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Working Paper

Capital tax competition with three tax instruments

Diskussionsbeiträge - Serie II, No. 347

Provided in Cooperation with:
Department of Economics, University of Konstanz

Suggested Citation: Eggert, Wolfgang (1997) : Capital tax competition with three tax instruments, Diskussionsbeiträge - Serie II, No. 347, Universität Konstanz, Sonderforschungsbereich 178 - Internationalisierung der Wirtschaft, Konstanz

This Version is available at:
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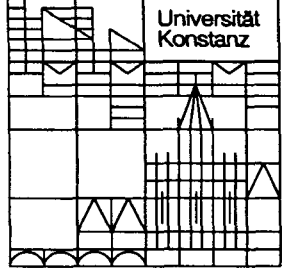
Diskussionsbeiträge



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Capital Tax Competition with Three Tax Instruments

D-78457 Konstanz

Serie II — Nr. 347
Juni 1997

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June 5, 1997

Abstract

The paper studies the role of capital mobility for efficiency of decentralized fiscal policies in a tax competition model where only a distorting wage, the residence-based and the source-based capital tax are available. We extend Bucovetsky and Wilson (1991) in deriving second-best taxation rules for small and large countries for each of the four possible combinations of tax instruments both in environments with an unconstrained and with a constrained set of tax instruments available to fiscal authorities. Whereas the model reproduces the result that countries underprovide local public goods in the absence of a residence-based capital tax, Nash equilibria are efficient in the two-tax cases if residence-based capital taxes but no source-based capital or else wage taxes are available. Moreover, aggregate production is situated on the world production frontier when the set of fiscal instruments is unrestricted.

JEL classification: H 73, H 77, H 21, F15

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*I thank Max Albert, Lucas Bretschger, Bernd Genser and Andreas Haufler for helpful comments and suggestions. All remaining shortcomings are my own responsibility.

1 Introduction

A flood of literature on capital tax competition among countries emphasizes the role of international capital mobility for efficiency of decentralized fiscal policy.[1] The literature mostly demonstrates that tax rates and levels of public goods provision are set at inefficiently low rates. As Zodrow and Mieszkowski (1986) and Oates and Schwab (1991) prove, the yield of a capital income tax levied within the boundaries of a country is not sustainable because of the investment distortions attributed to the source-based capital tax. So in these models each government's public expenditures must be financed by a tax on wage income or by a tax on worldwide capital income.

All of these conclusions are derived within models ignoring the fact that labor and capital are not fixed in supply within countries. The common explanation for the desire of wage and residence-based capital taxes in the standard analysis is that both taxes are lump-sum. Recent straightforward model extensions stress the implications of a more rigorous treatment of households' factor supply decisions in an international taxation framework. These reflections upon a more realistic view of capital tax competition have been carried out in contributions which can be divided into models of strategic interaction between large countries and optimal tax rules followed by small open economies.

A first counterexample against the standard result that Nash strategies of governments lead to an inefficient equilibrium is made by Frenkel, Razin and Sadka (1991) in a model of a small open economy in which saving 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 second-best tax competition equilibrium in residence-based capital taxes. However as an application of the inverse elasticity rule of optimal taxation, they also conclude that tax authorities of small countries 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. They infer that international tax harmonization is not welfare improving in this situation. Other contributions demonstrate that positive source-based capital taxes will be levied in a small open economy if there are constraints on labor or profit taxation or if foreigners own some part of the domestic capital stock [cf. Bruce (1992); Huizinga and Nielsen (1995)].

A second branch of the more recent literature on capital tax competition is initiated by the seminal article of Bucovetsky and Wilson (1991) which extends the standard framework outlined above by incorporating factor supply decisions in an international framework of

[1] Seminal articles are, among others, Gordon (1983), Wilson (1986) and Wildasin (1989). Other authors study tax competition in the context of a Leviathan type government [cf. Sinn (1992) and Rauscher (1996)] or stability issues [cf. Koch and Schulze (1997)].

identical, large countries. In contrast to Frenkel, Razin and Sadka (1991) here the world interest rate is not fixed so that countries are faced with a finite tax elasticity of capital. The main advantage of the identical country assumption are symmetric outcomes, thereby eliminating the tax authorities' incentives to use the tax system to manipulate the terms of trade.

