in each country. When the consumption (labor) taxes are used to maintain fiscal solvency the labor (consumption) taxes are held constant at their pre-tax-competition values.

The payoff function for the domestic country's strategic choice of capital income tax given a foreign capital income tax is denoted by $V(\tau_K|\tau_K^*)$. The corresponding foreign payoff function is denoted by $V^*(\tau_K^*|\tau_K)$. Hence, the home country reaction curve $\boldsymbol{\tau_K}(\tau_K^*)$ is given by $\boldsymbol{\tau_K} = argmax_{\tau K} V(\tau_K|\tau_K^*)$ and the foreign reaction curve $\boldsymbol{\tau_K^*}(\tau_K)$ is given by $\boldsymbol{\tau_K^*} = argmax_{\tau K^*} V(\tau_K^*|\tau_K)$.

Two important caveats with regard to the above characterization of optimal tax strategies are worth noting. First, there can be multiple solutions that satisfy conditions (a) and (b) because of the Laffer-curve effects of distortionary taxes. For a given pair (τ_K,τ_K^*) in $\Psi_k x \Psi_k^*$, bell-shaped "intertemporal" Laffer curves relating the present value of tax revenues to labor or consumption tax rates imply that there can be up to four combinations of foreign and domestic labor or consumption tax rates that produce present values of tax revenues equal to the present values of government outlays (with the labor or consumption tax of each country set in the efficient or the inefficient side of the corresponding Laffer curve). In this case, we assume that the outcome that Pareto-dominates the others prevails. This outcome will keep the endogenous labor or consumption taxes of both countries in the upward-sloping portion of the Laffer curve. The same outcome would obtain if we assume that countries play at this point a game over the consumption or labor tax rates, for given capital taxes. The Nash equilibrium would set the consumption or labor tax rates to the efficient side of the Laffer curve.

The second caveat relates to the possibility that solutions satisfying conditions (a) and (b) may not exist. This is possible because the international externalities of unilateral capital income tax cuts in one country cause a downward shift in the other country's intertemporal Laffer curve. As a result, it is possible that a given pair (τ_K,τ_K^*) in $\Psi_k x \Psi_k^*$ does not have a solution that can satisfy (b). This will occur when the intertemporal Laffer curve in at least one of the two countries lies below the present value of government outlays for all values of the country's labor or consumption tax rates. Hence, the reaction curves are well-defined only for pairs (τ_K,τ_K^*) in $\Psi_k x \Psi_k^*$ for which a solution that satisfies (a) and (b) exists, and they are discontinuous otherwise.

A *Nash equilibrium* for the capital-income-tax competition game is defined by a pair of capital income tax rates (τ_K^N,τ_K^{*N}) and the associated payoffs $V(\tau_K^N|\tau_K^{*N})$ and $V^*(\tau_K^{*N}|\tau_K^N)$ such that: (a) τ_K^N maximizes $V(\tau_K^N|\tau_K^{*N})$ given τ_K^{*N}, (b) τ_K^{*N} maximizes $V^*(\tau_K^{*N}|\tau_K^N)$ given τ_K^N, (c) the payoffs are supported by the prices and allocations corresponding to the competitive equilibrium for (τ_K^N,τ_K^{*N}), and (d) the fiscal solvency rules of both countries (setting either (τ_C,τ_C^*) or (τ_L,τ_L^*)) are satisfied. Thus, the Nash equilibrium satisfies $\tau_K^N = \boldsymbol{\tau_K}(\tau_K^{*N})$ and $\tau_K^{N*} = \boldsymbol{\tau_K^*}(\tau_K^N)$ (i.e., the Nash equilibrium is at the intersection of the reaction curves).

A *cooperative equilibrium* is defined as a pair (τ_K^C, τ_K^{*C}) that maximizes the weighted sum of country payoffs, $\lambda V(\tau_K|\tau_K^*) + (1-\lambda)V^*(\tau_K^*|\tau_K)$ for any $\lambda \in [0,1]$ subject to the constraint that each country is at least as well off as in the Nash equilibrium: $V(\tau_K^C|\tau_K^{*C}) \geq V(\tau_K^N|\tau_K^{*N})$ and $V^*(\tau_K^{*C}|\tau_K^C) \geq V^*(\tau_K^{*N}|\tau_K^N)$. Thus, there can be several cooperative equilibria supported by different λ's and the set of all cooperative equilibria determines the core of the players' contract curve. Cooperative equilibria are still tax-distorted competitive equilibria because cooperation undoes the effects of the international tax externalities but not those of domestic tax distortions.

One additional caveat of this analysis is that the tax competition games are one-shot games in which tax authorities meet once at date *t=0*. We implicitly assume that there is an institutional arrangement (such as an international tax treaty) that operates as a credible commitment mechanism preventing countries from deviating in the future from the outcome of the date-0 game. Still, even though the game is played once, the outcome of the game is influenced by three key dynamic features. First, the payoffs are dynamic because they capture the equilibrium dynamics that take the world economy from the pre-tax-competition equilibrium to the equilibrium determined by the new tax rates. Second, implicit in the determination of the payoffs are the intertemporal effects of the three international externalities of tax policy that we reviewed earlier. Third, the payoffs also consider that governments in each country access their corresponding domestic public debt markets in order to smooth intertemporally the impact of the fiscal solvency externality on the setting of taxes on consumption or labor.

We acknowledge that a limitation of the analysis of one-shot games is that it cannot address the time-inconsistency problems that regularly arise in the class of one-shot policy games like the ones studied here. It is interesting to note, however, that Klein, Quadrini and Rios-Rull (2001)) found that when time-inconsistency is taken into account, strategic interaction amongst two national tax authorities results in equilibrium strategies that feature large adjustments in capital income taxes in the first period followed by nearly time-invariant taxes.

4. Empirical Evidence on the Investment and Labor Supply Implications of Tax Policy

This section conducts an empirical analysis of the relationship between the Mendoza-Razin-Tesar estimates of effective tax rates and the observed behavior of investment rates and the supply of labor in industrial countries. The goals of this analysis are to examine whether the effects of taxes on the investment rate and the supply of labor predicted by the Neoclassical model of Section 2 can be identified in the data, and to provide evidence suggesting that there is international strategic interaction in the setting of domestic tax rates amongst large European countries.

Capital Income Taxes and the Investment Rate

The steady-state conditions (13) and (14) yield the prediction that at lower frequencies, and assuming a common structure of preferences and technology across countries, there should be a negative relationship between the investment rate and the tax on capital income. As Figure 4 illustrates, this prediction is consistent with the data of G-7 countries. The Figure plots a scatter diagram of investment-GDP ratios against capital income tax rates breaking down a sample for the 1971-1995 period into a panel of five 5-year averages for each country (for the sub-periods 1971-1975, 1976-1980, 1981-1985, 1986-1990 and 1990-1995). The panel is unbalanced because Italy's capital income tax rate can only be computed starting in 1980, so there are a total of 33 observations. Table 1 lists the results of a panel regression estimated with these data using White's method to obtain heteroskedasticity-consistent standard errors and covariance matrix. The Table lists results for the full panel as well as an alternative excluding Japan because its investment rates are systematically higher than those of the rest of the G-7 (see Figure 4). It also includes estimates for Random Effects regressions that include country dummies.

The results of this panel analysis indicate that an increase of 1 percentage point in the capital income tax rate induces a decline in the long-run investment rate of 0.11 to 0.14 percentage points. Moreover, excluding Japan, the variations in capital income tax rates account for about 40 percent of the cross-country variation in five-year averages of investment rates. These results are in line with the findings of Mendoza, Milesi and Asea (1997), who estimated a similar panel regression including data for 11 other OECD countries, adding other long-run explanatory variables of investment rates derived from endogenous growth theory (initial per-capita GDP, taxes on labor and consumption, the terms of trade and years of secondary education), and comparing estimates with and without instrumental variables. Their multi-variate, instrumental-variables regression explains 56 percent of the cross-country variation in investment rates and predicts that a 1-percentage point-increase in the capital tax rate reduces the investment rate by 0.12 percentage points.

The above results show that the negative relationship between domestic capital income taxes and incentives for domestic capital accumulation that is a key element of our model of tax competition is consistent with empirical evidence. Now we examine whether there is also evidence of cross-country strategic interaction in capital taxation. We provide two forms of evidence in this regard. First, we show that the cross-country correlations of tax rates increased sharply after financial liberalization. Second, we show that in the time series data for France there is evidence indicating that the French investment rate is affected by foreign capital income tax rates, and that these effects became more pronounced after financial liberalization.

Table 2 reports unconditional cross-country correlations of capital income tax rates for France, Germany, the United Kingdom and the United States during the 1970-1978 period (before financial integration in Europe) and during the 1979-1996 period (after financial integration). Italy is excluded because its series of capital income tax rates begins in 1980. The earliest date is set at 1970 because the capital income tax rates for France are available starting in this year. The main result in Table 2 is that the correlations of the UK capital tax rate with those of France and Germany increased sharply and converged to similar levels after financial liberalization (from 0.29 to 0.79 with France and from 0.16 to 0.75 with Germany). This is important evidence because the reaction functions of the tax authorities in the tax competition framework of Section 2 are upward slopping, so the best response to a foreign tax increase is a domestic tax increase. Note, however, that correlations are indicators of co-movement, not of magnitude, so the fact that the correlations are positive does not imply that Germany and France should have lowered their capital taxes sharply in response to the large cuts in the UK capital income tax. Table 2 also shows that the correlation of the German tax with the US tax also increased sharply after financial integration (from –0.1 to 0.52) and the correlation of the French and German capital tax rates fell from 0.82 to 0.57, while the rest of the correlation coefficients changed slightly. These results suggest that financial integration may have shifted the focus of capital tax interactions in Europe from the German-French tax differences to the differences between these two and the United Kingdom or the United States.

Next we examine the time series behavior of the investment rate in France, seeking to identify the short-run effects of the French capital income tax rate as well as those from other large European countries and the United States. Table 3 reports results of time series regressions of the French investment rate on the French capital tax rate and the capital tax rates of the United Kingdom and the United States for the full sample period 1970-1996 and for the sub-period of financial liberalization 1979-1996. Since the possibility of strategic interaction in tax rates implies that the regressors could be correlated with the residuals, the regressions are estimated using instrumental variables (with the lags of the tax rates and a time trend as instruments). The results for the 1979-1996 period show that all three tax rates have statistically-significant effects on the French investment rate at the 10 percent confidence level. Moreover, movements in the tax rates explain 60 percent of the time-series movements in the investment rate. An increase of 1 percentage point in the French capital tax lowers the investment rate by a similar amount, while an increase of 1 percentage point in either the UK or the US capital tax rates increase the French investment rate by slightly more than ¼ of a percentage point. The direction of these changes is consistent with the model because, keeping foreign tax rates constant, an increase in the domestic capital tax should lead to a lower rate of investment and, keeping

the domestic tax rate constant, an increase in the foreign tax rates should lead to a higher domestic investment rate.

