International Tax Competition

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- preliminary and incomplete -

December 2, 2011

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1 Introduction

In a world with high mobility of goods, capital, labor, factor inputs, or other taxable activities, and with ample opportunities for profit shifting, tax policy is likely to have strong fiscal externalities and to redistribute wealth and factor income internationally. This, in turn, has strategic implications for governments' tax policy choices, and implications for world welfare. It is not surprising that tax competition has received considerable attention both within politics and within academia.

Influential reports that placed tax competition on the policy agenda and shaped the discussion in the last two decades were the Ruding (1992) Committee Report,[1] the OECD Report on Harmful Tax Competition (1998), and the OECD Initiative on Tax Havens that emerged from this work. The Ruding Committee Report explicitly addressed the issue of tax competition and expressed concerns about 'special tax schemes designed to attract internationally mobile business, particularly in the financial sector'. The OECD report was much more explicit, identifying a number of possible problem areas, including tax havens, preferential tax treatments, information exchange and secrecy provisions which are at the core of what has been analysed in the theory of international tax competition.

Empirical work has analysed whether tax competition or fiscal competition more generally takes place, leading to a diversity of, partially surprising results. There is considerable evidence showing that countries' fiscal policies are interdependent, and many of the findings are is in line with main hypotheses derived from a theory of tax competition.[2] One of the taxes that seems to be most endangered in a world with mobile capital is the capital income tax. The evidence suggests that there is a systematic international co-movement of tax rates and a downward trend of effective tax rates in the last three decades. At the same time, the revenue from this tax base has not been declining. This has been seen as a puzzle and several, not necessarily mutually exclusive explanations have been put forward.[3] These explanations, and the theory of tax competition more generally, show that the picture in which countries mutually undercut each other in their tax rates in a Bertrand like race to the bottom is too simplistic as a description of the strategic interaction that is associated with tax competition.

A number of excellent previous studies exist, and it is important to highlight what is the gap that this survey fills, compared to these previous surveys which include Wilson (1999), Gresik (2001), Zodrow (2003), Wilson and Wildasin

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[1] Perhaps surprisingly, the committee argues for subsidiarity and flexibility and and for leaving ample discretion that can be used for tax competition, and even argues for more transparency and the means to increase capital mobility, that is, provide an environment in which tax competition can be expected to become stronger. See for assessments also Devereux (1992) and Vanistendael (1992).

[2] Because of superior data on a more homogenous set of jurisdictions, a large share of this literature considers fiscal competiton on the regional level. An early overview is by Brückner (2003). More recent contributions are Winner (2005), Carlsen, Langset and Rattso (2005), Overesch and Rinke (2009), Parry (2003), Revelli (2003), Boadway and Hayashi (2001), Büttner (2003), Mintz and Smart (2004), Binet (2003), Karkalakos and Kotsogiannis (2007), Gérard, Jayet and Paty (2010) and Jacobs, Lighthart and Vrijburg (2010). For a recent survey see also Zodrow (2010).

[3] These include Devereux, Griffith and Klemm (2002), Auerbach (2006), Clausing (2007), Sørensen (2007), Devereux, Lockwood and Redoano (2008).

(2004), Fuest, Huber and Mintz (2005), Zodrow (2010), Genschel and Schwarz (2011) and Boadway and Tremblay (2011). Our survey differs from these reviews in several respects. First, we focus on the aspect of strategic interaction, especially emphasizing the analogies between the theory of tax competition and competition models in the theory of industrial organization. This analogy is evident from some of the early contributions describing tax competition as an oligopoly game (Wildasin 1988, 1991; Wilson 1986, Bucovetsky 1991). Second, our focus is not on the questions and principles of international taxation more generally. The Handbook survey by Gordon and Hines (2002) describes optimality principles in international taxation and also touches upon enforcement effects in the context of international taxation that help understanding the international tax system as it is, and this survey is complementary to our approach. Along these lines, we also do not provide a treatment of current policy proposals such as a common consolidated corporate tax base that has been discussed in the European Union for several years. However, the theoretical insights collected in our survey also apply to such more practical policy questions. Third, we mostly disregard the important debate as regards firms' incentives to shift profits. The large literature on transfer pricing and the OECD approach to this issue, the discussion about profit shifting via multinational firms' internal financial architecture and the role of thin-capitalization rules, and the more recent discussion about the use of intra-firm trade of patents, trade-marks and other types of immaterial property rights for profit shifting does not receive the attention here that it may deserve. The survey by Gresik (2001) covers a large part of the early contributions on transfer pricing issues. The status of the discussion in the legal and economic literature on transfer pricing and other means of profit shifting is also provided in the collected volume by Schön and Konrad (2012), making a possible effort of surveying it here mostly redundant. Fourth, there is a strong connection between international tax competition and the fiscal competition that may take place within a country both between jurisdictions of the same type and between the different vertical layers of government inside a country. Zodrow (2010) focuses on the empirical evidence both on the sensitivity of capital flows on taxes and the evidence on the strategic interaction between governments in the context of tax competition. The survey by Boadway and Tremblay (2011) focuses on fiscal federalism but includes considerations of tax competition. We do not provide a comprehensive treatment of fiscal competition inside a federation, but we touch upon the topic, as there is an important relationship between internal governance structure and a country's choices in international tax competition, and we discuss how decision making by subnational layers of government may affect international tax competition.

One of the diagrams that is frequently used to illustrate the potential for strategic interaction between countries in the field of tax competition is Figure 1. The figure shows how the statutory corporate tax rates have developed in the last thirty years for different countries. The figure illustrates a number of aspects of this strategic interaction. First, there is a finite number of relevant players in the tax competition game. Second, the game is not static, with tax rates set once and for all times. Rather, tax competition evolves in a dynamic process in which different countries choose their tax rates repeatedly, and not in a synchronized fashion. The figure does not highlight some further important aspects: tax rate choices are political decisions and take place in countries that have very different internal government structures, and often have multiple layers of government.
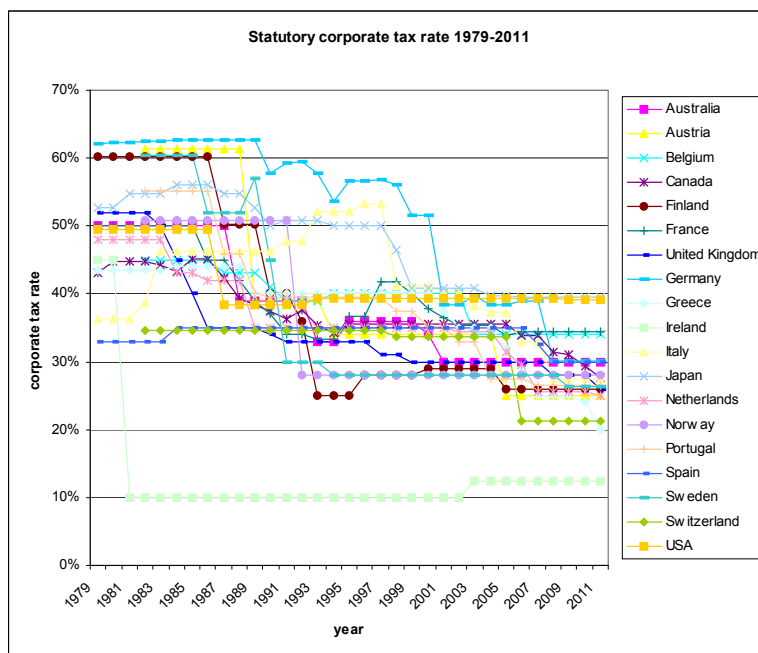
Figure 1: Statutory corporate tax rates from 1979 to 2011. Source: OECD

It does not make transparent whether, and to what degree the decisions of countries have been coordinated bilaterally or multilaterally. It also shows only one variable in the larger context of fiscal competition. The latter includes tax competition, accounting for a multiplicity of different tax and subsidy rates. It also includes further possible means of competition, such as the provision of infrastructure or other factor inputs. It also does not make transparent whether countries target individual firms and may offer them tax holidays or other financially advantageous packages. The literature on tax competition has addressed these and further issues, and we will consider many of these issues in what follows.

We start the survey focussing on competition between countries in which the government in each country is a single decision maker who acts strictly on behalf of representative citizens in the respective country. This basic framework is suitable for identifying the effects that are most closely related to the problem of tax competition. We then discuss aspects that interact with, and can partially change the nature of this competition. We consider constraints about what the respective governments can decide about, or on what they can cooperate and with whom they can cooperate. We also have a deeper look into the governmance structure of countries. This internal structure has implications for countries' actions. Countries need not be seen as unitary players, but may consist of several decision makers whose relationship is described by the governmental architecture of the country. Further, the relationship between the political decision maker and the population in the country is important. The politician may act on behalf of a representative citizen in a principal-agent relationship that may suffer from

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problems of commitment, hidden action and/or hidden information, causing some divergence between the actions chosen by the politician and the actions preferred by the representative citizen, but this divergence may also be used strategically, changing the countries' payoffs in their competition with other countries. Further, the problem of preference aggregation inside the country and its solution via democratic decision making or through influence activities may be relevant. Capital owners and workers, for instance, may have different preferences as regards the government's choices.

2 The standard tax competition framework

2.1 Uncoordinated action

The workhorse model Consider a world economy that consists of n countries $i = 1, ... n$. Each country is characterized by investment opportunities that are described by a product-of-capital function $f_i(k_i)$. There may be further factors of production, such as labor, publicly provided inputs and other relevant factors of production some of which can be used without payment of a user fee. In the workhorse model we take all these factors as exogenously given; they shape the function $f_i(k_i)$ but need not be considered in the formal analysis. The marginal product of capital, $f_i'(k_i)$, is assumed to be downward sloping, and this is an outcome that can be explained by these exogenous factors.

Capital is taxed at source. Each country chooses the per-unit tax $t_i \in [0, 1]$ that is levied on each unit of capital that is invested in country i in the equilibrium. This seemingly departs from an ad-valorem tax on the returns of capital, but as is well-known from standard theory of taxation, unit taxes and ad-valorem taxes have the same tax incidence in a framework with perfect competition.[4] This abstracts from the fact that tax competition may occur along a number of other dimensions and countries may use other instruments. These include a residence based tax[5], taxes that try to tax economic rents, taxes on labor, or combinations of these.

In the workhorse model, the total world capital stock is given and denoted by K, the net-return on capital denoted by ρ, and, together with price taking behavior of investors, the capital market equilibrium is determined by

$$f_i'(k_i) - t_i = \rho \text{ for all } i = 1, ... n \tag{1}$$

and

$$\sum_{i=1}^{n} k_i = K = \sum_{i=1}^{n} c_i. \tag{2}$$

The second equality is a budget equation: total capital invested needs to be equal to the sum of capital c_i owned by subjects in the different countries, with $c_i \geq 0$ denoting the amount of capital that is owned by subjects of country i.

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[4] For oligopolies, ad valorem taxes and unit taxes are not equivalent. Competition is stronger for ad valorem taxes (see Delipalla and Keen (1992)). A similar intuition applies if the tax rates themselves constitute the strategy spaces, as in the context of tax competition by Lockwood (2004), suggesting that tax competition in ad-valorem tax rates may lead to even stronger competitive pressure and lower equilibrium tax rates.

[5] In the simple benchmark framework with exogenous ownership of capital, residence based taxes are equivalent to lump-sum taxes and induce no strategic effects.

The government in each country has the following objective function:

$$W_i = f_i(k_i) - f_i'(k_i)k_i + \rho c_i + G_i(t_i k_i) \tag{3}$$

where the first two terms denote the return to domestic factors: total output in country i, minus the gross remuneration that is paid to the owners of the capital that is invested in country i, which is based on the assumption of a perfectly competitive capital market in each of the countries. The third term is the capital income net of taxes that accrues to the capital owners in country i, and the last term is the benefit of public funds.

In a non-cooperative static game with governments as players, the intervals of tax rates as their action spaces and payoff functions (3), each government maximizes its objective function by a choice of its tax rate, taking the (equilibrium) tax rate choices of all other countries as given, and anticipating the implications of the tax rate choice for the allocation of capital.

If all countries are symmetric as regards production opportunities ($f_i(.) = f_j(.) \equiv f(.)$), ownership of capital ($c_i = K/n$), and public goods preferences ($G_i(.) = G_j(.) \equiv G(.)$), then, if an interior symmetric equilibrium in pure strategies exists, the equilibrium is characterized by n identical first-order conditions

$$\frac{\partial W_i}{\partial t_i} = -f''(K/n)\frac{K}{n}\frac{\partial k_i}{\partial t_i} + \frac{\partial \rho}{\partial t_i}\frac{K}{n} + G'(t_i\frac{K}{n})(\frac{K}{n} + t_i\frac{\partial k_i}{\partial t_i}) = 0. \tag{4}$$

In this equilibrium the first-order conditions (4) jointly determine the equilibrium tax rates $t_i = t_j = t^*$. The solution $\mathbf{t}^* = (t^*, ..., t^*)$ can be compared with different benchmarks. One benchmark is autarchy. Another, more interesting benchmark is the combination of tax rates together with transfers between the countries that implement an equilibrium in the private markets that maximizes the sum of all countries' welfare. A necessary condition for this is the efficient provision of public funds. In an interior solution, this is described by the condition

$$G'(.) = 1 \text{ for all } i = 1, ...n. \tag{5}$$

This condition requires a given amount $T = \Sigma_i T_i$ of public funds, and this amount needs to be raised by taxes. As the global capital stock was assumed to be fully inelastic, this stock is a non-distortionary tax base, and T should be taken from this capital stock. If this is implemented by way of tax rates in the different countries, then, in order to generate an efficient allocation of capital across countries, the tax rates need to be the same in all countries, $t_i = t$ for all $i = 1, ...n$, and fulfill the global public budget constraint $tK = T$. Hence, the first-best set of tax rates is

$$t_i = \frac{T}{K} \text{ for all } i = 1, ...n. \tag{6}$$

Note that this uniform tax rate in all countries generates production efficiency here: The equalization of the marginal net return of capital in all countries together with a uniform tax rate causes an equalization of the gross marginal return of capital across countries. In general, this solution requires side-payments between the countries if they differ in their production capabilities f_i or in their utility-of-public-expenditure functions $G_i(.)$. For a world with perfectly identical countries, however, these side–payments are zero.

