

## NBER WORKING PAPER SERIES

A QUANTITATIVE ANALYSIS OF TAX COMPETITION  
V. TAX COORDINATION  
UNDER PERFECT CAPITAL MOBILITYEnrique G. Mendoza  
Linda L. TesarWorking Paper 9746  
<http://www.nber.org/papers/w9746>NATIONAL BUREAU OF ECONOMIC RESEARCH  
1050 Massachusetts Avenue  
Cambridge, MA 02138  
May 2003

We thank V.V. Chari, Michael Devereux, Jonathan Heathcote, Jim Hines, Pat Kehoe, Paul Klein, Vincenzo Quadrini, Assaf Razin and Peter Birch Sorensen for helpful suggestions and comments. We also thank seminar participants at the Minneapolis Fed, the New York Fed, NYU's Stern School of Business, the University Michigan, Michigan State University, the 2001 Meeting of the Society for Economic Dynamics, the joint Harvard-MIT International Workshop and the 4th Conference of the Analysis of International Capital Markets Research Training Network for their comments and suggestions. The views expressed herein are those of the authors and not necessarily those of the National Bureau of Economic Research.

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A Quantitative Analysis of Tax Competition v. Tax Coordination under Perfect Capital Mobility  
Enrique G. Mendoza and Linda L. Tesar  
NBER Working Paper No. 9746  
May 2003  
JEL No. F2, F42, E6, H2, H87

**ABSTRACT**

Theory predicts that strategically-determined tax rates induce negative externalities across countries in relative prices, the wealth distribution and tax revenue. This paper studies the interaction of these externalities in a dynamic, general equilibrium environment and its effects on quantitative outcomes of tax competition in one-shot games over capital income taxes between two governments that set time-invariant taxes and issue debt. Strategic payoffs correspond to welfare gains net of the cost of transitional dynamics in a standard neoclassical two-country model with exogenous balanced growth. The model is calibrated to European data for the early 1980s starting from a benchmark with symmetric countries. When countries compete over capital taxes adjusting labor taxes to maintain fiscal solvency, the Nash equilibrium replicates calibrated taxes, suggesting that European taxes can be the outcome of Nash competition. When consumption taxes are adjusted to maintain fiscal solvency, competition triggers a "race to the bottom" in capital taxes but this outcome is welfare-improving relative to calibrated taxes. Sensitivity analysis shows that competition can produce a "race to the top" in capital taxes and that the United Kingdom can benefit from tax competition with Continental Europe. Surprisingly, the gains from coordination in all of these experiments are small.

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"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)

"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)

## 1. Introduction.

Much of the open-economy macroeconomics literature on tax coordination 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 magnitude of the gains of tax coordination to assess the robustness of this premise.<sup>2</sup> The goal of this paper is to provide a quantitative assessment of tax competition and the benefits of tax coordination in a world with trade in financial capital. Our framework for analysis is a standard two-country, dynamic general equilibrium model driven by labor-augmenting technological change. 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.

Studies of international tax competition generally emphasize three global externalities of national tax policy that lead to strategic behavior. The first 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 so as to influence the terms of trade or the world real interest rate in their favor. The magnitude of these relative-price externalities has been shown in theory to depend 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)).

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<sup>2</sup> 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 second externality operates via a wealth-redistribution effect. Strategic cuts in taxes can be used to attract internationally mobile factors of production. 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 third externality is a fiscal solvency externality 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, tax competition may trigger a “race to the bottom” in which governments reduce taxes on mobile factors of production. This erodes 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-sloping 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 typically treats these three externalities separately and often 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 very large and that they 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 that would surely result from 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 in both countries. Hence, our previous results suggested 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 positive and normative effects of tax competition and tax coordination.

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 income 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 income 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 quite 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.

International competition over capital income taxation is currently a key issue for countries in the European Union. The 1997 report by the ECOFIN Ministers of the European Community (*The Package to Tackle Harmful Tax Competition*), and recent articles in the financial media (see, for example, *Financial Times*, May 2, 2003, p. 2) document recent rounds of competitive corporate income tax cuts throughout Europe. Ongoing negotiations over mutual reporting of non-resident capital income reflect similar concerns. In order to quantitatively assess the impact of tax competition in Europe, we calibrate our tax policy games to European data. This approach still allows for important differences in the tax structure at the initial status quo, since the data show that the United Kingdom taxes capital income significantly more than Continental Europe and the opposite holds for labor income (see Mendoza, Razin and Tesar (1994)).