Bucovetsky and Wilson (1991) derive the consequences of non-cooperative tax policy for efficiency of decentralized fiscal decisions in a tax competition game with two tax instruments. They only analyze a subset of situations which we consider here by restricting their analysis to Nash equilibria in labor and source-based capital taxes on the one hand and source- and residence-based capital taxes on the other hand. The main conclusions from their analysis are twofold. Firstly, in the absence of a residence-based capital tax the negative consequences of tax competition on welfare becomes the more severe the smaller a country's size. A variable number of competing jurisdictions is also discussed in the static framework of Hoyt (1991), who also shows that efficiency of the decentralized Nash equilibrium decreases with an increasing number of countries being involved in the tax competition game. Secondly, under the assumption that labor income is left untaxed, Bucovetsky and Wilson (1991) prove efficiency of a Nash equilibrium in source- and residence-based capital taxes. Both model predictions are related on their part to the Diamond-Mirrlees (1971) Production Efficiency lemma where the equilibrium with optimal commodity taxation should be on the frontier of the aggregate production set. In contrast to this result, efficiency can be obtained here under some conditions in spite of the absence of an optimal commodity tax system. In the framework of Bucovetsky and Wilson (1991), an optimal commodity tax system would generally involve non-zero taxes being levied on all factor incomes and an exclusion of fiscal authorities from every possibility to tax capital at source.

The main purpose of the present paper is to extend and link both branches of the literature. Whereas we noted above that most contributions in the field of capital tax competition restrict their analyses to a subset of tax instruments, the focus here is on the role of interactions between three distorting taxes in small and large countries.

For this purpose the paper analyses public finance aspects in a model of international trade. In the framework being applied, countries are connected by an international capital market and the households' relevant private commodities are present consumption, future consumption and time spent for leisure. We derive second-best taxation rules for different scenarios in which countries have an incomplete and a complete tax instrument set available. Differentiating between these scenarios on the basis of the alternative constraints placed on the set of three available tax instruments, the source-based capital tax, the residence-based capital tax and the wage tax will prove to be important. The paper

further allows to distinguish Nash equilibria of tax competition between small and large countries. This shows that there exist Nash equilibria both for small and large countries which are situated on the world's production set.

To be more precise, the analysis reveals that the scope for efficiency enhancing tax coordination is shown to be primarily a question of the constraints upon the set of tax instruments available for fiscal authorities. Assuming that a residence-based capital tax is not available, the following analysis confirms the earlier studies that tax competition leads to a globally inefficient outcome. Countries continue to underprovide local public goods even when wage taxation is introduced. This result holds particularly if the taxing country is small, since tax base effects become most severe in this case. To highlight the assumptions responsible for an inefficient tax structure when the set of tax instruments is incomplete, it is important to identify two fiscal externalities. Firstly, the availability of source-based capital taxes creates a positive fiscal externality for other countries in the form of capital inflows into these countries. Secondly, 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.

If on the other hand only wage taxes and residence-based capital taxes but no source-based capital taxes are available the resulting decentralized equilibrium is second-best efficient. This result is an the open economy version of the Diamond-Mirrlees (1971) Production Efficiency lemma. In our framework an optimal commodity tax system would generally involve non-zero taxes being levied on all factor incomes and an exclusion of fiscal authorities from every possibility to tax capital at source. Furthermore it is shown that this efficiency result also holds if taxes on investment and saving are the only taxes available.

Remarkably the conclusions for efficiency we outlined above change substantially if the set of available tax instruments is complete. Here governments use their tax instruments efficiently, never inducing fiscal externalities on other countries. Most notably source-based capital taxes are shown not to be in the optimal tax mix in the Nash equilibrium, even in the case of a large country. This seems to be in contradiction to the standard intuition, which is given for the absence of a source-based capital tax. The reason given for zero rates of source-based capital tax in the literature is that this phenomenon has mostly been regarded as an application of the inverse elasticity rule from optimal taxation theory. In contrast, source-based capital taxes are here endogenously set to zero despite of a finite tax elasticity of international capital movements. Production efficiency is established and unaffected by country size if the set of fiscal instruments available is unrestricted.

The program of the paper is as follows. Section two introduces the model and derives first-order conditions for a welfare-improving second-best tax reform. Section three studies

the Nash equilibrium between competing governments in large countries. Tax competition among identically small countries is then investigated in section four. Finally section five draws some conclusions and suggests possible extensions.