The Nash equilibrium outcome generically differs from such outcome. For symmetry, this is evident from the first-order conditions. Using symmetry, we have $c_i = k_i = K/n$, $G_i \equiv G$, $f_i \equiv f$, and using the the partials at the symmetric equilibrium, the first-order condition can be written as

$$G'(t^*k^*) = \frac{1}{1 + \frac{t^*}{k^*}\frac{n-1}{n}\frac{1}{f''(k^*)}}, \tag{7}$$

where t^* and $k^* = K/n$ are the Nash equilibrium values of tax rate and capital. Here, $\frac{t^*}{k^*}\frac{n-1}{n}\frac{1}{f''(k^*)}$ is the elasticity of the tax base with respect to the country's own tax rate. It follows from

$$\frac{t^*}{k^*}\frac{n-1}{n}\frac{1}{f''(k^*)} < 0 \tag{8}$$

that $G'(t^*k^*) > 1$, and this is a much discussed result. Tax competition may reduce public funds to an inefficient level. It may severely limit the government's ability to provide its citizens with the goods that need to, or are optimally financed by taxes, including a possibly desirable amount of income redistribution. The equation (7) also allows for some comparative static considerations. The distortion is larger if the elasticity of the tax base with respect to the own tax rate has a higher absolute value. Also, the tax base reacts more strongly the larger the number of countries. The underprovision problem becomes strongest as $n \to \infty$. Also, the concavity of the production function $f(k)$ matters. Intuitively, if country i increases its tax rate, for an unchanged allocation of capital, this decreases the net-return of capital in country i and makes an investment in this country less attractive, compared to other countries. Capital moves away from the country. This increases the marginal product of capital in country i and decreases the marginal product in the countries to which this capital flows. These changes counterbalance the initial effect and continue up to the point at which the net returns on capital have equalized. Hence, if the marginal product of capital reacts strongly to a change in capital [i.e., high $(-f''(k^*))$], then a small outflow of capital is needed to equalize the net returns of capital. Note that for a linear technology [i.e., $f''(.) = 0$], capital relocation cannot counterbalance existing differences in the net returns of capital, and the benchmark model is unlikely to have an interior equilibrium in this case. This case may describe financial capital reasonably well.

Leaving the strategic framework for a moment and making use of the small-country assumption, the market rate of interest $r = \rho$ can be taken as exogenous. Firms in country i then need to pay $r + t_i$ for attracting capital to the country. This implies $f_i'(k_i) = r + t_i$. Moreover, assuming that the government in country i has a distortion free source of government tax revenue - the shadow price of public funds is constant and equal to unity, such that $G_i(t_ik_i) = t_ik_i$. Accordingly, W_i reduces to

$$W_i = f_i(k_i) - rk_i + rc_i \tag{9}$$

where c_i is exogenous and constant. The optimal choice of t_i is given by

$$(f'(k_i) - r)(dk_i/dt_i) = 0, \tag{10}$$

and this yields $f_i'(k_i) = r$, or an optimal source tax on capital of $t_i = 0$. A small country cannot really gain in this case by a tax on the capital input.

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This result is independent of any symmetry assumption. In particular, it holds independent of whether the country i is a net supplier (for which $k_i < c_i$) or a net importer of capital (for which $k_i > c_i$) in the world capital market. The result is robust to some extent with respect to assumptions about the elasticity of labor supply. Intuitively, in the limit, the elasticity of capital supply dominates, even for moderately elastic labor supply.

The first-order condition (4) can also be used for obtaining an intuition about how different asymmetries affect the equilibrium outcome. Capital ownership contributes a negative term to the welfare effect of a tax rate increase, making a high tax rate less (more) attractive for countries with more (less) than average ownership of capital. Also, countries with a shadow price of public funds $G_i'(.)$ that is higher (lower) than average tend to choose a higher (lower) than the average tax rate. The role of asymmetry for the outcome of tax competition has been studied in more detail and will be discussed further below.

A linear version For a number of questions, a linearized version of the model is useful. First, linearize the marginal product function:

$$f_i'(k_i) = \max\{a_i - k_i, 0\} \text{ with } a_i > 0 \tag{11}$$

assuming that capital is not abundant:

$$K < \sum_{i=1}^{n} a_i \equiv A. \tag{12}$$

This turns the capital market equilibrium condition into

$$a_i - k_i - t_i = \rho \text{ for all } i = 1, ...n. \tag{13}$$

Finally, a linearized version of the valuation of public funds is

$$G_i = \begin{cases} (1 + \lambda_i) t_i k_i \text{ for } t_i k_i \leq \bar{G} \\ (1 + \lambda_i) \bar{G} \text{ for } t_i k_i > \bar{G}. \end{cases} \tag{14}$$

That is, the amount of the public good is equal to the amount of tax revenue, up to some point at which further expenditure on the public good do not further increase the amount of the public good. This upper limit $\bar{G}$ is considered to be sufficiently high not to be affecting the tax-competition equilibrium, but makes sure that the government would not like to confiscate all capital in the case of autarchy, and the public expenditure generates some surplus, which can be seen as the shadow price of public funds, with $(1 + \lambda_i) > 1$.

In this parametric version that has been used more recently by a number of authors (including Bucovetsky (2009)), the private market reactions to tax rate changes are

$$\frac{\partial k_i}{\partial t_i} = -\frac{n-1}{n} \tag{15}$$

$$\frac{\partial k_j}{\partial t_i} = \frac{1}{n} \tag{16}$$

$$\frac{\partial \rho}{\partial t_i} = -\frac{1}{n} \tag{17}$$

in the "interior range" - this range needs to be determined further, as corner solutions are likely. Major macroeconomic variables can also be determined in closed form for a range in which tax rates are not "too different" from each other. Using that $a_i - k_i - t_i = \rho$ holds for all i inside the interior range, we find that $A - K - \Sigma_{i=1}^{i=n} t_i = n\rho$. Accordingly, $a_i - k_i - t_i = A/n - K/n - \Sigma_{i=1}^{i=n} t_i/n$, or

$$k_i(t_1, ..., t_n) = \frac{K}{n} - \frac{A}{n} + a_i + \frac{\Sigma_{j=1}^{j=n} t_j}{n} - t_i. \tag{18}$$

In what follows we define the average tax rate $\frac{\Sigma_{j=1}^{j=n} t_j}{n} \equiv \tau$. Accordingly, the tax revenue in country i becomes

$$T_i(t_1, ..., t_n) = \left(\frac{K}{n} - \frac{A}{n} + a_i + \tau - t_i \right) t_i \tag{19}$$

and the net-return on capital becomes

$$\rho(t_1, ..., t_n) = \frac{A - K}{n} - \tau. \tag{20}$$

This can be used to calculate closed form solutions for reaction functions of countries for the "interior range". Inserting into the general first-order condition yields

$$t_i = \frac{(K - A + na_i)(1 + n\lambda_i) - c_i n}{n (n + 2n\lambda_i - \lambda_i)} + \frac{1 + \lambda_i n}{1 + n\lambda_i + (n - 1)(1 + \lambda_i)} \tau \tag{21}$$

and, expressing t_i as a function of all other tax rates only,

$$t_i(1 - \frac{1 + \lambda_i n}{1 + n\lambda_i + (n - 1)(1 + \lambda_i)} \frac{1}{n}) = \frac{(K - A + na_i)(1 + n\lambda_i) - c_i n}{n (n + 2n\lambda_i - \lambda_i)} \tag{22}$$

$$+ \frac{1 + \lambda_i n}{1 + n\lambda_i + (n - 1)(1 + \lambda_i)} (\frac{\Sigma_{j \neq i} t_j}{n}) \tag{23}$$

The function (22) can be used to make a few general observations:

(1) Tax rates are strategic complements: t_i is a function of the sum of the tax rates chosen by all other countries, and the optimal reply to a given sum of these other tax rates is increasing in this sum. This implies that any exogenous change that yields an increase in $\Sigma_{j \neq i} t_j$ will cause i to choose a higher tax rate, too.

(2) Suppose all countries are identical as regards the shadow price of public goods ($\lambda_i \equiv \lambda$), and as regards their local opportunities for production ($a_i \equiv a$), but differ in their ownership of capital. Let $t^* = (t_1^*, ..., t_n^*)$ be an interior equilibrium. For this equilibrium it holds that $t_i^* < t_j^*$ if $c_i > c_j$.[6] Intuitively, the capital tax reduces the incomes of the owners of the capital. This welfare cost is smaller in countries with inhabitants who own little capital. Accordingly,

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[6]To confirm this more formally, we can write the reaction functions for i and j for given equilibrium tax rates of all other countries as

$$t_i = R + Bt_j - Dc_i$$

suggesting that these functions cross for $t_i > t_j$ if $c_i < c_j$.

when deciding about their tax rate, capital rich countries face a welfare cost of higher taxes that countries with no or very little capital ownership do not face; in turn, this makes the capital rich countries less aggressive in their tax policy. A more general analysis of tax competition with differences in capital ownership is offered by Peralta and van Ypersele (2005).

(3) Suppose all countries are identical as regards the shadow price of public goods ($\lambda_i \equiv \lambda$), and as regards their ownership shares in the aggregate capital stock ($c_i \equiv K/n$). Let $t^* = (t_1^*, ..., t_n^*)$ be an interior equilibrium. For this equilibrium it holds that $t_i^* > t_j^*$ if $a_i > a_j$.[7] Intuitively, for uniform tax rates, countries with a small production sector would attract less capital. Their benefits from capital taxation are lower than for countries with a large production sector. However, if the inhabitants of these countries own the same amount of capital as those of other countries, the harm inflicted to the capital owners by these uniform taxes is the same for this country as for other countries. Accordingly, the sacrifice of higher taxes for capital owners' net income weighs more heavily compared to the benefit from higher tax revenue for this country than for countries with a larger production sector. A more detailed analysis of tax competition with differences in capital ownership can be found with Wilson (1991) and Bucovetsky (2009).

(4) Suppose all countries are identical as regards the production facilities ($a_i \equiv a$), and as regards their ownership shares in the aggregate capital stock ($c_i \equiv K/n$). Let $t^* = (t_1^*, ..., t_n^*)$ be an interior equilibrium. For this equilibrium it holds that $t_i^* > t_j^*$ if $\lambda_i > \lambda_j$.[8] Intuitively, country i values public goods more highly than country j, but their opportunity costs as regards private incomes of their capital owners and tax-base effects are the same. Consider now a situation in which the tax rates are the same in all countries, and in which countries are on the left-hand-side of the Laffer curve (higher own tax rate increases own tax revenue). In this case, all countries have the same sacrifice from an increase in their own tax rate, but country i has a higher benefit than country j.

(5) If the number n of countries increases, the reaction of country i to a change in the average tax rate of all other countries becomes smaller.

For using a graphical tool, it is useful to turn to the case with $n = 2$. For this case the reply function becomes

$$t_i = \frac{(1 + 2\lambda_i)(K - A + 2a_i) - 2c_i}{3 + 4\lambda_i} + \frac{1 + 2\lambda_i}{3 + 4\lambda_i} t_j \qquad (24)$$

and analogously for country 2. This reply function is drawn for the case of symmetry in Figure 2 for the case with $\lambda_1 = \lambda_2 = .5$ (i.e., $\frac{\partial t_i}{\partial t_j} = \frac{2}{5}$).

It shows the Nash equilibrium with tax rates (t^*, t^*) where the two reply functions intersect, and it shows the iso-welfare curves $W_1(t^*, t^*)$ and $W_2(t^*, t^*)$ at the Nash equilibrium. The iso-welfare curves for country 1 intersect $t_1(t_2)$ with a slope of zero: by the definition of $t_1(t_2)$, the country is in its optimum for

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[7]For a proof note that, for given equilibrium values of all tax rates other than t_i and t_j, the reaction functions of the two countries differ only by a different intercept. The intercept for i is higher than for j if $a_i > a_j$.

[8]Equation (..) can be solved for $t_i(t_j) = \alpha_i(\lambda_i) + \beta_i(\lambda_i)\Sigma_{s \notin \{i,j\}} t_s + \beta_i(\lambda_i) t_j$. For a given equilibrium, $\Sigma_{s \notin \{i,j\}} t_s^*$ is the same for both countries i and j. Hence, $\alpha(\lambda_i) + \beta(\lambda_i)\Sigma_{s \notin \{i,j\}} t_s^*$ constitutes the intercept, and $\beta(\lambda_i)$ the slope of the reply functions. Now, using (..) it turns out that both α and β are strictly increasing in λ_i. Accordingly, for $\lambda_i > \lambda_j$, the intercept of $t_i(t_j)$ and $t_j(t_i)$ must occur for $t_i > t_j$.
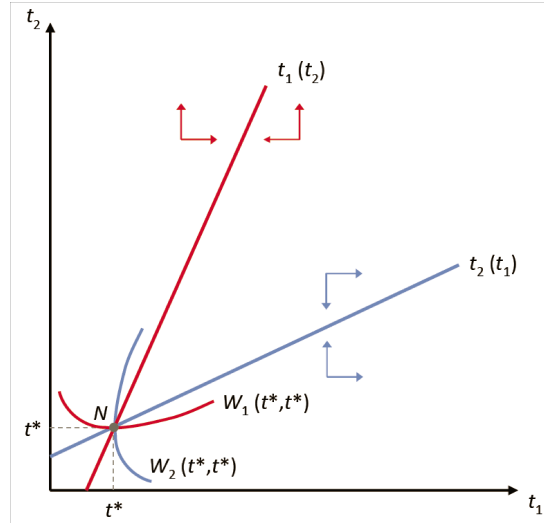
Figure 2: Nash equilibrium as the intersection of optimal reply functions in the linear model

a given t_2; hence, a small deviation in t_1 has only a second order effect for welfare along the curve $t_1(t_2)$. A similar argument explains the slope of $W_2(t^*, t^*)$ along $t_2(t_1)$. The curves $W_1(t^*, t^*)$ and $W_2(t^*, t^*)$ form a lense that describes the set of tax rate pairs (t_1, t_2) that, if implemented, yield a strict welfare improvement for both countries even in the absence of any transfers between them.