Comparing the above results with those for the full sample, which includes the period before financial integration, we find that including the data before 1979 results in a lower and statistically-insignificant coefficient for the US tax rate and in a lower coefficient on the French tax rate. Unfortunately, the 1970-1978 sample is too small to run hypothesis tests of changes in the regression coefficients before and after financial integration. However, we can examine the pattern of recursive estimates of OLS coefficients in the full sample. Figure 5 shows that indeed the period of financial integration displays important changes in the regression coefficients. The coefficients on the French and British tax rates change sharply after 1992, with the one for France dropping by as much as the one for the UK rose. The coefficient of the US tax rate increased gradually in the first half of the 1980s.

We also examined the data of the UK and Germany to assess whether we could find similar evidence of tax effects on the investment rate as we found for France. However, the regressions for these countries did not perform well. The tax coefficients were statistically-insignificant or were significant but with signs opposite to those found in the French data. Moreover, these regressions displayed problems of serial autocorrelation and non-stationarity that were not present in the regressions for France. This poor performance is relatively unsurprising because at the annual frequency investment rates are affected by several factors in addition to movements in tax rates and because of the short sample for which we can examine the investment-tax relationship. In this context, the surprise is the finding that domestic and foreign taxes can do so well in explaining the behavior of the French investment rate in a short sample of annual data.

Labor Supply and the Effective Tax on Labor

Just as in the case of the investment-capital tax link, the model's stationary equilibrium condition (17) predicts a negative relationship between the supply of labor and the effective tax wedge factor $(1-\tau_W)\equiv(1-\tau_N)/(1+\tau_C)$. However, empirical analysis of this long-run relationship is less straightforward because the consumption-output ratio enters as a determinant of the steady-state supply of labor. In turn, as the analysis of the steady state system showed, the resource constraint of the economy makes this ratio depend on the capital tax rate (which determines the investment rate) and on the dynamics of foreign asset accumulation (which determine the steady-state bond position because of the dependency on initial conditions of the long-run equilibrium). Moreover, the data on hours worked for G-7 countries that we gathered for the period 1970-2002 from the International Labor Organization are reported with different methodologies over time and across countries.

Generally, the early years of the sample are based on ISIC-2 standards while the late years of the sample conform to ISIC-3 standards. The concept of hours worked also varies across countries and methods (reporting different concepts like hours worked by wage earners, employees, salaried employees, or total employment).

Table 4 reports the results of two panel regressions of the long-run labor supply relationship for the same quinquennial averages used in the panel regressions of the investment rate, with and without Japan and including country dummies. The functional form estimated in these regressions is derived by re-formulating condition (17) in terms of a log-linear relationship linking the normalized ratio of hours worked to leisure hours to the log of the effective tax wedge and the log of the consumption-output ratio: $\ln(N/\ell) = \ln(\alpha/a) + \ln(1-\tau_w) - \ln(c/y)$. The regressions are estimated using the difference of the log terms for contiguous quinquennial averages to minimize the level bias resulting from the different methodologies used to collect hours worked data.

The regressions are able to identify a statistically significant long-run effect of the tax wedge on the leisure-labor ratio, but the coefficient is not unitary (contrary to what the model predicts). In the regression excluding Japan, the changes in the effective labor tax wedge account for about 16 percent of the cross-country differences in labor supply, and a change of one percentage point in the tax wedge factor (i.e., a decline in the effective labor tax) leads to a change in the *ratio* of labor to leisure of 0.4 percent. The coefficient on the consumption-output ratio was not found to be significant and hence we report only the results excluding this variable (the coefficient on the tax wedge is nearly invariant to whether the consumption-output ratio is included in the regression). The reason for the insignificant impact of the consumption-output ratio may be the endogeneity bias resulting from the fact that this ratio is an endogenous variable in the steady state system. Unfortunately, the sample is too small to consider estimation by instrumental variables to explore if addressing this issue can produce better results. However, we explored this issue further in time-series, country-specific regressions at the annual frequency and, as we show below, in some cases we found strong support in favor of the model's labor supply condition.

Since the optimality condition for labor supply in equation (17) holds at every date in the competitive equilibrium, and not just at steady state, it is interesting to explore the empirical relevance of the tradeoff between the effective labor tax wedge and labor supply in country-specific regressions using annual data. We estimate the log-linear relationship $\ln(N_t/\ell_t) = \beta_0 + \beta_1 \ln(1-\tau_{w,t}) + \beta_1 \ln(c_t/y_t)$ implied by condition (17), which sets coefficient conditions $\beta_0 = \ln(\alpha/a)$, $\beta_1 = 1$, $\beta_2 = -1$. Table 5 reports results in ordinary least squares (OLS) as well as results using instrumental variables (IV), to control for the potential endogeneity of the *c/y* ratio, and results estimated in first differences (FD).

The results of the labor supply regressions are striking, particularly those for France and the United States. For these two countries, the regression coefficients are always statistically significant and with the correct sign, regardless of the estimation method, and the regressions explain a large fraction of the observed variability of the logged labor-leisure ratio. In the case of France, this result is consistent with Prescott's (2003) argument that movements in the effective labor tax factor played an important role in explaining the decline in hours worked during the 1990s. Note, however, that the coefficient estimates for the tax factor and the consumption-output ratio are not in line with the conditions implied by equation (17), except for the coefficient on the *c/y* ratio for France which is statistically equivalent to –1. The results for Germany are less favorable. OLS and IV estimates yield significant coefficients on the tax factor that are close to those predicted by the theory, but do not produce significant coefficients on the *c/y* ratio, while the FD regression yields a significant coefficient on this ratio but not for the tax factor. The results for the UK are quite poor, but this is also the country for which we have the smallest sample period.

The intercepts in all the regressions shown in Table 5 are significant and with the sign predicted by the theory (since α is less than 1 and a is typically set at values higher than 1, $ln(\alpha/a)$ should be a negative number). Moreover, given the intercept estimates and setting $\alpha=0.64$ (the value determined using national accounts data in the calibration exercise of Section 5), we recovered the implied estimates of a shown in Table 5 using the coefficient restriction $\beta_0=ln(\alpha/a)$. Again the results for France and the U.S. are striking because they yield values of a that are very similar across the two countries in the range 2.32-2.65. The estimates for the UK vary over a wider range (2.13-3.21) and those for Germany are significantly lower (1.15-1.05). However, it is difficult to make cross-country comparisons of these estimates because of the differences in methodologies used to collect and report hours worked data described earlier. The estimates of a for France and the U.S., and to some extent those for the UK, are very close to the values typically set for this parameter in RBC studies aiming to calibrate models to match a labor allocation of 20 percent of the time endowment. In the calibration of the next section, for instance, the value of a implied by this calibration criterion is 2.66.

The finding that estimates of a are generally in excess of 1 and typically range between 2 and 3 plays an important role in the tax competition experiments. As the results will show, the model's ability to replicate the observed outcome that competition in capital income taxes did not result in a race to the bottom in these tax rates hinges critically on the supply of labor being "sufficiently elastic." With inelastic labor the tax on labor income and the consumption tax become nearly equivalent taxes that produce small distortions, and in this environment tax competition does results in a race to the bottom in capital income taxes.

5. Tax Competition: Calibration of the 1980s Status Quo and Solutions of the Games

We construct the pre-tax competition calibration so that the steady-state, balanced-growth equilibrium of a version of the model with two identical countries matches key features of macroeconomic and fiscal policy data for the three large economies of Continental Europe (CE), France, Italy and Germany. The countries in CE have similar macroeconomic features and also share similar tax structures. Later we also consider data for the United Kingdom to introduce asymmetry in initial tax structures. Since our goal is to characterize the outcome of tax competition under perfect international capital mobility, we calibrate the model using data for the early 1980s when barriers to capital mobility across Europe were largely being dismantled.[7] The calibrated values of technology and preference parameters, tax rates and government expenditure shares used in the pre-tax-competition calibration are listed in Table 1.

Figure 1 shows that capital income taxes have remained fairly constant since the early 1980s, hovering around 25-30 percent, with a significant increase in the capital tax rate in Italy in the early 1990s. Still, the capital tax rates of France, Germany and Italy have remained consistently below the capital income taxes in the UK. On the other hand, labor income taxes in the CE (see Figure 2) have steadily risen since the 1960s and are significantly higher than labor income tax rates in the UK. Consumption taxes used to differ significantly across all European countries, but the sustained efforts at indirect tax harmonization have resulted in significant convergence in effective consumption tax rates across CE and the UK over the course of the 1990s. For the purposes of the pre-tax competition calibration, we take the average of each of capital income, labor income and consumption tax rates across the CE countries in 1980 (26.5, 37.4 and 16.6, respectively).

Government expenditure shares have remained fairly steady since 1980. The 1980-1999 sample averages for France, Germany and Italy range between 17 and 24 percent. We use a value of g/y =0.18 for the calibration.

The values of preference and technology parameters listed at the top of Table 6 are taken from Mendoza and Tesar (1998). The post-WWII average growth rate of GDP in the OECD is 1.56 per cent per annum, but since a period in the model is defined to be one quarter we set $\gamma = 0.0039$. The intertemporal elasticity of substitution is set at ½, which implies $\sigma = 2$. National accounts data on the share of labor in GDP implies a value of $\alpha = 0.64$. Given these three parameter values, the CE average of the investment-output ratio in 1996 (adjusted to exclude public investment), which is x/y = 0.24, and the value of τ_K, the steady state conditions (13) and (14) yield a value for the depreciation rate of $\delta = 0.0161$ per quarter and a value for the subjective discount factor of $\beta = 0.993$. The steady-

[7] We are grateful to Peter Birch Sorensen for suggesting that we place our analysis in this context.

state real interest rate then follows from the balanced-growth condition $R = \beta^{-1} - \gamma\sigma$, so the implied real interest rate is 6.1 per cent per annum (1.46 percent quarterly). Steady state conditions (15)-(17), together with g/y, x/y, τ_C, τ_L, a calibrated steady-state labor supply allocation of 0.2, and the assumption that in the symmetric pre-tax competition steady state the share of net exports in GDP is zero in both countries, yield a value for the exponent of leisure in utility of $a = 2.675$ and solutions for the steady-state output shares of consumption and foreign asset holdings. The parameters of the adjustment cost function are set to $\eta = 10$ and $z = \gamma + \delta$.