The quantitative analysis starts with a simulation of two perfectly symmetric countries in which the pre-tax-competition status quo is calibrated to an “average” country in continental Europe with relatively high tax rates on labor income and relatively low taxes on capital income. The aim is to start with a scenario in which the three 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 induced by strategic choices on capital income taxes 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 experiments are striking. In the first experiment, the Nash equilibrium of the symmetric tax competition game with labor taxes adjusting in response to the fiscal solvency externality yields capital and labor tax rates that are remarkably close to the set of initial 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 the large differences between tax policy and real 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 case in which the fiscal solvency externality works through adjustments in the consumption tax, the results are markedly different. Tax competition triggers a race to the bottom in capital income tax rates, and the consumption tax rates in each country increase by 8 percent to maintain fiscal solvency. However, as the opening 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 a scenario calibrated to capture tax competition between the United Kingdom and Continental Europe (which incorporates observed differences in initial tax rates and transfer payments). We find that tax competition is immiserizing for Europe and welfare-improving for the UK when labor taxes must be used to maintain fiscal solvency. The UK starts the game with a lower labor income tax rate and a higher capital income tax rate. Tax competition results in a lower capital income tax in the UK and capital relocates from Continental Europe to the UK. The tax base in Europe erodes and therefore Europe must increase *both* capital and labor income tax rates to maintain fiscal solvency. The gains from coordination are small for both the UK and Europe, and do not allow Europe to recoup its losses from tax competition. In the tax competition game with adjustment in the consumption tax, we again observe the race-to-the-bottom in capital income taxes and both parties gain from competition. Coordination again yields only tiny welfare gains over the Nash outcome.

We conduct sensitivity analysis how our results vary with changes in initial debt levels, labor supply elasticity, and capital adjustment costs. The tax rates that emerge from tax competition are quite different from our benchmark case, and in some instances it is possible for countries to engage in a “race to the top” in capital income taxation. However, the finding that the gains from tax coordination are small is robust to the sensitivity analysis, ranging from 0.01 to 0.5 percent of trend consumption. Based on these findings we conclude 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 policy 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 calibrates the model to European data. Section 5 reports the results from the tax competition experiments and Section 6 concludes.

## 2. A Two-Country World Economy 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 as inputs, 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 long-run growth is driven by labor-augmenting technological change at rate  $\gamma$ . All variables, except leisure and labor input, are made stationary by dividing through by  $\gamma$  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 are modeled abstracting from any effects of taxes on economic growth over the long run. 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 quite 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,  $\ell_t$ :

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

In this expression,  $\beta$  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  $\sigma$ . Note that the stationary transformation of the model implies an effective discount factor given by  $\beta(1+\gamma)^{1-\sigma}$  instead of  $\beta$ .

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

$$(1 + \tau_c)c_t + (1 + \gamma) \left( k_{t+1} + q_t b_{t+1} + q_t^g d_{t+1} \right) + \left( \frac{\eta}{2} \left( \frac{x_t}{k_t} - z \right)^2 - 1 \right) k_t = \quad (2)$$

$$(1 - \tau_L)w_t L_t + (1 - \tau_K)(r_t - \delta)k_t + b_t + d_t + e_t$$

for  $t = 0, \dots, \infty$ , 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  $\tau_c$ ,  $\tau_L$ , and  $\tau_K$ , 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 discounted 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  $\eta$  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  $\delta$  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.<sup>3</sup>

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:

$$\ell_t + L_t = 1 \quad (3)$$

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

#### *Firms*

Firms employ labor and capital so as to maximize profits, taking factor prices as given. The production function is Cobb-Douglas:

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

where  $\alpha$  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.

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<sup>3</sup>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 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.

### *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  $t=0, \dots, \infty$ ; 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  $t=0, \dots, \infty$ . The period government budget constraint is given by:

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

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.<sup>4</sup> 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) each period:

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

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:

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

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<sup>4</sup> Note that (2), (5), and the no-Ponzi-game constraints on households and government imply that the present value of the trade balance equals  $b_0$ .

### 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  $t=0, \dots, \infty$  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:

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

$$b_t + b_t^* = 0 \quad (9)$$

### The Three International Externalities of National Tax Policy

The international externalities of tax policy operating in the model can be understood 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 optimality conditions for capital and bond allocations in the two countries (simplified here to ignore capital-adjustment costs) imply:

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

$$\frac{(1 + \gamma)u_1(c_t^*, L_t^*)}{\beta u_1(c_{t+1}^*, L_{t+1}^*)} = (1 - \tau_k^*)[F_1(K_{t+1}^*, N_{t+1}^*) - \delta] + 1 = R_t \quad (11)$$

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 we assume that government outlays are 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 they drive the traditional wedge between the marginal rate of substitution in consumption and leisure and the pre-tax real wage. Labor and consumption taxes have symmetric distortionary effects on account of this wedge, but they are not equivalent because labor is not the sole source of factor income

and capital and labor income are not taxed at the same rates.<sup>5</sup> Moreover, 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 Equilibrium and Tax Competition Framework

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 describing the balanced-growth stationary equilibrium of the home country are provided in Appendix A). With regard to fiscal policy, this calibration exercise specifies a pair of initial tax structures  $\tau = [\tau_c, \tau_L, \tau_k]$  and  $\tau^* = [\tau_c^*, \tau_L^*, \tau_k^*]$ , and time-invariant levels of transfer payments and government purchases in each country  $[g, e]$  and  $[g^*, e^*]$ . The solution to the stationary equilibrium yields a solution for the primary fiscal balances  $T$  and  $T^*$ , which represent the debt service of the steady-state stocks of public debt in each country.

