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Capital Tax Competition with Three Tax Instruments*

By Wolfgang Eggert**

1. Introduction

A flood of literature on capital tax competition among countries emphasizes the role of international capital mobility for the efficiency of decentralized fiscal policy in a world with distortionary taxation.[1] A first counterexample against the standard result that Nash strategies of governments lead to an inefficient equilibrium is made by Razin and Sadka (1991) in a model of a small open economy in which savings and labor supply decisions are endogenous. Basically, the main conclusion of their analysis is that a tax competition equilibrium in source-based capital taxes is Pareto inferior to a tax competition equilibrium in residence-based capital taxes. However, as an application of the inverse elasticity rule of optimal taxation theory, they also conclude that tax authorities abstain from taxing capital income if the residence-based capital tax is not enforceable. In this case, the full tax burden falls on the internationally immobile factors such as labor. When a wage tax is available, governments of small countries choose not to levy source-based capital taxes.[2]

In a seminal article, Bucovetsky and Wilson (1991) derive the consequences of non-cooperative tax policy for the efficiency of decentralized fis-

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1 Seminal articles are from, among others, Zodrow and Mieszkowski (1986), Wilson (1986) and Wildasin (1989). Other authors study the consequences of tax competition in the context of a Leviathan type government [cf. Sinn (1992), Edwards and Keen 1996)], introduce wage inflexibilities created by trade unions [cf. Lorz and Stähler 1997)] or discuss stability issues [cf. Koch and Schulze 1998)].

2 However, some contributions demonstrate that positive source-based capital taxes will be levied in a small open economy, if there are constraints on wage or profit taxation or, if foreigners own some part of the domestic capital stock [cf. Bruce (1992), Huizinga and Nielsen (1997)].

cal decisions in tax competition environments when countries are large and have an influence on the interest rate. They analyze a subset of situations which we consider here, by restricting their analysis to Nash equilibria in wage taxes and source-based capital taxes, on the one hand, and source- and residence-based capital taxes, on the other hand. The main conclusions of their analysis are twofold. In the first case, the set of available taxes includes a wage tax and a source-based capital tax. In a word, the argument is that the wage tax distorts the individual's labor/leisure choice and likely reduces the quantity of labor supplied. This leads to a decline in capital's marginal productivity and causes capital outflows. As Bucovetsky and Wilson prove, the decentral Nash equilibrium in wage taxes and source-based capital taxes is inefficient and governments underprovide public goods. We show that this result will no longer hold if governments are able to raise a residence-based capital tax in addition.

Secondly, under the assumption that wage income is left untaxed, Bucovetsky and Wilson prove the efficiency of a Nash equilibrium in source- and residence-based capital taxes. In the introduction, they justify the assumption that the wage tax is absent – while both capital taxes are supposed to be sustainable in this second scenario – and argue that an extension of Gordon's (1986) optimal taxation model to an international setting "eliminates any tendency for regional governments to underprovide public goods". However, this argument has not yet been proved formally. Moreover, wage taxes bear the larger part of public expenditures according to the data. Hence, a straightforward extension of previous models to the case of a tax competition game with a complete set of distortionary taxes is valuable – both from a theoretical and a practical perspective.

Our paper makes one primary point. By relaxing the constraints put upon the set of available taxes, we show that in an environment of identical, large countries, the desirability of a source-based capital tax disappears only if taxes on wages *and* savings (i.e. a residence-based capital tax) are available. If the set of available taxes is unconstrained, decentralized fiscal decisions of governments lead to an efficient Nash equilibrium, irrespective of the size of countries in the capital market. In fact, this result is closely related to the logic of Diamond-Mirrlees' (1971) Production Efficiency lemma, according to which the equilibrium with optimal commodity taxation should be on the frontier of the aggregate production set. In the framework being applied, an optimal commodity tax system would generally be equivalent to a direct tax system which involves non-zero taxes being levied on the incomes of all factors subject to choice (i.e. labor and savings).

The important generalization offered here may appear to conflict with the standard evidence supporting the absence of source-based capital taxes. The argument usually applied in the literature is mainly suggested by the inverse elasticity rule from optimal taxation theory. In the *price-taking* environment of small countries, production taxes will not be levied because of the high tax elasticity of international capital movements perceived by governments. Gordon (1992, p. 1161) argues "Diamond-Mirrlees showed that a small, open economy should not tax capital income at source". However, in the context of small countries, the zero source-based capital tax result only hinges upon the availability of some second tax instrument, i.e. a tax on wages [Razin and Sadka (1991)] and not on the availability of a direct tax system, which should be equivalent to an optimal commodity tax system. In contrast, in the *non-price-taking* environment of large countries used in this model, governments choose not to levy source-based capital taxes, despite a finite tax elasticity of international capital movements. In our framework, the zero tax result critically hinges upon the availability of wage taxes *and* residence-based capital taxes. Since both taxes must be available to derive a zero source-based tax on capital, it is this analytical setting of large countries which comes close to an international version of Diamond-Mirrlees' argument.

An implication of our analysis is that the constrained efficient scenario in Bucovetsky and Wilson's model – in which the wage tax is absent and a combination of residence-based and source-based capital taxes is available for fiscal authorities – proves to be Pareto inferior, when compared to the tax competition equilibria considered here, in which both wage and residence-based capital taxes exist. Moreover, our analysis clearly reveals that the scope for efficiency enhancing tax coordination is primarily a question of the constraints put upon the set of available taxes. A valuable side-effect of our analysis is that we link different branches of a huge body of literature on capital tax competition in a unified framework. In our concluding remarks, we provide a summary of existing results and our new results [cf. table 2].

The paper is structured as follows. Section two portrays the optimization problem of households and firms, derives first-order conditions for a welfare-improving tax reform and then introduces the Nash equilibrium on the capital market. Section three discusses efficient tax rules. Section four contrasts these efficient tax structures with those yielded in the Nash equilibrium. Finally, section five draws some conclusions and suggests possible extensions.

2. The Model and Nash Equilibrium

We follow Bucovetsky and Wilson (1991) and consider a system of n identical regions or countries. The identical countries are large and possess market power. However, governments choose the same tax rates in the Nash equilibrium. This enables us to restrict attention to symmetric outcomes, in which each country's net capital exports are zero. The incentives to manipulate the international distribution of income, via exploitation of terms of trade effects, are thereby eliminated. In all countries, a homogeneous good is produced, using capital and labor as factors of production. The price of output is normalized to equal one. In order to concentrate on the efficiency problems faced by countries competing for scarce capital, individuals are assumed to be internationally immobile, whereas capital is perfectly mobile.[3]

Before we discuss the tax competition issue, we must describe the building blocks of our model, i.e. the individual, the productive sector, the government and the Nash equilibrium. Turning first to the individual's problem, we employ a standard framework in which labor supply and savings decisions can be modeled. Consumers in each country live for two periods. In the first period, the representative consumer divides his given endowment between current consumption and savings in order to finance some part of second period consumption. During the second period, the individual chooses how much labor to supply and governments use the tax revenue collected in order to provide a local public good.[4]

Going into details, the individual in each country strives to maximize a well-behaved direct utility function that is separable between private and public goods:[5]

$$U(e-s, x, T-L) + \widetilde{U}(g) \;, \tag{2.1}$$

where e denotes capital endowment, s specifies savings, x stands for private consumption in the second period, T describes time endowment and L labor supply. Hence, $e-s$ denotes private consumption in the first period and

[3] Prominent articles which investigate into decentral fiscal decisions in models with international capital and household mobility are Burbidge and Myers (1994) and Wellisch (1995). The latter also allows for environmental spill-over effects. Different degrees of household mobility are analyzed and it is shown that Nash equilibria can be efficient if international transfers of resources are feasible. However, in these models, the world capital stock and world population are fixed. In contrast, our focus is on the distortions of factor supply decisions in an international context.

[4] A simplifying assumption of the model is that individuals do not supply labor in the first and capital in the second period (and do not derive utility from the public good in the first period). We adopt this specification for two reasons. First, we wish to focus attention on savings and labor supply decisions; the intertemporal dynamics on labor and capital markets are not our concern. Second, in keeping with most two-period tax competition analyses we simply wish to hold the model tractable, by allowing agents to optimize on two margins only.

[5] Due to the identity assumption, the equations for the countries are similar and we can exclude indices in the presentation.

$T - L$ leisure consumed. The government provides a local public good g that enters the utility function. Due to the usual separability assumption, goods consumed are independent of the level of public good supply, which is exogenous from the perspective of the consumer. Residents are price-takers and choose their levels of private consumption to maximize utility subject to the budget constraint:

$$(e - s) + \frac{x}{r - t^r} = \frac{w - t^w}{r - t^r} L + e \ , \tag{2.2}$$

where

$r - t^r$ = interest rate, r, net of the residence-based capital tax, t^r,
$w - t^w$ = gross wage rate, w, net of the wage tax, t^w.