The bottom panel of Table 6 shows that the model's pre-tax competition steady state does well at mimicking the GDP shares of key macroeconomic aggregates observed in European data. The calibration forces the model to reproduce the GDP shares of government expenditures and investment, and the trade balance is set equal to zero by the symmetry assumption. However, the consumption, tax revenue and net transfers shares are produced endogenously. The model generates slightly higher consumption-GDP and tax revenue-GDP ratios than is observed in the data (58 v. 57 percent and 38 percent v. 37 percent respectively).[8] The ratio of transfers to output (e/y) is roughly the same as the average of the observed transfers-GDP ratios for France, Italy and Germany in 1985. The 1985 average of net transfers (including subsidies and payments stemming from welfare, healthcare and other entitlement programs) as a share of GDP in the CE was 24 percent of GDP. Any remainder after the level of transfer payments is subtracted from the primary deficit (i.e., the gap between the levels of tax revenue and current expenditures) represents interest payments on the steady-state level of public debt (i.e., the Ricardian transfers described in Section 2). We keep the *level* of government expenditures and entitlement payments constant throughout all the tax competition calculations.

Tax Competition with Symmetric Countries

The first tax competition game we consider is based on the calibration to two symmetric European countries and it assumes that countries adjust labor tax rates to maintain fiscal solvency. We believe this is an interesting starting point for three reasons. First, in our framework, the consumption tax is close to a non-distortionary tax so that replacing the revenue lost from the reduction in the capital tax with an increase in the consumption tax is fairly painless. In reality, however, governments are likely to face more painful trade-offs by either cutting government expenditures that have some utility or production benefits or by raising another tax that has more distortionary effects. Second, much of the focus of the literature on tax competition (and certainly a concern of European policymakers) is that with increased capital mobility, the burden of taxation has shifted from capital

[8] Tax revenue as a share of GDP was fairly stable during the 1985-1999 period in France and the UK but it rose sharply in Germany and Italy, reflecting largely the process of debt reduction undertaken in these countries to reach the Maastricht guidelines. The average for the CE in 1985 tax was 37 percent.

onto labor. This experiment looks directly at the trade-off between capital and labor income taxes. Third, from a practical standpoint, a great deal of effort has gone into harmonizing indirect taxes in Europe. It seems unlikely that policymakers would undo the process of harmonization in indirect taxes but would instead use other instruments to maintain fiscal balance.

Section A.1. of Table 7 shows the capital and labor taxes and the welfare gains when countries play Nash and when they cooperate. Figure 6 shows the reaction curves of each country and the core of the contract curve under cooperation. Strikingly, the Nash equilibrium yields tax rates on capital and labor that are almost identical to the tax rates in the pre-tax competition equilibrium! This suggests that the tax rates observed in Europe at the time in which barriers to capital mobility were removed can be rationalized as the outcome of tax competition between countries in an environment of perfect capital mobility. Since tax rates at the Nash equilibrium differ very little from the tax rates at the pre-tax competition steady state, the prices and allocations at the Nash equilibrium also remain nearly unchanged and the effects of transitional dynamics on welfare calculations are negligible.

When countries cooperate, the resulting tax rates on capital income are *higher* than under the Nash equilibrium.[9] The capital income tax rises almost 10 percentage points and the labor income tax declines about 3 percentage points. This is because the labor income tax is highly distorting and it is in both countries' interest to substitute higher capital income taxes for somewhat lower labor income taxes. In this case, there are changes in prices and allocations at the new steady state under cooperative taxation and there are significant transitional dynamics between the pre-tax-competition equilibrium and this new steady state. Despite these changes, however, the welfare gains from cooperation over Nash are small, at roughly one quarter of one percent of trend consumption. Thus, these results may explain why little progress has been made in coordinating capital income taxes and why the burden of taxation has shifted onto labor, the immobile factor of production.

We next turn to the tax competition game when the consumption tax is used to maintain fiscal solvency (see Table 7, A.2 and Figure 7). Given the small distortion associated with increasing the consumption tax, Nash competition triggers the familiar "race to the bottom" in capital income taxes. Nash competition leads to a large reduction in the capital income tax in each country from 26.5 percent in the pre-competition equilibrium to a subsidy of 11.1 percent.[10] To maintain the present value of tax revenue equal to the present value of the unchanged government outlays, each country

[9] There exists a range of cooperative equlibria that are Pareto improvements over the Nash equilibrium. For symmetric games, we focus on the cooperative equilibrium for which the planner assigns equal weights to each country. For asymmetric games we report the full range of cooperative equilibria.

[10] Note that tax competition does not drive taxes on capital to zero in this model because countries are large enough to affect the world interest rate. At the point of zero capital income taxes, each country has an incentive

raises the consumption tax from 16.6 to 24.1 percent. Still, Nash competition is beneficial in the sense that households in both countries obtain a gain in lifetime utility relative to the pre-tax competition stationary state that is equivalent to an increase of 0.68 percent in consumption in every period. This welfare gain is much larger than existing estimates of the welfare gains of eliminating business cycles but it is also smaller than existing measures of the welfare gains of replacing capital income taxes with consumption taxes in the United States, which range between 2 and 4 percent (see Lucas (2003) and Mendoza and Tesar (1998)). Thus, our findings suggest that these estimates of the benefits of tax reforms may be significantly overstated because they do not take into account the high degree of international capital mobility and the incentives it provides for strategic behavior in tax policy setting.

The driving force of the "race to the bottom" in capital income taxes is the incentive that each country has to attempt to undercut the capital income tax in the other country, and use the resulting inflow of financial capital to help smooth the cost of increasing the capital stock. There are three limiting factors to this "race to the bottom." One is the trade-off between labor and leisure – as the capital stock increases, work effort must increase and at some point the marginal value of leisure offsets the consumption benefit from higher output. The second limiting factor is the fact that, since strategic interaction leads the two countries to cut capital taxes simultaneously, access to global capital markets cannot help households reduce the welfare cost of having to expand the capital stock by borrowing from abroad, and hence they must sacrifice lower current consumption for higher future consumption (as they would in a closed economy undertaking a tax reform). Although the real interest rate increases to compensate for this sacrifice, the households' private rate of discount places a limit on the extent to which they are willing to forego current consumption. The last limiting factor is the distortion of the consumption tax. In the model, this distortion is generally weaker than the distortions of the capital and labor taxes, but at some point increasingly large subsidies on capital income would need to be traded for increasingly large consumption taxes that would induce large distortions.

In the Nash game, policymakers fail to internalize the impact of the reduction in the capital income tax in each country on the world interest rate. When countries cooperate and the joint effect on the interest rate is internalized, each country prefers a somewhat smaller subsidy of 3 percent relative to the noncooperative subsidy of 11.1 percent. Because of the shift to more efficient taxation, the welfare gain from tax coordination relative to the pre-tax-competition equilibrium is now larger than under Nash competition at 0.72 percent of lifetime consumption. However, the result that cooperation yields only small incremental utility gains remains intact. The incremental welfare gain from cooperation over tax competition is only 0.04 percent of trend consumption, a tiny fraction of the

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to subsidize capital, pushing up the world interest rate and forcing some of the costs of capital accumulation onto

gains from simply playing Nash. These findings suggest that if there are small costs involved in coordinating tax policy, these costs would likely eliminate the incentives for cooperation.

Tax Competition between the UK and Continental Europe

The second set of tax competition experiments we consider are aimed at studying how a tax competition game between the UK and CE might play out. In this case, we introduce important asymmetries in tax rates into the pre-tax competition equilibrium by calibrating it to the 1980 tax rates observed in the UK and CE. As illustrated in Figures 1 through 3, the UK has higher capital income tax rates than the CE countries and significantly lower labor income tax rates. Tax rates on capital, labor and consumption in the former are set at 26.5, 37.4 and 16.6 percent (respectively) and in the UK at 53.0, 25.0 and 14.0 percent. All other parameters of the baseline calibration remain unchanged.

Part B.1 of Table 7 shows the outcome when CE and the UK adjust the labor tax to preserve fiscal solvency. Tax competition now results in a substantial increase in UK welfare of 3.87 percent and a substantial welfare loss for CE of 2.17 percent. Tax competition leads to a large decline in the capital income tax rate in the UK from 53 to 20 percent, inducing a large relocation of capital from the CE to the UK. As a consequence, the tax base in the CE countries erodes, and the tax authorities on the continent are forced to increase *both* the capital and labor income taxes to balance the budget. With cooperation, the capital income tax rate is *higher* in both regions relative to the Nash outcome. However, even under cooperation, CE ends up worse off than in the pre-tax-competition equilibrium. The welfare loss (gain) for CE (UK) under cooperation is between 1.93 (3.88) and 2.17 (4.16) percent depending on the country weighs in the cooperative payoff function. This suggests that, relative to a pre-tax competition baseline calibrated to tax rates observed in 1980, CE was at a disadvantage relative to the UK in the process of financial integration – given the higher initial labor taxes in the CE countries, any move to engage in cooperative or noncooperative tax competition with the UK under perfect mobility of financial capital would be immiserizing for the CE countries.

As before, the results are different when countries can use the consumption tax to maintain fiscal solvency. As shown in Table 7, B.2, tax competition once again produces a race to the bottom in taxation of capital and substantial welfare gains for both countries, as they replace distortionary capital income taxes with higher, more efficient consumption taxes. The lion's share of the gains from tax competition goes to the UK (5.3 percent of trend consumption), but the continent also enjoys a positive welfare gain of 0.35 percent.

The gains from tax coordination remain small in the above two tax competition experiments between CE and the UK. The largest gain from cooperation is 0.29 percent of trend consumption, and

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the rest of the world.

it is obtained by the UK in the case in which the labor tax adjusts to maintain fiscal solvency and the weigh of the UK in the cooperative payoff function is set to maximize the payoff to the UK without making CE worse off than under the Nash outcome.

