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Follow the Leader?
Evidence on European and U.S. Tax Competition

by

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Abstract: This paper contributes to the small empirical literature that attempts to estimate tax reaction functions of national governments competing with other national governments. Our focus is on European countries. After presenting a simple theoretical model, we estimate reaction functions both for a pure Nash model and for a model in which the U.S. can act as a Stackelberg leader while the European countries compete with each other in a Nash way. Our empirical tests provide evidence that European countries interact strategically with their neighbors to set capital tax rates but not to set labor tax rates and follow the lead of the United States in setting capital tax rates after 1986. In fact, our results suggest that the tax rates of non-tax haven European countries are more responsive to changes in U.S. rates than to their own neighbor's rates. However, we find no evidence that either the haven or non-haven countries reacted to the tax changes of the United States before 1986, the year of a major U.S. tax reform. We also reject the hypothesis that the countries in our sample have become more competitive in recent years. This is interesting given that our data span the time period during which tax competition is alleged to have become more intense.

1. Introduction

It is often alleged that countries will compete in setting tax rates on mobile factors such as capital. If true, increased tax competition could have a profound impact on fiscal systems worldwide, possibly altering revenue, progressivity, the mix of taxes and the overall efficiency of the tax system. Many argue that tax competition will lead to less reliance on taxes on capital and more reliance on taxes on labor, possibly reflecting more closely the benefits that different groups receive in terms of public services.

A large theoretical literature on tax competition has developed beginning with papers such as Zodrow and Mieszkowski (1986), Wilson (1986), Wildasin (1988), Bond and Samuelson (1989), Kanbur and Keen (1993) and recently surveyed in Wilson (1999). The basic argument is that countries recognize that taxes can be avoided by relocation in the case of capital taxes or cross-border purchases in the case of consumption taxes. Consequently, the tax rates set by other countries can influence the tax rate set by a given country. Most of the theoretical models of tax competition that have been developed consider a Nash game. Gordon (1992) provides an interesting exception to this by considering a Stackelberg game. He suggests that the United States may have been large and influential enough to have played the role of a Stackelberg leader. We follow Gordon's lead in this paper and examine empirically the role of the United States vis-à-vis Europe in the setting of tax rates.

Empirical examination of tax competition has lagged behind the development of theoretical models and is quite recent. Moreover, most of the empirical work, surveyed by Brueckner (2001), concentrates on tax competition between governmental units within a country.[1] Several recent papers in this literature such as Besley and Rosen (1998), Goodspeed (2000, 2002), Hayashi and Boadway (2000), and Esteller-Moré and Solé-Ollé (2001) investigate Stackelberg behavior of the central government vis-à-vis lower level governments within a country. A small empirical literature has recently begun that attempts to estimate tax reaction functions of national governments competing against other national

[1] Goodspeed (1998) discusses the similarities between the fiscal federalism and international tax literatures on tax competition.

governments. For instance, Devereux, Lockwood, and Redoano (2002) and Besley, Griffith, and Klemm (2001) estimate Nash reaction functions for OECD countries. Both studies find a positively sloped Nash reaction function, but do not consider the possibility of Stackelberg behavior as suggested by Gordon.

Our primary goal in this paper is to estimate the reaction function of European countries. We do so both for a pure Nash model and for a model in which the U.S. can act as a Stackelberg leader while the European countries also compete with each other in a Nash way. We also address a number of interesting questions concerning tax competition and their estimation that have been raised in the literature, many by Slemrod (2001). First, if capital is mobile and labor is relatively immobile, one would expect a steeper reaction function for capital relative to labor taxes. Second, the effects of mobile capital on countries' capital accounts have been powerfully demonstrated by the series of exchange rate crises that swept through Asia and the world in the late 1990's. If capital is becoming more responsive to the international economic environment and governments recognize this, one would expect capital tax reaction functions to become steeper over time. If the U.S. is acting as a Stackelberg leader, one would expect the period after the 1986 U.S. Tax Reform Act to be of particular interest. Moreover, Altshuler, Grubert, and Newlon (2001) find that the assets of U.S. multinationals became more sensitive to differences in corporate tax rates between 1984 and 1992. Third, to the extent that taxes vary because of different demands for public services, it is important to control for income.[2] Fourth, the level of other taxes and total public spending may be important in estimating the reaction function of any particular tax. Fifth, it is important to control for country specific characteristics, such as a predilection for a larger public sector, a more progressive tax system or agglomeration economies.[3] Sixth, it is important to control for changes that occur in a particular year that are common across countries, such as a world business cycle or shock. Finally, tax havens may behave differently from other countries since they actively market themselves based on their tax advantages.

[2] The large Tiebout literature is instructive in estimating demand for public services among many jurisdictions.
[3] Baldwin and Krugman (2000) develop a model in which agglomeration economies play a particularly important role in tax competition.

The remainder of the paper is organized as follows. The next section presents a simple theoretical model. Section 3 discusses our empirical methodology. Section 4 presents our data and results. Among our main findings are that countries respond positively to changes in capital taxes of their neighbors, but do not respond to changes in their neighbors' labor taxes, and that European countries that are not tax havens follow U.S. corporate tax changes after 1986, but not before. The estimated slope of the European reaction to U.S. capital tax changes after 1986 indicates an elasticity of about 0.73 while the estimated elasticity with respect to neighbors' tax changes is about 0.6. Section 5 concludes.