Thus, (2.2) simply states that the present value of private consumption must equal net lifetime earnings. Using the definitions introduced in (2.2) and solving the problem defined above in the usual way, we arrive at the following standard first-order conditions [see equations (A.2) in the appendix]:

$$U_s / U_x = r - t^r, \tag{2.3.a}$$

$$U_L / U_x = w - t^w, \tag{2.3.b}$$

where subscripts denote partial derivatives here and in the subsequent analysis. Hence, $\partial U / \partial s \equiv U_s$ denotes the marginal utility of savings and $\partial U / \partial x \equiv U_x$ the marginal utility of consumption in period two. The term $\partial U / \partial L \equiv U_L$ represents the marginal utility of labor.

We note that the effects of parameter changes on the utility maximizing quantities of factors supplied are difficult to sign at this level of generality. Using the implicit function rule along with (2.3), it can be shown that the effects of price changes on *uncompensated* labor supply, L, and savings, s, are generally ambiguous, due to the interaction of income and cross-price substitution effects.

Focusing on *compensated* factor supply, from the second-order conditions follows that own-price effects of compensated labor supply, $\mathfrak{L}$, and savings, $\mathfrak{s}$, are positive, and the symmetry of the Slutsky matrices implies equality of all compensated cross-price elasticities [see eqs. (A.7) in the appendix]. Following Bucovetsky and Wilson, we assume that leisure is a Hicksian substitute with first period's consumption. Hence:

$$\mathfrak{s}_r > 0, \qquad \mathfrak{L}_w > 0, \qquad \mathfrak{s}_w = \mathfrak{L}_r < 0 \ ,$$

where subscripts represent partial derivatives. Therefore, $\mathfrak{s}_r$ denotes the reaction of compensated savings due to a change in the rate of interest, and $\mathfrak{L}_w$ states the effects on compensated labor supply induced by wage changes. Cross-price effects on compensated savings and labor supply are represented by $\mathfrak{s}_w, \mathfrak{L}_r$.

In the next step, we use the Slutsky equations. This establishes the following relationship between uncompensated and compensated derivatives:[6]

$$\phi \equiv kL_w - lL_r = k\mathfrak{L}_w - l\mathfrak{L}_r \ , \tag{2.4a}$$

$$\psi \equiv ls_r - ks_w = l\mathfrak{s}_r - k\mathfrak{s}_w \ , \tag{2.4b}$$

where k denotes national investment and l labor used.

The productive sector of each country is described by a constant-returns-to-scale production function, $f(k,l)$, which exhibits the usual properties of positive and decreasing marginal products, $f_k > 0$, $f_l > 0$, $f_{kk} < 0$, $f_{ll} < 0$. Again, derivatives are indicated by subscripts. The familiar zero-profit condition is given by:

$$f(k,l) - (r + t^s)k - wl = 0 \ . \tag{2.5}$$

In (2.5) a source-based capital tax, t^s, is introduced as the third tax instrument. The tax is levied on all capital invested in the country. The first-order conditions for firm optimization require that:

$$f_l - w = 0 \ , \tag{2.6a}$$

$$f_k - (r + t^s) = 0 \ . \tag{2.6b}$$

As the labor and capital markets are competitive, profit maximization, in the choice of labor and capital by firms, implies that marginal products of labor and capital must be equated to their marginal cost. Using (2.6) in (2.5), we differentiate the resulting expression $f(k,l) = f_k k + f_l l$ with respect to k and l, which shows:

$$f_{lk} = -f_{kk}\frac{k}{l} \ , \tag{2.7a}$$

$$f_{kl} = -f_{ll}\frac{l}{k} \ . \tag{2.7b}$$

6 As can be shown using the Slutsky decompositions presented in the appendix, income effects simply cancel out in (2.4), in the transition from uncompensated to Hicksian formulae. To derive (2.4), notice that the full employment condition for the labor market requires $l = L$. Moreover, savings equal investment $k = s$ in the closed country as well as in a symmetric Nash equilibrium.

Finally, implicitly differentiating (2.5) and using (2.6) yields a negatively-sloped factor price frontier:

$$\frac{\partial w}{\partial r} = -\frac{k}{l} \ . \tag{2.8}$$

In passing, it should be noted that, from (2.6b), under source-based capital taxation, a tax wedge is driven between the marginal productivity of capital, f_k, and the world interest rate, r. A higher source-based capital tax increases the marginal cost of capital and hence distorts firms' investment decisions. In contrast, a residence-based capital tax drives a wedge between the rate of time preference and the interest rate [see (2.3a)]. As a result, it is not the investment decision, but the willingness of residents to supply capital, which will be distorted.

Each government maximizes the utility of the representative consumer by choosing capital and wage taxes, assuming that the tax rates of all other jurisdictions are not a function of one's own choice of rates. Or, equivalently, each government's behavioral assumption is that of Nash conjectures concerning its competitors, and it chooses the set of factor prices that maximizes welfare, subject to the resource constraint R:

$$R \equiv t^w L + t^r s + t^s k - c(g) = 0 \ , \tag{2.9}$$

where $c(g)$ denotes the per capita cost function of public good production, which is assumed to increase monotonically. Since all costs are measured in units of the numéraire, c_g equals the marginal rate of transformation between the numéraire and the public good [cf. Wildasin (1984, p. 231)].

The objective function of the government is the individual's indirect utility function. Due to the separability of the direct utility function, the level of public good supply, g, enters the indirect utility function:

$$V \equiv U\big(e - s(t^s, t^r, t^w), x(t^s, t^r, t^w), T - L(t^s, t^r, t^w)\big) + \tilde{U}(g) \ , \tag{2.10}$$

which the government strives to maximize, subject to the public resource constraint (2.9). The Lagrangean of the problem:

$$\mathcal{W} \equiv V(\ldots) - \Lambda R \ , \tag{2.11}$$

is supposed to be strictly concave in each of the taxes, in order for the second-order conditions to hold. The Lagrange parameter, Λ, will be reinterpreted below.

In the opening paragraph of the paper we argued that the efficiency properties of a tax competition game are primarily a question put upon the set of available taxes. Hence, the main theme of the paper is to consider a variety of institutional settings as special cases of a unified framework. For various reasons, governments may not have the complete set of wage (t^w), residence-based (t^r) and source-based (t^s) capital taxes at their disposal. For instance, a residence-based capital tax is difficult to enforce in the European Community for compliance reasons. Therefore, it is sensible to consider solutions of the maximizing problem (2.11) to situations in which all taxes are feasible for fiscal policy, as well as solutions to situations in which governments only have access to an incomplete set of taxes, i.e. the rate of one instrument is zero. The first-order conditions of the government's problem read:

$$\text{(2.12a)} \quad \frac{\partial \mathcal{W}}{\partial t^s} = -U_s \frac{\partial s}{\partial t^s} + U_x \frac{\partial x}{\partial t^s} - U_l \frac{\partial L}{\partial t^s} - \Lambda k - \Lambda k \left(\frac{\partial L}{\partial t^s} \frac{t^w}{k} + \frac{\partial s}{\partial t^s} \frac{t^r}{k} + \frac{\partial k}{\partial t^s} \frac{t^s}{k} \right) = 0 \; ,$$

$$\text{(2.12b)} \quad \frac{\partial \mathcal{W}}{\partial t^r} = -U_s \frac{\partial s}{\partial t^r} + U_x \frac{\partial x}{\partial t^r} - U_l \frac{\partial L}{\partial t^r} - \Lambda s - \Lambda s \left(\frac{\partial L}{\partial t^r} \frac{t^w}{s} + \frac{\partial s}{\partial t^r} \frac{t^r}{s} + \frac{\partial k}{\partial t^r} \frac{t^s}{s} \right) = 0 \; ,$$

$$\text{(2.12c)} \quad \frac{\partial \mathcal{W}}{\partial t^w} = -U_s \frac{\partial s}{\partial t^w} + U_x \frac{\partial x}{\partial t^w} - U_l \frac{\partial L}{\partial t^w} - \Lambda L - \Lambda L \left(\frac{\partial L}{\partial t^w} \frac{t^w}{L} + \frac{\partial s}{\partial t^w} \frac{t^r}{L} + \frac{\partial k}{\partial t^w} \frac{t^s}{L} \right) = 0,$$

$$\text{(2.12d)} \quad \frac{\partial \mathcal{W}}{\partial g} = \tilde{U}_g + \Lambda c_g = 0 \; .$$

Due to our assumptions about the utility function, the identification of optimal tax rates can be separated from the problem of determining optimal public good supply, which would generally require solving system (2.12) simultaneously. The separability assumption facilitates the optimization problem to a great extent, by enabling a two-stage solution. First, the government sets public consumption to satisfy the modified Samuelson condition (2.12d). Then, in the second stage, the government chooses tax rates according to first-order conditions (2.12a) - (2.12c).