Robustness Analysis

We consider next three experiments that provide intuition for the factors that affect the magnitude of the gains from coordination and help us assess the robustness of our results (see Table 8). We take as the benchmark the symmetric, labor-for-capital income tax experiment. We examine in turn the effects of assuming a large foreign asset position (or a large trade imbalance) in the pre-tax competition equilibrium, inelastic labor supply and small capital adjustment costs. The results of the benchmark experiment are provided in section A of Table 8 for comparison.

i. Initial non-zero foreign debt: In the experiments conducted so far, the two countries were assumed to have balanced trade in the pre-tax-competition stationary state. Thus, they engaged in tax competition starting with zero net foreign asset positions. In this first robustness experiment we relax this assumption. Non-zero creditor and debtor positions introduce an important source of asymmetry that strengthens strategic incentives to use taxes to influence the world real interest rate. The debtor (creditor) country has an extra incentive to use capital income taxes to reduce (increase) the interest rate. To capture the effect of this asymmetry we modify the benchmark model so that the "home" country enters tax competition as a net debtor with a stock of debt of 10 percent of GDP. As expected, we find that the home and foreign country have very different reaction functions than in the symmetric case. The foreign country, as a net creditor, benefits from an increase in the world interest rate and therefore has an incentive to push for lower taxes on capital. The home country is hurt by tax competition, suffering a small welfare loss of one one-hundredth of a percent of trend consumption while the foreign country gains one-tenth of a percent of trend consumption. The effect of the strengthened incentives for strategic behavior is most noticeable in the incremental gains from tax coordination. Depending on the country weighs in the cooperative payoff function, the gains from cooperation can be as high as 0.76 percent for the debtor country (three times more than in the symmetric benchmark case).

ii. Elasticity of labor supply: This second experiment explores how the results from the symmetric benchmark case change when labor supply becomes inelastic. Inelastic labor supply does away with the three limiting factors of the "race to the bottom" in capital income tax rates discussed earlier. In fact, the labor tax is now a non-distorting tax since the supply of labor is independent of the tax wedge on wages. As we showed in Mendoza and Tesar (1998), making the supply of labor inelastic in a two-country neoclassical balanced growth model has two important effects on the positive and normative outcomes of change in capital income taxes: (a) it enlarges the efficiency gains (and hence the welfare

gains) of capital income tax cuts and (b) it weakens the international externalities of tax policies. The first effect is well known in the closed-economy literature on tax reforms. The second effect occurs because with inelastic labor a unilateral cut in τ_K by one country cannot alter the *long-run* capital, labor and output allocations and factor prices of the other country. These prices and allocations can only experience transitional deviations from their initial values. As a result of these two effects, Nash competition now triggers a strong race-to-the-bottom effect and countries end up with higher subsidies on capital relative to the benchmark case. Cooperation results in an even higher subsidy on capital that settles at around 15 percent. The gains from tax competition relative to the pre-tax competition equilibrium are relatively large (0.8 percent) but the incremental gains from cooperation relative to the Nash outcome are again very small (0.01 percent).

iii. Capital adjustment costs

The last robustness experiment studies the effects of a sharp reduction on capital adjustment costs. This experiment is interesting because one aspect in which our analysis differs from much of the previous work on tax competition is in that it aims to capture the dynamic adjustment process that results from changes in tax policy. One way to compare our dynamic results with the more standard, static analysis is to reduce the adjustment cost parameter and allow the economy to transition quickly to the new steady state under tax competition. The results of this exercise are reported in section D of Table 8. The results are indeed closer to the conventional wisdom – tax competition triggers a race to the bottom in the capital income tax rate which in turn reduces welfare in both countries. This is because a reduction in the capital income tax rate induces a more immediate reallocation of capital across countries. When the impact of their behavior on world prices is internalized, tax rates on capital increase relative to their initial benchmark and welfare improves. Although the gains from cooperation are larger than in most of the other cases we study, they are still less than one percent of trend consumption.

6. Conclusions.

In this paper we studied quantitative outcomes of international tax competition in a two-country version of the workhorse neoclassical balanced-growth model with exogenous, labor-augmenting technological change. We studied numerical solutions of one-shot games over time-invariant capital income tax rates in a framework that incorporates the three basic cross-country externalities of tax policy emphasized in the international tax competition literature (the relative-price, wealth-redistribution, and fiscal solvency externalities). The two countries trade a homogeneous good and one-period bonds under conditions of perfect mobility of financial capital. As a result, changes in capital income taxes can induce large reallocations of physical capital across countries even though physical capital is not traded directly.

National tax authorities are benevolent and assess the payoff of their capital-income-tax strategies in terms of the welfare gains, net of welfare costs of transitional dynamics, accruing to their countries' residents. These welfare gains are computed as cardinal equivalents of the lifetime utility variations induced by the changes in competitive equilibrium allocations obtained under alternative tax strategies. The tax authorities also have access to domestic debt markets so that their tax policies must be set to satisfy the constraint that the present value of tax revenue matches the present value of a predetermined, time-invariant level of government outlays (i.e., current purchases plus entitlement payments). Hence, countries are allowed to smooth the effects of the fiscal solvency externality on the tax burden over time. We consider the case in which competition over capital income taxes is undertaken using labor taxes to maintain fiscal solvency, as well as the case in which consumption taxes are used instead.

The framework we used in the quantitative analysis generalizes the standard setup used in many theoretical studies on international tax competition, yet it is subject to some caveats. One important caveat is that we do not address issues of time inconsistency and dynamic strategic interaction. The payoffs of our experiments are dynamic, in that they reflect levels of lifetime utility pertaining to each country along intertemporal competitive equilibrium paths, but the tax authorities are assumed to meet once and to remain committed to the tax structure obtained as the outcome of the one-shot game. Two other potentially important caveats are that we ignore potential production and utility benefits of government expenditures as well as the effects of tax competition on long-run growth. However, the effects of productive government expenditures are approximated by assuming that the fiscal solvency externality forces upward adjustments in distortionary tax rates, and the assumption abstracting from long-run-growth effects of taxation seems to be supported by existing empirical evidence.

Despite these caveats, our quantitative framework captures the key features of tax competition in open economies in a fully dynamic general equilibrium setup. The quantitative analysis starts from a pre-tax competition calibration set to mimic basic macroeconomic and fiscal policy features of the three large economies of Continental Europe (France, Germany and Italy) as properties of the steady-state, balanced-growth equilibrium of a variant of the model with two perfectly symmetric economies. Remarkably, when labor taxes adjust to respond to the fiscal solvency externality, the Nash equilibrium of tax competition over capital income taxes yields capital and labor tax rates that are very similar to those observed in Europe in the early 1980s. The net gains from cooperation in this case are small at .26 percent of trend consumption. This suggests that the factor income tax rates prevailing in Europe could be rationalized as the outcome of tax competition, and that the lack of progress in further

tax policy coordination in the region could reflect the fact that the costs of coordination exceed the small benefits.

In the case in which the fiscal solvency externality triggers adjustments in consumption taxes, Nash competition in capital income taxes produces a staggering "race to the bottom" in capital tax rates. However, contrary to the conventional wisdom that this reduction in capital taxes is harmful to society, we find that European countries could make welfare gains of about 0.7 percent in lifetime consumption compared to the pre-tax competition equilibrium. The race to the bottom is harmful in the formal sense that the cooperative equilibrium dominates the Nash outcome, but we find that quantitatively in this game of capital-for-consumption taxes the gains from tax coordination are negligible at less than 0.04 percent. Yet, the welfare gains that we obtained for the drastic cuts in capital income taxes replaced by consumption taxes are roughly 1/5 of the welfare gains obtained in similar experiments reported in quantitative closed- and open-economy studies of tax reforms that used similar models as ours but abstracting from strategic interaction in the design of national tax policies by financially integrated economies. Thus, existing estimates of the welfare gains of tax reforms aimed at replacing capital income taxes with indirect taxes in economies that are highly integrated to global financial markets can be significantly overestimated.

The data show that tax structures differ markedly between the United Kingdom and France, Germany and Italy. In particular, the UK has significantly lower labor income taxes and higher capital income taxes. We modify the pre-tax competition calibration of our model to introduce this asymmetry and quantify the potential effects of capital income tax competition between the UK and the large economies of Continental Europe. The model predicts that, because of strong tax distortions implied by the high level of its labor income taxes, Continental Europe is handicapped for playing this game. The UK could make significant welfare gains by engaging in Nash competition (3.9 percent of trend consumption if the labor tax adjusts to maintain fiscal solvency, and 5.3 percent of trend consumption if the consumption tax adjusts instead). Continental Europe suffers a large welfare loss of 2.2 percent in the capital-for-labor-tax game, and obtains a small gain of 0.3 percent in the capital-for-consumption tax game. Yet, in all of these experiments the benefits of international tax policy coordination remain negligible. Continental Europe fares poorly under both the Nash and the cooperative outcomes because of the significantly less efficient tax system it starts with at the pre-tax-competition status quo.

We explore the robustness of our findings to three important modifications of the initial pre-tax-competition calibration for symmetric countries. First, we allow for countries to differ in that one starts as a net debtor and the other as net creditor in the pre-tax-competition equilibrium. Second, we make labor inelastic, so that the labor tax becomes a non-distorting tax. Third, we lower capital

adjustment costs to speed up significantly the transitional dynamics between the pre- and pos-tax-competition equilibria. The results show that faster transitional dynamics and asymmetries between net creditors and debtors can increase the gains of tax coordination, up to 0.76 percent of trend consumption. Reducing the elasticity of labor supply increases the domestic efficiency gains of reducing capital income taxes and weakens the three international externalities of unilateral capital income tax cuts. As a result, instead of replicating the observed capital and labor taxes in Continental Europe, the capital-for-labor tax game with inelastic labor supply results in a strong "race to the bottom" in capital income taxes reminiscent of the outcome obtained in the capital-for-consumption tax game. Nash competition yields a welfare gain of 0.8 percent relative to the pre-tax-competition calibration but the gains from tax policy coordination are once again negligible.

To conclude, the findings of this paper suggest that countries with relatively inefficient tax systems can experience significant welfare losses if, as a byproduct of financial integration, they find themselves competing over capital income taxes against countries with relatively efficient tax systems. In this case, and from the perspective of the efficiency effects of direct and indirect taxes emphasized in this paper, harmonization of indirect taxation is undesirable because it forces countries to respond to the adverse effects of tax competition on tax revenues by raising highly-distorting labor income taxes. Harmonization of taxation on immobile factors and freedom to adjust consumption taxes to make up for the tax revenue lost to capital income tax competition would be far more desirable.

References

Bovenberg, A. L., "Capital Taxation in the World Economy," in F. van der Ploeg, ed. *The Handbook of International Macroeconomics*, Cambridge, MA: Blackwell Publishers, 1994, pp. 116-150.

Bucovetsky, S., "Asymmetric Tax Competition," *Journal of Urban Economics*, 1991, *30*, pp. 167-181.

Chamley, C.P., "The welfare cost of capital income taxation in a growing world economy," *Journal of Political Economy,* 1981*,* 89, pp. 468-96.

Chari, V.V., L. Christiano and P.J. Kehoe, "Optimal Fiscal Policy in a Business Cycle Model," *Journal of Political Economy*, August 1994, *102*(4), pp. 617-52.