2. Theoretical Background

A number of game-theoretic models of tax competition have been developed. Most of these consider governments competing against each other in a Nash game. For instance, Zodrow and Mieszkowski (1986) model governments operating in small open economies which take the return to capital as given. Wilson (1991) also considers a Nash game among large governments who realize that they impact the return to capital. An interesting departure from the Nash game is explored in Gordon (1992). Gordon considers a game in which one country is a Stackelberg leader and finds that in certain cases capital income taxes can be sustained when countries use a tax-credit system to alleviate double-taxation.

We develop below a simple model inspired by Gordon's contention that the U.S. may have acted as a Stackelberg leader in setting it's capital taxes. Suppose that there are n countries and consider country i. The representative consumer of country i is endowed with perfectly mobile capital and a fixed factor labor. Capital and labor are combined to produce output according to a constant returns to scale production function. Income from the endowment of capital, K_i^*, and from the fixed factor can be used to consume a private good, X_i, or a public good, G_i. The public good is financed by levying a tax on capital. Profit-maximization by perfectly competitive firms implies that a firm's demand for capital satisfies:

$$\frac{\partial f_i}{\partial K_i} = r + t_i \tag{1}$$

where r is the after-tax return to capital and t_i is the per unit tax on capital. The capital market equilibrium condition is:

$$\sum_i K_i (r + t_i) = \sum_i K_i^* \tag{2}$$

where K_i is the demand for capital in country i.

We will assume that one of the n countries is large and acts as a Stackelberg leader when choosing its tax rate. Other countries are assumed to be small and act as Nash competitors with each other and as a Nash follower with respect to the Stackelberg leader. Since the leader is a large country, its actions will impact the before-tax rate of return necessary to attract capital according to the capital market equilibrium condition. In particular, total differentiation of the capital market equilibrium condition indicates $\partial r/\partial t_L < 0$ where t_L denotes the leader's tax rate. Although the follower is small and does not directly affect the after-tax return when it changes its tax rate, it recognizes that the return to capital depends on the tax rate chosen by the leader.

Suppose that a country taxes all capital located within its borders and also taxes domestic capital located overseas in conjunction with a tax-credit system to alleviate double taxation. The tax-credit will be assumed to be limited to the domestic tax rate. Tax revenues are:

$$T_i = t_i K_i + \max(t_i - t_j, 0)(K_i^* - K_i) \tag{3}$$

The first term is the revenue collected within country i's borders. If country i's tax rate is less than country j's tax rate, no additional revenue is collected. If country i's tax rate is greater than country j's, country i will collect additional revenue equal to the difference between the tax rates times the amount of overseas capital. Note that a territorial tax system corresponds to the case in which country i's tax rate is less than country j's tax rate, so we do not consider this as a separate problem.

In the empirical section we will be interested in estimating the follower's reaction function. We therefore consider here the maximization problem faced by a follower, country i. Country i's problem

will be to select a tax rate to maximize the utility of the representative consumer:

$$\begin{aligned} &\max_{t_i} u(X) + v(G_i) \\ &s.t. \quad X_i = f(K_i) - (r + t_i)K_i + rK_i^* \\ &G_i = t_i K_i + \max(t_i - t_j, 0)(K_i^* - K_i) \end{aligned} \tag{4}$$

where utility is assumed to be additively separable. The first order conditions from this problem, which define the reaction function, are

$$\frac{\partial u}{\partial X_i}\left(\frac{\partial f}{\partial K_i}\frac{\partial K_i}{\partial t_i} - \left[(r + t_i)\frac{\partial K_i}{\partial t_i} + K_i \right] \right) + \frac{\partial v}{\partial G_i}\left(K_i + t_i \frac{\partial K_i}{\partial t_i} \right) = 0 \qquad \text{if } t_i > t_j \tag{5.1}$$

$$\frac{\partial u}{\partial X_i}\left(\frac{\partial f}{\partial K_i}\frac{\partial K_i}{\partial t_i} - \left[(r + t_i)\frac{\partial K_i}{\partial t_i} + K_i \right] \right) + \frac{\partial v}{\partial G_i}\left(K_i + t_i \frac{\partial K_i}{\partial t_i} - (t_i - t_j)\frac{\partial K_i}{\partial t_i} + (K_i^* - K_i) \right) = 0 \quad \text{if } t_i < t_j \tag{5.2}$$

We can simplify the first order conditions by using the fact that profit-maximization by perfectly competitive firms implies that a firm's demand for capital satisfies (1) above. Substituting for $\partial f_i/\partial K_i$ and rewriting the first order condition yields

$$\frac{\frac{\partial v}{\partial G_i}}{\frac{\partial U}{\partial X}} = \frac{1}{1 + \varepsilon_{K,t}} \quad if \quad t_j > t_i \tag{6.1}$$

$$\frac{\frac{\partial v}{\partial G_i}}{\frac{\partial U}{\partial X}} = \frac{1}{\frac{K_i^*}{K_i} + \frac{t_j}{t_i}\varepsilon_{K,t}} \quad if \quad t_j < t_i \tag{6.2}$$

The tax rate will be chosen to equate the marginal rate of substitution between public and private goods to the tax-price. The tax price depends on the degree to which capital flees a jurisdiction as it increases its tax rate, the elasticity of capital with respect to the tax rate denoted $\varepsilon_{K,t}$. The greater is the response of capital to an increase in the tax rate, the higher is the tax-price and the lower is the optimal tax rate.