2 The model

Consider a system of n identical regions or countries that produce an homogeneous good with the same constant-returns-to-scale technology using capital and labor as factors of production. To concentrate on the capital tax competition issue, individuals are assumed to be internationally immobile, whereas capital is perfectly mobile.[2]

Following Bucovetsky and Wilson (1991) saving and labor supply are endogenous. Consumers in each country are identical and live for two periods. In the first period, the representative consumer divides his endowment between current consumption and saving in order to finance some part of second period consumption. During the second period, the individual chooses how much labor to supply and competitive firms produce the private goods which also serves as an input in public production. Likewise in the second period, governments use the tax revenue collected to provide a local public good. The price of private output is normalized to equal one.[3]

Going into details, we assume that the individual agent strives to maximize a well-behaved direct utility function that is separable between private and public goods:

$$U(\chi, x, F) + \tilde{U}(g) \quad , \tag{2.1}$$

where χ and x denote private consumption in period one and two, F is leisure consumed in the second period and g is public good supply. Due to the separability assumption, goods consumed are independent of the level of public good supply, g, which is determined by

[2] It has been shown by Burbidge and Myers (1994) that perfect household mobility ensures efficiency of decentralized fiscal policy even if capital is internationally mobile since regional governments internalize all fiscal externalities in their own interest due to the migration constraint ensuring equal utilities of residents in each region. However, they distinguish different degrees of household mobility and in their central results they provide evidence that there exist efficient situations with non-perfectly mobile households in which the larger of two countries voluntarily places transfer payments in the smaller country's favor.

[3] A simplifying assumption of our model is that agents do not supply labor and capital in the first period (and do not derive utility from the public good in the first period). We adopt this specification for three reasons. First, we wish to focus attention on the choice between savings and labor supply decisions. The intertemporal dynamics on labor and capital markets are not in our concerns. Second, in keeping with most two-period tax competition analysis, we simply wish to hold the model tractable by allowing agents to optimize on two margins only. Finally, we assumed separability of private and public consumption due to our observation that substitutional or complementary effects between private and public consumption are impossible to ascertain precisely.

the government and thus exogenous from the perspective of the consumer. Residents are price-takers and choose their levels of private consumption to maximize utility subject to the two-period budget constraint:

$$\chi + \frac{x}{(r-v)} = \frac{(w-z)}{(r-v)}(T-F) + y \quad , \tag{2.2}$$

where

$(r-v)$ = real rate interest, r,[4] net of the residence-based capital tax,[5] v,
$(w-z)$ = gross wage rate, w, net of the wage tax, z,
$(y-\chi)$ = saving, equivalent to capital supplied by residents, s,
$(T-F)$ = labor supply, L,
y, T = initial resource and time endowments.

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, one arrives at the following first-order conditions:[6]

$$-U_s/U_x = (r-v) \quad , \tag{2.3a}$$

$$-U_l/U_x = (w-z) \quad . \tag{2.3b}$$

These first-order conditions have some well-known implications. Intuitively, one can see from (2.3a) that whether consumption rises or falls over time, depends on whether the net market rate of capital return, $(r-v)$, is larger or smaller than the individual's time preference rate. If the net interest rate is higher, the consumption path would be rising over time. This makes sense. The net interest rate measures the return in additional saving, whereas the individual's time preference rate gives the individual's loss from waiting to consume. If the rate of return exceeds the rate of time preference it pays to consume later, otherwise it does not. A similar argumentation applies to (2.3b) for the trade-off between leisure and private good consumption. If the individual's rate of substitution on the left hand side of (2.3b) exceeds the net wage rate, $(w-z)$, marginal labor supply falls since the individual's marginal esteem for leisure consumption goes beyond that for private good consumption. From this intuition follows that in the optimum equations (2.3) necessarily have to be fulfilled.

Note however, 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) one can show that the effects of price changes on labor

[4]Notice that, for the reason of algebraic simplicity, r as defined above is greater than one.

[5]Under the residence principle the tax is levied on capital owned by domestic residents.

[6]Derivations of this and all the following expressions are relegated into the appendix.

supply, $L(\cdot)$, and saving, $s(\cdot)$, functions generally can not be signed due to the ambiguity of income and cross-price substitution effects.