Chari, V.V. and P.J. Kehoe, "International Coordination of Fiscal Policy in Limiting Economies," *Journal of Political Economy*, 1990, pp. 617-36.

Chennels, L. and R. Griffith, *Taxing Profits in a Changing World*, Institute for Fiscal Studies, London, 1997.

Cooley, T. F. and G.D. Hansen, "Tax Distortions in a Neoclassical Monetary Economy," *Journal of Economic Theory*, December 1992, *58*(2), pp. 290-316.

Correia, I.H., "Gains from Coordination," Bank of Portugal Working Paper, 1998.

Daveri, F. and G. Tabellini, "Unemployment, Growth and Taxation in Industrial Countries," *Economic Policy*, April 2000.

De Bonis, V., "Regional Integration and Factor Income Taxation," Working Paper, download from **www.inomics.com**.

Devereux, M.P., "Tax Competition and the Impact on Capital Flows," in H. Siebert, ed., *Locational Competition in the World Economy*, Tubingen: Mohr, 1996.

The Economist, "A Survey of Globalization and Tax: The mystery of the vanishing taxpayer," January 9, 2000.

Eggert, W., "International Repercussions of Direct Taxes," Working Paper, download from **www.inomics.com**, 1999.

Frenkel, J.A., A. Razin and E. Sadka, *International Taxation in an Integrated World*, Cambridge: MA, MIT Press, 1991.

Frey, B.S. and R. Eichenberger, "To Harmonize or to Compete? That's not the Question," *Journal of Public Economics*, 1996.

Giovannini A. and J.R. Hines, Jr., "Capital Flight and Tax Competition: Are There Viable Solutions to Both Problems?" in A. Giovannini and C. Mayer, eds., *European Financial Integration*, Cambridge: Cambridge University Press, 1991, pp. 172-210.

Haufler, A., *Taxation in a Global Economy*, Cambridge: Cambridge University Press, 2001.

Hines, J.R., "Lessons from Behavorial Responses to International Taxation," *National Tax Journal*, 1999.

Huber, B., "Tax Competition and Tax Coordination in an Optimum Income Tax Model," *Journal of Public Economics*, March 1999, 71:3, pp. 441-458.

Huizinga, H. and S.B. Nielsen, "Capital Income and Profit Taxation with Foreign Ownership of Firms," *Journal of International Economics*, 1997.

_____., "Is Coordination of Fiscal Deficits Necessary?" download from **www.inomics.com**, 1998.

Kanbur, R., and M. Keen, "Jeux sans frontiers: Tax Competition and Tax Coordinations when Countries Differ in Size," *American Economic Review*, 1993, *83*, pp. 877-892.

Keen, M. and J. Edwards, "Tax Competition and the Leviathan," *European Economic Review*, 1996.

Keen, M. and M. Marchand, "Fiscal Competition and the Pattern of Public Spending," *Journal of Public Economics*, October 1997, 66:1, pp. 33-54.

King, R.G., C.I. Plosser, and S.T. Rebelo, "Production, Growth and Business Cycles, I: The Basic Neoclassical Model," *Journal of Monetary Economics*, March/May 1988, *90*(358), pp. 314-29.

Klein, P., V. Quadrini, and J. Rios-Rull, "Optimal and time-consistent fiscal policy with international mobility of capital: Why does the U.S. tax capital more than Europe?" University of Pennsylvania Working paper, 2001.

Lockwood, B., "Tax Competition and Coordination under Origin and Destination Principles: A Synthesis," Mimeo, Department of Economics, University of Warwick, 1999.

Lopez-Garcia, M. "On Welfare and Revenue Effects of Indirect Tax Harmonization," *Economics Letters*, 60:2, 1998, pp. 185-93.

Lucas, R.E. Jr., "Supply-Side Economics: An Analytical Review," *Oxford Economic Papers*, April 1990, *42*(2), pp. 293-316.

Mendoza,E.G., "The International Macroeconomics of Taxation and the Case *Against* European Tax Harmonization," in *Contemporary Economic Policy: Essays in Honor of Assaf Razin*, edited by E. Heplman and E. Sadka, Cambridge University Press, forthcoming, 2002

Mendoza, E.G. and L.L. Tesar, "The International Ramifications of Tax Reforms: Supply-Side Economics in a Global Economy," *American Economic Review*, March 1998, 88:1, pp. 226-45.

Mendoza, E.G., G.M. Milesi-Ferretti and P. Asea, (1997), "On the Ineffectiveness of Tax Policy in Altering Long-run Growth: Harberger's Superneutrality Conjecture," *Journal of Public Economics*, 66, 99-126.

Mendoza, E.G., A. Razin and L.L. Tesar, "Effective Tax Rates in Macroeconomics: Cross-Country Estimates of Tax Rates on Factor Incomes and Consumption," *Journal of Monetary Economics*, December 1994, 34:3, pp. 297-323.

OECD, *Harmful Tax Competition – An Emerging Global Issue*. Report of the OECD Committee on Fiscal Affairs, Paris, 1998.

Persson, T. and G. Tabellini, "Double-Edged Incentives: Institutions and Policy Coordination," in G. Grossman and K. Rogoff, eds. *Handbook of International Economics*, Vol III, New York: North-Holland, 1995.

Prescott, Eward C. (2003), "Why Do Americans Work So Much More Than Europeans?" Staff Report 321, Research Department, Federal Reserve Bank of Minneapolis.

Razin, A. and E. Sadka, "Integration of the International Capital Markets: The Size of Government and Tax Coordination," in A. Razin and J. Slemrod, eds. Taxation in the Global Economy, Chicago: University of Chicago Press, 1990, pp. 331-48.

_____., "International Tax Competition and Gains from Tax Harmonization," *Economics Letters*, 1991.

Razin, A. and C.W. Yuen, "International Fiscal Policy Coordination and Competition," in F. van der Ploeg, ed. *The Handbook of International Macroeconomics*, Cambridge, MA: Blackwell Publishers, 1994, pp. 116-150.

_____., "Labor Mobility and Fiscal Coordination," *Journal of Public Economics*, 1997.

Rehme, G., "Economic Growth, (Re)-Distributive Policies, Capital Mobility and Tax Competition in Open Economies," Working Paper ECO 97/24, European University Institute. Florence Italy, 1997.

Rodrik, D. and T. van Ypersele, "Capital Mobility, Distributive Conflict and International Tax Coordination," *Journal of International Economics*, 2001, 54(1).

Sinn, H.W., "Tax Harmonization and Tax Competition in Europe," *European Economic Review,* 1990, 34, pp. 489-504.

Sorensen, P.B., "The Case for International Tax Coordination Reconsidered," *Economic Policy*, October 2000, 31, pp.431-472.

_____., "International Tax Coordination: Regionalism versus Globalism," forthcoming in the *Journal of Public Economics*, 2003.

_____., "TAXCOM – A Model of Tax Competition and Tax Coordination," Technical Working Paper, Economic Policy Research Unit, University of Copenhagen, 1999.

Tanzi, V. and L.A. Bovenberg, "Is there a Need for Harmonizing Capital Income Taxes within EC Countries?" in H. Siebert, ed., *Reforming Capital Income Taxation*, Tubingen: Mohr, 1990, 171-97.

van Ypersele, Tanguy, "Coordination of Capital Taxation Among a Large Number of Asymmetric Countries," Tilburg University Working Paper, 1998.

Wildasin, D.E., "Nash Equilibria in Models of Fiscal Competition," *Journal of Public Economics*, 1988, 35, pp. 229-40.

Table 1. Investment Rate Regressions for 1971-1995 panel of Quinquennial Averages

	standard panel		Random Effects	
	All countries	Excluding Japan	All countries	Excluding Japan
capital tax rate	-0.140	-0.144	-0.144	-0.108
	(0.0459)*	(0.0284)*	(0.0607)**	(0.0337)**
intercept	28.329	26.782	28.294	27.426
	(1.9672)*	(1.1676)*	(1.8788)*	(1.2962)*
adj. R2	0.103	0.389	0.073	0.477
F	4.669	18.215	2.265	13.309
D.W.	0.832	1.399	0.825	1.974
no. of observations	33	28	33	28

Note: All regressions estimated by OLS using White's Heteroskedasticity-consistent standard errors and covariance. Standard errors in parentheses (* denotes that the coefficient is statistically siginficant at the 1 percent confidence level, ** denotes that the coefficient is statistically significant at the 5 percent confidence level). Random effects regressions include country-specific dummies.

Table 2. Cross-Country Correlations of Capital Income Tax Rates

	France	Germany	United Kingdom	United States
Sample: 1970-1978				
France	1.000	0.818	0.293	-0.032
Germany	0.818	1.000	0.157	-0.100
United Kingdom	0.293	0.157	1.000	0.473
United States	-0.032	-0.100	0.473	1.000
Sample: 1979-1996				
France	1.000	0.568	0.792	0.184
Germany	0.568	1.000	0.746	0.521
United Kingdom	0.792	0.746	1.000	0.350
United States	0.184	0.521	0.350	1.000

Table 3. Time Series Regressions of the French Investment Rate

	Full sample 1971-1996	Post-financial integration 1979-1996
Capital tax rates:		
France	-0.768	-1.042
	(0.1996)*	(0.4899)**
UK	0.223	0.267
	(0.0738)*	(0.0908)*
US	0.102	0.297
	(0.2736)	(0.1476)***
intercept	28.329	28.294
	(1.9672)*	(1.8788)*
adj. R2	0.642	0.605
F	18.701	9.904
D.W.	1.798	1.485
no. of observations	26	18

Note: The regressions were estimated by Two-Stage Least Squares using as instruments the lags of the three tax rates, an intercept, and a time trend. Standard errors are in parentheses (* denotes that the coefficient is statistically-signifcant at the 1 percent confidence level, ** denotes that the coefficient is statistically significant at the 5 percent level, and *** denotes that the coefficient is statistically significant at the 10 percent level).

Table 4. Labor-Leisure Ratio Regressions for a 1971-1995 Panel of Quinquennial Averages

	All countries	Excluding Japan
Change in log tax factor	0.338	0.406
	(0.1396)**	(0.1405)**
adj. R2	--	0.157
Log likelihood	48.815	47.230
D.W.	2.394	1.976
no. of observations	21	17

Note: Regressions estimated by OLS using White's Heteroskedasticity-consistent standard errors and covariance. Standard errors in parentheses (** denotes that the coefficient is statistically siginficant at the 5 percent confidence level). The regressions include country dummies that were siginicant at the 5 percent level for all countries and the 1 percent level for the regression excluding Japan.