The empirical work will attempt to estimate the slope of the follower's reaction function. For simplicity we derive below the slope of the follower's reaction function for the case of a territorial tax system (or, equivalently, the case of a tax credit system in which the follower's tax rate is less than the leader's). With respect to the leader, the slope of the follower's reaction function can be derived by differentiating (5.1) with respect to the leader's tax rate. This yields:

$$- u_{XX} K_i \frac{\partial X_i}{\partial t_L} - u_X \frac{\partial K_i}{\partial r} \frac{\partial r}{\partial t_L} + v_{GG} \frac{\partial G_i}{\partial t_L} \left(K_i + t_i \frac{\partial K_i}{\partial t_i} \right) + v_G \frac{\partial K_i}{\partial r} \frac{\partial r}{\partial t_L} + v_G t_i \frac{\partial K_i^2}{\partial t_i t_L} \qquad (7)$$

Examination of this derivative indicates that it is ambiguous in sign. To give some intuition, we group the terms into three categories: the first order impact on public and private spending (terms 2 and 4), the second order impact on public and private spending (terms 1 and 3), and the impact on the elasticity of capital (term 5).

The first order impact on public and private spending. Terms 2 and 4 derive from the fact that a lower tax rate for the leader increases the after-tax return to capital which will result in less capital located in country *i*. This will lower consumption of the public good and the private good. Country *i* needs to increase its tax rate to maintain public consumption (hence term 4 is positive) but needs to decrease its tax rate to maintain private consumption (hence term 2 is negative). However, adding term 2 and term 4 together yields:

$$u_X \frac{\partial K_i}{\partial r} \frac{\partial r}{\partial t_L} \left(\frac{v_G}{u_X} - 1 \right) > 0 \qquad (8)$$

where the positive sign follows from the first order condition: fearful of capital flight, the tax-price perceived by the follower is greater than 1. Hence, the first order impact on private and public spending indicates that when the leader decreases its tax rate, country *i* will follow by decreasing its rate.

The second order impact on public and private spending. Terms 1 and 3 derive from the fact that a decrease in the leader's tax rate lowers public consumption and may raise or lower private consumption; this can be confirmed by differentiating the constraints:

$$\frac{\partial G}{\partial t_L} = t_i \frac{\partial K_i}{\partial r} \frac{\partial r}{\partial t_L} > 0 \tag{9}$$

$$\frac{\partial X}{\partial t_L} = \frac{\partial r}{\partial t_L}(K_i^* - K_i) > 0 \text{ if capital importer, } < 0 \text{ if capital exporter} \tag{10}$$

Hence, a fall in the leader's tax rate reduces the follower's public good consumption and makes it more valuable on the margin. Other things equal, the follower would like to consume more of the public good and additional consumption of the public good entails a higher tax rate for the follower; hence term 3 is negative. If the follower is a capital importer, private consumption also falls and becomes more valuable on the margin, but additional consumption of the private good entails a lower tax rate for the follower and term 1 is positive.[4] If the follower is a capital exporter, a fall in the leader's tax rate increases private consumption which becomes less valuable on the margin. The follower would like to consume less of the private good which entails a higher tax rate for the follower and term 1 is negative. Hence, the second order impact on private and public spending (terms 1 plus 3) is negative for a capital exporter and ambiguous in sign for a capital importer.

The impact on the elasticity of capital. Term 5 arises from the possibility that a change in the leader's tax rate changes the response of country *i*'s capital to a change in its tax rate. The sign of this term obviously depends on the sign of the cross-tax derivative. To the extent that a lower leader tax rate increases the response of K_i to change in t_i, the elasticity and tax-price perceived by country *i* is higher and the follower would decrease its tax rate, making this term positive. More generally, the term is ambiguous in sign.

3. Empirical Methodology

The theory that underlies the empirical work is a strategic model of tax competition that

[4] Capital importer and capital exporter are used somewhat loosely to mean the cases for which $K_i^* < K_i$ and $K_i^* > K_i$, respectively.

allows for one large country to act as a Stackelberg leader. Empirically, our goal is to estimate a reaction function for the followers. Previous empirical work in tax competition has worked within a Nash competition model. We follow this literature in that we also allow the followers to be Nash competitors with each other. In addition, we also allow the Nash competitors to be followers in a Stackelberg game with a large country. Our focus is on European countries acting as Nash competitors with each other, and viewing the United States as a Stackelberg leader.[5]

We begin by estimating a basic Nash game between countries. The basic estimating equation for the Nash game is:

$$\tau_{i,t} = \beta \sum_{j \neq i} \omega_{ij} \tau_{j,t} + X_{i,t}\theta + d_i\phi + d_t\varphi + \varepsilon_i \tag{11}$$

where i indexes countries and t indexes time, τ_i is our tax rate measure, X_i is a vector of exogenous control variables, ω is a weighting matrix discussed further below, β, θ, ϕ, and φ are estimated parameters (θ being a vector of estimates), d_j is a set of country fixed effects, d_t is a set of time fixed effects, and ε_i is an error term. We investigate several variations of this estimating equation, including whether the slope of the reaction function has changed over time.