Once the prices and allocations of the pre-tax competition equilibrium are determined, we calculate the payoff that each country receives under a particular choice of capital tax strategies played by each country's fiscal authority. These payoffs 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. Welfare gains 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 welfare calculations take 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.<sup>6</sup> Both the transitional dynamics and the new long-run equilibrium need to be solved simultaneously because models of the class we study here display dependency on initial conditions in the long-run allocations of foreign bonds, and because

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<sup>5</sup> 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.

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:

$$\sum_{t=0}^{\infty} \left[ \prod_{\tau=0}^t R_{\tau}(\tau, \tau^*) \right]^{-1} (g+e) = \sum_{t=0}^{\infty} \left[ \prod_{\tau=0}^t R_{\tau}(\tau, \tau^*) \right]^{-1} \left[ \tau_K (r_t(\tau, \tau^*) - \delta) k_t(\tau, \tau^*) + \tau_L w_t(\tau, \tau^*) N_t(\tau, \tau^*) + \tau_C c_t(\tau, \tau^*) \right] \quad (15)$$

The left-hand-side of (15) 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  $(\tau, \tau^*)$ . The right-hand-side of (15) 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  $(\tau_K, \tau_K^*)$ , the home-country government could satisfy the above constraint (i.e., maintain intertemporal fiscal solvency) with any combination of  $\tau_C$  and  $\tau_L$  that solves equation (15). However, the equation cannot be solved in closed form for these endogenous tax adjustments because the equilibrium prices and allocations in both sides of (15) 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.

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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.

In this environment of international tax competition, 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, and
- (b) the 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 can choose its capital income tax rate from values in discrete grids:  $\tau_K \in \Psi_K = \{\tau_{K,1} < \tau_{K,2} < \dots < \tau_{K,M}\}$  and  $\tau_K^* \in \Psi_K^* = \{\tau_{K,1}^* < \tau_{K,2}^* < \dots < \tau_{K,M}^*\}$ . Hence the tax strategy space is defined by the set of  $M \times N$  capital income tax rate pairs  $(\tau_K, \tau_K^*)$  in  $\Psi_K \times \Psi_K^*$ . 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  $(\tau_L, \tau_L^*)$  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  $\tau_K(\tau_K^*)$  is given by  $\tau_K = \operatorname{argmax}_{\tau_K} V(\tau_K | \tau_K^*)$  and the foreign reaction curve  $\tau_K^*(\tau_K)$  is given by  $\tau_K^* = \operatorname{argmax}_{\tau_K^*} V(\tau_K^* | \tau_K)$ .

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  $(\tau_K, \tau_K^*)$  in  $\Psi_K \times \Psi_K^*$ , 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  $(\tau_K, \tau_K^*)$  in  $\Psi_K \times \Psi_K^*$  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  $(\tau_K, \tau_K^*)$  in  $\Psi_K \times \Psi_K^*$  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  $(\tau_K^N, \tau_K^{*N})$  and the associated payoffs  $V(\tau_K^N | \tau_K^{*N})$  and  $V^*(\tau_K^{*N} | \tau_K^N)$  such that: (a)  $\tau_K^N$  maximizes  $V(\tau_K^N | \tau_K^{*N})$  given  $\tau_K^{*N}$ , (b)  $\tau_K^{*N}$  maximizes  $V^*(\tau_K^{*N} | \tau_K^N)$  given  $\tau_K^N$ , (c) the payoffs are supported by the prices and allocations corresponding to the competitive equilibrium for  $(\tau_K^N, \tau_K^{*N})$ , and (d) the fiscal solvency rules of both countries (setting either  $(\tau_C, \tau_C^*)$  or  $(\tau_L, \tau_L^*)$ ) are satisfied. Thus, the Nash equilibrium satisfies  $\tau_K^N = \tau_K(\tau_K^{*N})$  and  $\tau_K^{*N} = \tau_K^*(\tau_K^N)$  (i.e., the Nash equilibrium is at the intersection of the reaction curves).

A *cooperative equilibrium* is defined as a pair  $(\tau_K^C, \tau_K^{*C})$  that maximizes the weighted sum of country payoffs,  $\lambda V(\tau_K^C | \tau_K^{*C}) + (1-\lambda)V^*(\tau_K^{*C} | \tau_K^C)$  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  $\lambda$ '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.

It is important to note that the tax competition games modeled here 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. Pre-Tax Competition Calibration**

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 (or the “C3”), France, Italy and Germany. The C3 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.<sup>7</sup> 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.