Table 5. Time Series Regressions of the Labor-Leisure Optimality Condition

	France			Germany			United Kingdom			United States		
	OLS	IV	FD	OLS	IV	FD	OLS	IV	FD	OLS	IV	FD
Log tax factor	0.501	0.527	0.188	0.834	0.927	0.015	-0.021	-2.204	0.033	0.722	0.767	0.369
	(0.0494)*	(0.0523)*	(0.1023)***	(0.1305)*	(0.1004)*	(0.1234)	(0.2580)	(2.9603)	(0.1132)	(0.0485)*	(0.0586)*	(0.0965)*
Log c/y ratio	-0.959	-1.176	-0.305	0.024	0.084	-0.673	-0.079	1.145	-0.213	-0.532	-0.497	-0.382
	(0.1512)*	(0.2145)*	(0.1614)***	(0.1726)	(0.2471)	(0.2340)*	(0.1831)	(1.7647)	(0.1577)	(0.0392)*	(0.0710)*	(0.1004)*
Intercept	-1.315	-1.421		-0.584	-0.492		-1.200	-1.611		-1.290	-1.258	
	(0.0834)*	(0.1076)*		(0.1404)*	(0.1711)*		(0.0621)*	(0.5204)*		(0.0305)*	(0.0475)*	
implied *a*	2.384	2.649		1.148	1.046		2.126	3.205		2.324	2.251	
adj. R2	0.869	0.857		0.770	0.758	0.027				0.974	0.973	0.357
F	57.177	49.973		44.620	42.273		0.588	0.505		491.071	440.894	
Log likelihood	62.790		62.017	62.590		70.334	50.638		49.071	105.220		100.489
D.W.	1.935	2.189	1.434	1.545	1.701	1.307	0.749	1.608	1.058	1.675	1.715	2.124
no. of observations	18	18	18	27	27	26	15	15	14	27	27	26.000
sample period	79-96	79-96	79-96	70-96	70-96	71-96	82-96	82-96	83-96	70-96	70-96	71-96

Note: The dependent variable is the log of the ratio of the fraction of hours worked per week relative to leisure hours (defined as 1 minus the fraction of hours worked. OLS are ordinary least squares regressions, IV are instrumental variables regressions (using as instruments the intercept and the lagged logs of the effective labor tax factor and the capital tax rate), and FR are regressions in first differences. All estimates use White's heteroskedasticity consistent standard errors and covariance (* denotes that the coefficient is statistically significant at the 1 percent confidence level, ** denotes that the coefficient is statistically significant at the 5 percent confidence level, and *** dentoes that the coefficient is statisticlally significant at the 5 percent confidence level)

TABLE 6: Parameter Values and Pre-tax Competition, Steady-
for Calibration to

Parameter		
Technology and		
	δ	0.016
	α	0.64
	γ	0.003
	η	10
	B	0.99
	σ	2
	a	2.67
Tax policy parameters (in		
	τ_K	26.5
	τ_L	37.4
	τ_C	16.6

Pre-tax competition, balanced-growth allocations

	Data	Mode
c/y	0.57[a]	0.58
x/y	0.24[a]	0.24
g/y	0.18[b]	0.18
tb/y	-0.02[a]	0
tax	0.37[c]	0.38
net	0.24[c]	0.24

Data sources: Tax rates are authors' estimates based on the methodology described in Razin and Tesar (1994). Consumption, investment, trade balance and government expenditure are based on OECD National Income Accounts. Tax revenue and net transfers are from the Revenue Statistics for the OECD countries

a. Average for France, Germany and Italy in 1980.

b. Average of France (1980), Italy (1980) and Germany (1991).

c. Average of France, Italy and Germany in 1985.

Table 7: Nash and Cooperative Equilibria of Capital Income Tax Competition

		Tax Rates			Welfare gain (percent)		Net gains from cooperation
		Initial	Nash	Cooperative Equilibri [a]	Nash	Cooperative Equilibri [a]	
A. Symmetric game							
1. Labor tax adjusts to maintain revenue neutrality (Figure)							
	τ_K	0.265	0.269	0.371	0.021	0.284	0.263
	τ_L	0.374	0.373	0.344			
2. Consumption tax adjusts to maintain revenue neutrality (Figure)							
	τ_K	0.265	-0.113	-0.031	0.684	0.722	0.038
	τ_C	0.166	0.242	0.225			
B. Asymmetric game							
1. Labor tax adjusts to maintain revenue neutrality (Figure)							
a. C3	τ_K	0.265	0.295	[0.31, 0.37]	-2.17	[-2.17, -1.929]	[0, 0.241]
	τ_L	0.374	0.397	[0.376, 0.390]			
b. UK	τ_K*	0.530	0.195	0.245	3.87	[3.882, 4.156]	[0.012, 0.286]
	τ_L*	0.025	0.317	[0.306, 0.309]			
2. Consumption tax adjusts to maintain revenue neutrality							
a. C3	τ_K	0.265	-0.152	[-0.115, -0.10]	0.349	[0.349, 0.365]	[0.001, 0.016]
	τ_C	0.166	0.263	[0.253, 0.255]			
b. UK	τ_K*	0.530	-0.092	[-0.05, -0.0325]	5.285	[5.288, 5.313]	[0.003, 0.028]
	τ_C*	0.140	0.272	[0.259, 0.263]			

a. For the symmetric case the Table shows all data for the Cooperative equilibrium in which the planner assigns equal weights to the two games it shows data for the range of all Cooperative equilibria that are Pareto improvements over the Nash outcome. The range of tax rates lowest to the highest tax rate for the set of Cooperative equilibria. Note, however, that the lower the capital tax rate, the higher the labor tax rate must be to

Table 8: Sensitivity analysis of symmetric labor-for-capital income tax game

	Tax Rates			Welfare gain (percent)		Net gains from cooperation
	Initial	Nash Equilibrium	Cooperative Equilibria[a]	Nash Equilibrium	Cooperative Equilibria[a]	
A. Benchmark case						
τ_K	0.265	0.269	0.371	0.021	0.284[a]	0.263
τ_L	0.374	0.373	0.344			
B. Home country net debtor (tb/y = -0.10)						
Net debtor						
τ_K	0.265	0.290	[0.37, 0.42]	-0.011	[0.028, 0.773]	[0.039, 0.762]
τ_L	0.374	0.368	[0.322, 0.329]			
Net creditor						
τ_K*	0.265	0.260	[0.36, 0.39]	0.113	[0.126, 0.690]	[0.013, 0.577]
τ_L*	0.374	0.375	[0.348, 0.352]			
C. Inelastic labor supply (a = 0.0001)						
τ_K	0.265	-0.088	-0.148	0.801	0.814[a]	0.013
τ_L	0.374	0.434	0.443			
D. Small capital adjustment costs (= 0.5)						
τ_K	0.265	0.190	0.340	-0.400	0.131[a]	0.531
τ_L	0.374	0.394	0.354			

a. For symmetric games the Table shows data for the Cooperative equilibria in which the planner assigns equal weights to the two countries. For asymmetric games it shows data for the range of all Cooperative equilibria that are Pareto improvements over the Nash outcome. The range of tax rates are reported from lowest to highest across the set of Cooperative equilibria. Note, however, that the lower the capital tax rate, the higher the labor tax rate must be satisfy budget balance.