We then turn to a specification that incorporates a Stackelberg leader and in which we allow the followers to be Nash competitors with each other. Accordingly, the basic estimating equation for the followers in this game is:

$$\tau_{i,t} = \beta \sum_{j \neq i} \omega_{ij} \tau_{j,t} + X_{i,t}\theta + \tau_{L,t-1}\eta + d_i\phi + T_t\psi + \varepsilon_i \tag{12}$$

where i indexes the follower countries, $\tau_{L,t-1}$ is the lagged tax rate of the leader, η and ψ are estimated coefficients, and T is a time trend which we include since we are unable to include time dummies for this specification.[6] We investigate several variations of this estimating equation, including whether the slope of the reaction function has changed.

[5] We also tested whether Germany acted as a Stackelberg leader. Our tests rejected this hypothesis. With respect to Nash competitors, it is possible that OECD countries that are not part of Europe may behave strategically, but we view European countries as a natural sub-set of all OECD countries.

[6] We use the lagged value for the leader since our assumption is that the Stackelberg leader moves first.

The key coefficient for understanding the slope of the reaction function with respect to other Nash competitors is β. It is therefore particularly important to understand the construction of the weighting matrix ω. The weights reflect the influence of each neighbor's tax rate on the "own" country tax rate. The first step in this type of analysis is setting the weights. A weighting scheme that seems particularly appealing to us is based on the gravity equation which has been found to explain well trade relations. According to the gravity equation, weights are assigned based (inversely) on the distance between the own country and all countries for which interactions are assumed. One such scheme assigns a weight of one to contiguous countries (states, counties, etc.) and zero to all others (see, for example, Besley and Case 1995). These weights are normalized to add to one. We follow this simple weighting scheme in our analysis. However, in assigning weights to neighbors we have ignored relatively small bodies of water separating countries. Appendix table 1 shows our classification of the geographic neighbors of the countries in our dataset.[7]

We investigate several variations of the basic regressions (11) and (12). With respect to the Nash specification, we estimate the model for both capital and personal tax competition. One would expect tax competition to be particularly pronounced for mobile capital and relatively sedate for immobile labor. Second, one might suspect that globalization and increased mobility of capital would lead to steeper reaction functions over time. Indeed, Altshuler, Grubert and Newlon (2001) find that the location of the assets of U.S. multinationals became more sensitive to differences in corporate tax rates between 1984 and 1992. If governments perceive this change, their perceived tax price would increase, lowering the tax rate on capital.

With respect to the Stackelberg specification, we also explore whether the reaction function of the follower European countries became steeper with respect to the U.S. lead. Here we take the 1986 U.S. Tax Reform Act, which significantly lowered the U.S. statutory corporate tax rate while

[7] An example of a country whose neighbors' are assigned ignoring small bodies of water is the United Kingdom. Instead of assuming that the United Kingdom has no interaction with European countries, we consider the possibility that the federal government strategically interacts with Belgium, France, Ireland and the Netherlands. In our view, this is consistent with assigning countries based on borders.

broadening the base, as the possible turning point. It is possible that the Tax Reform Act of 1986 (hereafter, TRA'86) combined with the relaxation of capital controls in Europe and technological advances resulted in European nations treating the U.S. as a Stackelberg leader after 1986.

We also explore the possibility that European tax havens view the United States differently than do other European countries. We follow Hines and Rice (1994) and classify Ireland, Luxembourg, and Switzerland as tax havens. These countries are likely to be playing a somewhat different game since they actively market themselves as low tax countries. We therefore test whether their behavior vis-a-vis the U.S is significantly different from the other European countries of our sample.

Several econometric issues arise in the estimation of equations (11) and (12). First, the tax rates appearing on the right hand side are clearly endogenous if all countries are playing Nash: country *j* responds to a change in country *i*'s tax rate just as country *i* responds to a change in country *j*'s tax rate. This problem can be addressed through the spatial econometric approach employed by Case, Hines and Rosen (1993) in their study of expenditure competition, or by using an instrumental variable technique. We employ the latter solution, which Kelejian and Prucha (1998) show is also consistent in the presence of a second possible problem, spatial error dependence. We explain our instrumental variables approach more fully below. The use of fixed country effects in (11) and (12) eliminates a third possible problem, omission of unobserved country characteristics that do not vary over time. Baldwin and Krugman (2000) suggest that agglomeration economies, which tend to be fixed over time, may be particularly important for understanding tax competition across countries. We use the method of first-differencing to implement fixed effects.[8] A fourth possible problem, common shocks that impact all countries, is addressed by including time dummies.