Figures 1 through 3 plot the time series of capital, labor and consumption taxes in the C3 and the UK over the 1965-97 period. These tax rates are updated estimates of the effective tax rates proposed by Mendoza, Razin and Tesar (1994). 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 C3 (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 the C3 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 C3 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 1 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  $\frac{1}{2}$ , 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 C3 average of the investment-output ratio in 1996 (adjusted to exclude public investment), which is  $x/y = 0.24$ , and the value of  $\tau_k$ , the steady state conditions (A.1) and (A.2) in the Appendix 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-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 (A.3)-(A.5), together with  $g/y$ ,  $x/y$ ,  $\tau_c$ ,  $\tau_L$ , 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 1 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).<sup>8</sup> 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 C3 was 24 percent of GDP. Any remainder after the level of transfer payments is subtracted from the

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<sup>7</sup> We are grateful to Peter Birch Sorensen for suggesting that we place our analysis in this context.

<sup>8</sup> 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 C3 in 1985 tax was 37 percent.

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.

## **5. Quantitative Outcomes of Tax Competition and Tax Coordination**

### **a. Tax Competition with Symmetric Countries**

The first tax competition game we consider is based on the calibration to two symmetric European countries described in Section 4 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 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 2 shows the capital and labor taxes and the welfare gains when countries play Nash and when they cooperate. Figure 4 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.<sup>9</sup> 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 2.A.2 and Figure 5). 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.<sup>10</sup> To maintain the present value of tax revenue equal to the present value of the unchanged government outlays, each country 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

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<sup>9</sup> There exists a range of cooperative equilibria 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.

<sup>10</sup> 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 to subsidize capital, pushing up the world interest rate and forcing some of the costs of capital accumulation onto the rest of the world.

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 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.

b. Tax Competition with Asymmetric Countries

The second set of tax competition experiments we consider are aimed at studying how a tax competition game between the UK and C3 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 the C3. As illustrated in Figures 1 through 3, the UK has higher capital income tax rates than the C3 and significantly lower labor income tax rates. Tax rates on capital, labor and consumption in the C3 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 2 shows the outcome when the C3 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 the C3 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 C3 to the UK. As a consequence, the tax base in the C3 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, the C3 ends up worse off than in the pre-tax-competition equilibrium. The welfare loss (gain) for the C3 (UK) under cooperation is between 1.93 (3.88) and 2.17 (4.16) percent depending on the country weights in the cooperative payoff function. This suggests that, relative to a pre-tax competition baseline calibrated to tax rates observed in 1980, the C3 are at a disadvantage relative to the UK in the process of financial integration – given the higher initial labor taxes in the C3, any move to engage in cooperative or noncooperative tax competition with the UK under perfect mobility of financial capital would be immiserizing for the C3.

As before, the results are different when countries can use the consumption tax to maintain fiscal solvency. As shown in Table 2.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 the C3 and the UK. The largest gain from cooperation is 0.29 percent of trend consumption, and it is obtained by the UK in the case in which the labor tax adjusts to maintain fiscal solvency and the weight of the UK in the cooperative payoff function is set to maximize the payoff to the UK without making the C3 worse off than under the Nash outcome.

c. 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 3). 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 3 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 40 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 weights 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  $\tau_K$  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 3. 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.

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## APPENDIX A

### The Steady-State, Balanced-Growth Equilibrium

The model's competitive equilibrium along a steady-state, balanced-growth path is summarized by the following system of five simultaneous equations:

$$\frac{k}{y} = \frac{\beta(1+\gamma)^{1-\sigma}(1-\alpha)(1-\tau_k)}{(1+\gamma) - \beta(1+\gamma)^{1-\sigma}[1-\delta(1-\tau_k)]} \quad (\text{A.1})$$

$$\frac{x}{y} = (\gamma + \delta) \frac{k}{y} \quad (\text{A.2})$$

$$\frac{c}{y} = 1 - \frac{x}{y} - \frac{g}{y} - \frac{nx}{y} \quad (\text{A.3})$$

$$\frac{nx}{y} = \left[ \beta(1+\gamma)^{1-\sigma} - 1 \right] \frac{b}{y} \quad (\text{A.4})$$

$$L = \frac{\left( \frac{1-\tau_L}{1+\tau_C} \right) \alpha}{a \frac{c}{y} + \left( \frac{1-\tau_L}{1+\tau_C} \right) \alpha} \quad (\text{A.5})$$

These are the equations for the home country. An analogous system applies to the foreign country, with the additional condition that the world bond market clears. Equation (A.1) 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 (A.2) is the law of motion for capital accumulation evaluated at steady state, which determines the steady-state investment rate,  $x/y$ . Equation (A.3) 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 (A.4) is the foreign-asset evolution equation along a balanced-growth path. Since the parameter restrictions set in equation (1) of the main text imply  $\beta(1+\gamma)^{1-\sigma} < 1$ , equation (A.4) implies that a long-run positive (negative) foreign asset position finances a long-run trade deficit (surplus).