The diagram with reply functions can also be used to analyse asymmetries. Consider, for instance, reply functions as in Figure 3 that map the case of a more asymmetric distribution of capital ownership and symmetry otherwise. It shows an equilibrium in which the country with the higher stock of capital (country 1 here) chooses a substantially lower tax rate than the capital poor country, in line with the intuition that the capital poor country has a lower opportunity cost of taxing capital, because the owners of this capital are citizens of another country, and hence, their sacrifice is not part of the welfare considerations in the capital poor country. Note that the lens that describes pairs of tax rates that yield a Pareto improvement compared to the Nash equilibrium at (t_1^*, t_2^*) need not have an intersection with the line $t_1 = t_2$. This means that there need not be a common tax rate that improves welfare for both countries compared to the Nash equilibrium. More generally, if countries could commit on a common harmonized tax rate, starting from a Nash equilibrium between sufficiently asymmetric countries, there need not be a common harmonized tax rate that makes all countries better-off.

(6) The tax rates in the tax competition equilibrium can be more dispersed than the tax rates that maximize joint welfare. To see this, consider $n = 2$ and let $\lambda_1 = 0$ and $\lambda_2 = 2$, and let the two countries be perfectly symmetric otherwise, i.e., $a_1 = a_2 \equiv a$, and $c_1 = c_2 \equiv c$. In this case the tax rates that maximize joint welfare must yield the same marginal productivity of capital in both countries; but for an interior solution, by (11), $f_1' = f_2'$ requires $a - k_1 = a - k_2$. This condition holds in the capital market equilibrium only if $t_1 = t_2$. On
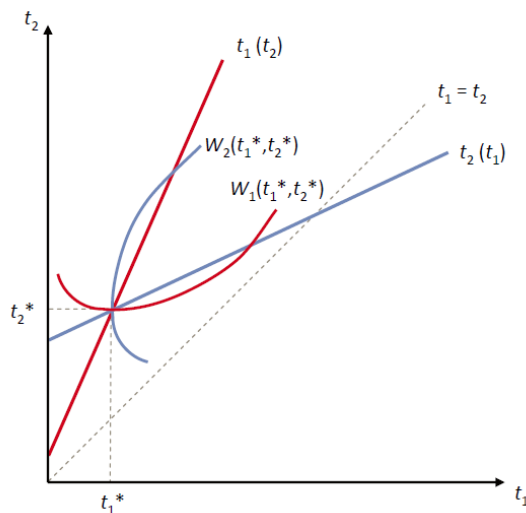
Figure 3: Asymmetric countries in the linear model. This diagram depicts a situation in which no harmonized tax rate exists that yields a Pareto improvement copared to the tax competition outcome.

the other hand, as is evident from (24), for $\lambda_1 = 0$ and $\lambda_2 = 2$, the equilibrium tax rates are $t_1 = \frac{2}{7}c$ and $t_2 = \frac{6}{7}c$.

Sequential decision making   Timing is an essential aspect in strategic games. Most analyses of tax competition assume that the countries choose their actions simultaneously. And given that there is no obvious reason for why one government should be able or be forced to commit on a tax rate earlier than other countries, this is a natural assumption. On the other hand, there is evidence that tax reforms in different countries do not occur all simultaneously, and this leads to the question how possible sequentiality of choices among governments can change the outcome. The question has been addressed in theoretical contributions by Wang (1999) for indirect taxes, and Kempf and Rota-Graziosi (2010) who address endogenous timing, using the workhorse model with capital taxes at source. Altshuler and Goodspeed (2002) look at sequentiality from an empirical point of view.[9]   Their results suggest that sequential choices existed since the 1986 US tax reform between the US and European countries, with the USA acting as a Stackelberg leader and European countries acting as followers vis-a-vis the USA and simultaneously vis-a-vis each other.

The most direct approach for an analysis of Stackelberg leadership in tax competition is a graphical analysis that builds on the reply functions (24). Figure 4 shows the same reply functions for the linear variant of the workhorse model as in Figure 2, and the Nash equilibrium that emerges from simultaneous tax-rate choices. Suppose now that, for some reason, country 1 has to

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[9]Stackelberg leadership if the more central governmental tier is also standardly assumed in the literature that discusses tax competition within a federation (see, e.g., Hayashi and Boadway (2001) and the many contributions citing this paper....)
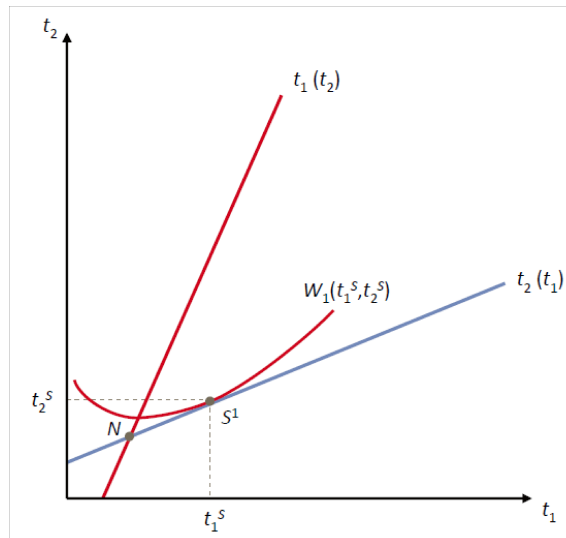
Figure 4: Stackelberg equilibrium

choose a tax rate t_1 first and country 2 is the follower who observes this choice and chooses t_2 on the basis of this observation. In this case, country 1 anticipates that, whatever, t_1, country 2 will choose $t_2(t_1)$ in line with its reply curve. Hence, by choosing t_1 and anticipating subgame perfect play, the country can essentially choose from all combinations $(t_1, t_2(t_1))$ that are graphically described by the reply function $t_2(t_1)$. If country 1 optimizes, it chooses the point along $t_2(t_1)$ that maximizes the country's objective function. Graphically, such a point is found where an iso-payoff curve for country 1 is tangent to $t_2(t_1)$, as it is drawn in Figure 4. A conclusion that follows is that, in a Stackelberg equilibrium, both countries choose higher taxes if they choose sequentially. The intuition for this result is the strategic complementarity of tax rates: starting from the Nash equilibrium, if country 1 chooses a tax rate that exceeds the Nash equilibrium tax rate, then this does not yield an advantage for the country if the other country continues to choose the Nash equilibrium tax rate. And this would happen in the simultaneous game, because country 2 would have no reason to anticipate this deviation from $t_1 = t^*$. However, if country 1 chooses first and country 2 can observe this choice, country 2 re-optimizes its choice and finds that, given $t_1 > t^*$, its optimal tax rate choice is also higher. By $t_1 > t^*$, country 1 induces a higher t_2, and it is this strategic effect that benefits country 1. In turn, in the Stackelberg equilibrium, both countries end up with higher tax rates, and both countries are better-off than in the Nash equilibrium. Also, this is clear from inspection of Figure 4, as both countries are on higher iso-payoff curves at the Stackelberg equilibrium than at the Nash equilibrium. Note also that, starting from a symmetric situation, country 2 gains more than country 1 if they choose sequentially rather than simultaneously.

While sequential choice is in the interest of all countries, it requires commitment. As the Stackelberg follower is seemingly advantaged, the commitment problem is one of staying flexible and out-waiting the other country. Procedural

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rules, the timing of government formation etc. may yield some differences in the timing in different countries. But the cyclicity of most of these institutional procedures does not answer clearly the question who has to move first. A solution to this problem comes from the theory of endogenous sequential choices. This theory has been developed in the context of duopoly first by Hamilton and Slutzky (1990) and applied to the context of tax competition duopolies by Kempf and Rota-Graziosi (2010). A Stackelberg leader-follower outcome can typically be obtained as the outcome of a game which is augmented by an earlier stage in which each country first chooses its timing of choice (what Hamilton and Slutzky call "the extended game with observable delay"). Let there be two points of time for tax rate choices: $h \in \{e(arly), l(ate)\}$, with the point $l(ate)$ occurring after the point $e(arly)$ in the time line. Let all countries first and simultaneously choose whether it would like to choose and fix its tax rate at time e or l. One can then show that there is a subgame perfect equilibrium in which one country, say, country 1, chooses $h_1 = e$ and the other country 2 chooses $h_2 = l$, and with the Stackelberg game just discussed as the continuation game.

To confirm this, we need to show that, assuming subgame perfect play in all possible continuation games, $h_1 = e$ and $h_2 = l$ are mutually optimal replies. Suppose that, for whatever reason, country 1 assumes that country 2 chooses l. Then country 1 has essentially two options. It can also choose $h_1 = l$. In this case both countries choose their tax rate at time l and simultaneously. They end up in the Nash equilibrium (t^*, t^*). Alternatively, country 1 can choose $h_1 = e$. In this case they end up in the sequential subgame with country 1 the Stackelberg leader and country 2 the follower (with an equilibrium S^1 in Figure 5). As has just been discussed, this outcome is superior to the Nash equilibrium outcome for country 1. Hence, $h_1^*(h_2 = l) = e$. Turn now to country 2. One needs to confirm that, given $h_1 = e$, country 2 prefers $h_2 = l$. Suppose the country 2 anticipates $h_1 = e$. Then the country has essentially two options. It can choose $h_2 = e$. This yields simultaneous tax rate choices in the continuation game, and the equilibrium is the Nash equilibrium with tax rates (t^*, t^*). Country 2 can choose $h_2 = l$ instead. In this case the subgame is the Stackelberg game discussed above, and country 2 is better off in the Stackelberg equilibrium than in the Nash equilibrium.

Two problems remain with this concept. One problem is the coordination problem. Both countries prefer the Stackelberg game to the Nash game. But they typically prefer being in the position of Stackelberg follower, i.e., be the country that chooses $h = l$, if the other country chooses $h = e$. If the countries cannot coordinate on who becomes follower and who becomes leader, they may randomize independently about their commitment choices. This leads to a symmetric equilibrium with mixed strategies at the stage in which they choose timing. In some of the subgames the mixed strategies lead to (e, e) or (l, l), in which case a Nash game follows as the continuation game, and in some of the subgames they manage to end up with (e, l), leading to the Stackelberg equilibrium S^1 (in Figure 5), or (l, e) leading to the Stackelberg equilibrium S^2 in the continuation game.

Kempf and Rota-Graziosi (2010) invokes the risk-dominance criterion to argue that - focussing on country differences in capital productivity - the less productive country is more likely to be the leader. If the countries become sufficiently asymmetric, this order of moves can even become Pareto dominant. The second problem that remains is to explain what makes the commitment
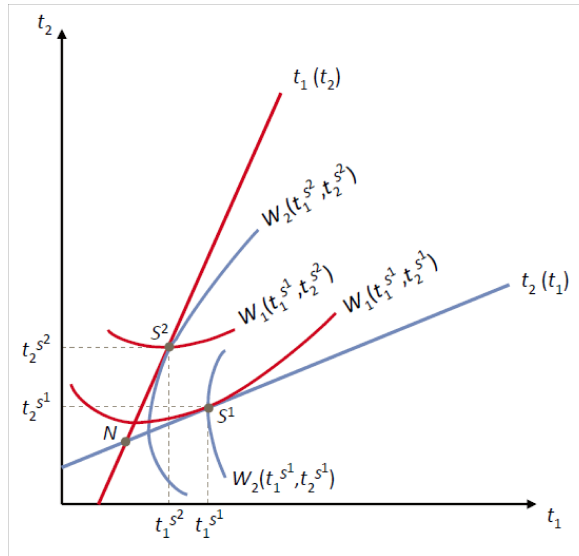
Figure 5: Endogenous sequencing in the tax rate choices.

feasible and credible at the commitment stage. Note that, for the existence of the equilibrium with sequential choices it is not necessary that the two players can observe each other's choice of timing. It is sufficient that they make these choices and that they assume about each other that the respective other country made this choice. What is needed, however, is that there is commitment. If the Stackelberg leader who announces a tax rate at time e can revise this choice at time l, then such a revision would be desirable for the leader; moreover, anticipating the optimal revision at time l, both countries would end up in the Nash equilibrium.

The strategic role of internal governance structure The analysis of tax competition surveyed so far abstracts from the complex multi-player decision making process which leads to national tax policy choices. It reduces this process to national decisions as if these were made by single players who make decisions in the interest of their citizens. In fact, many countries have multilayered governance systems, with each government drawing with different taxes on partially overlapping tax bases, often complemented by systems of intergovernmental grants.