In the following, we concentrate on the second stage of the optimization process, assuming that the government sets public supply according to (2.12d) in the first stage. Multiplying the terms in brackets in (2.12) by minus one yields the effects of increasing one tax instrument, t^s, t^r or t^w, on all tax bases, which are denoted by variables $\varepsilon_k, \varepsilon_s$ and ε_l. We largely follow Schöb (1994, p. 91) and define the tax effects, represented by $\varepsilon_k, \varepsilon_s$ and ε_l, as tax elasticities. In the next step, we carry out some straightforward manipulations, in order to simplify (2.12). Using the first-order conditions of the representative individual and the property of linear homogeneity of the production function, the following conditions (with instruments being optimized shown in parentheses) characterize an efficient allocation [see the prove in eqs. (A.8) - (A.11) in the appendix]:

$$(2.13a) \qquad (t^s): \qquad -\Lambda = U_x/(1-\varepsilon_k)\ ,$$

$$(2.13b) \qquad (t^r): \qquad -\Lambda = U_x/(1-\varepsilon_s)\ ,$$

$$(2.13c) \qquad (t^w): \qquad -\Lambda = U_x/(1-\varepsilon_l)\ .$$

Using system (2.13), it is easy to describe any tax reform which either replaces one particular tax by another, or finances a marginal unit of additional public good supply by increasing a tax. From these conditions it follows that a tax reform is desirable if, and only if, the marginal cost of public funds, Λ, associated with the tax increased, is lower than the marginal cost of the tax lowered [cf. Kay (1980), Schöb (1994)]. Notice, in the optimum, the marginal cost of all available taxes are equalized. If they are not equal, the existing tax system is not optimal. If marginal costs do not match, those taxes with the largest values should be reduced, since collecting revenue via these taxes would lead to a larger welfare loss per unit of revenue than would taxes with low marginal costs. Technically, this means that all first-order conditions of instruments chosen endogenously must simultaneously hold with strict equality, whereas the conditions of instruments being unfeasible due to exogenous restrictions are redundant. If the government only has two of the three taxes at its disposal, the optimal tax structures for all three possible combinations of the remaining two taxes are:

$$(2.14) \qquad \frac{t^s}{t^r} = \frac{\frac{\partial s}{\partial t^r}k - \frac{\partial s}{\partial t^s}s}{\frac{\partial k}{\partial t^s}s - \frac{\partial k}{\partial t^r}k} \qquad \wedge \qquad t^w = 0\ ,$$

$$(2.15) \qquad \frac{t^s}{t^w} = \frac{\frac{\partial l}{\partial t^w}k - \frac{\partial l}{\partial t^s}l}{\frac{\partial k}{\partial t^s}l - \frac{\partial k}{\partial t^w}k} \qquad \wedge \qquad t^r = 0\ ,$$

$$(2.16) \qquad \frac{t^r}{t^w} = \frac{\frac{\partial l}{\partial t^r}l - \frac{\partial l}{\partial t^w}s}{\frac{\partial s}{\partial t^w}s - \frac{\partial s}{\partial t^r}l} \qquad \wedge \qquad t^s = 0\ .$$

If the set of available taxes is unconstrained, the first-order conditions of all instruments in (2.13) have to be fulfilled with strict equality. Hence:

$$(2.17a) \qquad \frac{t^s}{t^r} = \frac{k\left(\frac{\partial l}{\partial t^w}\frac{\partial s}{\partial t^r} - \frac{\partial l}{\partial t^r}\frac{\partial s}{\partial t^w}\right) + l\left(\frac{\partial l}{\partial t^r}\frac{\partial s}{\partial t^s} - \frac{\partial l}{\partial t^s}\frac{\partial s}{\partial t^r}\right) + s\left(\frac{\partial l}{\partial t^s}\frac{\partial s}{\partial t^w} - \frac{\partial l}{\partial t^w}\frac{\partial s}{\partial t^s}\right)}{k\left(\frac{\partial k}{\partial t^w}\frac{\partial l}{\partial t^r} - \frac{\partial k}{\partial t^r}\frac{\partial l}{\partial t^w}\right) + l\left(\frac{\partial k}{\partial t^r}\frac{\partial l}{\partial t^s} - \frac{\partial k}{\partial t^s}\frac{\partial l}{\partial t^r}\right) + s\left(\frac{\partial k}{\partial t^s}\frac{\partial l}{\partial t^w} - \frac{\partial k}{\partial t^w}\frac{\partial l}{\partial t^s}\right)}\ ,$$

$$(2.17b) \qquad \frac{t^s}{t^w} = \frac{k\left(\frac{\partial l}{\partial t^r}\frac{\partial s}{\partial t^w} - \frac{\partial l}{\partial t^w}\frac{\partial s}{\partial t^r}\right) + l\left(\frac{\partial l}{\partial t^s}\frac{\partial s}{\partial t^r} - \frac{\partial l}{\partial t^r}\frac{\partial s}{\partial t^s}\right) + s\left(\frac{\partial l}{\partial t^w}\frac{\partial s}{\partial t^s} - \frac{\partial l}{\partial t^s}\frac{\partial s}{\partial t^w}\right)}{k\left(\frac{\partial k}{\partial t^w}\frac{\partial s}{\partial t^r} - \frac{\partial k}{\partial t^r}\frac{\partial s}{\partial t^w}\right) + l\left(\frac{\partial k}{\partial t^r}\frac{\partial s}{\partial t^s} - \frac{\partial k}{\partial t^s}\frac{\partial s}{\partial t^r}\right) + s\left(\frac{\partial k}{\partial t^s}\frac{\partial s}{\partial t^w} - \frac{\partial k}{\partial t^w}\frac{\partial s}{\partial t^s}\right)}\ ,$$

$$(2.17c) \qquad \frac{t^r}{t^w} = \frac{k\left(\frac{\partial k}{\partial t^r}\frac{\partial l}{\partial t^w} - \frac{\partial k}{\partial t^w}\frac{\partial l}{\partial t^r}\right) + l\left(\frac{\partial k}{\partial t^s}\frac{\partial l}{\partial t^r} - \frac{\partial k}{\partial t^r}\frac{\partial l}{\partial t^s}\right) + s\left(\frac{\partial k}{\partial t^w}\frac{\partial l}{\partial t^s} - \frac{\partial k}{\partial t^s}\frac{\partial l}{\partial t^w}\right)}{k\left(\frac{\partial k}{\partial t^w}\frac{\partial s}{\partial t^r} - \frac{\partial k}{\partial t^r}\frac{\partial s}{\partial t^w}\right) + l\left(\frac{\partial k}{\partial t^r}\frac{\partial s}{\partial t^s} - \frac{\partial k}{\partial t^s}\frac{\partial s}{\partial t^r}\right) + s\left(\frac{\partial k}{\partial t^s}\frac{\partial s}{\partial t^w} - \frac{\partial k}{\partial t^w}\frac{\partial s}{\partial t^s}\right)}\ .$$

On the basis of these criteria, evaluations of distortionary tax systems will be carried out in the next sections.

We now turn to the Nash equilibrium. According to (2.14) - (2.17), the rationally acting government in each of the n countries must take the responses of households and firms into account when choosing instruments. In the following, indices $\{i, a\}$ stand for home and for the $(n-1)$ countries abroad. Factors supplied and demanded, $\{k^j, s^j, l^j, L^j\} \forall j \in \{i, a\}$, and factor prices, $\{w^j, r\}$ $\forall j \in \{i, a\}$, can be derived as implicit functions of the tax instruments $\{t_j^s, t_j^r, t_j^w\}$ $\forall j \in \{i, a\}$ from the system:

$$U_l^j - (w_j - t_j^w) U_x^j = 0 \quad \forall j \in \{i, a\} \ , \tag{2.18a}$$

$$U_s^j - (r - t_j^r) U_x^j = 0 \quad \forall j \in \{i, a\} \ , \tag{2.18b}$$

$$f_l^j - w^j = 0 \quad \forall j \in \{i, a\}, \tag{2.18c}$$

$$f_k^j - (r + t_j^s) = 0 \quad \forall j \in \{i, a\}, \tag{2.18d}$$

$$l^j - L^j = 0 \quad \forall j \in \{i, a\}, \tag{2.18e}$$

$$k^i - s^i + (n-1)(k^a - s^a) = 0 \ , \tag{2.18f}$$

where we have 11 equations in the 11 endogenous variables. The equations denote in pairs the first-order conditions of households and firms in all countries, given by (2.3) and (2.6) respectively, and the market clearing conditions for national labor and the international capital markets. The latter implicitly determines the world rate of capital return and is defined by the requirement that capital balances, summed over all countries, add up to zero.