Equation (A.5) 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. Note that (A.5) applies also at any date  $t$  along the equilibrium path, replacing the steady-state consumption-output ratio in the right-hand-side with the corresponding  $c_t/y_t$  ratio. Note also the differences in the long-run incidence of the different taxes. The capital income tax affects  $k/y$ ,  $x/y$  and, through the effect of changes in  $x/y$  on  $c/y$ , the equilibrium 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 (A1)-(A5) 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 to two symmetric European countries, 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 in Section 3, and then solve the system (A1)-(A5) 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.

**TABLE 1: Parameter Values and Pre-tax Competition, Steady-State Allocations for Calibration to Europe**

Parameter values

Technology and preferences

$\delta$	0.0161
$\alpha$	0.64
$\gamma$	0.0039
$\eta$	10
B	0.993
$\sigma$	2
a	2.675

Tax policy parameters (in percent)

$\tau_K$	26.5
$\tau_L$	37.44
$\tau_C$	16.62

Pre-tax competition, balanced-growth allocations (GDP ratios)

	Data	Model
c/y	0.57 <sup>a</sup>	0.58
x/y	0.24 <sup>a</sup>	0.24
g/y	0.18 <sup>b</sup>	0.18
tb/y	-0.02 <sup>a</sup>	0
tax revenue/y	0.37 <sup>c</sup>	0.38
net transfers/y	0.24 <sup>c</sup>	0.24

Data sources: Tax rates are authors' estimates based on the methodology described in Mendoza, Razin and Tesar (1994). Consumption, investment, trade balance and government expenditure ratios 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 2: Nash and Cooperative Equilibria of Capital Income Tax Competition**

		Tax Rates			Welfare gain (percent)		Net gains from cooperation
		Initial	Nash	Cooperative Equilibria <sup>a</sup>	Nash	Cooperative Equilibria <sup>a</sup>	
<b>A. Symmetric game</b>							
<u>1. Labor tax adjusts to maintain revenue neutrality (Figure 6)</u>							
	$\tau_K$	0.265	0.269	0.371	0.021	0.284	0.263
	$\tau_L$	0.374	0.373	0.344			
<u>2. Consumption tax adjusts to maintain revenue neutrality (Figure 7)</u>							
	$\tau_K$	0.265	-0.113	-0.031	0.684	0.722	0.038
	$\tau_C$	0.166	0.242	0.225			
<b>B. Asymmetric game</b>							
<u>1. Labor tax adjusts to maintain fiscal solvency</u>							
a. C3	$\tau_K$	0.265	0.295	[0.31, 0.37]	-2.17	[-2.17, -1.929]	[0, 0.241]
	$\tau_L$	0.374	0.397	[0.376, 0.390]			
b. UK	$\tau_K^*$	0.530	0.195	0.245	3.87	[3.882, 4.156]	[0.012, 0.286]
	$\tau_L^*$	0.250	0.317	[0.306, 0.309]			
<u>2. Consumption tax adjusts to maintain fiscal solvency</u>							
a. C3	$\tau_K$	0.265	-0.152	[-0.115, -0.10]	0.349	[0.349, 0.365]	[0.001, 0.016]
	$\tau_C$	0.166	0.263	[0.253, 0.255]			
b. UK	$\tau_K^*$	0.530	-0.092	[-0.05, -0.0325]	5.285	[5.288, 5.313]	[0.003, 0.028]
	$\tau_C^*$	0.140	0.272	[0.259, 0.263]			