Figure 6 shows three prototype countries with very different federal structures that may compete with other countries. Let us briefly discuss two dimensions along which countries can differ in their federal structure. The prototype country A is a fully centralized country in which the choices about tax rates and the tax system are made on the most central level. This country resembles most closely the type of players usually considered in the context of tax competition in other sections of this survey, where a single country is represented by one single player. Country B has one central government and a considerable number of regional governments. Country C has even more layers of government, or several parallel governments, all drawing on the same national tax base, but no
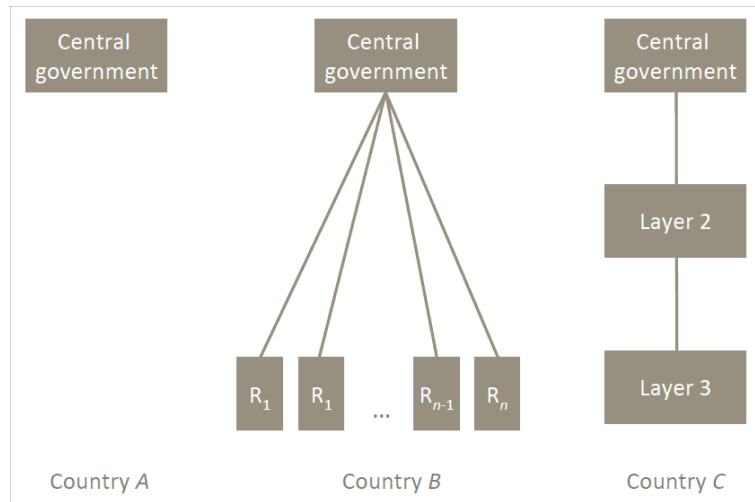
Figure 6: Different prototypes of governance: the unitary state, federalism with horizontal decentralization, and multiple layers of competing governments.

horizontal competition between regions inside the country. The additional layers of government should generally cause even higher tax rates, as more decision makers independently extract tax revenue from the same tax base. Country C suffers only from vertical tax competition inside the country.

Consider country B more closely. Suppose the central and the local governments choose independently a unit tax on capital at source. The capital that is applied in region i will then be taxed both by the central government and by the local government. In each region these unit taxes add to the total tax burden on capital in the respective region. The central government uses these revenues on behalf of the population in the whole country. Accordingly, this part of the tax revenue that is generated in a region benefits the citizens from this region as well as citizens from other regions, and the tax rate choice of the central government will be guided by the preferences of the citizens in all regions. In contrast, the regional government does not care much about the benefits that the tax revenue that is collected by the central government generates in the other regions. The regional government may therefore care more about the own, regional tax revenue, and attribute a shadow price to central tax revenue that is too low if considered from a country-wide welfare perspective. When the region decides about its tax rate, it anticipates that this will make some tax base flow away or cause other distortions that generally diminish the revenue accruing to the central level. However, it attributes a too low shadow price to this loss in federal revenue. The region has insufficient incentives to take these side effects appropriately into account. As a result the regions may pursue a tax policy that is too aggressive and charge too high taxes, thereby distorting the composition of regional versus central tax revenue and the provision of local and central public goods that are funded by these revenues. Also, the double taxation of the same tax base by the different layers of government may cause an aggregate tax burden resulting in country B that is too high. These effects

of vertical tax competition and its interplay with horizontal tax competition between regions and between nations has been analysed and is well understood by now (see Keen and Kotsogiannis 2002, 2004, and Wrede 1999).

Within federations, particularly if regions have some tax autonomy, often there are systems of interregional or vertical intergovernmental transfer systems in place. These systems have often been analysed in isolation. In isolation, this analysis can lead to policy conclusions about the disincentive effects of such systems to implement effective systems of tax enforcement in the different regions, and to conclusions about other negative incentive effects of such systems. It is therefore interesting to note that horizontal and vertical transfer systems inside a federal country can and partially do counterbalance the internal forces of vertical and horizontal tax competition inside a country and can partially correct for the problems caused by interregional or vertical tax competition (see, e.g., Fenge and Wrede 2007, Kelders and Koethenbuerger 2010 and Kotsogiannis 2010).

The incentives for vertical and horizontal internal tax competition play also a role if a country competes with other countries in the context of international tax competition. For instance, a country such as country C has a tendency to choose a higher tax rate on capital than a country of type A, and this is sustained also in a framework with international tax competition with countries of types A and C. The internal governance structure of a country has strategic effects. It affects the tax rate choices in the country. And as this is anticipated in other countries, it changes the equilibrium choices in other countries as well. Wilson and Janeba (2005) and Kessing et al. (2009) highlight this latter strategic effect in different competition frameworks. A structure that induces vertical tax competition can be advantageous or a disadvantage, and which of these applies also depends on the nature of tax competition. As the choice of governance structure is a long-term decision and cannot be adjusted in the short run as easily as the tax rate, the governance structure could be used as a commitment by which countries can position themselves in a framework of international tax competition. To illustrate this, consider a source based tax on capital applied in the respective country. More independent vertical tiers of governance lead to a higher effective tax rate chosen in this country. This higher overall tax rate will be anticipated by other countries. Provided that tax rates are strategic complements internationally, this higher overall tax rate will induce the competitors to this country to also choose higher tax rates. This strategic effect is similar to the commitment of a Stackelberg leader who may also benefit from it. However, this advantage becomes small in the context of many competitors, and smaller than the negative side effect of deviating from what would have been the tax rate chosen from the perspective of unitary state. Hence, if the number of competitors of the country is sufficiently large, the overall effect will typically work to the disadvantage of this country in the context of capital taxation at source.

Pure profits and international portfolio diversification An important issue which is eliminated from the picture in the workhorse model is the treatment of pure profits and the ownership shares in these. The assumption underlying the analysis in the workhorse model is that aggregate production is a function of internationally mobile capital and other, internationally immobile

factor inputs. If some of these inputs are attached to the location and can costlessly be used, then the ownership of the production facilities in a country may include entitlements in pure profits. Following the ideas outlined in Huizinga and Nielsen (1997, 2002, 2008) and Fuest (2005), we strip down their frameworks to consider a pure source tax on capital, with pure profits. Production in each country occurs with a technology that uses only capital as the variable factor, but also applies a fixed factor (other than labor), which can be thought of as a natural public good that is available in the respective country. In this case, $f_i(k_i) - f_i'(k_i)k_i$ measures pure profits that accrue to the owners of the production facilities in country i. Let α_{ij} be the share that is owned by entrepreneurs in country i in the production facilities in country j. If national governments strictly maximize the aggregate rents of the inhabitants of a country, then the welfare function (3) becomes

$$W_i = \sum_{j=1}^{n} \alpha_{ij}(f_j(k_j) - f_j'(k_j)k_j) + \rho c_i + G_i(t_i k_i). \tag{25}$$

Assuming an interior equilibrium characterized by the first-order conditions, this equilibrium is determined by

$$\frac{\partial W_i}{\partial t_i} = \sum_{j=1}^{n} \alpha_{ij}(-f_j''(k_j))k_j\frac{\partial k_j}{\partial t_i} + \frac{\partial \rho}{\partial t_i}c_i + G'(t_i k_i)(k_i + t_i\frac{\partial k_i}{\partial t_i}) = 0. \tag{26}$$

The welfare cost of an increase in the own tax rate t_i is modified. The increase in the tax induces a relocation of capital away from this country and towards other countries. But this has different welfare effects than in the absence of international portfolio investment. First, the country i bears only the share α_{ii} of any loss in production rents $(f_i(k_i) - f_i'(k_i)k_i)$ as the inhabitants of this country own only a share α_{ii} in these rents. Second, the inhabitants in i benefit from the increase in production rents that accrue in other countries, proportional to the shares α_{ij} which they own in these rents. Starting from the values $(t^*, ..., t^*)$ that characterize a Nash equilibrium for $\alpha_{ii} = 1$ and $\alpha_{ij} = 0$ for the case of fully symmetric countries, the first-order welfare effect of an increase in the country's own tax rate is

$$\sum_{j=1}^{n} \alpha_{ij}(-f''(\frac{K}{n}))\frac{K}{n}\frac{\partial k_j}{\partial t_i} - (-f''(\frac{K}{n}))\frac{K}{n}\frac{\partial k_j}{\partial t_i} \tag{27}$$

$$= \sum_{j \neq i} \alpha_{ij}(-f''(\frac{K}{n}))\frac{K}{n}\frac{\partial k_j}{\partial t_i} + (1 - \alpha_{ii})f''(\frac{K}{n})\frac{K}{n}\frac{\partial k_i}{\partial t_i}.$$

The welfare effect of the tax rate increase is positive for $\alpha_{ii} \in (0,1)$ and $\alpha_{ij} \in (0,1)$. Taking into consideration the strategic complementarity of tax rates, this implies that international portfolio diversification should weaken tax competition and lead to higher equilibrium tax rates than in the benchmark case.[10]

This analysis suggests a strategic relationship between the degree of international firm ownership and the strength of tax competition forces. A high degree

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[10] Huizinga and Nicodeme (2006) interpret their empirical findings on the relationship between international ownership and corporate taxes a being in line with this finding.

of international ownership reduces the incentives for a race to the bottom. As each single portfolio investor is small and may therefore safely disregard the effect of own portfolio choice for the tax competition, overall changes in portfolio choices that are driven by other considerations, such as the openness of capital markets, incentives for international risk diversification, transaction cost of international portfolio diversification etc., may influence the strength of tax competition. If the portfolio investors in a country could coordinate on a joint portfolio policy and if the national capital owners are less interested in the public good than the policy maker (or the median voter), then they could choose to reduce their international investment activities. Indigenization - national ownership in national firms and their profits is a well-known means to reduce the government's incentive to generate tax revenue from them.

The indigenization effect that is explored here is well-known from other contexts. For instance, it has been argued that indigenization or joint ventures with host country citizens reduces the incentives of the national government in the host country to expropriate or nationalize foreign direct investment. Konrad and Lommerud (2001) show that the problem of ex-post opportunistic behavior can also be moderated if the host country government has incomplete information about the true profitability of the FDI project, and if a large share of the foreign company is owned by citizens of the host country. Key for their argument is that this incomplete information shields an information rent of the firm from being extracted, even if the host government applies the most sophisticated extortionary means to extract as much revenue as possible. Similarly, it has been argued that a country with souvereign debt should be less inclined to default on its government debt if this debt is mainly held by nationals (Broner, Martin and Ventura, 2010).

2.2 Coordination

The benchmark model of tax competition reveals that the tax rate choice of a country can have several external effects for other countries. First, a higher tax rate in one country typically drives out capital from this country into other countries, benefiting these other countries by broadening the capital tax base there and increasing their tax revenues. This effect is known as the *tax base effect*. Second, the tax increase makes capital more abundant in other countries, causing an expansion of production there. This may also benefit these other countries. Further, the increase in the tax rate reduces the net return on capital, and this reduces the remuneration for capital earners. Generally, this is disliked by the owners of capital, and imposes a burden on the capital owners, not only in this respective country, but also the owners of capital in other countries. Generically, these different external effects do not cancel each other. Hence, the tax competition equilibrium can be expected to be inefficient. Countries may coordinate their tax policies in order to overcome these inefficiencies. In this section we first discuss coordination in which all countries cooperate. We then turn to cases of regional coordination and to partial coordination.

Full coordination and harmonization Using the benchmark model of tax competition, we can illustrate the potential and also the problems of tax coordination. Figure 2 shows a whole area of combinations of taxes (t_1, t_2) for which welfare in both countries is higher than in the Nash equilibrium. For identical

countries, there is a whole range of harmonized taxes ($t_1 = t_2$) for which both countries are better-off. If countries can negotiate a cooperative outcome, they should end up in the core. This is the locus between the points A and B which is characterized by combinations of (t_1, t_2) for which iso-welfare curves are tangent to the range of Pareto improvements. And with identical countries, one of these points in the core has ($t_1 = t_2$). More generally, in a framework with complete information and full commitment, with governments that maximize a well-specified welfare function of their respective country as players, it is an application of standard welfare theory that there exists a planning solution that is at least as good as any decentralized equilibrium outcome. And if the decentralized solution suffers from externalities between the players, it generically holds that an appropriately chosen central planner solution exists that yields a strictly higher welfare in each of the countries than in the decentral outcome. Of course, as we also know from standard economics, the central planner solution is a Nirwana outcome. It typically requires too much. For instance, it typically requires the absence of problems of asymmetric information and it typically requires full commitment - that is, the ability to write and implement fully binding contracts on all matters of relevance. And it requires that these contracts are written prior to any possible unilateral action by which a single player can tilt the cooperative outcome to his own favor. In an international context with sovereign countries being the decision makers, full commitment and its enforcement is probably the most serious hurdle, but information problems can also be an obstacle. The set of Pareto efficient outcomes is useful as an efficiency benchmark, however, as the welfare outcomes for more plausible institutional frameworks can be compared with this benchmark. In what follows we consider some of these institutional frameworks that involve elements of coordination.

Limits to coordination   As one possible limitation of the amount of cooperation, countries may be unable to coordinate on specific tax policies, but may be able to coordinate on a range of possible taxes. One example of such types of limited cooperation is the EU agreement on a lower limit of VAT taxes. Lower and/or upper limits for possible tax rate choices leave countries some flexibility to react to structural or macroeconomic developments or changes in the shadow price of public funds in their countries and may be more appealing for the countries' decision makers than a fully rigid system of coordinated taxes that can be changed and adjusted to their needs only by a unanimous renegotiation agreement. However, such lower or upper bounds may have surprising consequences for welfare in the resulting tax competition equilibrium.