Table 1

Comparative Static Results

$$\frac{\partial k}{\partial t^s} = \frac{n-1}{n} \frac{1 - f_{ll} L_w}{f_{kk}} + \frac{f_{ll} Z - kls_r}{nN} \ , \qquad \frac{\partial k}{\partial t^r} = -\frac{n-1}{n} \frac{f_{ll} l}{f_{kk} k} L_r + \frac{f_{ll} Z - kls_r}{nN} \ ,$$

$$\frac{\partial s}{\partial t^s} = -\frac{n-1}{n} \frac{k}{l} s_w + \frac{f_{ll} Z - kls_r}{nN} \ , \qquad \frac{\partial s}{\partial t^r} = -\frac{n-1}{n} s_r + \frac{f_{ll} Z - kls_r}{nN} \ ,$$

$$\frac{\partial l}{\partial t^s} = -\frac{n-1}{n} \frac{k}{l} L_w + \frac{k f_{kk} Z - l^2 L_r}{lnN} \ , \qquad \frac{\partial l}{\partial t^r} = -\frac{n-1}{n} L_r + \frac{k f_{kk} Z - l^2 L_r}{lnN} \ ,$$

$$\frac{\partial k}{\partial t^w} = -\frac{n-1}{n} \frac{f_{ll} l}{f_{kk} k} L_w + \frac{l f_{ll} Z - k^2 l s_w}{knN} \ ,$$

$$\frac{\partial s}{\partial t^w} = -\frac{n-1}{n} s_w + \frac{l f_{ll} Z - k^2 l s_w}{knN} \ , \qquad \text{where} \quad Z \equiv l\phi s_r + k L_w \psi - \phi\psi \ ,$$

$$\frac{\partial l}{\partial t^w} = -\frac{n-1}{n} L_w + \frac{f_{kk} Z - kl L_w}{nN} \ , \qquad N \equiv kl - f_{ll} l \phi - f_{kk} k \psi \ .$$

Our basic analytical objective is to solve the capital market equilibrium (2.18) for the own-tax induced changes in k^i, s^i, l^i. Cramer's rule can be applied after full differentiation of (2.18) to obtain the influence of a marginal increase in the domestic tax. Comparative static effects are derived in the appendix A.3 and summarized in table 1.[7] In the next step, we insert the equations into the relevant first-order conditions for the local government (2.14) - (2.17) and distinguish different fiscal scenarios by the number of available taxes. A unique condition, indicating the optimal tax structure, is immediately yielded for each of the underlying tax environments.

3. Efficient Tax Policy

As a benchmark, let us first consider the case of full coordination. The identity assumption used in the present framework makes the characterization of efficient fiscal policies more convenient, since there will never be a reason for factor movements between countries equal in all respects. Due to the absence of a motive for trade in the model, the best a government in an open economy can do, is to replicate the tax structure in the closed country. Against this benchmark, we can discuss the Nash equilibrium in the next section.[8]

To characterize the tax structure in the closed economy, we take advantage of our formulation of the capital market clearing condition (2.18f). For $n = 1$, the home country is closed to international capital flows and we have $\frac{\partial k}{\partial t^s} = \frac{\partial s}{\partial t^s} = \frac{\partial k}{\partial t^r} = \frac{\partial s}{\partial t^r}$ from the comparative static effects summarized in table 1. Of course, for $n = 1$, we also obtain $\frac{\partial l}{\partial t^s} = \frac{\partial l}{\partial t^r}$. There is no distinction between a source-based and a residence-based capital tax, which should be obvious, since tax bases match in the closed economy, as (2.18f) collapses to $k = s$. The government only has one capital tax, and the tax rate is determined by the revenue requirement.

7 Notice that we can exclude indices after total differentiation of (2.18), as a consequence of the identity assumption.

8 In our Arrow-Debreu economy, a unique equilibrium should exist under the assumptions (i) of identical countries, (ii) each populated with a representative consumer which (iii) has quasi-concave preferences and (iv) given that production technology is convex. In contrast, Gottfried (1996) demonstrates that non-uniqueness of efficient allocations is relevant in tax competition models in which countries are unequal, if a government voluntarily makes transfers of resources to the other in order to control international factor movements. However, as DePater and Myers (1994) argue, a unique, efficient allocation exists, which is represented by the closed economy's allocation, if countries are identical in all respects. Hence, under the assumptions (i) - (iv), there should exist a unique equilibrium.

This result is also reflected by tax rules. Inserting the comparative static effects, given by table 1, into the relevant first-order conditions of the government (2.15) and (2.16) and yields in the closed economy setting:

$$\text{(3.1a)} \qquad \frac{t^s}{t^w} = \frac{\phi}{\psi} \, ,$$

$$\text{(3.1b)} \qquad \frac{t^r}{t^w} = \frac{\phi}{\psi} \, ,$$

according to which t^s and t^r denote an identical tax instrument. The sum of t^s and t^r determines the capital tax rate. Keeping this in mind, we can use (3.1a), (3.1b) and any combination of t^s, t^r to characterize the tax structure in a closed economy, which is the efficient benchmark for the subsequent analysis.

4. Tax Policy in an Integrated World

We now consider tax structures in an open economy in three scenarios, when governments have access to a wage tax, a source-based capital tax and a residence-based capital tax in any combination of two instruments. Moreover, we also consider the case when all three taxes are available simultaneously.

The assumption of identical countries makes the model much like a closed economy, albeit with different tax elasticities perceived by governments if the country is opened. In contrast to the benchmark, the perceived tax elasticities of the source-based tax, ε_k, and the residence-based tax, ε_s, are generally different when $n > 1$, as can be seen from the comparative static results given in table 1. Hence, both capital taxes are no longer identical instruments for a government. Table 1 as well suggests that the tax elasticity of the wage tax, ε_l, is also likely to change in transition from the benchmark to the case $n > 1$. According to the intuition of optimal taxation theory [formally by conditions (2.13)], these changes of the perceived tax elasticities have a distinct impact upon the tax structures chosen by a government engaged in capital tax competition. In the following analysis of the efficiency properties of a Nash equilibrium, the incentives of governments to set taxes strategically will be examined in detail.

However, beforehand we shall shortly derive some results referring to the subsequent discussion. The influence of a marginal increase in the domestic tax on the home capital balance, $M \equiv k - s$, is given by:

$$\frac{\partial M}{\partial t^r} = \frac{n-1}{n}\frac{f_{kk}ks_r - f_{ll}lL_r}{f_{kk}k}\ , \tag{4.1a}$$

$$\frac{\partial M}{\partial t^s} = \frac{n-1}{n}\frac{l + f_{kk}ks_w - f_{ll}lL_w}{f_{kk}l}\ , \tag{4.1b}$$

$$\frac{\partial M}{\partial t^w} = \frac{n-1}{n}\frac{f_{kk}ks_w - f_{ll}lL_w}{f_{kk}k}\ . \tag{4.1c}$$

With $\partial M/\partial t^s < 0$ and $\partial M/\partial t^r > 0$, the capital market equilibrium satisfies the conditions for local dynamic stability. Equation (4.1c) then implies that $\partial M/\partial t^w < 0$. As the following analysis proves, the tax induced effects on the net capital balance represent the crucial effects in the present model for the incentives that exist for a fiscal authority in an open country to pursue non-cooperative tax policy, when factor supply is endogenous.[9]

To proceed, we first analyze the outcome of the Nash tax competition game with two taxes, so that the set of fiscal instruments is constrained. Then, we analyze the tax competition game with a complete set of three tax instruments.

No residence-based capital taxes: Before turning to our own results, we shall discuss briefly the two scenarios which where previously analyzed by Bucovetsky and Wilson (1991). In the first case, the government can only impose wage and source-based capital taxes. Hence, the first-order condition (2.13b) is redundant, since the residence-based capital tax is not allowed [$t^r = 0$]. Taking this into account and inserting the comparative static effects, given by table 1, into condition (2.15) yields:

$$\frac{t^s}{t^w} = \frac{f_{kk}k\phi}{f_{kk}k\psi + (n-1)(f_{ll}l\phi + f_{kk}k\psi - kl)}\ , \tag{4.2}$$

which states that the rates of both taxes are positive under our assumptions. In the case of a closed country, $n = 1$, equation (4.2) shortens to the benchmark tax structure (3.1a):

$$\frac{t^s}{t^w} = \frac{\phi}{\psi}\ .$$

A comparison of (4.2) and (3.1a) proves that decentralized fiscal decisions lead to an inefficient equilibrium, given the available taxes. Since the coun-

9 In order to contrast equations (4.1) with the incentives in the standard static model, it can be recorded that the effects reduce to $\partial M/\partial t^s < 0$, $\partial M/\partial t^r = 0$ and $\partial M/\partial t^w = 0$ with exogenous factor supply. The intuition is that residence-based capital taxes and labor taxes are lump-sum when factor supply is given.

try's size, n, is relevant to the optimal tax ratio in an open country, one or both taxes in (4.2) are set at an inefficient level. Moreover, notice the absence of source-based capital taxes in the *small* country case, $n \to \infty$. This is a well-established result in the literature [cf. Razin and Sadka (1991)]. Equation (4.2) is also closely linked to proposition two in Bucovetsky and Wilson (1991), which states that the outcome of decentral fiscal decisions is inefficient, if governments are constrained to the use of wage and source-based capital taxes only. Of course, if labor is inelastic in supply, then complete reliance on wage taxation is supported by (4.2) and (3.1a) for efficiency reasons, as ϕ is equal to zero and a first-best efficient equilibrium would be reached. The design of an efficient tax system would be a fairly easy task.

The interpretation of the result is as follows. From (4.1), by raising both wage and source-based capital taxes, net capital outflows into the rest of the world would be induced, thereby decreasing the world interest rate. International capital movements, produced by a domestic tax increase, make foreign countries better off for two reasons. First, their own capital tax base enlarges due to the induced capital inflows, and second, the rent of the immobile factor rises to maintain zero profits in private production. Since labor supply is endogenous in the model, this cannot be the whole story. Here, a higher wage rate, induced by capital inflows, leads to a change in labor supply and wage tax revenue. This fiscal externality is just as much neglected by the home government in the Nash equilibrium, as the fiscal externality which is usually being considered, i.e. the tax-base erosion induced by source-based capital taxes.