From the second-order conditions it follows that the own-price effects of compensated labor supply, $\mathfrak{L}(\cdot)$, and saving, $\mathfrak{s}(\cdot)$, functions are positive, and the symmetry of the Slutsky matrices implies equality of all compensated cross-price elasticities. Following Bucovetsky and Wilson (1991), we assume that leisure is an Hicksian substitute with first period's consumption. Hence:

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

Uncompensated price effects are decomposed using Slutsky equations. This establishes the following relationships between uncompensated and Hicksian derivatives:[7]

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

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

where variables k, l denote firms' capital and labor demand.

The productive sector of each country is described by an aggregate production function, $f(k,l)$, which is standard neoclassical and relates each country's output to the level of capital, $k(\cdot)$, and labor, $l(\cdot)$, demanded by firms. The production function can either be interpreted literally as representing the technology of a single firm or as the aggregate production function of a set of identical firms. A formal demonstration of such an aggregation argument is given in Sargent (1979). Normalizing the price of output to equal one and abstracting from depreciation, one ends up with the familiar profit-maximization conditions for labor and capital:

$$f_l - w = 0 \quad , \tag{2.5a}$$

$$f_k - (r+u) = 0 \quad . \tag{2.5b}$$

In accordance with the capital tax competition literature, a property tax rather than a tax on capital income is modelled in (2.5b). The tax is levied according to the source principle on all capital invested in the economy. As the labor and capital markets are competitive, profit maximization in the choice of labor and capital by firms implies from conditions (2.5) that the marginal products of labor and capital must be equated to their marginal costs.

[7] As it can be shown using the Slutsky decompositions carried out in the appendix, income effects simply cancel out in (2.4) in transition from uncompensated to Hicksian formulas. To derive (2.4) notice additionally that the full employment condition for the labor market requires ($l = L$). Moreover saving equals capital demand, ($k = s$), in the closed country as well as in a symmetric Nash equilibrium.

From condition (2.5b) follows that capital demand is a decreasing function of the interest rate due to a positive and diminishing marginal productivity of capital. Additionally, condition (2.5a) shows that when the wage rate rises, firms respond to the increase in costs by reducing labor demand. Therefore both own-price effects on factor demands are unambiguously negative. The requirement that profits equal zero in equilibrium defines a negatively-sloped factor-price frontier and ensure positive cross-price derivatives:

$$l_w < 0 \quad , \qquad k_r < 0 \quad , \qquad l_r = -k_r \frac{l}{k} > 0 \quad , \qquad k_w = -l_w \frac{k}{l} > 0 \quad . \tag{2.6}$$

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 is choosing the set of net-factor prices that maximizes welfare subject to the budget constraint, R:

$$R \equiv zL + vs + uk - c(g) = 0 \quad , \tag{2.7}$$

where $c(g)$ denotes the per capita cost function of public good production which is assumed monotonically increasing. 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: 231)].

The objective function of the government in each of the countries is the representative 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:

$$V \equiv U\left(y - s(r,w,u,v,z), x(r,w,u,v,z), T - L(r,w,u,v,z)\right) + \tilde{U}\left(g\right) \quad , \tag{2.8}$$

which the government strives to maximize subject to the budget constraint (2.7). The Lagrangean of the problem:

$$\mathcal{W} \equiv V\left(\ldots\right) - \Lambda R \quad , \tag{2.9}$$

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

As we made clear in the introduction, 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 tax instruments, u, v, z, 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 (2.9) to situations in which all tax instruments are feasible for fiscal policy, as

well as solutions to situations in which governments only have access to an incomplete tax instrument set, i.e. the rate of the tax instrument is zero. The first-order necessary conditions read:

$$\frac{\partial \mathcal{W}}{\partial u} = -U_s s_u + U_x x_u - U_l L_u - \Lambda k - \Lambda k \left(L_u \frac{z}{k} + s_u \frac{v}{k} + k_u \frac{u}{k} \right) = 0 \quad , \tag{2.10a}$$

$$\frac{\partial \mathcal{W}}{\partial v} = -U_s s_v + U_x x_v - U_l L_v - \Lambda s - \Lambda s \left(L_v \frac{z}{s} + s_v \frac{v}{s} + k_v \frac{u}{s} \right) = 0 \quad , \tag{2.10b}$$

$$\frac{\partial \mathcal{W}}{\partial z} = -U_s s_z + U_x x_z - U_l L_z - \Lambda L - \Lambda L \left(L_z \frac{z}{L} + s_z \frac{v}{L} + k_z \frac{u}{L} \right) = 0 \quad , \tag{2.10c}$$

$$\frac{\partial \mathcal{W}}{\partial g} = \tilde{U}_g + \Lambda c_g = 0 \quad . \tag{2.10d}$$