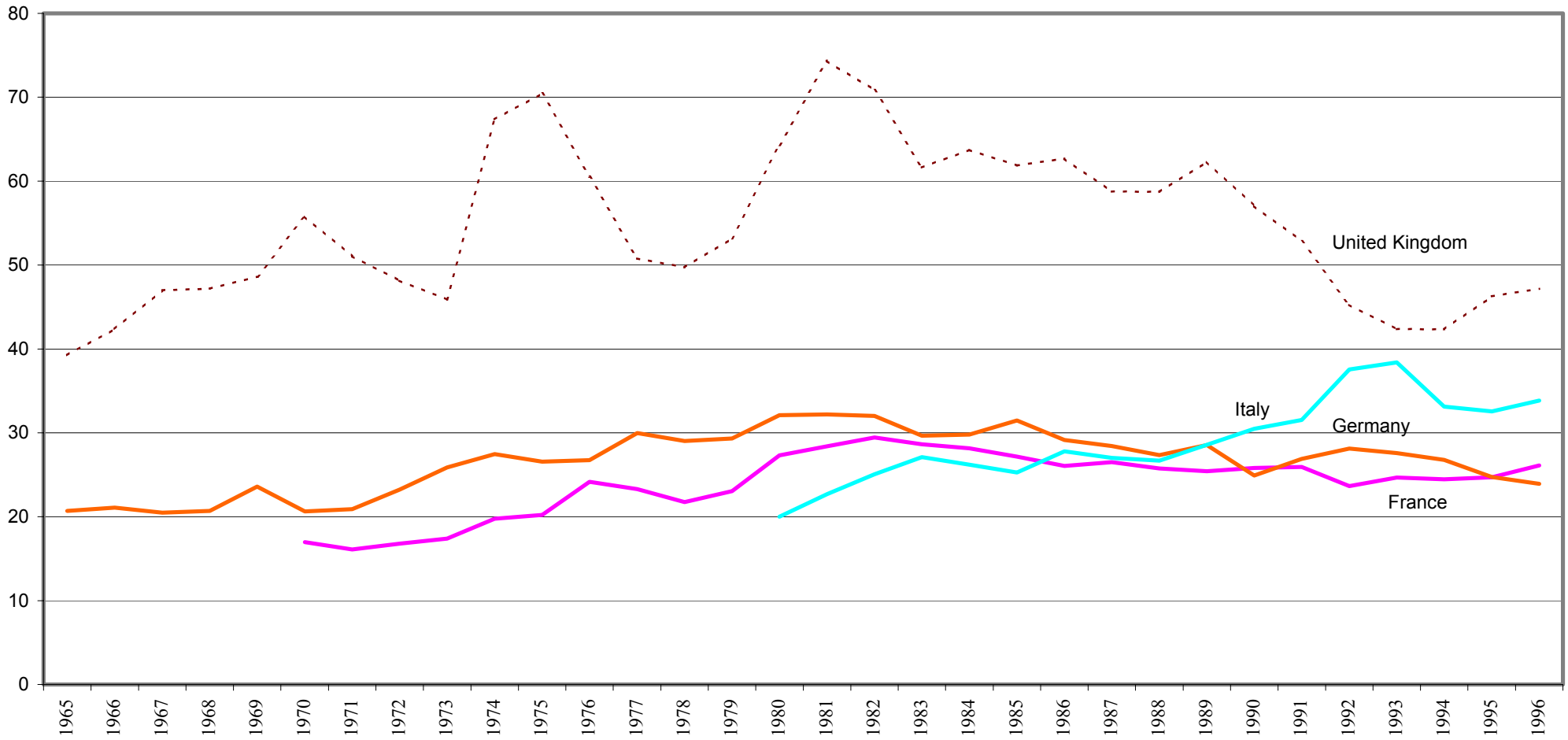
a. For the symmetric case the Table shows all data for the Cooperative equilibrium in which the planner assigns equal weights to the two countries. For asymmetric games it shows data for the range of all Cooperative equilibria that are Pareto improvements over the Nash outcome. The range of tax rates are reported from lowest to 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 satisfy budget balance.