No wage taxes: In the second case, when the government is not permitted to use the wage tax [$t^w = 0$], the optimal tax structure for the remaining two taxes, t^s, t^r, is yielded by inserting the comparative static results of table 1 into equation (2.14):

$$\frac{t^s}{t^r} = \frac{f_{kk} k \psi}{f_{ll} l \phi - kl} \; . \tag{4.3}$$

According to condition (4.3), both taxes are set at positive rates and they finance marginal public expenditures, since, as under (2.4), variables ϕ, ψ are strictly positive due to our assumptions. Notice that this result does not functionally depend on the number of countries, n, and holds, whatever the number of countries involved in the tax game may be. Furthermore, any combination of t^s and t^r establishes the tax ratio in the benchmark, since t^s and t^r depict one instrument for $n = 1$. It follows that exposing the economy to international capital mobility does not cause any additional distortions, in comparison with the benchmark case. On the basis of this argument, we conclude that the tax structure (4.3) is efficient, given that neither lump-sum taxes or other, distortionary taxes are additionally available. Condition (4.3) reconstructs the finding of Bucovetsky and Wilson (1991) in their proposition three.

The intuition behind the above result is that a decrease in foreign countries' source-based capital tax causes negative and positive fiscal externalities at home. First, a negative tax base effect depicts the standard fiscal externality which is usually considered. In addition, a second externality occurs, since the lower source-based capital tax in foreign countries leads to an increase in the interest rate, which raises both national capital supply and fiscal revenue stemming from the residence-based capital tax. A similar argument applies to a decrease in foreign residence-based capital taxes, which increases foreign capital supply and hence lowers the world interest rate. On the one hand, a lower interest rate reduces capital supply and revenue of the residence-based capital tax at home, but on the other hand, a lower interest rate strengthens home capital demand and hence the tax base of the source-based capital tax. We therefore conclude that the tax base externalities in equation (4.3) are directly competing.

Unconstrained set of fiscal instruments: This is the first of our scenarios which have not been discussed in the existing literature. Instead of assuming that public goods can be financed on the margin by two distorting taxes, we now postulate that tax revenue can be derived from all three distortionary taxes. Hence, we relax the assumption proposed in the previous cases that the set of available taxes is constrained. However, when governments have access to the complete set of tax instruments, which includes labor, residence-based and source-based capital taxes, this implies that the marginal cost of public funds must be derived from solving the set of equations (2.13) simultaneously. Inserting the comparative static results [see table 1] into conditions (2.17), the tax rule for this scenario is:

$$\frac{t^s}{t^r} = 0 \, , \tag{4.4a}$$

$$\frac{t^s}{t^w} = 0 \, , \tag{4.4b}$$

$$\frac{t^r}{t^w} = \frac{\phi}{\psi} \, . \tag{4.4c}$$

Following (4.4), a government abstains from taxing capital at source when all three taxes are available, whereas positive source-based capital taxes are levied in all the previous cases (4.2) - (4.3), when either the residence-based capital tax or the labor tax is unavailable. Moreover, as mentioned in the opening paragraph of this paper and shown in our discussion of (4.2), the existing literature proved that a small country, $n \to \infty$, abstains from taxing capital at source if the labor tax is available additionally. In contrast, our result is that the government of a *large* country does not impose source-based capital taxes. It is shown here that the source-based capital tax vanishes in the setting of large countries if, and only if, taxes on the incomes of *all* factors subject to choice are available.

It should also be noted that the number of countries n plays no role in (4.4). Moreover, the tax structure in the benchmark is just replicated by (4.4). Therefore, the open country's aggregate consumption lies on the benchmark of a closed country's consumption possibility frontier, and we conclude that the decentral Nash equilibrium is efficient.

At a first glance, our argument that source-based capital taxes are not levied in a tax competition game between large countries may be surprising, because it seems to be in sharp contrast to the intuition stemming from the inverse elasticity rule of optimal taxation. This suggests that the source-based capital tax is levied at some positive rate, since the own tax elasticity of international movements is finite for a large country. Hence, it could be predicted that the source-based capital tax is part of the tax scheme in the large country case, even in the absence of terms of trade considerations. However, here the result is that the government voluntarily abstains from taxing capital at source. This result is closely related to the Diamond and Mirrlees (1971) Production Efficiency lemma, which shows that aggregate consumption lies on the production frontier in the presence of an optimal commodity tax system. In our framework, an optimal commodity tax system is equivalent to an optimal mix of residence-based capital and wage taxes. Since governments have access to the full range of tax instruments, the optimal tax system can be implemented. This does not include a source-based capital tax, due to the investment distortions attributed to that instrument. This proves that the results of Diamond-Mirrlees remain valid in an international context. Moreover, there is no scope for an international tax harmonization program, aiming at increasing worldwide efficiency by coordinating decentralized fiscal policies.

No source-based capital taxes: We now postulate that the level of t^s is fixed at zero $[t^s = 0]$ and that tax revenue must come from distortionary taxes on wages, t^w, and savings, t^r, alone. However, we have already proved that the government chooses $t^s = 0$ in the decentral Nash equilibrium, when a full set of tax instruments is available. Hence, $t^s = 0$ is an insignificant constraint for the optimal tax problem and we can derive the tax structure between t^r and t^w as a corollary of our result in the previous case:[10]

[10] Equation (4.5) is also yielded by inserting the market reactions summarized in table 1 into the relevant condition (2.16).

$$\frac{t^r}{t^w} = \frac{\phi}{\psi} \; . \tag{4.5}$$

According to (4.5), the tax structure in the decentralized equilibrium is independent of country size and replicates the benchmark (3.1b). Therefore, the Nash equilibrium is efficient when taxes can be levied on the incomes of all factors subject to choice. From our discussion in the previous case, it should be obvious that the argument of the Production Efficiency lemma also applies here. To complete, we consider this result more intuitively. Notice that, from (4.1), wage and residence-based capital taxes exert a reverse influence on the country's net capital balance. Firstly, as discussed above, the wage tax will tend to reduce domestic investment and increases capital supply in other countries with a more favorable tax climate. The induced international capital movements depict a positive fiscal externality for foreign tax authorities. Secondly, a domestic increase in the residence-based capital tax tends to shorten capital supply for the whole world, thereby increasing the world interest rate and inducing a negative fiscal externality in other countries. According to (4.5), the Nash equilibrium is efficient. We conclude that the influence of the wage tax externality is directly competing with the effects induced by the residence-based capital tax. Therefore, the simultaneous use of both taxes allows a country to effectively insulate itself against the fiscal externalities provoked by other countries' fiscal policies.

The absence of the source-based capital tax in the three tax equilibrium (4.4) also has some implications for the sequence of the tax competition games in two taxes that have been considered in (4.3) and (4.5). The result that the source-based tax is not levied in the optimum with an unconstrained set of taxes, reveals for the equilibria with a constrained tax set that – although both tax combinations ensure efficiency – the tax mix of a wage and a residence-based capital tax yields an equilibrium situation which is Pareto superior to the combination of a residence-based with a source-based capital tax.

Using the following figure, the theoretical results of the optimal direct tax problem can be summarized diagrammatically. It stylizes the situation of a single country. The horizontal axis measures composite private consumption and the vertical axis public good supply. The shaded area below $\overline{T^o T^o}$ is the world's production set under second-best optimal taxation. In the situations in which we proved the efficiency of decentralized fiscal policies, the production possibility frontier of an open country coincides with that of the closed country's. This is due to our assumption of identical countries, which leads to the absence of a motive for trade in the model. The curve $\overline{T^n T^n}$ stylizes the production possibility frontier as *perceived* by a typical government in the inefficient situations in which the residence-based

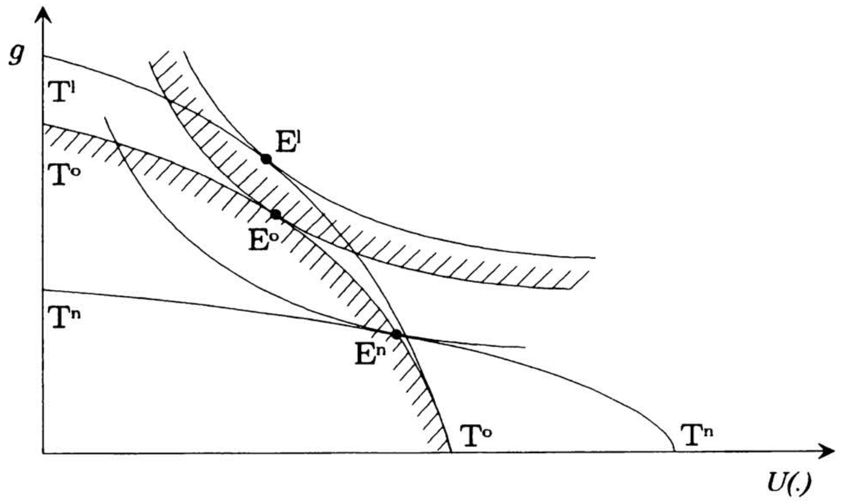

Figure: Constrained efficiency with a complete set of instruments

capital tax is unavailable. The shift of the perceived production possibility frontier, compared to the autarky locus, is based on an intuitively reasonable elasticity argument. Given the Nash assumption of fixed tax rates in other regions, each government expects large capital movements, due to its own tax changes [cf. eqs. (4.1)]; this results in an increase of marginal costs for all available taxes [cf. eqs. (2.13)]. To see the effects on the level of public good supply, consider first-order condition (2.12d). Since tax competition raises the shadow price of the public good Λ, the marginal utility of the public good $\tilde{U}_g$ must rise in the Nash equilibrium. From the perspective of a typical government, the opportunity cost of an additional unit of public spending is perceived to be higher and this explains the flatter gradient of $\overline{T^n T^n}$ in the absence of residence-based capital taxes.