Due to our assumptions on the utility function, the identification of second-best optimal tax rates can be separated from the problem of determining optimal public good supply, which generally would require solving system (2.10) simultaneously. The separability assumption facilitates the optimization problem to a great deal by enabling a two-stage solution. First, the government sets public consumption to satisfy the modified Samuelson condition (2.10d). Then, in the second stage, the government chooses tax rates according to first-order conditions (2.10a)-(2.10c).

In the following we concentrate on the second stage of the optimization process, assuming that the government sets public supply according to (2.10d) in the first stage. Multiplying the terms in brackets in (2.10) by minus one yields the tax base elasticities of all three instruments, τ_u, τ_v, τ_z, equal to the own-tax elasticity when the cross-price effect is zero. In a next step we carry out some straightforward manipulations in order to simplify (2.10).[8] Using the first-order conditions of the representative agent and the property of linear homogeneity of the production function, the following conditions (with instruments being optimized shown in parentheses) characterize an efficient allocation:

$$(u): \qquad \Lambda = 1/(1-\tau_u) \quad , \tag{2.11a}$$

$$(v): \qquad \Lambda = 1/(1-\tau_v) \quad , \tag{2.11b}$$

$$(z): \qquad \Lambda = 1/(1-\tau_z) \quad . \tag{2.11c}$$

With these definitions 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 (2.11) 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)]. Notice that in the optimum the marginal costs (MCF) of all available taxes are equalized. If they are not equal, the existing tax system is not second-best optimal. In the case that the MCFs do not match, those

[8] See the derivation in section A.3 of the appendix.

taxes with the largest values should be reduced since collecting revenue via these taxes leads to a larger welfare loss for a unit of revenue than would taxes with low MCFs. Technically, that means that all first-order conditions of instruments chosen endogenously must simultaneously hold with strict equality whereas the conditions of instruments being not feasible due to exogenous restrictions are redundant.[9] On the basis of this criterion evaluations of second-best tax systems will be carried out in the following sections.

The equations above describe a closed economy when no lump-sum taxes but only income taxes are available. The world economy includes at least one additional country, characterized by similar equations. The identical countries are linked by perfect capital mobility. In the following sections, our basic objective is to identify the conditions under which decentralized fiscal policies lead to globally efficient outcomes. The identity assumption makes the following analysis of open economies' fiscal policies more convenient since there will never be a reason for factor movements apart from differences in taxation. Due to the absence of a motive for trade in the model, the best decentralized decision-making of local governments can do is to replicate the second-best tax structure of a closed economy.

3 Tax policy when countries are large

Consider a system of n identical countries competing against each other for internationally mobile capital. Indices $\{i, a\}$ stand for home, respectively for the $(n-1)$ countries abroad. The identical countries are large so that they possess market power and choose the same tax rates in 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.

Rationally acting governments have to take market responses of households and firms into account when choosing their instruments. Factors supplied and demanded $\{k^j, s^j, l^j, L^j\}$ $\forall j \in \{i, a\}$ can be derived as implicit functions of $\{u_j, v_j, z_j\}$ $\forall j \in \{i, a\}$ from the following

[9]The solutions of system (2.11) for the optimal tax structures in situations with an incomplete and complete set of tax instruments are given by equations (A.11)-(A.14) in the appendix.

equations system:

$$-U_l^j - (w_j - z_j)U_x^j = 0 \quad \forall j \in \{i, a\} \quad , \tag{3.1a}$$

$$-U_s^j - (r - v_j)U_x^j = 0 \quad \forall j \in \{i, a\} \quad , \tag{3.1b}$$

$$f_l^j - w_j = 0 \quad \forall j \in \{i, a\} \quad , \tag{3.1c}$$

$$f_k^j - (r + u_j) = 0 \quad \forall j \in \{i, a\} \quad , \tag{3.1d}$$

$$l^j - L^j = 0 \quad \forall j \in \{i, a\} \quad , \tag{3.1e}$$

$$k^i - s^i + (n-1)\left(k^a - s^a\right) = 0 \quad . \tag{3.1f}$$

The equations denote in pairs the first-order conditions of households and firms in both countries, given by (2.3) and (2.5), respectively, and the market clearing conditions for national labor and the international capital market. 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. In the following we take advantage of this formulation of the capital market clearing condition. For $(n = 1)$ the home country is closed to international capital flows. Then the welfare effects of tax changes are identical to the case of one large country which is the second-best efficient benchmark for all the subsequent analysis.