Peralta and van Ypersele (2006) analyse the welfare effects of a common lower bound and of a combination of lower and upper bound. Starting from an asymmetric Nash equilibrium N with (t_1^*, t_2^*) in the fully uncoordinated situation with $t_1^* < t_2^*$, a common lower bound of $t_i = t_0 < t_1^*$ does not change the Nash equilibrium with simultaneous tax rate changes. A bound t_0 that is inside the interval (t_1^*, t_2^*) generally binds country 1 and typically induces the country to choose this lower bound. This is illustrated in the graphical exposition of the two-country case in Figure 7. The new best reply function $t_1(t_2)$ is kinked at t_0 - and also $t_2(t_1)$ has a kink, but for country 2 this kink happens in a region that is irrelevant for the equilibrium. The change of t_1 from t_1^* to t_0, taken in isolation, would benefit country 2, but would reduce welfare in country 1.
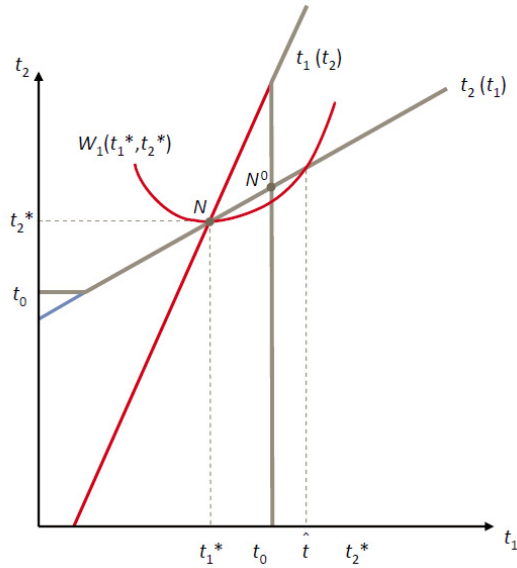
Figure 7: A lower bound of tax rates

Country 2 whose optimal choice is typically not constrained by the lower bound will not continue to choose t_2^* in the new equilibrium. Anticipating $t_1 = t_0$ it will choose its optimal reply $t_2(t_0)$. Strategic complementarity of tax rates suggests that this optimal reply is a tax rate that is higher than t_2^*. This change should be beneficial for both countries. A new equilibrium for the lower bound t_0 is N^0. The overall welfare effect for country 1 in this equilibrium compared to the unconstrained Nash equilibrium is therefore unclear. In the context of Figure 7, t_0 sufficiently close to t_1^* should benefit both countries. This is due to the fact that the marginal increase in t_1 starting at t_1^* has as a zero first-order effect for the welfare of country 1, whereas the strategic reaction of country 2 has a strictly positive first-order effect for country 1's welfare. In the figure, any lower bound $t_0 \in (t_1^*, \hat{t})$ induces an increase in both countries' welfare. Lower bounds in the range $t_0 \in (\hat{t}, t_2^*)$ reduce the welfare of country 1.[11]

The situation becomes less clear-cut if countries choose their tax rates sequentially. If countries 1 and 2 choose sequentially, with country 1 as the Stackelberg leader, Wang (1999) considers minimum tax rates higher than the lower of the two tax rates chosen in the unconstrained equilibrium. He assumes that the small region (the country with the low tax rate) is the Stackelberg follower and shows that the Stackelberg leader gains, whereas the follower loses from this minimum tax. In particular, imposing a minimum tax that is binding for the Stackelberg follower compared to the tax rate choice in the unconstrained Stackelberg equilibrium, may induce the Stackelberg leader to choose a lower tax rate.

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[11] Peralta and Ypersele (2006) show, however, that this result need not hold more generally. In their framework, a minimum tax reform that introduces a lower bound only is never unanimously accepted by both countries.
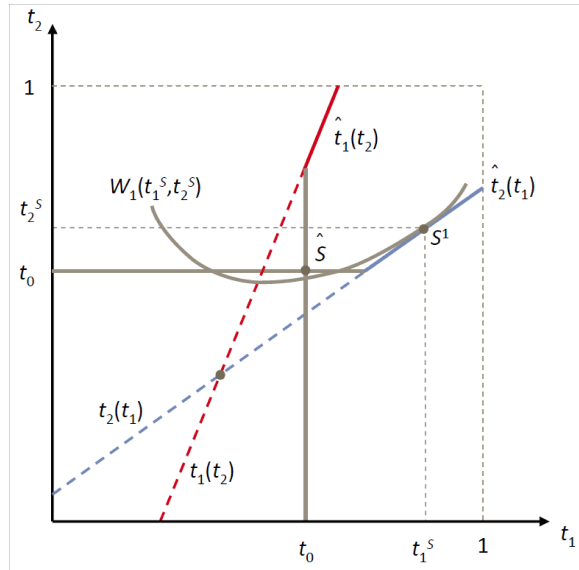
Figure 8: A minimum tax that is lower than any of the tax rates that emerge in the unconstrained Stackelberg equilibrium may reduce the tax rates in the equilibrium.

Konrad (2009) considers minimum taxes that are even lower than the lower of the two tax rates chosen in the unconstrained equilibrium. He shows that such seemingly unconstraining floors change the nature of the equilibrium and may induce all countries to reduce their tax rates, compared to the tax rates in the unconstrained Stackelberg equilibrium. The intuition for this result can be gained from Figure 8. It shows the unconstrained reply functions $t_1(t_2)$ and $t_2(t_1)$ as the dashed lines, and a Stackelberg equilibrium with country 2 as the follower. This equilibrium is the pair of tax rates that is most preferred among all tax rates along the reply function $t_2(t_1)$ of country 2, and this is point S^1. A floor on the tax rate as low as t_0 changes the reply functions, inducing kinks in the reply functions. With a lower bound of t_0, the reply functions $\hat{t}_1(t_2)$ and $\hat{t}_2(t_1)$ are drawn as closed lines with these kinks. Also, the range of possible tax rates is constrained now, as tax rates lower than t_0 are ruled out. In the Stackelberg equilibrium, country 1 chooses the point along $\hat{t}_2(t_1)$ for the range $t_i \geq t_0$ that maximizes country 1's payoff. While S^1 was optimal for country 1 in the unconstrained situation, now $\hat{S}$ yields higher payoff for country 1. Intuitively, without a floor, a choice of $\hat{t}_1 = t_0$ would induce a very low tax rate chosen by country 2 in the unconstrained situation. However, as country 2 cannot reduce its tax rate below t_0, the reaction induced by the choice of $\hat{t}_1 = t_0$ is much less drastic than in the unconstrained situation. This makes such a choice more attractive. As a result of this discrete change in the nature of the equilibrium, the Stackelberg leader is better-off and the follower is worse-off in the constrained equilibrium.

Regional coordination in tax alliances A coordinated simultaneous co-ordination across the world may be difficult to achieve, as there is no supra-national agency that could enforce such an agreement. However, supra-national structures such as the European Union may enable its members to commit on joint action. In this case the question emerges whether it is in the interest of this subset of countries to take joint actions. These joint actions, or more specifically, their choice of tax rates will be anticipated by non-member countries. Non-member countries' own optimal tax rate may then be different from the tax rate they choose in the fully non-cooperative Nash equilibrium. Joint action by this subset of countries will therefore induce a strategic effect on the tax rate choices of non-member countries. Even if the member-countries benefit from joint action in the absence of such strategic effects (at least, they cannot do worse), it is not clear a priori if the overall outcome of this coordinated action is beneficial for them.

This problem has been discussed formally by Konrad and Schjelderup (1999), and the general question can be addressed in a modified version of the reaction curve diagram for the linear model, extending this model to three symmetric countries, labelled 1, 2 and 3 in this subsection. We denote the symmetric Nash equilibrium by the uniform tax rate $t_1 = t_2 = t_3 = t^*$. We ask if countries 1 and 2 could gain if, rather than maximizing their own welfare individually and ending up in this Nash equilibrium, join forces and credibly and publicly agree on choosing a common tax rate $t_1 = t_2 \equiv t_A$ that maximizes their joint welfare $W_A \equiv W_1 + W_2$, where W_i is defined as in (3) for all countries $i = 1, 2, 3$.

The benchmark case of comparison is the fully non-cooperative Nash equilibrium. To characterize this equilibrium, we derive the reaction functions $t_i(\mathbf{t}_{-i})$ from the first-order conditions $\partial W_i(t_1, t_2, t_3)/\partial t_i = 0$, where $\mathbf{t}_{-i}$ is the pair of the tax rates in the two countries other than i. In a symmetric equilibrium the reaction functions are identical hyperplanes that intersect in one single point with coordinates $t_1 = t_2 = t_3 = t^*$. If countries 1 and 2 form an alliance and choose the same tax rate $t_1 = t_2 = t_A$, we can ask whether they can increase their welfare if they jointly depart from the Nash equilibrium values and both choose a slightly higher tax rate, assuming first that country 3 still chooses $t_3 = t^*$. Formally, at $(t_1, t_2, t_3) = (t^*, t^*, t^*)$,

$$\frac{\partial(W_1 + W_2)}{\partial t_A} = \frac{\partial(W_1 + W_2)}{\partial t_1} + \frac{\partial(W_1 + W_2)}{\partial t_2} = \frac{\partial W_2}{\partial t_1} + \frac{\partial W_1}{\partial t_2} > 0 \qquad (28)$$

where use is made of the first-order conditions $\partial W_i/\partial t_i = 0$. Intuitively, if both countries 1 and 2 slightly increase their tax rate starting at the non-cooperative Nash equilibrium, the direct first-order effect of the increase in their own tax rate on their own welfare is zero, because the deviation occurs at the local optimum. However, country 1 gains from country 2's tax rate (and vice versa) due to a tax-base effect. The increase in t_2 drives capital away from country 2 and part of this capital relocates to country 1. This effect is a first-order effect. The same applies for t_1 and country 2's welfare. Of course, country 3 benefits even more than the two countries, as country 3 has a first-order tax base effect from the increase in each of the tax rates t_1 and t_2. This argument shows why the formation of an alliance among as subgroup is beneficial for its members, if the non-members do not react to this coordinated action. As country 3 anticipates the increase in country 1's and country 2's tax rate, country 3 will choose a different tax rate and we have to search for the new equilibrium. The new

equilibrium is obtained as a set of taxes (t_A, t_A, t_3) that fulfills two conditions. First, given that countries 1 and 2 both choose t_A, the choice t_3 maximizes $W_3(t_A, t_A, t)$ among all possible choices of t for country 3. Moreover, the joint tax rate t_A maximizes the sum of $W_1(t, t, t_3) + W_2(t, t, t_3)$ for all possible choices of $t_1 = t_2 = t$. Whether or not the coordinated choice of countries 1 and 2 improves their joint welfare in the new equilibrium will crucially depend on the new equilibrium value of t_3.

For a graphical illustration of the problem let us boil down the problem to two dimensions as in Figure 8. The horizontal axis denotes possible (positive) values of t_3. The vertical axis denotes possible values of the other two countries, requiring that they choose the same tax rates ($t_1 = t_2$). The non-cooperative fully uncoordinated Nash equilibrium is at the point at which all countries choose the tax rate t^*. We can draw a subset of the optimal reply hyperplane $t_3(\mathbf{t}_{-3})$ into this diagram which indicates the optimal choice for country 3 if the two other countries choose $t_1 = t_2 = t$ for all possible values of t, and this subset is represented by the line $r_3(t)$. This quasi-reply function is typically upward sloping - suggesting that tax rates are strategic complements. For the linear model, this can be confirmed from (22). Similarly, we can map a subset of the reply hyperplane that describes the optimal reply of country 1 to possible choices of t_2 and t_3 along the set for which $t_2 = t_1(t_2, t_3)$. This subset is denoted $r_{1/2}(t_3)$ and is also a positively sloped curve due to the strategic complementarity of tax rates. The intersection between $r_3(t)$ and $r_{1/2}(t_3)$ is the fully non-cooperative Nash equilibrium N. Finally, we can ask what is the optimal choice $t_1 = t_2 = t_A$ by the alliance for each possible t_3. This yields the third curve $R_A(t_3)$ in the diagram. This curve is also upward sloping by strategic complementarity of tax rates. Moreover, for every t_3, it is true that $R_A(t_3) > r_{1/2}(t_3)$. This can be explained intuitively as follows. Recall that $r_{1/2}(t_3)$ is the individually optimal replies of countries 1 and 2 to a given t_3, with countries 1 and 2 already anticipating the optimal reply of the respective other of the two countries. Suppose, for instance, that $(r_{1/2}(t_3), r_{1/2}(t_3), t_3)$ is on this curve. For their individually opimal replies r_1 and r_2 the two countries do not take into account the mutially beneficial effect they encounter if they both increase their tax rates at $r_{1/2}(t_3)$ for given unchanged t_3. This mutually beneficial effect was established by (28), however. Accordingly, if they maximize their joint welfare for given t_3, then, starting from $(r_{1/2}(t_3), r_{1/2}(t_3))$ they can increase their welfare by a joint and symmetric increase in their tax rates, up to some point where a further increase in their joint tax rates just does not yield a further increase in $W_1 + W_2$. By definition, these joint tax rates are reached by moving vertically up, starting in $(r_{1/2}(t_3), r_{1/2}(t_3), t_3)$, until reaching the curve $R_A(t_3)$.

Note further that the intersection between $r_3(t)$ and $R_A(t_3)$ marks the Nash equilibrium N in the game between the alliance subgroup and the stand-alone country: by definition, at this intersection (t^*, t^*, t^*) it holds that $r_1(t_2, t_3) = r_2(t_1, t_3) = r_3(t_1, t_2)$ at $t_1 = t_2 = t_3 = t^*$. As a next step we discuss whether the alliance is better off or worse off at N_A than at N. For this purpose we determine the slope of iso-welfare curves in the diagram. Each combination of (t, t, t_3) has the same tax rates for countries 1 and 2. Accordingly, $W_1(t, t, t_3) = W_2(t, t, t_3)$ for any coordinate (t, t, t_3) inside the diagram. Consider the slope of an iso-welfare curve $W_1 + W_2 = W_A$ for countries 1 and 2 at N. Both countries clearly benefit from an increase in t_3 starting from $\mathbf{t}^*$. Also, both countries benefit from a move upward, i.e., by an increase in t_A starting from $\mathbf{t}^*$. This effect has been
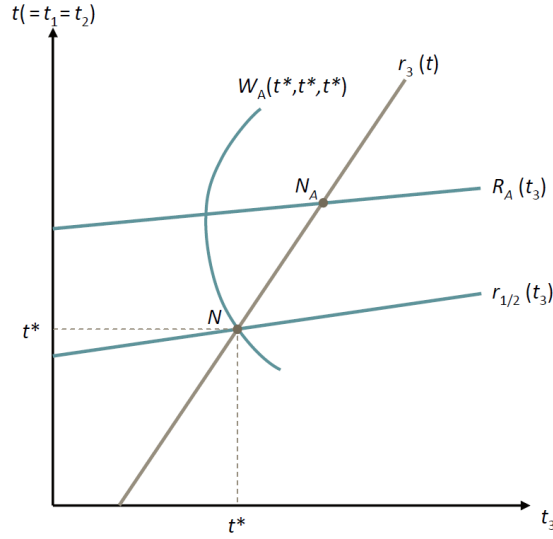
Figure 9: Regional tax harmonization is beneficial

demonstrated in (28). Moving vertically upward starting from N increases W_A exactly until the reaction function $R_A(t_3)$ is reached at $R_A(t^*)$, by the definition of $R_A(t_3)$. Accordingly, the iso-welfare curve $W_A(\mathbf{t}^*)$ through N has a negative slope at N, and the slope becomes vertical where the curve intersects $R_A(t_3)$. Note finally that by the positive slope of all reaction curves, N_A is to the right of the intersection of the iso-welfare curve $W_A(t^*, t^*, t^*)$ with $R_A(t_3)$. This, in turn, implies that welfare for countries 1 and 2 is higher at N_A than at N.