Figure 1

Capital Income Tax Rates in France, Germany, Italy and the UK: 1965-96

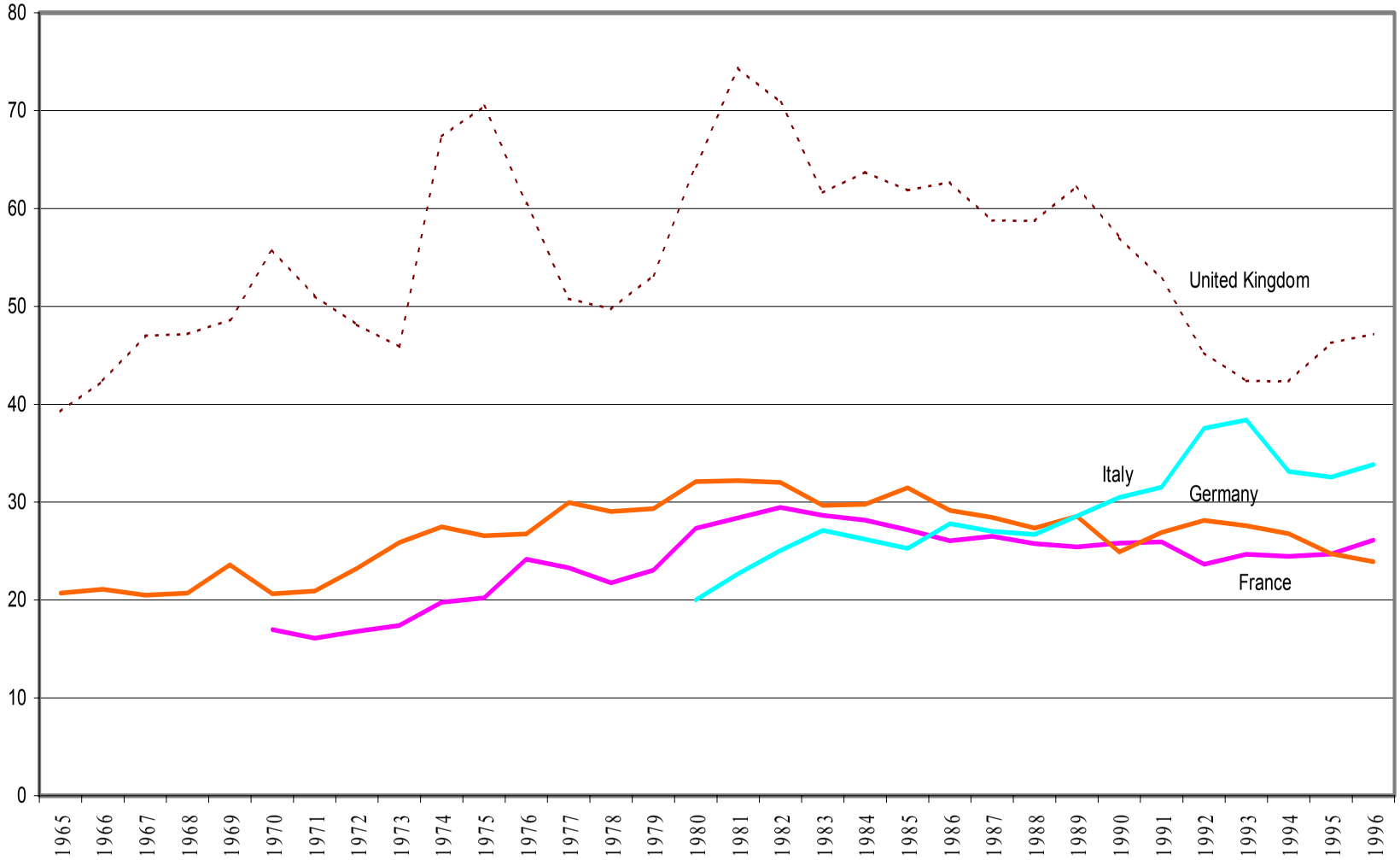


Figure 2

Labor Income Tax Rates in France, Germany, Italy and the UK: 1965-96

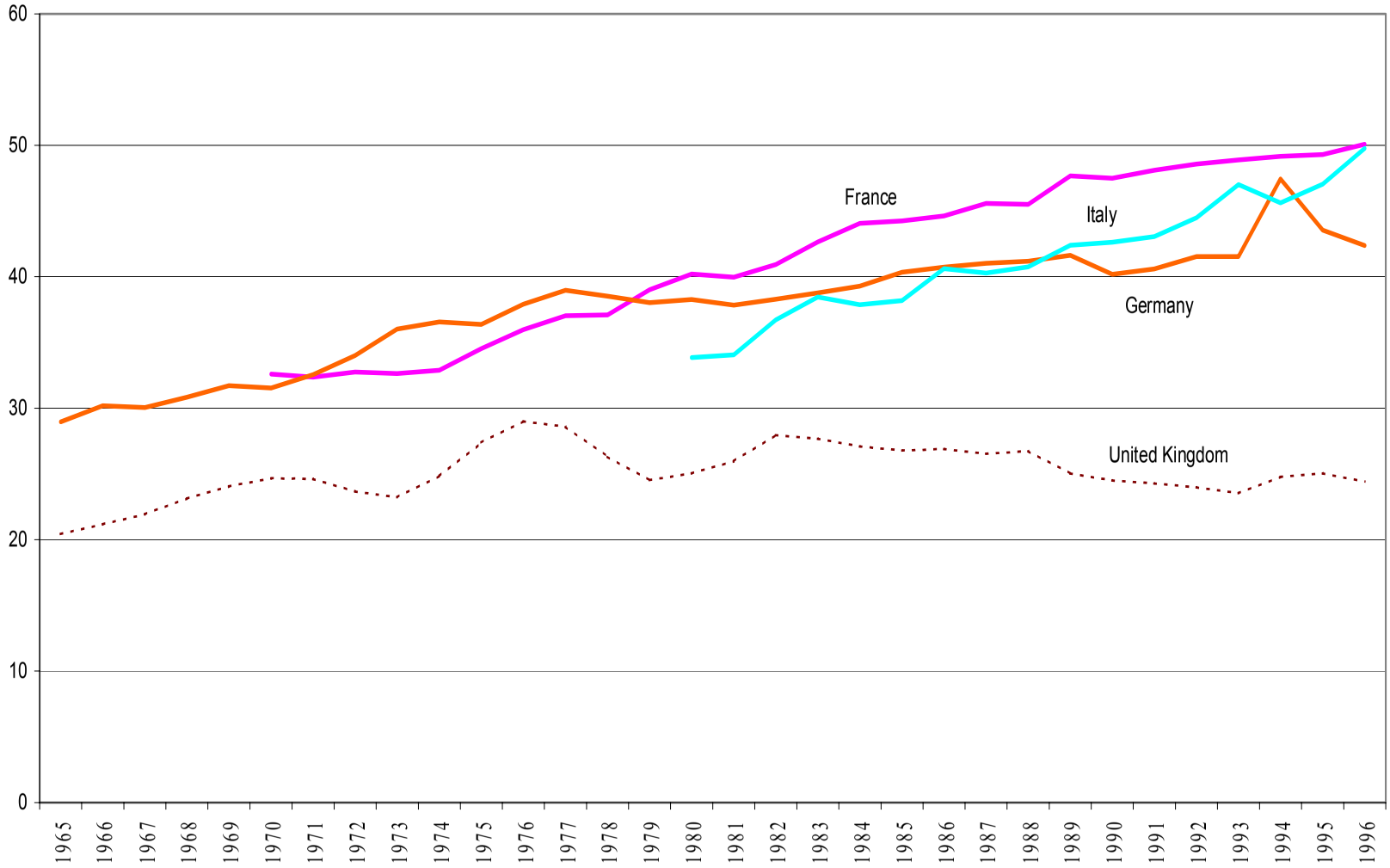


Figure 3:
Consumption tax rates in France, Germany, Italy and the United Kingdom: 1965-96

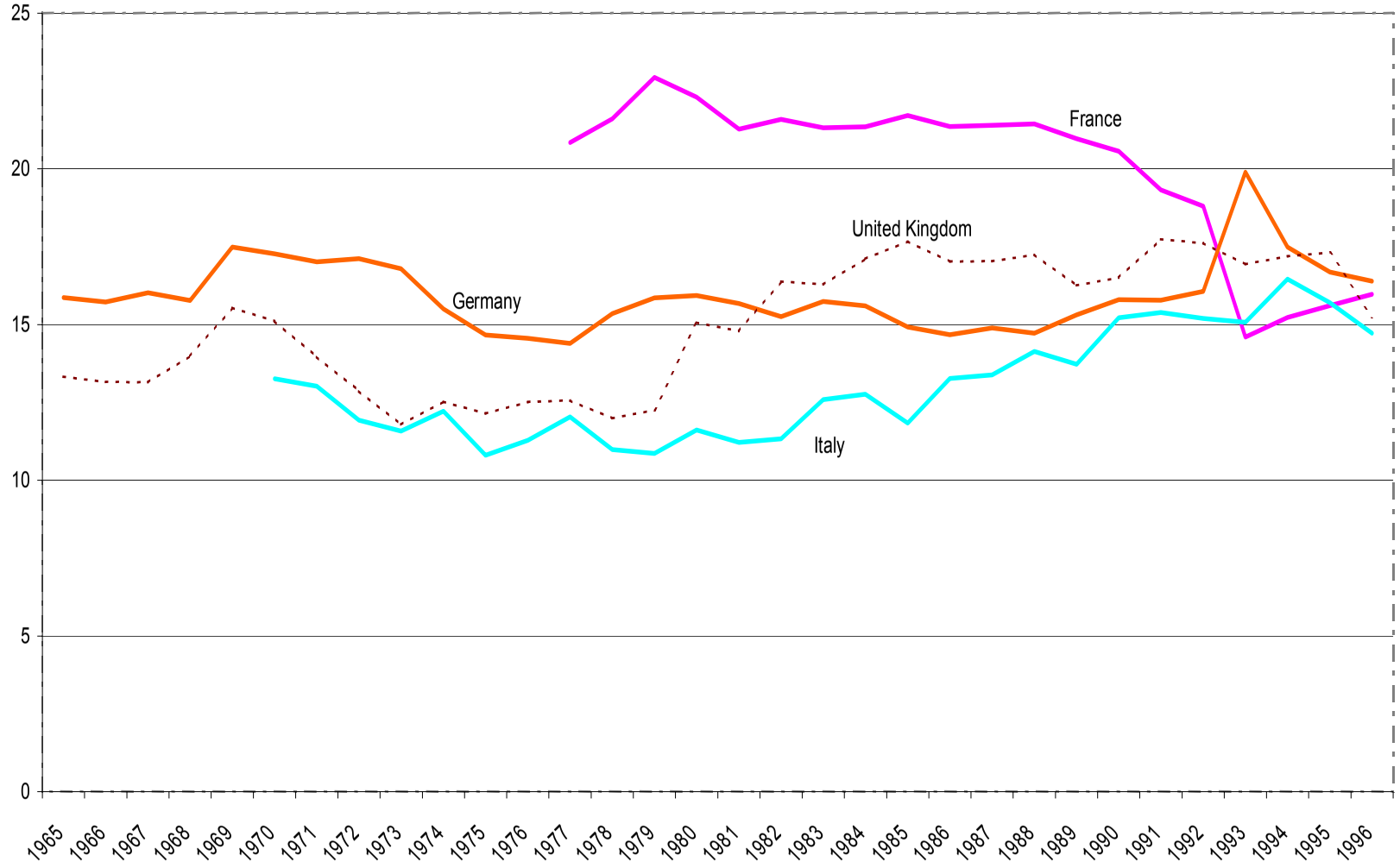


Figure 4. Capital IncomeTax Rates and Investment Rate: G-7 Countries
(1971-1995 in 5-year averages)