As noted, we adopt the instrumental variables (IV) approach to deal with the endogeneity of the tax rates. To explain our approach more fully, let $\omega_i t_{-i}$ represent the neighbor tax rate for country

[8] We use two year intervals in first-differencing since political processes can be slow in practice. At the same time, our two-year window minimizes the loss in data that would result from a longer interval.

i. If country 1, for example, had two neighbors, countries 2 and 3, then $\omega_1 \tau_{-1} = \frac{1}{2}\tau_2 + \frac{1}{2}\tau_3$. The neighbor co-variates, $\omega_i X_{-i}$ are defined similarly. We obtain fitted values of the neighbors' tax rates by regressing each country's "neighbor" tax rate, $\omega_i t_{-i}$ on $\omega_i X_{-i}$ and own state co-variates, X_i. The fitted values are then used as instruments for neighbors' tax rates in the second stage. This estimation method generates consistent estimates of the parameters in our regressions.

We include GDP per capita, total government spending (as a percentage of GDP) and the lagged value of our personal tax measure as control variables. High corporate tax rates in a country could be a by-product of a relatively high demand for public services. As a result, corporate taxes may vary due to differences in the demand for services. If the demand for government services is positively correlated with income, then it is important to control for any differences in income across countries. We use per-capita GDP as a measure of country income.

Corporate taxes may also be positively correlated with government spending. The reasoning is as follows: as government spending as a percentage of GDP increases rates and revenues from all taxes may increase.[9] Thus, variation across countries in corporate rates may be correlated with variation in spending levels. This suggests including government spending as a co-variate.

We include the personal tax rate (revenues from taxes on labor income as a percentage of GDP) to control for any relationship between our personal and corporate rate measures that may explain differences in corporate rates across countries. For instance, if countries behave as if government revenues are fixed, then any changes in corporate tax revenues as a percentage of GDP will need to be matched by corresponding changes in other revenue sources. Hence, personal and corporate revenues may be negatively correlated. Further, the theoretical model in Gordon (1986) suggests that tax competition will lead to a movement away from taxes on mobile factors toward taxes on immobile factors. These arguments suggest that we control for differences in the personal

[9] Slemrod (2001, page 3) refers to this relationship as the "empirical prediction of the tax mix folk theorem." As Slemrod recounts, the folk theorem, popular in tax policy circles, is as follows: "all taxes have weaknesses, and the marginal social cost of the weaknesses increase with the tax system's reliance on any given tax." Accordingly, tax systems should collect revenues from a variety of taxes and should not rely heavily on any one form of tax.

rate. However, they also suggest that personal and corporate rates are chosen simultaneously making the personal rate endogenous. To remedy this problem we use the lagged value of the personal tax rate as an explanatory variable.

The first stage regression used to generate instruments for neighbors' tax rates is:

$$\omega_i(\tau_{-i,t} - \tau_{-i,t-2}) = C + \gamma_1\omega_i(GDP_{-i,t} - GDP_{-i.,t-2}) + \gamma_2\omega_i(S_{-i,.t} - S_{-i,t-2}) + \gamma_3\omega_i(P_{-i,t-1} - P_{-i,t-3}) + \gamma_4(GDP_{i,t} - GDP_{i,t-2}) + \gamma_5(S_{i,t} - S_{i,t-2}) + \gamma_6(P_{i,t-1} - P_{i,t-3}) + \gamma_7 d_t + \varepsilon \quad (13)$$

where C is a constant term, $\omega_i\tau_{-i}$ is country i's "neighbors'" tax rate, $\omega_i GDP_{-i}$ is country i's "neighbors'" GDP per capita, $\omega_i S_{-i}$ is the spending rate (total tax revenues/GDP) for country i's neighbor, $\omega_i P_{-i}$ is the personal tax rate (tax revenues/GDP) for country i's neighbor, and d_t denotes a set of year dummies. Note that we include a constant term in equation (13) to allow for the possibility that the constant term in each yearly regression may vary across time.[10] The fitted values for the neighbor tax rates are used as instruments in the second stage regression:

$$\tau_{i,t} - \tau_{i,t-2} = C + \beta_1(\tau^*_{-i,t} - \tau^*_{-i,t-2}) + \beta_2(GDP_{i,t} - GDP_{i,t-2}) + \beta_3(S_{i,t} - S_{i,t-2}) + \beta_4(P_{i,t-1} - P_{i,t-3}) + \beta_5 d_t + \varepsilon \quad (14)$$

where $\tau^*_{-i,t}$ is the fitted value of the neighbors' tax rate. Recall that we include a time trend in our estimates of reaction functions for the Stackelberg leader game. Since we include the U.S. tax rate in this set of estimates we cannot add time dummies.

4. Data and Results

4.1 Data

We use data for 1968 to 1996 from the OECD Revenue Statistics. This data source provides us with a relatively long time-series of country tax revenue detail that is comparable across countries. As a result, we are able to test whether countries have become more responsive to changes in their

[10] Our results are not sensitive to including the constant term.