The analysis which has been discussed here for three countries can easily be extended to more than three symmetric countries, with a subset of these forming an alliance. Conconi, Perroni and Riezmann (2008) essentially use partial tax coordination in a context with downward pressures on tax rates due to tax competition on the one hand side and upward pressures on tax rates due to time consistent confiscatory taxation. Coordination by a suitably chosen size of the subgroup may be used to find the right balance for this trade-off. Hauffler and Wooton (2006) apply a related logic in a competition for direct investment. Sørensen (2004) explores a similar logic, focussing on the amount of redistributive taxation, rather than on the provision of public goods. His analysis also offers simulations of the welfare effects of regional (subgroup) versus global coordination, compared to fully uncoordinated tax competition. His results suggest that the beneficial effect of partial coordination for the subset of coordinating countries is small in comparison to the benefit for the country that is not part of the coordinating subgroup. Simulation results with a similar flavour and allow for asymmetries between the countries are by Brochner, Jensen and Svensson (2007).

In the case of Europe and potentially other supra-national entities, the set of candidate countries that may enter into a regional coordination agreement is given exogenously or has been determined by other factors outside the context of the tax competition problem. Where this is not the case, the formation of

subgroups becomes a challenging theoretical question. Members of the coordinating subgroup benefit, but their gains are typically smaller than those of outsiders. If there are n countries, the formation of a subgroup of 2 is a Pareto improvement to no group formation at all. But which country should voluntarily give in and join the subgroup, and which country can happily stay outside and enjoy even higher benefits? Moreover, an enlargement of the group from m to $m+1$ may be a further Pareto improvement up to some group size. However, among symmetric countries, if the number of countries is sufficiently large, this process typically comes to a natural stop: if, for instance, the subgroup consisted of $n-1$ countries already, the one remaining outsider is typically better-off as a free-rider than by joining the alliance. The process of alliance formation and the question of alliance stability is a matter that is typically very sensitive to the assumptions made about the formation process.

Preferential tax regimes versus uniform treatment Countries typically control a number of tax bases which differ in their elasticity to tax rate changes. This holds both in a closed economy and in an open economy in which tax bases may be internationally mobile, and it raises the question of whether governments should tax different tax bases uniformly or discriminate between them. A considerable set of results exist on this matter suggesting that it may be crucial whether an interior equilibrium in pure strategies prevails in which all tax bases react smoothly to tax rate changes or not. Relevant references are Janeba and Peters (1999), Keen (2001), Janeba and Smart (2003), Haupt and Peters (2005), Bucovetsky and Haufler (2007), Hong and Smart (2010). We will elaborate more on this.

Partial coordination The analyis of global tax coordination and of tax coordination in a region or a strict subset of the set of all countries considered here looked at the case in which governments have exactly one instrument, and in which coordination is about the choice of this instrument. Countries often have more than one instrument and also several targets. Partial coordination in such contexts can mean that all countries agree on restrictions as regards some, but not all of their instruments. Keen and Marchand (1997), for instance, consider coordination of tax rates in a framework in which countries can continue to compete along another dimension, which is their decisions about infrastructure investment, and which works like an input subsidy. Fuest and Huber (1999) consider a framework with four tax or subsidy instruments. These analyses suggest that one may not expect too much from coordination negotiations, even if they yield some positive results in terms of partial coordination. If countries have more instruments than goals, some of the instruments may be redundant, and coordinated action that fixes the value of this instrument at some level can be undone by changes in the other variables. And even if the instruments are not redundant in a strict sense, and instruments are only imperfect substitutes, coordinated action that fixes the value of one instrument may imply that the substitute instrument may be used more strongly for the competition.

2.3 Dynamic aspects

Tax competition takes place in a dynamic framework. This has several implications. Where there is an unknown, possibly infinite number of repetitions,

the results for infinitely repeated games may become relevant for describing the outcome of tax competition. A second aspect of these dynamics is that decisions are made sequentially. Some early decisions may generate stock effects that determine the environment in which later decisions take place. More to the point: the capital stock is the result of earlier decisions on savings and consumption, and this may generate time consistency problems for the optimal tax policy which may interact with the effects of tax competition. A third aspect is the relationship between stocks and flows and the trade-off between taxing the stocks or attracting the flow of new capital. We consider these three aspects consecutively.

Infinitely repeated interaction Observers of tax policy notice that tax laws change from time to time, and there is no reason for an end of this process. This makes the folk theorems of infinitely repeated games potentially relevant for tax competition. One can ask whether the benefits of coordination or tax harmonization can be obtained in a fully non-cooperative game due to the infinite repetition. Analyses of this problem are Cardarelli et al. (2002), Catenaro and Vidal (2006), Kessing et al. (2006) and Kiss (2011). The latter considers a symmetric set-up with n countries and uses simple trigger strategies to generate efficient tax harmonization as a non-cooperative equilibrium outcome. He also shows that the introduction of a minimum tax that is higher than the tax in a static Nash equilibrium may destabilize an existing efficient equilibrium.

The following multi-period version of the linear model with two countries can illustrate these ideas. Generalizing the linear framework to an infinitely repeated game with the static game as a state game, the local strategies of countries in a given period s are their tax rate choices t_1^s and t_2^s which may generally be functions of the whole history. Let $W_i(t_1^s, t_2^s)$ be the period payoff of country i in period s if the tax rates are t_1^s and t_2^s in that period, and let

$$\sum_{s=k}^{\infty} \delta^s W_i(t_1^s, t_2^s) \tag{29}$$

be the discounted present value of payoffs for all periods from period k on that emerge from a series of tax rate choices $(t_1^k, t_2^k), (t_1^{k+1}, t_2^{k+1}), ...$, with δ as the discount factor that is invariant over time and the same for both countries. Further, let (t^*, t^*) be the static symmetric Nash equilibrium tax rates, and let (t^O, t^O) be the efficient tax rates that implement the symmetric Pareto optimum. Suppose the players follow the following simple local strategies:

$$t_1^0 = t_2^0 = t^O, \ t_i^s = t^O \text{ if } (t_1^{s-1}, t_2^{s-1}) = (t^O, t^O), \tag{30}$$
$$\text{and } t_1^s = t^* \text{ if } (t_1^{s-1}, t_2^{s-1}) \neq (t^O, t^O)$$
$$\text{for all } s \geq 1.$$

These strategies constitute an equilibrium with $(t_1^s, t_2^s) = (t^O, t^O)$ for all $s = 0, 1, ...$ if the condition

$$\sum_{s=0}^{\infty} \delta^s W_i(t^O, t^O) \geq W_i(t_i(t^O), t^O) + \sum_{s=1}^{\infty} \delta^s W_i(t^*, t^*) \tag{31}$$

is fulfilled, where $t_i(t^O)$ is the tax rate that maximizes i's period payoff for a given choice of t^O for the respective other country. This condition is more likely

to be fulfilled if the discount factor δ is higher. Note that, in the benchmark model, $t^* < t_i(t^O) < t^O$.

We can also discuss a binding agreement in period 0 that none of them will ever use a tax rate lower than some $t_{\min}$ with $t_{\min} \in \{t^*, t_i(t^O)\}$. Such an agreement changes the equilibrium of the static game. The Nash equilibrium of the static game is no longer (t^*, t^*) as $t_i = t^*$ is infeasible. Instead, Nash reversion will imply that the countries both choose $t_{\min}$. Applying this to the logic of infinitely repeated interaction, note that the minimum tax rate does not affect the left-hand side of (31). Also, $W_i(t_i(t^O), t^O)$ will not be affected. However, reversion to the static Nash equilibrium is less harmful for the two countries. It yields a present value of the discounted sum of period payoffs $W_i(t_{\min}, t_{\min})$. Accordingly, if a country deviates from t^O, its immediate gain is the same as without a minimum tax, but the present value of future payoffs does not drop by that much. The relevant condition for whether an equilibrium with sustained cooperation on efficient tax rates exists becomes

$$\sum_{s=0}^{\infty} \delta^s W_i(t^O, t^O) \geq W_i(t_i(t^O), t^O) + \sum_{s=1}^{\infty} \delta^s W_i(t_{\min}, t_{\min}). \tag{32}$$

This, in turn, implies that a minimum tax that exceeds the Nash tax rate tightens the condition on the discount factor.

Endogenous savings and time consistent taxation So far we considered the world capital stock as exogenous. In a dynamic perspective, the current capital stock is the outcome of consumption and savings choices made in earlier periods. This fact has been noted early on in the context of capital income taxation, and its implications for international capital taxation have been explored (Gordon 1986). A simple strategic setting which is a natural extension of the workhorse model and allows to analyse optimal and time consistent tax choices considers n countries $i = 1, 2, ...n$ in a dynamic framework with two periods $\theta = 0$ and $\theta = 1$ that is a simplified version of the two-period framework analysed by Huizinga (1995) is as follows. A (representative) individual is born in period 0 with an endowment of capital that is equal to κ in each of the two countries and decides how much to save (c_i) and how much to consume $(\kappa - c_i)$ in this period. At the beginning of period 1, the sum of these savings $\Sigma_i c_i$ determine the world capital stock K, and period 1 is very similar to the economy in the static workhorse model. Capital market clearing internationally requires

$$\Sigma_i c_i = \Sigma_i k_i. \tag{33}$$

These investments determine aggregate output $f(k_i)$. The remuneration for capital is determined on a competitive market with its marginal product: $f'(k_i)$. The government in country i levies a unit capital tax t_i, and this leads to an international capital market equilibrium with market clearing (33) and with the same net return on capital

$$\rho = f'(k_i) - t_i \text{ for all } i = 1, ..., n. \tag{34}$$

Finally, we assume $G_i(t_i k_i)$ as it was introduced in the linear model, and a uniform shadow price of public funds:

$$G_i = \begin{cases} (1 + \lambda)(t_i k_i) \text{ for } t_i k_i \leq \bar{G} \\ (1 + \lambda)\bar{G} \text{ for } t_i k_i > \bar{G}. \end{cases} \tag{35}$$

Overall, assuming additively separable period utilities with concave consumption utility $u(\kappa - c_i)$ in period θ, the objective functions of welfarist governments can now be stated as

$$W_i = u(\kappa - c_i) + f(k_i) - f'(k_i)k_i + \rho c_i + G_i(t_i k_i). \tag{36}$$

Before analysing the equilibrium outcome for $n > 1$, we discuss two benchmark outcomes for $n = 1$, which reduces the problem to a special case of the analysis of Kydland and Prescott (1980) which they used to show the pitfalls of time consistent capital taxation. The optimal tax program considered from the perspective of period 0, prior to a savings choice, consists of a choice t such that the marginal opportunity cost of extracting one additional revenue unit from capital taxation equals the shadow price of public funds, which is equal to $(1 + \lambda)$ here. The representative individual chooses savings according to

$$u'(\kappa - c_1) = f'(c_1) - t_1. \tag{37}$$

This makes use of $k_1 = c_1$ for $n = 1$. The first-order condition connects the tax rate t_1 with the amount of savings c_1, where c_1 is a decreasing function of t_1.

The government takes this relationship $c_1(t_1)$ into consideration when choosing t_1 optimally. The first-order condition for the government is (after simplifying)

$$\frac{\partial W_1}{\partial t_1} = -u'(\kappa - c_1)\frac{\partial c_1}{\partial t_1} + (f'(c_1) - t_1)\frac{\partial c_1}{\partial t_1} - c_1 + (1 + \lambda)(c_1 + t_1\frac{\partial c_1}{\partial t_1}) = 0. \tag{38}$$

This reduces to

$$1 + \lambda = \frac{1}{1 + \frac{t_1}{c_1}\frac{\partial c_1}{\partial t_1}} \tag{39}$$

and typically this elasticity rule just balances the benefit of additional public good with the marginal opportunity cost of taxation that includes the marginal excess burden from the distortion of the consumption-savings decision. Typically, thid condition singles out one tax rate that induces the second-best optimal amount of savings.

In comparison, once the individual savings decisions have been made, and c_1 is exogenous and fixed, the marginal welfare cost of taxing capital is equal to $1 < 1 + \lambda$. The welfare maximizing government chooses its tax rate at the beginning of period 1. Assuming that a unit tax exceeding full exproproation is not feasible, the welfare optimum is attained either at $t_1 = 1$ if $c_1 \leq \bar{G}$, or at t_1 that solves $t_1 c_1 = \bar{G}$ if $c_1 > \bar{G}$. This high tax rate will be anticipated by the individuals already in period 0 and anticipation of this tax will generally discourage savings. Even though the ex-post optimal tax does does not change the capital stock at the point when it is introduced, it imposes an excessive excess burden due to its anticipation. The confiscatory tax can reduce savings, thereby causing a maximum distortion in the savings-consumption decision without generating any revenue. In particular, in an economy in which aggregate savings are formed by many individuals, there is typically an equilibrium in which $c_1 = 0$. Hence, the time consistent capital tax is too high from a welfare point of view.