From standard microeconomic theory, the optimal tax equilibrium is given by the highest indifference curve on the production set; in figure 1 this is indicated by points E, and the optimal tax structures are given by the slope of the tangency through points E. Clearly, the representative consumer attains a higher indifference locus in the constrained efficient Nash equilibrium, denoted by point E^o, compared to in the inefficient equilibrium in point E^n. Notice that $\overline{T^n T^n}$ crosses $\overline{T^o T^o}$ in E^n, since the international allocation of capital is undistorted in a symmetric Nash equilibrium.

Finally, notice that in the absence of wage taxes, Nash equilibria are only third-best efficient in a strict sense. A first-best allocation, represented by point E^l, could be established in the presence of a lump-sum tax. Public good supply is second-best optimal when no lump-sum, but only distorting taxes are available. Public good supply is third-best optimal under the constraints that (i) the tax scheme chosen in an internationally well integrated country is identical to that chosen in the closed country benchmark and (ii) that governments cannot implement a direct tax system which is equivalent to an optimal commodity tax system, given the absence of a wage tax.

5. Conclusions

This paper has focused on the optimal mix of direct taxes when a country faces domestic or international constraints on the set of available taxes. Due to the existence of international fiscal externalities, the opening of a country's borders does not necessarily leaves unaffected a country's consumption possibilities. It has been shown that all three direct taxes considered generally exert an influence on the tax bases of foreign countries. First, the availability of source-based capital taxes creates a positive fiscal externality for other countries, in the form of capital inflows into these countries. Second, the wage tax distorts the home labor market. Due to the process of factor substitution in private production capital flows out of the country in response to an increase in the wage tax. Third, the residence-based capital tax distorts the decision to save and may generate welfare losses in other countries, because of the changes in the world interest rate caused by a shortened capital supply. As has been emphasized throughout the analysis, all international effects are of particular relevance from a perspective orientated towards the efficiency of decentralized fiscal policies.

Table 2

Classification and Summary of Results

	Cases[a]	A	B	C	D
	Set of fiscal instruments	t^s, t^r	t^s, t^w	t^r, t^w	t^s, t^r, t^w
	Instrument not available	t^w	t^r	t^s	–
a	Tax structure in a Nash equilibrium of identical large countries	$t^s > 0$, $t^r > 0$	$t^s > 0$, $t^w > 0$	$\mathbf{t^r > 0}$, $\mathbf{t^w > 0}$	$\mathbf{t^s = 0}$, $\mathbf{t^r > 0}$, $\mathbf{t^w > 0}$
b	Tax structure in a Nash equilibrium of small countries	$t^s > 0$, $t^r > 0$	$t^s = 0$, $t^w > 0$	$t^r > 0$, $t^w > 0$	$t^s = 0$, $t^r > 0$, $t^w > 0$
	(constrained) efficient equilibrium	yes[b]	no	yes	yes

[a] Our results stand out by using bold type [Cases Ca and Da].

[b] As has been shown in the present analysis, the equilibrium in case Aa is Pareto inferior to cases Ca, Da.

The conclusions that can be drawn are many and diverse. Table 2 summarizes our results and classifies them into the conclusions of the existing literature. First of all, the present analysis has proved that even large countries, which exert an influence on the interest rate, abstain from taxing capital at source in the symmetric Nash equilibrium, when the set of available taxes is unrestricted [case Da]. In contrast, Razin and Sadka (1991) prove the absence of a source-based tax on capital income in a price-taking environment [cases Bb and Db]. However, in the context of small countries an optimal tax system need not be available to ensure that governments choose $t^s = 0$ [case Bb vs. Db]. As we have argued, our result in case Da is more directly related to the Diamond-Mirrlees Production Efficiency lemma, since the production tax only vanishes in a non-price-taking environment if an optimal tax system can be implemented.

It should also be pointed out that independent of a country's size, the efficiency of decentralized fiscal decisions can be established, regardless of whether residence-based capital taxes are combined with source-based or wage taxes [cases Aa and Ca]. We therefore formally generalized the conclusion given by Bucovetsky and Wilson – their analysis is restricted to cases Aa, Ba. Furthermore, it has been shown in the analysis that although both tax combinations in cases Aa and Ca establish efficiency, a mix of a residence-based with a source-based capital tax is Pareto inferior to a situation in which residence-based capital and wage taxes are available [case Aa vs. Ca].

Finally, as far as the comparison of inefficient equilibria in which governments only have access to an incomplete set of taxes [cases Ba, Bb] is concerned, we noted that positive source-based taxes are optimally levied in a large country, whereas the small country abstains from taxing capital at source.

This paper has analyzed an economy which, by necessity, is highly stylized. Only the main shortcomings of our model shall be outlined here. First, the interactions between factor and differentiated commodity taxation have been neglected. The unique private consumption good has been chosen as numéraire. There was no room for a meaningful analysis of different commodity taxes. As far as factor taxation is concerned, we excluded any kind of tax credits for source-based capital taxes. Finally, we abstracted from underemployment, whereas a realistic analysis of most countries would incorporate underemployment. In the real world, countries are likely to have a much stronger incentive for attracting capital, as was the case in the theoretical model. We hope to integrate some of these aspects into future research.

A. Appendix

The basic purpose of the appendix is to derive the expressions portrayed in the main text. As a first step, factor supply responses must be derived.

A.1 Households

Using (2.1) and (2.2) we can write the Lagrangean as follows:

$$\mathcal{L} \equiv U(e-s, x, T-L) - \lambda(x - (w - t^w)L - (r - t^r)s) \ . \tag{A.1}$$

The first-order conditions are:

$$\frac{\partial \mathcal{L}}{\partial s} = -U_s + \lambda(r - t^r) = 0 \ , \tag{A.2a}$$

$$\frac{\partial \mathcal{L}}{\partial x} = U_x - \lambda = 0 \ , \tag{A.2b}$$

$$\frac{\partial \mathcal{L}}{\partial L} = -U_l + \lambda(w - t^w) = 0 \ , \tag{A.2c}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda} = (w - t^w)L + (r - t^r)s - x = 0 \ . \tag{A.2d}$$

Straightforward manipulations give (2.3) in the main text. Further, notice that $\lambda = U_x > 0$, from condition (A.2b). Next, we completely differentiate first-order conditions (A.2):

$$\begin{pmatrix} 0 & r-t^r & -1 & w-t^w \\ r-t^r & U_{ss} & -U_{sx} & U_{sl} \\ -1 & -U_{sx} & U_{xx} & -U_{xl} \\ w-t^w & U_{sl} & -U_{xl} & U_{ll} \end{pmatrix} \begin{pmatrix} d\lambda \\ ds \\ dx \\ dL \end{pmatrix} = \begin{pmatrix} -s & -L \\ -\lambda & 0 \\ 0 & 0 \\ 0 & -\lambda \end{pmatrix} \begin{pmatrix} dr - t^r \\ dw - t^w \end{pmatrix} . \tag{A.3}$$

A maximum implies that the principal minors of the bordered Hessian on the left hand side of (A.3) must be of the following signs:

$$A \equiv -U_{ss} + 2(r - t^r)U_{sx} - (r - t^r)^2 U_{xx} > 0 \ , \tag{A.4a}$$

$$B \equiv -U_{ll} + 2(w - t^w)U_{xl} - (w - t^w)^2 U_{xx} > 0 \ , \tag{A.4b}$$

$$\begin{aligned} -C \equiv\ & {U_{sl}}^2 - U_{ll}U_{ss} + 2(r-t^r)(U_{ll}U_{sx} - U_{sl}U_{xl}) + (r-t^r)^2({U_{xl}}^2 - U_{ll}U_{xx}) + \\ & 2(w-t^w)\Big(U_{sl}\big((r-t^r)U_{xx} - U_{sx}\big) + U_{xl}\big(U_{ss} - (r-t^r)U_{sx}\big)\Big) + \\ & (w-t^w)^2({U_{sx}}^2 - U_{ss}U_{xx}) < 0 \ . \end{aligned} \tag{A.4c}$$