Our basic analytical objective is to solve the system (3.1) for the own-tax induced changes in k^i, s^i, l^i and to insert them into the relevant first-order conditions for the local government (2.11). We distinguish four different fiscal scenarios by the number of available tax instruments. Straightaway a unique condition indicating the optimal tax structure is yielded for each of the underlying tax environments. These conditions are then rewritten in such a way that they become comparable with the conditions for second-best efficient allocations in a closed country.

However, beforehand we shall shortly derive some results referring to the subsequent discussion. Cramer's rule can be applied after differentiation of (3.1) in order to obtain the influence of a marginal increase in the domestic tax on the home capital balance $M \equiv k - s$:[10]

$$M_u = \frac{n-1}{n} \frac{k_r \left(kL_w - ls_w\right) |\mathcal{U}| - k}{k \left(L_w - l_w\right) |\mathcal{U}|} \quad , \tag{3.2a}$$

$$M_v = \frac{n-1}{n} \frac{lk_r L_r - kl_w s_r}{k \left(L_w - l_w\right)} \quad , \tag{3.2b}$$

$$M_z = \frac{n-1}{n} \frac{lk_r L_w - kl_w s_w}{k \left(L_w - l_w\right)} \quad , \tag{3.2c}$$

where $|\mathcal{U}|$ denotes the determinant of the firm's second-order conditions which has to be strictly positive for a maximum. With $M_u < 0$ and $M_v > 0$ the capital market equilibrium

[10]Notice, that we can drop indices after total differentiation of (3.1) as a consequence of the identity assumption.

satisfies the conditions for local dynamic stability. This can be guaranteed, assuming that first-period consumption is a normal good and an Hicksian substitute with leisure, and that $L_w \gtreqless 0$. Equation (3.2c) then immediately implies $M_z < 0$. 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 to non-cooperative tax policy when factor supply is endogenous.[11]

To proceed, we first analyze the outcome of the Nash tax competition game with two tax instruments so that governments are constrained in the set of second-best fiscal instruments available to them. Then we hand in the analysis of a tax competition game with a complete set of tax instruments.

No wage taxes: If the government is not permitted to use the wage tax, the optimal tax structure for the remaining set of two fiscal instruments, u, v, is yielded by totally differentiating (3.1) and then inserting the comparative static results into first-order conditions (2.11a) and (2.11b):

$$\frac{u}{v} = -\frac{lk_r\psi}{k\,(k - k_r\phi|\mathcal{U}|)}|\mathcal{U}| \quad . \tag{3.3}$$

According to condition (3.3), both taxes are set at positive rates and 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. Hence the second-best optimal tax structure in the benchmark of a closed economy, $(n = 1)$, is just replicated in the case of an internationally well integrated country. It follows that opening up the economy to international capital mobility does not cause any additional distortions in comparison with the benchmark case of a closed economy. The tax structure given by (3.3) is constrained Pareto efficient, given that there are no lump-sum taxes or wage taxes available. In so far condition (3.3) reconstructs the finding of Bucovetsky and Wilson (1991) in their proposition three. However, in their article the signs of the tax rates are not made explicit.

In order to interpret the efficiency result we follow the intuition given there: The presence of both taxes allows a country to manipulate gross and net returns to capital. As a consequence each country is effectively able to insulate itself from the fiscal externalities produced by another country's tax policy. In the absence of fiscal externalities, decentralized fiscal decisions lead to an efficient outcome, given the set of available tax instruments. Moreover, notice that in contrast to the Diamond-Mirrlees (1971) Production Efficiency

[11] In order to contrast equations (3.2) with the incentives in the standard static model, it can be recorded that the effects reduce to $M_u < 0$, $M_v = 0$ and $M_z = 0$ with factor supply given exogenously.

lemma efficiency here is established by (3.3) despite the absence of an optimal commodity tax system which in our model generally requires the infeasible tax on wages to be used.