Summarizing these results so far, ex-post optimal taxation leads to excessive taxation in the solitary economy. Return now to $n > 1$. As has been shown in the benchmark analysis, tax competition has a tendency to drive down tax rate

levels. Kehoe (1989) argued that this competition effect may be desirable in a situation in which the government cannot credibly commit on a capital tax early on and suffers from the Kydland-Prescott (1980) time consistency problem. If we open up for tax competition between a set of such identical economies, this competition will drive down equilibrium tax rates compared to these excessive levels. Can tax competition with tax rate choices based on existing savings lead to the same equilibrium outcome as the ex-ante optimal program of capital taxation in the solitary economy?

The answer is that this can happen, but such an outcome is non-generic. To see that it can happen, consider first the downward sloping function $c_1(t_1)$. Denote the ex-ante optimal tax rate as t^s and the the respective savings as c^s. In a solitary economy, these savings are identical with the capital stock k^s. Now turn to the case of n symmetric, identical countries with tax competition and tax rates chosen at the beginning of period 1. Suppose that the citizens in each of these countries expect that the tax rate that is to be chosen at the beginning of period 1 is t^s. Then there is an equilibrium in which the individually optimal consumption choices in period 0 induce savings in each country equal to c^s.

We now ask whether, for these given endowments, there is a symmetric Nash equilibrium in the tax competition game that really induces t^s as the tax rate. At period 1 the economy is in a condition that is essentially equivalent with the static tax competition problem that has been solved in the benchmark case, with capital endowments $c_i = c^s$ in each of the n countries. We can use the elasticity formula (7) that characterizes the tax rate in a symmetric tax competition equilibrium for a given stock of capital $k^* = c^s$, replacing also G' by $(1 + \lambda)$. This condition becomes

$$1 + \lambda = \frac{1}{1 + \frac{t^*}{c^s} \frac{n-1}{n} \frac{1}{f''(c^s)}} \tag{40}$$

and has typically one solution $t^*(c^s, n)$. If $t^* = t^s$, then the expectations of the individuals that induced their savings of c^s were justified and tax competition can indeed implement the ex-ante efficient outcome with t^s and c^s. For $n = 1$, we return to the case of excessive ex-post efficient taxation for the case of the solitary economy, with $t^* > t^s$. However, $t^*(c^s, n)$ is a downward sloping function of n. Assuming away the indivisibility problem for n, and depending on the shape of the production function f, for sufficiently large n the the solution to (...) may just be equal to t^s. In this case the forces of tax competition just compensate for the ex-post inefficiently high incentives to confiscate capital. Put differently, the pressure of competition allows the country to credibly commit on a tax rate that is lower than the high tax rate on capital that would be the time consistent solution in the solitary economy. In some instances, the downward pressure on tax rates due to tax competition can even exactly compensate the incentives for excessive time consistent taxation.

Kehoe's (1989) result is a result in the tradition of Lipsey and Lancaster (1956). In a world with several distortions, they may re-inforce or counterbalance each other. We can also conclude that a combination of some degree of tax competition and of time-consistent capital taxation will only accidentally lead to efficient taxation. Generically the outcome will be inefficient. In particular, if countries are asymmetric, it will typically be the case that the degree of tax competition that is just desirable from the perspective of one country will be

suboptimal for other countries. The argument has one further problem. It relies on the idea that the world capital stock is fixed once the savings decisions are made, but this capital remains mobile internationally once it has been formed and can be shifted between the countries as a reaction to the tax rate choices. It is true that single investors can sell their assets in one country and purchase assets in another country. Capital is, hence, mobile on the individual level. However, on the aggregate country level, at a given year, most of the capital assets in one country are fixed and essentially immobile and can be taxed at source.[12]

An analysis that develops a more credible mechanism but is in the spirit of Kehoe (1989) is by Janeba (2000). He considers a firm that has built up production capacities in a country and and now is exposed: the government of this country may be tempted to generously extract a major share of the firm's output as tax revenue. To address this hold-up problem, the firm may build up production capacities in excess to what it is actually planning to use, and to distribute this total capacity among at least two different countries. Due to this excess capacity, it can always shift production temporarily to the location in which the ongoing production conditions and tax rules are most attractive. Similar to a framework with Bertrand competition, the governments at the different locations will compete for being the current locus of production for the firm, and the net fiscal revenue the governments can extract in this situation drops to zero. The firm has the cost of building up excess capacities, as only these allow the firm to shift production as a reaction to the fiscal conditions provided in the different locations, but the advantage is that the actual production that constitutes the tax base is truely mobile even in the short run and can easily be shifted.

Stock effects and agglomeration In a dynamic framework a major distinction is between the stock of capital invested in a country that is typically embodied in physical capital that is completely immobile or very expensive to relocate, and the flow of additional net investment in a given period. When countries choose their tax rate in a given period, they have to distinguish between two effects of a high tax rate. A high tax rate will generate much revenue from taxing the existing, old stock of capital. However, a high tax may discourage the formation of new capital and may discourage investors of new capital in this ongoing period, particularly if this high tax has to be paid by them also on this new capital in the ongoing period (Wildasin 2003). The competition for new capital occurs via the choice of the tax rate in a given period, and new capital is more likely to flow into countries with a lower ongoing rate. The choice of a low tax rate makes a country an attractive location for new investment, but brings in little tax revenue in the ongoing period.

This is the trade-off for the tax policy of a government that would like to generate a large present value of revenue from taxation of the stock of capital in a sequence of periods. In a strategic environment, a large stock of old capital can be a disadvantage for a country that competes for new capital with other

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[12]Andersson and Konrad (2003a, 2003b) explore a similar logic in the context of human capital investments, arguing that the international mobility of human capital can cure the problems created by time-consistent taxation of human capital that emerged in a closed economy. Unlike physical capital, human capital is, in fact, mobile ex-post. It is embodied in persons, but the persons are mobile.

countries: A country which has a large stock of capital has a higher opportunity cost from a reduction in its tax rate in the ongoing period than a country which has less old capital. The country with a large stock sacrifices more current tax revenue than the other country (Janeba and Peters, 1999; Marceau, Mongrain, and Wilson, 2010). For this reason, some countries may decide to extract as much as possible from the given stock of capital invested there, and leave it to other countries to attract the new investment, and this may lead to capital rich countries with high taxes and a lack of investment dynamics, and young emerging countries with low taxes and dynamic investment.

There exists an important countervailing force to this divergence in tax rates, however, if a large installed capital base has positive externalities for new investors. Such agglomeration advantages may make it attractive for new investment to locate in the country that has the large capital base, even if the tax rates are higher there than in other countries without capital agglomerations of comparable size. Baldwin and Krugman (2004) analyzed the tax competition outcome in a framework with such agglomeration advantages. They showed that an optimal tax policy of the country with the large agglomeration advantages can be limit taxation (in analogy to limit pricing in competition policy): the country chooses a tax that constitutes a strictly positive net fiscal burden for new investors, but it makes the tax sufficiently low such that this burden is smaller than or just equal to the benefits from joining the agglomeration, compared to investing in a competitor country without such agglomeration advantages, even if this competitor country chooses a zero tax. If this equilibrium exists, it can perpetuate agglomeration advantages.

Whether such a perpetuated equilibrium with limit taxation exists, and under what conditions the equilibrium is one with capital-rich high-tax countries which exploit their existing capital and suffer from lack of new investment on the one side, and capital-poor low-tax countries with strong growth is analysed by Konrad and Kovenock (2009). They show that both outcomes are possible, and which outcome emerges in the equilibrium depends on the size of the agglomeration benefit for newly attracted capital, and on the quantity of newly attracted capital in comparison to the stock of existing capital that cannot escape from taxation. They also consider the case in which existing capital and new capital can be taxed at different rates, or in which newly attracted capital receives tax holidays. In this case the agglomeration is more stable, but also the tax revenue is very small in the long run, as there is strong competition for the newly attracted capital. Empirically, asymmetric equilibrium in which one country or region chooses a high-tax strategy and extracts from the existing immobile capital base and the other country or countries compete for new investments in Russia has been the motivation for the analysis by Cai and Treisman (2005) who study this type of asymmetric equilibrium.

Information and information exchange   Relevant references: Dhillon, Perroni, Scharf (1999); Keen and Lighthart (2006, 2007).

3   Departures from the benchmark model

The benchmark model of tax competition considers a unit tax on capital. We already discussed that this is mainly for simplicity. However, this does not mean

that a replacement of the respective strategy variables or an extension of the set of such variables is inconsequential for the outcome. We already discussed a replacement of a unit tax with an ad-valorem tax rate on the return of capital, highlighting that this will generally foster tax competition. We will now briefly discuss other dimensions of competition, and the possibility of multi-dimensional action spaces.

3.1 Public goods and infrastructure expenditure

Some part of literature focuses on the choice of expenditure as the governmental decision variables, including the quantities of public goods expenditure for the resident citizens and quantities of public inputs or infrastructure that enters into the payoff functions of the mobile tax base. This approach must be considered with care. Unlike the choice of tax rates or the definition of the tax base, the admissible range of expenditure choices of one country depends on the financial constraints of the country, which, in turn, may depend on other country's actions. If the model is simply closed by assuming that a suitable tax rate needs to be chosen for equalizing the expenditure chosen and the tax revenue generated, care needs to be taken to make sure that all possible levels of expenditure that are in the strategy spaces of countries can also be generated by appropriately chosen taxes; and this condition needs to be fulfilled for any possible expenditure choice for any expenditure choice made by the other players, that is, also for expenditure choices that are not equilibrium choices. Some expenditure that would be the payoff maximizing choice for the country along the equilibrium path may become infeasible for this country if the other countries deviate from the equilibrium path, and this is not compatible with a proper description of an action space. We will address this issue and possible remedies for this problem in more detail in a later version.

3.2 Bidding for firms

The benchmark model of tax competition considers capital as a continuously divisible quantity that flows between countries, and where these flows affect the marginal product of capital in the different countries. This describes changes in the capital endowments at the intensive margin and assumes a perfectly competitive market for capital inside each country. Where countries compete for foreign direct investment, this is often not a competition for additional capital that is then used at the intensive margin, but a competition for individual firms; i.e., it is competition at the extensive margin and makes the taxed subjects strategic players. The literature has attributed considerable attention to this fact. A number of contributions consider the bidding for firms by countries that benefit from attracting the firm or a larger share of its capital in their country. Reasons for these benefits can be a reduction in per-capita cost of provision of public goods or inputs[13], increases in wage income[14], to generate technological spillovers and other external effects from attracting FDI, trade cost considerations trade cost due to local production, and others. Haufler and Wooton (1999), for instance, analyse the competition between two countries for a foreign owned monopolist and show that a large home market benefits the

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[13] See, e.g., Black and Hoyt (1989).
[14] Among these contributions is Haaparanta (1996).

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country with the larger home market if there are trade costs. The role of trade cost and market size is also important in the context of other types of imperfect competition and this paper can be seen as the starting point of a large literature that explores these effects.[15]

Ferrett and Wooton (2010a) provide a simple and fairly general framework of two countries bidding for one firm. They consider two countries A and B who can make bids y_A and y_B for attracting a firm that comes from the rest of the world. Let π_A and π_B be the gross profits of the firm from locating in A and B, respectively, and $\Gamma = \pi_A - \pi_B \geq 0$ the difference between these gross profits. Further, let w_A and w_B be the additional benefit that accrues to country A and B, respectively, if the country (and not the other country) attracts the firm. Further, let σ_A and σ_B be the shares in the firm owned by citizens of country A and B, respectively, suggesting that the welfare that accrues to country i is

$$\sigma_i(\pi_i + y_i) - y_i + w_i \text{ if } i \text{ attracts the firm} \qquad (41)$$
$$\sigma_i(\pi_{-i} + y_{-i}) \text{ if } -i \text{ attracts the firm.}$$

Assuming a suitable tie-breaking rule for the case in which a firm is just indifferent, one can characterize the equilibrium as follows: The country i that loses just makes a bid for which it is indifferent whether to lose or win, which is the case if $y_i^* = \sigma_i(\pi_i - \pi_j + y_i^* - y_j^*) + w_i$. The winning country j makes a bid that is just large enough to win against this bid, i.e., it bids $y_j^* = \pi_i + y_i^* - \pi_j$. Note that this latter condition implies $\pi_i - \pi_j + y_i^* - y_j^* = 0$, and, hence, $y_i^* = w_i$, whereas $y_j^* = \pi_i - \pi_j + w_i < w_j$. This equilibrium has nice features. First, the firm allocates where it generates the higher welfare. Second, both the bids and the equilibrium allocation is independent of ownership shares in the firm. Intuitively, the winning country makes a bid that is just large enough to attract the firm, i.e., for which $\pi_i - \pi_j + y_i - y_j = 0$. This condition is sufficient, however, for making the owners of the firm just indifferent about whether the firm locates in A or B.