**Table 3: Sensitivity analysis of symmetric labor-for-capital income tax game**

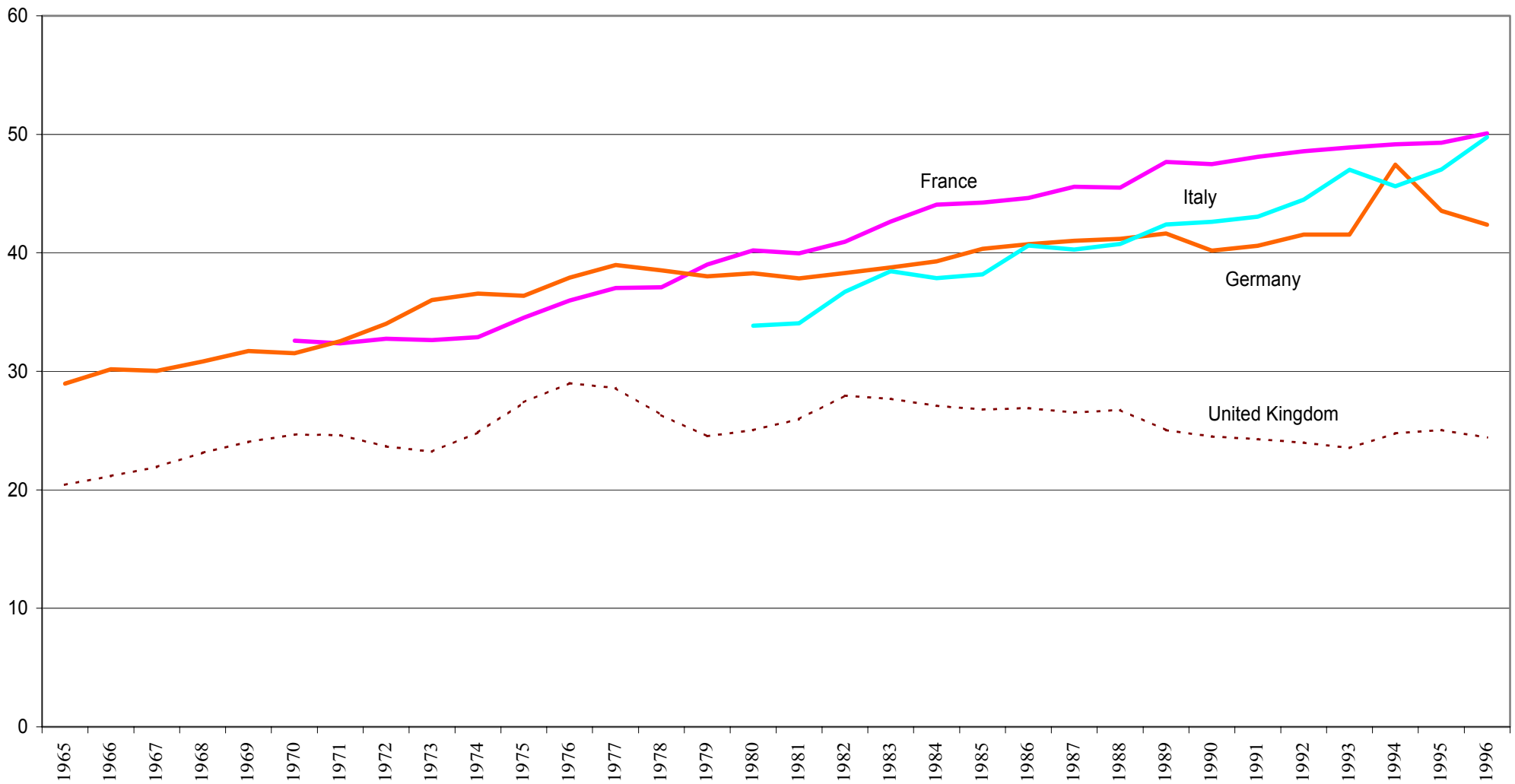
	Tax Rates			Welfare gain (percent)		Net gains from cooperation
	Initial	Nash Equilibrium	Cooperative Equilibria <sup>a</sup>	Nash Equilibrium	Cooperative Equilibria <sup>a</sup>	
<b>A. Benchmark case</b>						
$\tau_K$	0.265	0.269	0.371	0.021	0.284 <sup>a</sup>	0.263
$\tau_L$	0.374	0.373	0.344			
<b>B.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