Nash competitor's and the Stackelberg leader's tax rates over time.[11] We calculate a measure of corporate and individual tax rates by dividing revenues from each tax by gross domestic product.[12] Although this measure has the virtue of being available from the late 1960s for our sample, it is troublesome for a few reasons. First, the ratio of corporate tax revenues to GDP may vary due to economic factors that are unrelated to changes in the underlying corporate tax structure of a country. Second, as with any average effective tax measure it does not necessarily capture the tax incentive to invest in a given country in any year since it is a function of both present and previous investment decisions of firms as well as economic factors. As a result, it is an imperfect measure of corporate tax burdens. However, alternative measures of corporate tax burdens, such as those calculated by considering the tax burden of marginal investments in different assets, are also problematic (see, among others, Slemrod 2001 for further discussion) and have only been calculated from the 1980s onward.

The OECD data breaks tax revenues down by level of government. We calculate corporate and personal tax rates at the overall level (federal, state, and local tax revenues). Our theoretical model assumes that the "agent" setting taxes controls the federal tax rate. Whether tax rates at lower level of governments are inputs into the agent's decision is, in our opinion, an open question. By including local and state level taxes in our tax measure we allow for the possibility that the federal government takes both the overall and federal tax burden into account when setting its tax parameters. We repeated our analysis using tax rates calculated using federal tax revenues as the numerator and found little difference in the empirical estimates.

[11] Besley, Griffith and Klemm (2001) also use the OECD Revenue Data to estimate Nash fiscal reaction functions for OECD countries. Devereux, Lockwood and Redoano (2002) use three measures of corporate taxes in their analysis: statutory rates, effective marginal tax rates, and effective average tax rates. The effective tax rate measures are based on those proposed in Devereux and Griffith (2002). These measures are calculated by considering the taxation of hypothetical marginal investments in different asset classes. While there are many advantages of using these hypothetical effective tax rate measures, they are available for a relatively short time frame and are thus inappropriate for our analysis.

[12] Corporate tax revenues are class 1200 "taxes on income, profits and capital gains of corporations." Personal tax revenues are class 1100 "taxes on income, profits and capital gains of individuals."

4.2 Results

Our main findings are reported in Table 1 for the Nash model and Table 2 for the Stackelberg model. We first summarize the main results and then give a more detailed discussion of each table. With respect to the Nash model, we find that countries respond positively to changes in capital taxes of their neighbors, but do not respond to changes in their neighbors' labor taxes. The estimated slope of the corporate tax reaction function indicates an elasticity of about 0.75 for the average country in our sample, and this appears to be stable over time for our sample period. With respect to the Stackelberg model, we find that European countries follow U.S. corporate tax changes after 1986, but not before. The estimated slope of the European reaction to U.S. changes after 1986 indicates an elasticity of about 0.73 for all countries and 0.84 for non-tax havens. We find that European countries also reacted to their neighbors' changes at the same time; the estimated elasticity with respect to neighbors falls slightly to about 0.60.

Nash Model

Table 1 presents estimates of reaction functions for Nash tax-setting games between European neighbors. The estimates in the first column suggest that the slope of the corporate tax reaction function is positive and highly significant. The coefficient on the neighbors' corporate tax change is positive, almost one in magnitude, and significant at a more than one percent confidence level. Using sample means, this suggests that a ten percent decrease in the neighbors' corporate tax rates induces about a 7.5 percent decrease in a country's corporate rate. The magnitude of the effect of an individual neighbor's tax change on a country's tax rate depends on the neighbor's weight. The average number of neighbors for a country in our data set is about four which suggests that, at the sample means, a ten percent decrease in a neighbor's tax rate leads to about a 2 percent decrease in the own country tax rate.

All of the country control variables in the regressions shown in column 1 of Table 1 are

significant at conventional confidence levels. Countries with higher incomes, as measured by GDP per capita, have higher corporate tax rates, *ceteris paribus,* and greater levels of spending are also positively associated with corporate tax rates. Consistent with the idea that tax rates are set subject to a government revenue constraint, the coefficient on the lagged personal tax rate in column 1 is negative and highly significant.

Interestingly, we do not find the same results when we investigate the impact of neighbors' personal tax changes on own country personal tax rates. Column 2 shows that the coefficient on the neighbor rate is now negative and not significantly different from zero. This suggests that countries do not set personal tax rates strategically most likely because labor is less mobile than capital.[13] Somewhat surprisingly, the estimated coefficient on per capita GDP is negative and statistically significant: higher average incomes are associated with lower average personal tax rates.

To test whether strategic interaction between European countries has changed over the sample period we included an interaction between the neighbors' corporate tax rate and a dummy for years prior to a particular year in the 1980s.[14] In addition to a possibly general increase in the mobility of capital over our time period, capital controls had been lifted in many European countries by the 1980s. As a result, the corporate tax rates in neighboring countries may have had more influence on cross-border capital flows after than before the 1980s. Interestingly we do not find support for this hypothesis. None of the interaction terms between the neighbor tax rate and the 1980s year dummies were significant. Our tests do not provide evidence that countries are setting corporate tax rates more competitively in recent periods.

Stackelberg Model

In table 2 we continue to assume that European countries behave as Nash competitors with each other, but we further investigate whether they behave as if the U.S. were a Stackelberg leader

[13] The results of Besley, Griffith, and Klemm (2001) also support the idea that taxes on more mobile factors react more strongly than those on more immobile factors.
[14] We tried all years from 1980 to 1990.

when setting corporate taxes. Column 1 shows estimates of the impact of a change in neighbors' and U.S. tax rates on own country corporate tax rates. The coefficient on the neighbors' tax rate falls from about .97 to .80 but remains significant at a greater than 1 percent confidence level. The U.S. rate (lagged) is not statistically different from zero.