Allocation efficiency can easily be destroyed. Kessing et al. (2009), for instance, apply a very similar auction framework to study the asymmetry that emerges if one country is a unitary country, and the other country is a federal union. Fiscal externalities and free-riding problems within the federal union generate a disadvantage for the federal union in a bid competition with a unitary country. A further, large group of effects is related to the dynamic nature of investment, particularly in a multi-period framework. The analysis of King et al.(1993) alludes to some of these effects. First, the location choice of a firm may involve sunk costs and may reduce the firm's mobility, making it exposed to the host government that may be tempted to extract from this firm. This is true not only if the firm becomes fully immobile, but also if some capital investment is made that is immobile or loses some of its value if it is relocated. As a result, and unless there are other means to overcoming this hold-up problem, governments may compensate firms for the extraction of tax revenue that comes later by making upfront subsidies. Second, a government of a country may incur cost of investing in infrastructure in order to increase the profitability of a firm should it locate in this country. If countries can coordinate as regards their investment choices, this may cause a non-cooperative equilibrium with

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[15]This literature includes Raff (2004), Bjorvatn and Eckel (2006), Ferrett and Wooton (2010b), Becker and Fuest (2010) and Haufler and Wooton (2010).

asymmetric investment choices in which one country invests much and the other country little.[16]

4　Agency issues

The problem of tax competition has induced a heated debate about whether tax competition is good or bad from a welfare perspective. In the workhorse model tax competition is certainly bad from a welfare point of view. If governments strictly maximize the welfare of their respective homogenous populations and essentially act as these populations themselves would do, a centralized, coordinated choice of tax rates is the equivalent of the central planning outcome. If the tax rate choices are made on the central level, any decentralized equilibrium set of tax rates could equally well be implemented, but many tax rate combinations that cannot emerge in the decentralized setting are available to a central planner, making the central planning outcome at least as good as the decentralized outcome. Hence, coordinated tax rate choices are at least as good as decentralized choices, and potentially superior to decentralized decision making (at least in the absence of commitment problems of dynamic decision problems). And, as there are several externalities at work in the context of tax rate choices on the country level, it is not surprising that the decentralized competition outcome is generically inferior to the central planner solution.[17]

The comparison between a decentralized tax competition equilibrium outcome and a centrally coordinated solution in the context of fully benevolent government is evidently not an adequate comparison. If it were, for the same reason all private market economies should be transformed back into centrally planned economies. Both centralized political decision making and decentralized decision making suffers from a number of problems other than the possible externalities between decentralized decision makers. And this needs to be taken into consideration for an evaluation of independent national tax policies. Many of these problems have to do with the fact that policy decisions are not well described as the choices of a benevolent dictator who maximizes the utility of a representative citizen in the respective country. Political decision making by countries accounts for distributional conflict inside the country. Special interest groups may lobby for their preferred tax policy. The electoral process, on the other hand, gives the median voter a key role. Further, if the current government implements decisions that reflect the current preferences of its constituency, then this causes severe commitment problems for the government. And perhaps most importantly, power is delegated to governments, and this generates a number of accountability problems between the government and its constituency, even if there were no divergence of interests inside this constituency. This accountability problem has been the main argument in the debate about whether tax competition may serve as a second-best policy, correcting for some of the inefficiencies that may emerge from the accountability problem. We start with a consideration of this latter problem.

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[16] An elegant means to overcome the problem of opportunistic behavior of the host government ex post is Janeba (2000), discussed above.

[17] This reasoning is most prominently made in Sinn's (1997) selection principle, who basically argues that governmental tasks should be centralized if the activities of one country government generate externalities to other countries.

4.1 Tax competition and Leviathan

To study the role of tax competition as an instrument for increasing the accountability of national government, Edwards and Keen (1996) modify the benchmark model with n identical countries. They assume that the government in each country i may use some of the tax revenue T_i for the provision of a public good $t_i k_i - C_i \geq 0$ which is liked by the population. They may use the amount $C_i \geq 0$ for purposes that benefit the politicians, but not the population. The payoff function that governs a government's choices of t_i and G_i is

$$L_i = x_i + G(t_i k_i - C_i) + v(C_i), \tag{42}$$

where $x_i = f_i(k_i) - f_i'(k_i)k_i + \rho c_i$ is the private consumption of the representative citizen. Assuming an interior solution, for any given tax revenue T_i that accrues as an outcome of the choices of $t_1, ..., t_n$ and the capital movements induced by this, the government allocates this T_i to C_i and G_i according to $G_i'(T_i - C_i) = v'(C_i)$, and this allocation rule is independent of other governments' choices. When the government chooses its tax rate t_i and anticipates the tax rate choices of the other country governments, it also anticipates that G_i and C_i change as a function of this tax rate choice as

$$\frac{d(t_i k_i - C_i)}{d(t_i k_i)} = 1 - \frac{dC_i}{d(t_i k_i)}. \tag{43}$$

Maximization of (L_i) by a choice of t_i yields the first-order condition which, using symmetry between the countries, can be simplified to

$$G'(.) = \frac{1}{1 + \frac{t}{k}\frac{n-1}{n}\frac{1}{f''(k)}} \tag{44}$$

with t and k denoting equilibrium values in the symmetric equilibrium. The question whether a uniform increase in all tax rates starting from the symmetric equilibrium levels then boils down to the question whether

$$\frac{d(t_i k_i - C_i)}{d(t_i k_i)}\frac{1}{1 + \frac{t}{k}\frac{n-1}{n}\frac{1}{f''(k)}} > 1. \tag{45}$$

The first term on the left-hand-side measures the increase in funds used for public good provision if the Leviathan receives additional tax revenue, and the second term measures the marginal impact on the representative citizen's welfare that is caused by an increase in these funds by one marginal unit. The product of these two expressions measures the marginal benefit due to enhanced public good provision by an expansion of T_i by one marginal unit. The right-hand side is the reduction in private consumption by this marginal unit.

Applying again the graphical tool, we can illustrate the Leviathan equilibrium for the two-country case. Consider Figure 10 that resembles Figure 2 but gives the curves slightly different interpretations. The equilibrium N is the pair of tax rates that is determined by the intersection of two reply functions $t_1^L(t_2)$ and $t_2^L(t_1)$. The iso-payoff functions $L_1(t^L, t^L)$ and $L_1(t^L, t^L)$ for the two Leviathans that pass through the Nash equilibrium are drawn as dashed lines and in grey. The combinations (t_1, t_2) in the lense formed by these curves constitute combinations of tax rates that would make both Leviathans better-off.
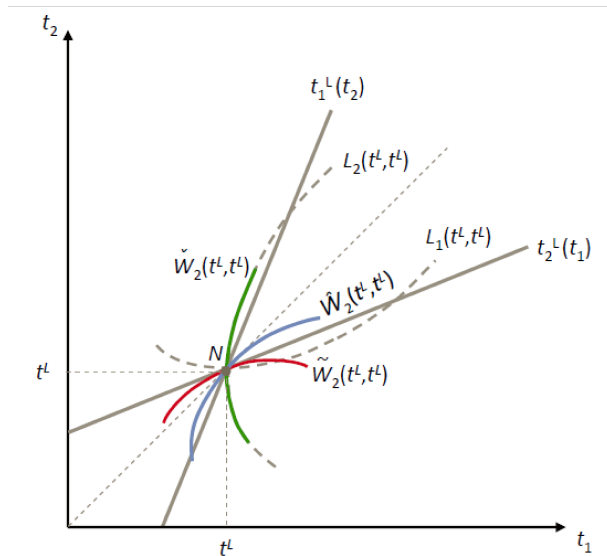
Figure 10: Leviathans optimal replies and national welfare

To determine whether a movement along the 45°-line from N to the upper-right is in the interest of the representative citizens, we need to consider the iso-welfare curves of the representative citizen. These curves at N depend on how much public good the representative citizen receives at N, and how much more public good they receive if higher tax rates are chosen. To illustrate, we can consider three cases. One case is a Leviathan who has no private consumption use from diverting public money: $v(C_i) = v'(C_i) \equiv 0$. In this case we are back to the benchmark case in which the Leviathan chooses $C_i \equiv 0$ and where the Levathan's and the representative citizen's payoff functions coincide, illustrated by the green iso-welfare curve $\check{W}_2(t^L, t^L)$ for the representative citizen of country 2. Starting from a symmetric equilibrium, a small uniform increase in tax rates is beneficial for the citizens in that benchmark model. The second case is illustrated by the iso-welfare curve $\hat{W}_2(t^L, t^L)$. It represents the critical case in which the welfare is just constant for a small variation in $t_1 = t_2$ starting from N. Finally, $\tilde{W}_2(t^L, t^L)$ represents a case in which the representative citizen does not like an increase in tax rates at N.

4.2 Accountability and benchmarking

Many supporters of independence of nation states with respect to their choices of tax rates or their tax systems more generally hint at a potentially important source of dynamic efficiency gains caused by this competition. They argue that, similar to competition between firms, the competition of nations for mobile factors, goods or individuals may make country leaders more entrepreneurial, lead to welfare increasing innovations, and reduce bureaucratic slack. Also, they argue that inter-country comparisons make it easier to rate governments and distinguish between government with higher or lower ability, and with more or

less service orientation with respect to its citizens. Much of this discussion takes place in the context of studying decentralization. However, many of the general insights of this literature also apply to fiscal competition between nations.

4.3 Voters' choices

Apart from benevolent government or selfish dictators, voting and the political process is an important element of political decision making, and this also holds for the choices of taxes. Several approaches exist that describe democratic decision making, and have been applied to the context of tax rate choices in a framework with tax competition. Brueckner (2001) and Fuest and Huber (2001) consider a median voter framework, and Ihori and Yang (2009) consider a citizen-candidate model to describe the intra-jurisdictional decision process.

A general insight from these models is that the political process may distort the intra-jurisdictional tax rate choice away from what a benevolent planner would have chosen, and this political distortion has to be compared with the distortions that are introduced through the various fiscal externalities in the context of tax competition. To illustrate this in the context of the linearized framework, suppose that voters in a country differ only regarding one dimension, e.g., their shares in the capital that is owned by each single voter. In particular, let the two countries be identical with respect to λ, c, a, etc.. Suppose further that, in each country, the median voter has ownership in capital that is lower than the mean ownership in the country: $c_m < c$. These assumptions directly yield the reply functions $t_i(t_j)$ from 24) as

$$t_i^m(t_j) = \frac{(1+2\lambda)(K-A+2a)-2c_m}{3+4\lambda} + \frac{1+2\lambda}{3+4\lambda}t_j \qquad (46)$$

A median voter's choice changes the intercept in the reply function, and for $c_\mu < c$, this reinforces the effect of tax competition. This yields reply functions $t_i^m(t_j)$ that are obtained from $t_i(t_j)$ by a downward shift, a depicted in Figure 11.

Similarly, if the median voter has a lower (higher) valuation of the public good than the λ of the benevolent government, then this has ambiguous effects. It makes the slope of the reply function less steep, and it also changes the intercept in a less predictable way.

4.4 Delegation of tax rate choices

Instead of choosing the tax rate in order to maximize national welfare, the "decision maker" in country i may also delegate the choice of t_i to an agent who follows a particular agenda. Median voter choice of a representative government is one example for this more general approach to political decision making, in which the decision is delegated to a decision maker who maximizes an objective function that differs from the social welfare function. Depending on the incentives that can be given to the delegate, this may lead to somewhat extreme forms of delegation. For instance, suppose that country 2 anticipates that country 1 delegated decision making in a way that generated a reply function $\hat{t}_1(t_2)$. Anticipating this behavior, country 2 may delegate the decision in an extreme way: $t_2 \equiv \arg\max_{t_2 \in [0,1]} W_2(t_1, \hat{t}_2(t_1))$. I.e., country 2 chooses the most preferred combination (t_1, t_2) on the opportunity locus generated by $\hat{t}_1(t_2)$. But
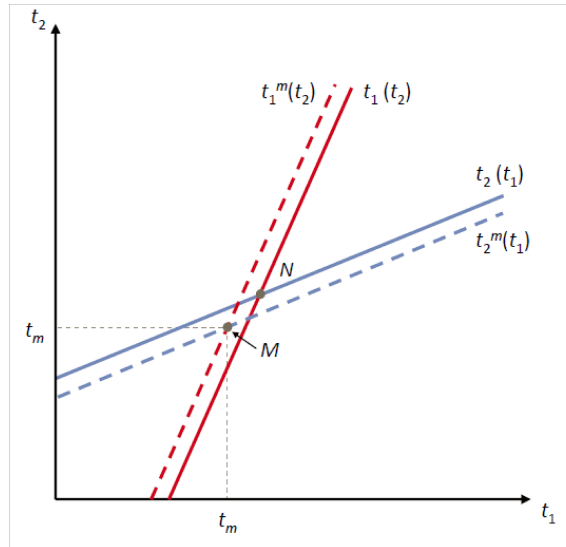
Figure 11: Median voters and tax competition

then $\hat{t}_1(t_2)$ is typically not the optimal delegation decision from the perspective of country 1. It turns out that simultaneous delegation by the two countries may actually lead to an extreme delegation: $\hat{t}_1 \equiv t^*$ and $\hat{t}_2 \equiv t^*$. The Nash equilibrium is -perhaps surprisingly- also an equilibrium of the simultaneous delegation game.

Brückner (2001) compares the strategic incentives to delegate decision making in the context of tax competition with a context in which the delegates coordinate on a cooperative outcome. If cooperation is anticipated, the decision maker who chooses the national delegate can also affect the outcome by the incentives given to the delegate. In this choice the decision maker typically faces a trade-off between enhancing overall efficiency and distributional advantages obtained from the interaction between the delegates. As he shows, this may cause that a median voter appoints a delegate who is interested in low taxes.

4.5 Lobbying by interest groups

We can also allow for lobbying activities by some powerful groups. Just as the median voter is likely to be less capital rich than the mean per capita amount of capital ownership, we may expect that the capital owners would not simply like to give in to the median voter outcome. Instead, they may lobby in the political process, trying to shift the reply function "downward" towards lower capital taxes. Applied to the worhorse model here, this should actually foster the effects of tax competition. Chirinko and Wilson (2010) report evidence suggesting that business campaign contributions in a country may affect the tax reaction function and influence tax policy.
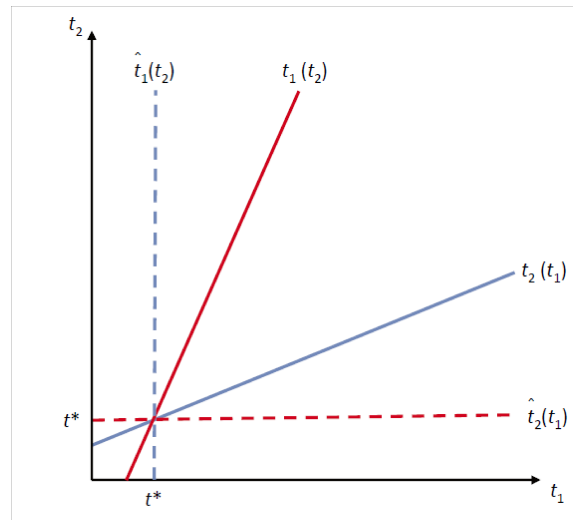
Figure 12: Perfect commitment and tax competition

5 Conclusions

To be written.

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