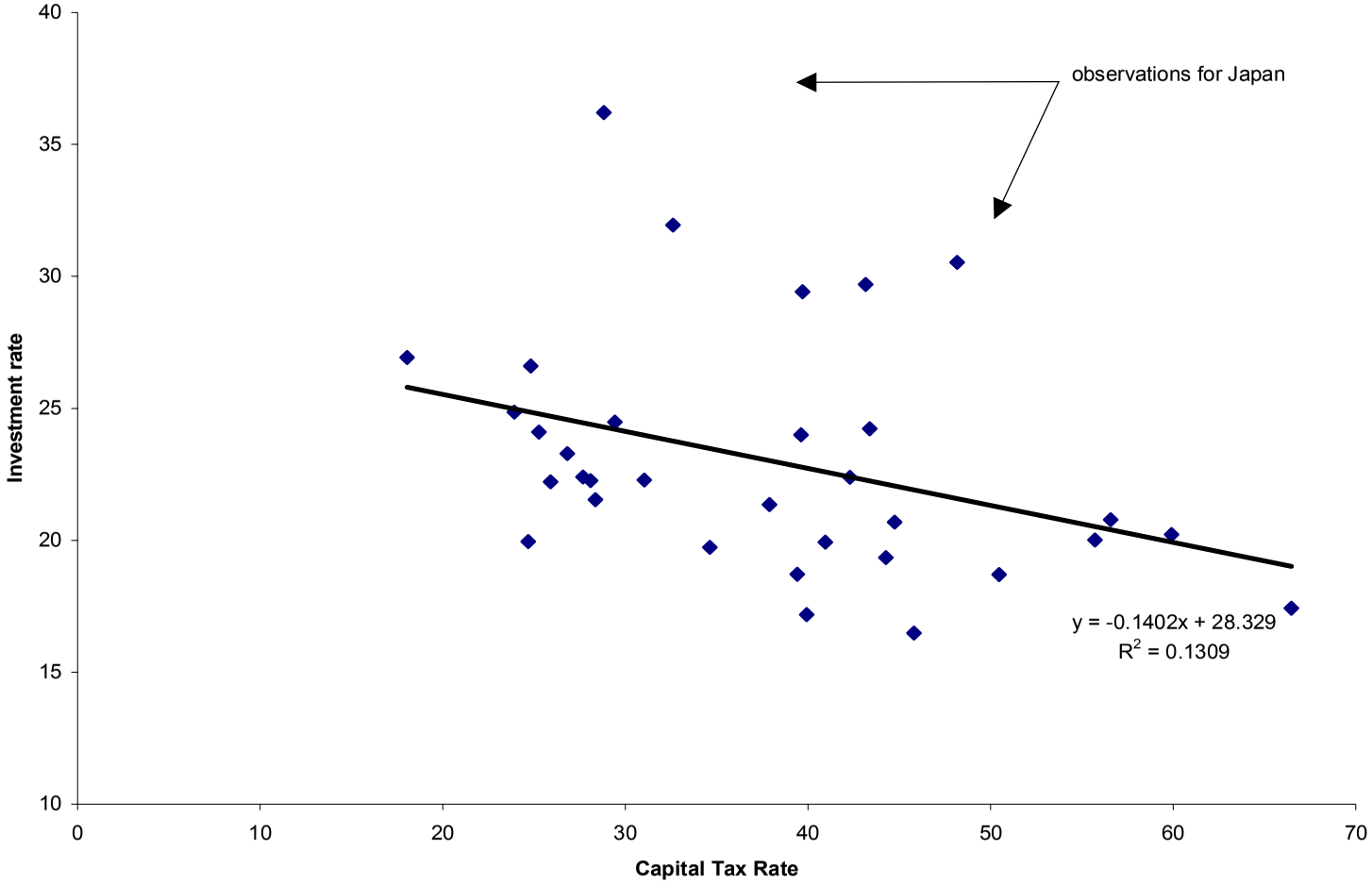
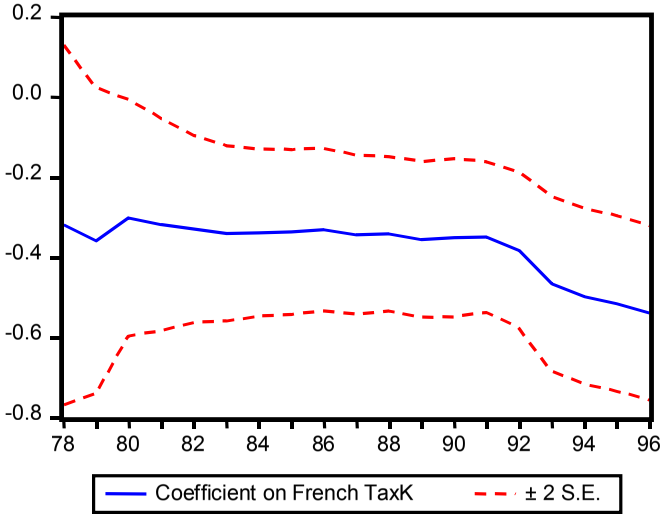
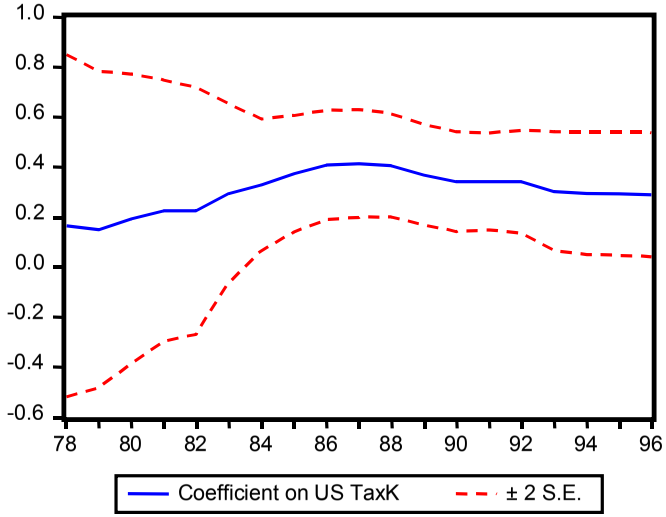
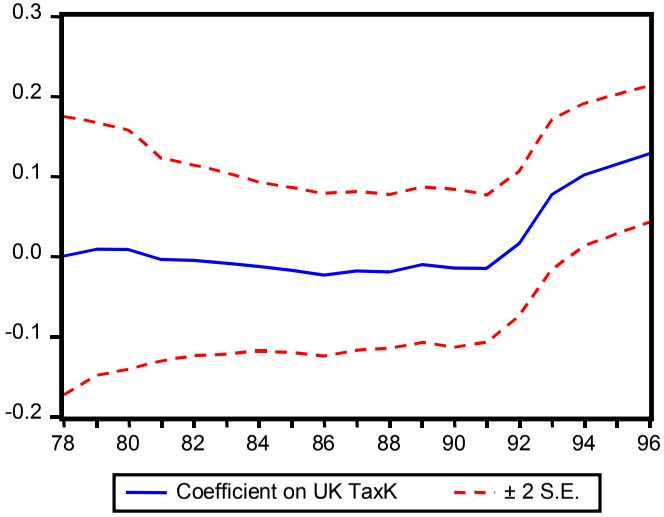


Figure 5. Recurisve Estimates of Coefficients in OLS Regression of French (sample period: 1970-1996, adj.







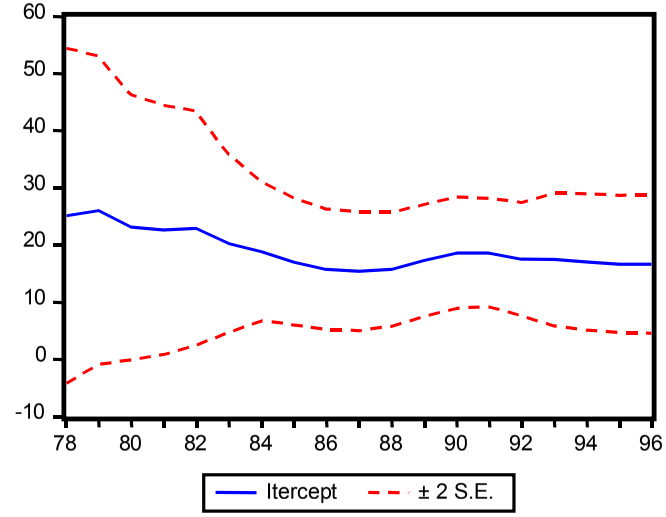


Figure 6: Reaction Curves for Symmetric Tax Competition
over Capital Income Tax Rates with Adjustment in Labor Income Tax

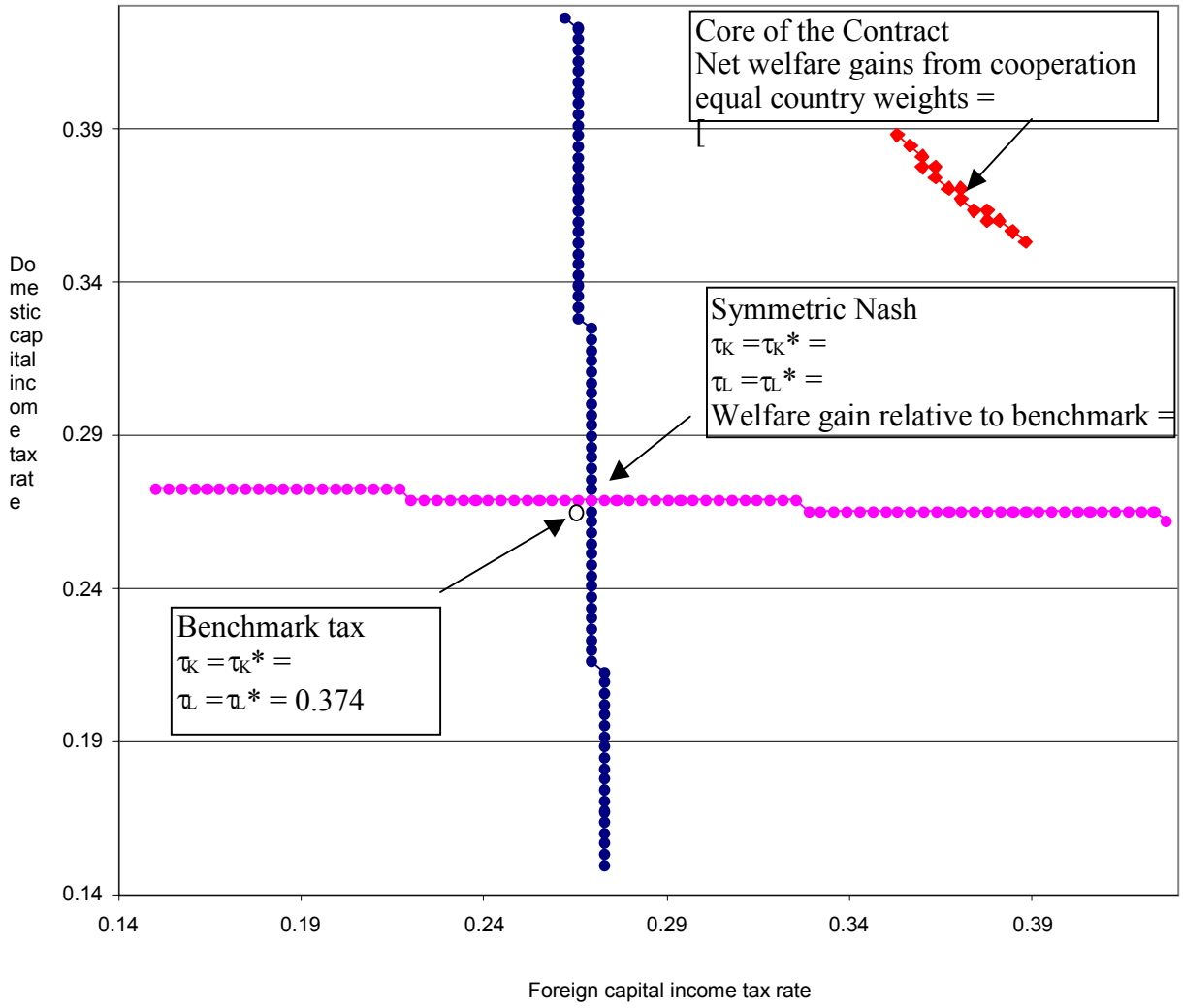


Figure 7: Reaction Curves for Symmetric Tax Competition over Capital Income Tax Rates with adjustment in Consumption