In the second column of table 2, we explore whether the U.S. became a Stackelberg leader after TRA'86. To do this we include a dummy variable that equals one for observations prior to and including 1986 and an interaction term between this variable and the U.S. tax rate. The estimated coefficient shows the difference (if any) between the responsiveness of corporate tax rates to U.S. tax changes before and after TRA'86.

The estimates in the second column suggest that the Europeans did act as if the U.S. were a Stackelberg leader following the U.S. tax act. The coefficient on the neighbors' tax rate falls slightly to about .77 but remains highly statistically significant. The coefficient on the U.S. rate is .524 and is also highly significant. At the sample means, a 10 percent decrease in U.S. rate leads to a 7.3 percent decrease in the own rate. For the neighbors' tax rate the elasticity is 0.6. Somewhat surprisingly, calculated at the sample mean, the U.S. has a larger impact on country corporate tax rates than the average neighbors' rate. Furthermore, the coefficient on the lagged U.S. tax rate prior to TRA'86 is -.025 and is not statistically different from zero.[15] The positive and statistically significant coefficient on the interaction term indicates that the difference between the coefficient on the U.S. rate before and after 1986 is different from zero.

In the third and fourth columns we explore whether the "tax havens" in our sample (Ireland, Luxembourg, and Switzerland) responded differently to changes in the U.S. rate either before or after TRA'86.[16] To start we add a dummy variable for whether the observation is from a "tax haven" and an interaction term between the haven dummy and the U.S. tax rate to the column 1 specification.

[15] We estimate the coefficient and obtain the t-stat on the neighbor tax rate prior to 1986 by running the same regression but replacing the pre-1986 dummy with a variable that equals one if the observation is for the later period (1987-1996).

[16] As mentioned in section 2, our classification of European tax havens follows Hines and Rice (1994).

The coefficient on the interaction term in the third column, haven dummy*U.S. tax rate, is not statistically different from zero at conventional levels suggesting that that there is no difference in strategic interaction with the U.S. between havens and all others. However, when we further test whether havens and non-havens behave differently vis-à-vis the U.S. before and after 1986 in column four, we do find a difference: the U.S. is a Stackelberg leader for non-tax haven European countries after 1986, but not for tax havens. Evaluated at the sample means, the estimated elasticity of corporate tax rates with respect to the U.S. rate is about 0.84.

As in table 1, the estimated coefficients on country spending and the personal tax rate are statistically significant and have the expected signs. However, the coefficient on GDP per capita is not significant in the table 2 regressions.

Recall that in table 1 we use year dummies to control for time specific effects that are common across countries. Since we include the U.S. tax rate in table 2 we cannot use year dummies and instead introduce a trend variable. Replacing the common time trend with country specific time trends had little effect on our results.

5. Conclusions

We present a simple model of tax competition, inspired by Gordon (1992), in which one country acts as a Stackelberg leader in setting it's capital taxes. Our focus is on the slope of the reaction functions of the followers which may be positive or negative depending on the impact of tax changes on public and private spending as well as the elasticity of capital. Our empirical work provides estimates of reaction functions for the standard tax competition model in which each country plays a Nash game as well as the Stackelberg game considered in our theoretical model.

Our empirical tests provide further evidence that, at least for European countries, the slope of the Nash reaction function for corporate tax-setting games is positive. Recent papers by Devereux, Lockwood, and Redoano (2002) and Besley, Griffith, and Klemm (2001) also present evidence of

positively sloped reaction functions for OECD countries. In contrast to this line of research, we also estimate reaction functions that include the tax rate of a Stackelberg leader, the United States, and allow for the possibility that tax havens may compete differently than other European countries. Our results suggest that the tax rates of non-haven European countries are more responsive to changes in U.S. rates than to their own neighbor's rates. However, our results also suggest that the U.S. has not acted as a leader throughout all of our sample period. We find no evidence that either the haven or non-haven European countries reacted to the tax changes of the United States before 1986, the year of the major U.S. reform. Interestingly, we also reject the hypothesis that the countries in our sample have become more competitive with each other in recent years. Our data span the time period in which tax competition is alleged to have become more intense. However, we are unable to detect a change in the slope of the Nash reaction function in the 1980s, a period after which capital mobility presumably increased. Finally, we present results that suggest quite strongly that European countries do not set personal tax rates strategically.