Using Cramer's rule on (A.3), we can identify the effects of price changes on the quantities of factors supplied:

$$s_r = -\frac{D}{C}\,, \qquad s_w = -\frac{E}{C}\,, \tag{A.5}$$
$$L_w = -\frac{F}{C}\,, \qquad L_r = -\frac{G}{C}\,,$$

where C is given by definition (A.4c) and:

$$D \equiv \begin{vmatrix} 0 & -s & -1 & w-t^w \\ r-t^r & -U_x & -U_{sx} & U_{sl} \\ -1 & 0 & U_{xx} & -U_{xl} \\ w-t^w & 0 & -U_{xl} & U_{ll} \end{vmatrix}, \quad E \equiv \begin{vmatrix} 0 & -L & -1 & w-t^w \\ r-t^r & 0 & -U_{sx} & U_{sl} \\ -1 & 0 & U_{xx} & -U_{xl} \\ w-t^w & -U_x & -U_{xl} & U_{ll} \end{vmatrix},$$

$$F \equiv \begin{vmatrix} 0 & r-t^r & -1 & -L \\ r-t^r & U_{ss} & -U_{sx} & 0 \\ -1 & -U_{sx} & U_{xx} & 0 \\ w-t^w & U_{sl} & -U_{xl} & -U_x \end{vmatrix}, \quad G \equiv \begin{vmatrix} 0 & r-t^r & -1 & -s \\ r-t^r & U_{ss} & -U_{sx} & -U_x \\ -1 & -U_{sx} & U_{xx} & 0 \\ w-t^w & U_{sl} & -U_{xl} & 0 \end{vmatrix}.$$

In a similar manner, (A.3) can be used to decompose the uncompensated effects in Hicksian price effects and income effects. These Slutsky decompositions directly imply that:

$$s_r = \mathfrak{s}_r + s\frac{\partial s}{\partial x}\,, \qquad s_w = \mathfrak{s}_w + L\frac{\partial s}{\partial x}\,, \tag{A.6}$$
$$L_w = \mathfrak{L}_w + L\frac{\partial L}{\partial x}\,, \qquad L_r = \mathfrak{L}_r + s\frac{\partial L}{\partial x}$$

where:

$$\mathfrak{s}_r \equiv \lambda\frac{B}{C} > 0\,, \qquad \mathfrak{L}_w \equiv \lambda\frac{A}{C} > 0\,, \qquad \mathfrak{s}_w \equiv \lambda\frac{H}{C} = \lambda\frac{K}{C} \equiv \mathfrak{L}_r\,. \tag{A.7}$$

Notice that determinants A, B and C are already defined by conditions (A.4). Additionally:

$$H \equiv \begin{vmatrix} 0 & -1 & w-t^w \\ r-t^r & -U_{sx} & U_{sl} \\ -1 & U_{xx} & -U_{xl} \end{vmatrix}, \qquad K \equiv \begin{vmatrix} 0 & r-t^r & -1 \\ -1 & -U_{sx} & U_{xx} \\ w-t^w & U_{sl} & -U_{xl} \end{vmatrix}.$$

A.2 Governments

In the second stage of the optimization process, we concentrate on the relevant conditions for the three taxes, which are repeated here for convenience:

(A.8a) $$\frac{\partial \mathcal{W}}{\partial t^s} = -U_s\frac{\partial s}{\partial t^s} + U_x\frac{\partial x}{\partial t^s} - U_l\frac{\partial L}{\partial t^s} - \Lambda k - \Lambda k\left(\frac{\partial L}{\partial t^s}\frac{t^w}{k} + \frac{\partial s}{\partial t^s}\frac{t^r}{k} + \frac{\partial k}{\partial t^s}\frac{t^s}{k}\right) = 0\ ,$$

(A.8b) $$\frac{\partial \mathcal{W}}{\partial t^r} = -U_s\frac{\partial s}{\partial t^r} + U_x\frac{\partial x}{\partial t^r} - U_l\frac{\partial L}{\partial t^r} - \Lambda s - \Lambda s\left(\frac{\partial L}{\partial t^r}\frac{t^w}{s} + \frac{\partial s}{\partial t^r}\frac{t^r}{s} + \frac{\partial k}{\partial t^r}\frac{t^s}{s}\right) = 0\ ,$$

(A.8c) $$\frac{\partial \mathcal{W}}{\partial t^w} = -U_s\frac{\partial s}{\partial t^w} + U_x\frac{\partial x}{\partial t^w} - U_l\frac{\partial L}{\partial t^w} - \Lambda L - \Lambda L\left(\frac{\partial L}{\partial t^w}\frac{t^w}{L} + \frac{\partial s}{\partial t^w}\frac{t^r}{L} + \frac{\partial k}{\partial t^w}\frac{t^s}{L}\right) = 0\ ,$$

Using the first-order conditions for the maximization problem of the consumer, (A.2a) - (A.2c), and inserting the definitions of the tax elasticities of all three instruments, $\varepsilon_k, \varepsilon_s, \varepsilon_l$, into equations(A.8) yields:

(A.9a) $$\frac{\partial \mathcal{W}}{\partial t^s} = \lambda\left(\frac{\partial x}{\partial t^s} - (r-t^r)\frac{\partial s}{\partial t^s} - (w-t^w)\frac{\partial L}{\partial t^s}\right) - \Lambda k(1-\varepsilon_k) = 0\ ,$$

(A.9b) $$\frac{\partial \mathcal{W}}{\partial t^r} = \lambda\left(\frac{\partial x}{\partial t^r} - (r-t^r)\frac{\partial s}{\partial t^r} - (w-t^w)\frac{\partial L}{\partial t^r}\right) - \Lambda s(1-\varepsilon_s) = 0\ ,$$

(A.9c) $$\frac{\partial \mathcal{W}}{\partial t^w} = \lambda\left(\frac{\partial x}{\partial t^w} - (r-t^r)\frac{\partial s}{\partial t^w} - (w-t^w)\frac{\partial L}{\partial t^w}\right) - \Lambda L(1-\varepsilon_l) = 0\ .$$

Equation (2.8) and the labor market clearing condition, $L = l$, are used after total differentiation of (A.2d) to obtain:

(A.10a) $$k = -\frac{\partial x}{\partial t^s} + (r-t^r)\frac{\partial s}{\partial t^s} + (w-t^w)\frac{\partial L}{\partial t^s}\ ,$$

(A.10b) $$s = -\frac{\partial x}{\partial t^r} + (r-t^r)\frac{\partial s}{\partial t^r} + (w-t^w)\frac{\partial L}{\partial t^r}\ ,$$

(A.10c) $$L = -\frac{\partial x}{\partial t^w} + (r-t^r)\frac{\partial s}{\partial t^w} + (w-t^w)\frac{\partial L}{\partial t^w}\ .$$

Condition (A.2d) shows that $\lambda = U_x$. Inserting equations (A.10) into conditions (A.9) gives:

(A.11a) $$U_x k + \Lambda k(1-\varepsilon_k) = 0\ ,$$

(A.11b) $$U_x s + \Lambda s(1-\varepsilon_s) = 0\ ,$$

(A.11c) $$U_x l + \Lambda l(1-\varepsilon_l) = 0\ .$$

Straightforward manipulations yield conditions (2.13) in the main text.

A.3 Comparative Statics

The market responses of households and firms must be derived from totally differentiating (2.18), which yields under the assumption of identical countries:

$$\text{(A.12a)} \qquad L_w dw^j - L_w dt_j^w + L_r dr - L_r dt_j^r - dL^j = 0 \qquad \forall j \in \{i, a\}\ ,$$

$$\text{(A.12b)} \qquad s_w dw^j - s_w dt_j^w + s_r dr - s_r dt_j^r - ds^j = 0 \qquad \forall j \in \{i, a\}\ ,$$

$$\text{(A.12c)} \qquad f_{ll} dl^j + f_{lk} dk^j - dw^j = 0 \qquad \forall j \in \{i, a\}\ ,$$

$$\text{(A.12d)} \qquad f_{kl} dl^j + f_{kk} dk^j - dr - dt_j^s = 0 \qquad \forall j \in \{i, a\}\ ,$$

$$\text{(A.12e)} \qquad dl^j - dL^j = 0 \qquad \forall j \in \{i, a\}\ ,$$

$$\text{(A.12f)} \qquad dk^i - ds^i + (n-1)(dk^a - ds^a) = 0\ .$$

Next, we use the labor market clearing conditions (A.12e). Then we eliminate the wage and the interest rate by inserting (A.12c) and (A.12d) everywhere in (A.12):

$$\text{(A.13)} \qquad \begin{aligned} L_w(f_{ll} dl^j + f_{lk} dk^j) - L_w dt_j^w + L_r(f_{kl} dl^j + f_{kk} dk^j - dt_j^s) - L_r dt_j^r - dl^j &= 0 \quad \forall j \in \{i, a\}, \\ s_w(f_{ll} dl^j + f_{lk} dk^j) - s_w dt_j^w + s_r(f_{kl} dl^j + f_{kk} dk^j - dt_j^s) - s_r dt_j^r - ds^j &= 0 \quad \forall j \in \{i, a\}, \\ f_{kl} dl^i + f_{kk} dk^i - dt_i^s - f_{kl} dl^a - f_{kk} dk^a + dt_a^s &= 0\ , \\ dk^i - ds^i + (n-1)(dk^a - ds^a) &= 0\ . \end{aligned}$$