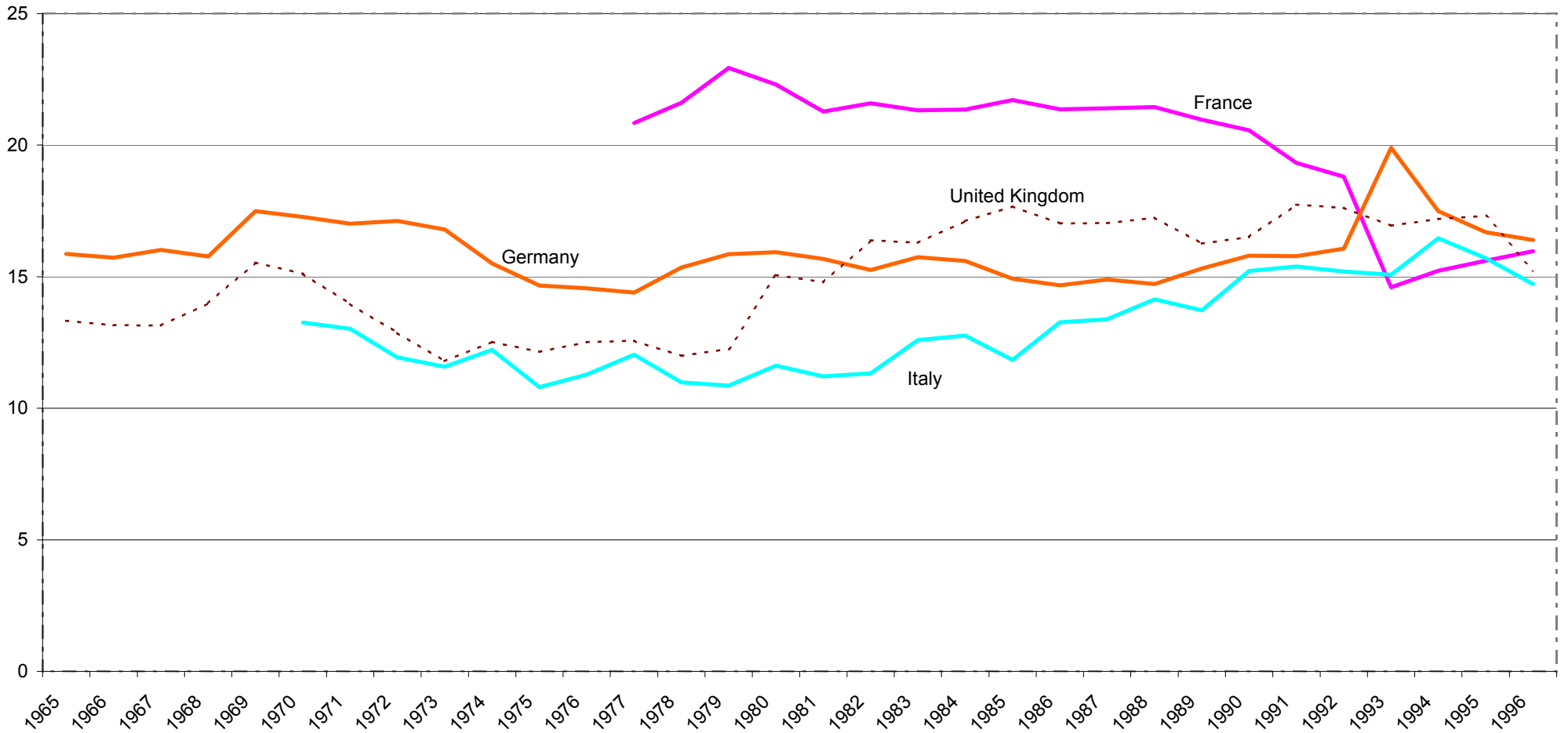




Figure 4: Reaction Curves for Symmetric Tax Competition Game over Capital Income Tax Rates with Adjustment in Labor Income Tax Rates

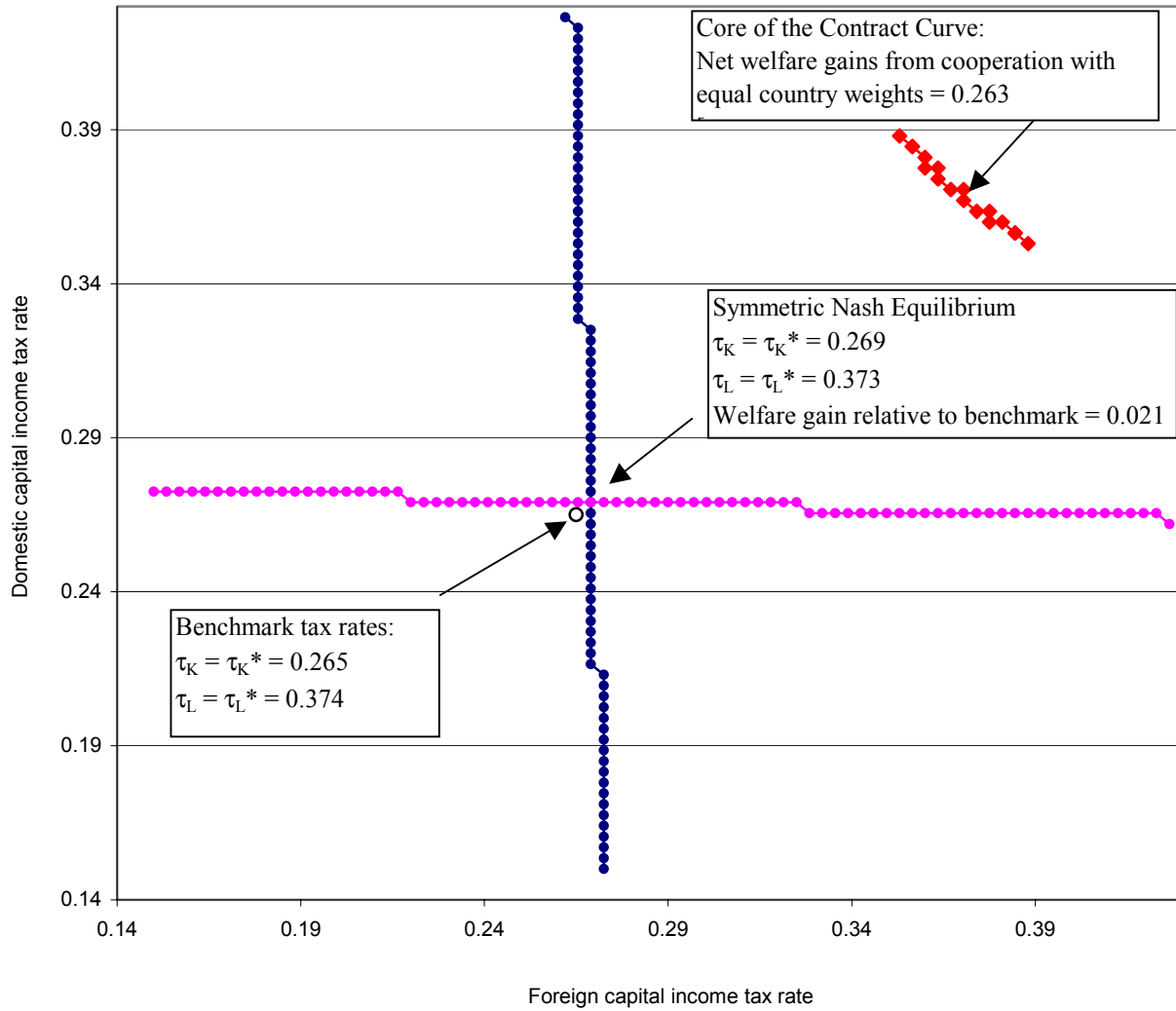


Figure 5: Reaction Curves for Symmetric Tax Competition Game over Capital Income Tax Rates with adjustment in Consumption Tax Rates