Table 1
Estimates of Reaction Functions for Nash Tax Setting Games
(1970-1996)

	Dependent variable:	
	Country corporate tax (t-[t-2])	Country personal tax (t-[t-2])
Neighbors' corporate tax (t-[t-2])	0.966***	
	(0.331)	
Neighbors' personal tax (t-[t-2])		-0.141
		(0.216)
Country GDP per capita/100 (t-[t-2])	0.037**	-0.045*
	(0.020)	(0.025)
Country spending (t-[t-2])	0.135***	0.396***
	(0.017)	(0.021)
Country personal tax lagged ([t-1]-[t-3])	-0.153***	
	(0.030)	
Country corporate tax lagged ([t-1]-[t-3])		-0.138**
		(0.059)
Constant	-0.002	-0.002
	(0.002)	(0.002)
Year dummies?	Yes	Yes
Adjusted R-squared	0.166	0.488

Notes: Corporate tax equals corporate tax revenues divided by GDP. Personal tax equals personal tax revenues divided by GDP. Spending equals total tax revenue divided by GDP. Numbers in parentheses are standard errors. GDP per capita is divided by 100 for scaling purposes. All regressions include year dummies and are estimated using instrumental variables (see text for details). Number of observations = 442. * denotes statistical significance at a 10 percent confidence level, ** at a 5 percent level and *** at a 1 percent level.

Table 2
Estimates for Stackelberg Tax Setting Games
(1971-1996)

	Dependent variable: Country corporate tax (t-[t-2])			
	(1)	(2)	(3)	(4)
Neighbors' corporate tax (t-[t-2])	0.803***	0.772***	0.780***	0.795***
	(0.265)	(0.274)	(0.266)	(0.227)
Lagged U.S. corporate tax ([t-1] - [t-3])	0.054	0.524***	0.015	0.599***
	(0.080)	(0.164)	(0.083)	(0.179)
Country GDP per capita/100 (t-[t-2])	0.012	0.021	0.010	0.019
	(0.015)	(0.015)	(0.015)	(0.015)
Country spending (t-[t-2])	0.123***	0.124***	0.125***	0.127***
	(0.017)	(0.017)	(0.017)	(0.017)
Country personal rate lagged (t-[t-2])	-0.151***	-0.148***	-0.149***	-0.145***
	(0.029)	(0.030)	(0.029)	(0.030)
Dummy for pre-1986		0.003**		0.003**
		(0.001)		(0.001)
Haven dummy (=1 for Ireland, Luxembourg, Switzerland)			0.000	0.001
			(0.001)	(0.001)
Lagged U.S. rate * dummy for pre-1986		-0.549***		-0.686***
		(0.178)		(0.197)
Haven dummy * lagged U.S. rate			-0.260	-0.392
			(0.161)	(0.423)
Haven dummy * dummy for pre-1986				-0.001
				(0.002)
Haven dummy * dummy for pre-1986 * lagged U.S. tax rate				0.755*
				(0.463)
Time trend (year/1000)[1]	-0.019	1.169	0.000	1.151
	(0.431)	(0.764)	(0.430)	(0.763)
Constant	0.003	-0.232	-0.001	-0.231
	(0.085)	(0.151)	(0.085)	(0.152)
Adjusted R-squared	0.135	0.158	0.134	0.161

[1] We also ran regressions with country specific trend variables with little change in the results.

Notes: Corporate tax equals corporate tax revenues divided by GDP. Personal tax equals personal tax revenues divided by GDP. Spending equals total tax revenue divided by GDP. Numbers in parentheses are standard errors. Instrumental variables estimation (see text for details). Number of observations = 459. * denotes statistical significance at a 10 percent confidence level, ** at a 5 percent level and *** at a 1 percent level.

Appendix Table 1
Geographic Neighbors

Country	Neighbors
Austria	*Germany* *Italy* *Switzerland*
Belgium	*France* *Germany* *Luxembourg* *Netherlands* *United Kingdom* *Ireland*
Denmark	*Germany* *Norway* *Sweden*
Finland	*Norway* *Sweden*
France	*Belgium* *Italy* *Luxembourg* *Spain* *Switzerland* *Germany* *United Kingdom* *Ireland*
Germany	*Austria* *Belgium* *Denmark* *France* *Italy* *Luxembourg* *Netherlands* *Sweden* *Switzerland*
Greece	*Italy* *Turkey*
Ireland	*United Kingdom* *Belgium* *Netherlands* *France*
Italy	*Austria* *France* *Germany* *Greece* *Switzerland*
Luxembourg	*Belgium* *France* *Germany*
Netherlands	*Belgium* *Germany* *United Kingdom* *Ireland*
Norway	*Denmark* *Finland* *Sweden*
Spain	*France*
Sweden	*Denmark* *Finland* *Germany* *Norway*
Switzerland	*Austria* *France* *Germany* *Italy*
Turkey	*Greece*
United Kingdom	*Belgium* *France* *Netherlands* *Ireland*

Appendix Table 2
Summary Statistics

	Mean	Standard deviation
Country tax variables (t-[t-2])		
Corporate tax	0.000739	0.00658
Personal tax	0.00246	0.0109
U.S. tax rate	-0.00103	0.00476
Interaction terms		
U.S. corporate tax rate*dummy for pre-1986	-0.00149	0.00421
U.S. tax rate*haven dummy	-0.000183	0.00204
U.S. tax rate*haven dummy*dummy for pre-1986	-0.000265	0.00186
Country variables (t-[t-2])		
GDP per capita/100	0.0208	0.0272
Spending /GDP	0.00666	0.0187

Notes: Corporate tax and personal tax equal corporate and personal tax receipts, respectively, divided by GDP. Spending equals total tax receipts divided by GDP.

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