We use equations (2.4) and (2.7) in (A.13) which gives in matrix notation:

$$\text{(A.14)} \qquad \begin{pmatrix} -\frac{f_{kk}}{l}\phi & 0 & 0 & 0 & \frac{f_{ll}}{k}\phi - 1 & 0 \\ 0 & -\frac{f_{kk}}{l}\phi & 0 & 0 & 0 & \frac{f_{ll}}{k}\phi - 1 \\ \frac{f_{kk}}{l}\psi & 0 & -1 & 0 & -\frac{f_{ll}}{k}\psi & 0 \\ 0 & \frac{f_{kk}}{l}\psi & 0 & -1 & 0 & -\frac{f_{ll}}{k}\psi \\ f_{kk} & -f_{kk} & 0 & 0 & -f_{ll}\frac{l}{k} & f_{ll}\frac{l}{k} \\ 1 & n-1 & -1 & 1-n & 0 & 0 \end{pmatrix} \begin{pmatrix} dk^i \\ dk^a \\ ds^i \\ ds^a \\ dl^i \\ dl^a \end{pmatrix} = \begin{pmatrix} L_r & L_r & L_w \\ 0 & 0 & 0 \\ s_r & s_r & s_w \\ 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} dt_i^r \\ dt_i^s \\ dt_i^w \end{pmatrix}.$$

The determinant of the Hessian on the left hand side of (A.14) is equal to $n f_{kk} \frac{kl - f_{ll} l \phi - f_{kk} k \psi}{kl} < 0$. We can apply Cramer's rule to (A.14) and solve for the own-tax induced market reactions in country i:

$$\frac{\partial k}{\partial t^s} = \frac{n-1}{n}\frac{(f_{ll}lL_r - k + f_{ll}\phi)(f_{ll}l\phi - kl + f_{kk}k\psi)}{f_{kk}kN} + \frac{l(f_{ll}L_r\psi - ks_r + f_{ll}\phi s_r)}{nN} ,$$
$$\frac{\partial s}{\partial t^s} = \frac{n-1}{n}\frac{(ls_r - \psi)(f_{ll}l\phi - kl + f_{kk}k\psi)}{lN} + \frac{l(f_{ll}L_r\psi - ks_r + f_{ll}\phi s_r)}{nN} ,$$
$$\frac{\partial l}{\partial t^s} = \frac{n-1}{n}\frac{(lL_r + \phi)(f_{ll}l\phi - kl + f_{kk}k\psi)}{lN} + \frac{k(f_{kk}L_r\psi - lL_r + f_{kk}\phi s_r)}{nN} ,$$
$$\frac{\partial k}{\partial t^r} = \frac{n-1}{n}\frac{f_{ll}lL_r(f_{ll}l\phi - kl + f_{kk}k\psi)}{f_{kk}kN} + \frac{l(f_{ll}L_r\psi - ks_r + f_{ll}\phi s_r)}{nN} ,$$
$$\frac{\partial s}{\partial t^r} = \frac{n-1}{n}\frac{s_r(f_{ll}l\phi - kl + f_{kk}k\psi)}{N} + \frac{l(f_{ll}L_r\psi - ks_r + f_{ll}\phi s_r)}{nN} ,$$
$$\frac{\partial l}{\partial t^r} = \frac{n-1}{n}\frac{L_r(f_{ll}l\phi - kl + f_{kk}k\psi)}{N} + \frac{k(f_{kk}L_r\psi - lL_r + f_{kk}\phi s_r)}{nN} ,$$
$$\frac{\partial k}{\partial t^w} = \frac{n-1}{n}\frac{f_{ll}lL_w(f_{ll}l\phi - kl + f_{kk}k\psi)}{f_{kk}kN} + \frac{l(f_{ll}L_w\psi - ks_w + f_{ll}\phi s_w)}{nN} ,$$
$$\frac{\partial s}{\partial t^w} = \frac{n-1}{n}\frac{s_w(f_{ll}l\phi - kl + f_{kk}k\psi)}{N} + \frac{l(f_{ll}L_w\psi - ks_w + f_{ll}\phi s_w)}{nN} ,$$
$$\frac{\partial l}{\partial t^w} = \frac{n-1}{n}\frac{L_w(f_{ll}l\phi - kl + f_{kk}k\psi)}{N} + \frac{k(f_{kk}L_w\psi - lL_w + f_{kk}\phi s_w)}{nN} ,$$

where the definition

$$N \equiv kl - f_{ll}l\phi - f_{kk}k\psi ,$$

has been used. Finally, using (2.4) yields the equations given by table 1 in the main text.

References

Bruce, N. (1992): 'A note on the taxation of international capital income flows.' The Economic Record 68, 217 - 221.

Bucovetsky, S. / J. D. *Wilson* (1991): 'Tax competition with two tax instruments.' Regional Science and Urban Economics 21, 333 - 350.

Burbidge, J. B. / G. M. *Myers* (1994): 'Population mobility and capital tax competition.' Regional Science and Urban Economics 24, 441 - 459.

DePater, J. A. / G. M. *Myers* (1994): 'Strategic capital tax competition: A pecuniary externality and a corrective device.' Journal of Urban Economics 36, 66 - 78.

Diamond, P. A. / J. A. *Mirrlees* (1971): 'Optimal taxation and public production.' American Economic Review 61, 8 - 27 and 261 - 278.

Edwards, J. / M. *Keen* (1996): 'Tax competition and Leviathan.' European Economic Review 40, 113 - 134.

Gordon, R. H. (1986): 'Taxation of investment and savings in a world economy.' American Economic Review 76, 1086 - 1102.

– (1992): 'Can capital income taxes survive in open economies?' Journal of Finance 47, 1159 - 1180.

Gottfried, P. (1996): 'Multiple Gleichgewichte und dezentrale Allokationspolitik.' Jahrbücher für Nationalökonomie und Statistik 215, 688 - 703.

Huizinga, H. / S. B. *Nielsen* (1997): 'Capital income and profit taxation with foreign ownership of firms.' Journal of International Economics 42, 149 - 165.

Kay, J. A. (1980): 'The deadweight loss from a tax system.' Journal of Public Economics 13, 111 - 119.

Koch, K.-J. / G. G. *Schulze* (1998): 'Equilibria in tax competition models.' In Trade, growth, and economic policy in open economies, ed. K.-J. Koch and K. Jaeger Essays in Honor of H.-J. Vosgerau (Berlin et al.: Springer).

Lorz, J. O. / F. *Stähler* (1997): Who is afraid of capital mobility?, vol. 824 of Kiel Working Papers (The Kiel Institute of World Economics).

Razin, A. / E. *Sadka* (1991): 'International tax competition and gains from tax harmonization.' Economics Letters 37, 69 - 76.

Schöb, R. (1994): 'On marginal cost and marginal benefit of public funds.' Public Finance 49, 87 - 106.

Sinn, S. (1992): 'The taming of the Leviathan: Competition among governments.' Constitutional Political Economy 3, 177 - 196.

Wellisch, D. (1995): 'Can household mobility solve basic environmental problems?' International Tax and Public Finance 2, 245 - 260.

Wildasin, D. E. (1984): 'On public good provision with distortionary taxation.' Economic Inquiry 22, 227 - 243.

– (1989): 'Interjurisdictional capital mobility: Fiscal externality and a corrective subsidy.' Journal of Urban Economics 25, 193 - 212.

Wilson, J. D. (1986): 'A theory of interregional tax competition.' Journal of Urban Economics 19, 296 - 315.

Zodrow, G. R. / P. *Mieszkowski* (1986): 'Pigou, Tiebout, property taxation and the underprovision of local public goods.' Journal of Urban Economics 19, 356 - 370.

Zusammenfassung

Die Literatur zum Steuerwettbewerb um mobiles Kapital zwischen großen Ländern identifiziert ein steuerpolitisches Szenario, in dem positive Kapitalsteuern nach dem Quellenlandprinzip erhoben werden und das Bereitstellungsniveau öffentlicher Güter effizient ist. Demgegenüber demonstriert diese Arbeit in zwei zusätzlichen Szenarien, daß sich fiskalische Externalitäten auch dann aufwiegen, wenn die Entscheidungsträger Zugriff auf die Einkommen aller von den Haushalten angebotenen Produktionsfaktoren haben. In Gegensatz zu den existierenden Arbeiten wird gezeigt, daß Regierungen großer Länder Kapitalsteuern nach dem Quellenlandprinzip nur dann nicht erheben, wenn sie über ein vollständiges Instrumentarium verfügen.

Abstract

The literature on capital tax competition among large countries identifies a fiscal environment in which positive source-based capital taxes are levied and public goods are provided efficiently. However, as this paper demonstrates in two additional scenarios, fiscal externalities are also offset when a government has access to taxes on the incomes of all factors subject to choice. In contrast to the existing literature, it is proved that governments of large countries choose not to tax capital at source if, and only if, a full set of taxes exists.

JEL-Klassifikation: H 73, H 77, H 21.