No residence-based capital taxes: For $v^i = 0$ the first-order condition (2.11b) is redundant. Taking this into account and inserting the comparative statics of the differentiated system (3.1) into (2.11) yields:

$$\frac{u}{z} = \frac{\phi\left(k^2 L_w - l^2 k_r\right)|\mathcal{U}|}{(n-1)\left(k^2 - k k_r \phi |\mathcal{U}|\right) l + \psi\left(k^2 L_w - l^2 k_r n\right)|\mathcal{U}|} \quad , \tag{3.4}$$

which states that the rates of both taxes are positive if leisure consumption is a normal good. In the case of a closed economy, $(n = 1)$, equation (3.4) shortens to:

$$\frac{u}{z} = \frac{\phi}{\psi} \quad . \tag{3.5}$$

A comparison of (3.4) and (3.5) proves that decentralized fiscal decisions lead to an inefficient equilibrium, given the available tax instruments. Since the country's size, n, is relevant to the optimal tax ratio in an open economy, one or both taxes in (3.4) are set at an inefficient level. To see this, notice that from (3.4) the ratio of both taxes is unambiguously positive under the assumption that leisure is a normal good. Hence for any $(n > 1)$ the fraction (u/z) is strictly lower than in the closed economy benchmark of (3.5). A central planner aiming to achieve global efficiency, would establish a tax structure that is equal to the closed economy benchmark. The interpretation of this result is only partially familiar from standard tax competition problems. The intuition here is that, from (3.2), raising both wage and source-based capital taxes induce net capital outflows into the rest of the world, thereby decreasing the world interest rate.[12] International capital movements produced by a domestic tax increase make foreign countries better off, because firstly their own capital tax base enlarges due to the induced capital inflows and secondly the rent of the immobile factor rises to maintain zero profits in private production everywhere. Since labor supply is endogenous in this model, this can not be the whole story. Here an higher wage rate induced by capital inflows leads to a change in labor supply and wage tax revenue. This fiscal externality provoked by the wage tax 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.

Equations (3.4) and (3.5) are closely linked to proposition two in Bucovetsky and Wilson (1991), stating that the outcome of decentral fiscal decisions is inefficient if governments are constrained to solely use wage and source-based capital taxes. Of course, if labor is inelastic in supply, complete reliance on wage taxation is supported by (3.4)

[12] The effects on the world interest rate are given by (A.16) in the appendix.

and (3.5) for efficiency reasons, as ϕ is equal to zero and a globally efficient equilibrium is reached.

No source-based capital taxes: From inserting the market reactions derived from (3.1) into the relevant first-order conditions in (2.11) follows:

$$\frac{v}{z} = \frac{\phi}{\psi} \quad . \tag{3.6}$$

According to (3.6), the decentralized equilibrium is independent of country size and thus second-best efficient. Both taxes are used at positive rates under our assumptions if governments have no access to source-based capital taxes. This result is related to the Diamond-Mirrlees (1971) Production Efficiency lemma that the equilibrium with optimal commodity taxation should be on the boundary of the aggregate production set. For the apparent reason that a typical household's private consumption is financed out of wage and capital income, an optimal commodity tax system in this model generally includes a residence-based capital tax and a wage tax.

To consider this result in more detail, notice that, from (3.2), labor and residence-based capital taxes exert a reverse influence on the country's net capital balance. Firstly, as discussed above, the labor tax will tend to reduce the supply of capital to that country and increase capital supply to other countries which are now offering a more favorable tax climate. The effect on international capital movements depicts a positive fiscal externality for foreign tax authorities. Secondly, the 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 (3.6), the Nash equilibrium is constrained Pareto efficient. We conclude that the influence of the wage tax externality on world prices and the net capital balances stands exactly opposed to the effects induced by the residence-based capital tax. Therefore simultaneous use of both tax instruments allows a country to effectively insulate itself against fiscal externalities provoked by other countries' fiscal policies. As a direct consequence of this, there is no scope for welfare enhancing tax harmonization measures when a source-based capital tax is not included in the set of tax instruments available to governments.

Unconstrained set of fiscal instruments: In this case governments have a complete tax instrument set available. The second-best taxation rule for this scenario is:

$$\frac{u}{v} = 0 \quad , \tag{3.7a}$$

$$\frac{u}{z} = 0 \quad . \tag{3.7b}$$

Following (3.7) the typical government abstains from taxing capital at source. Production efficiency is supported and the country's aggregate consumption lies on the benchmark of a closed economy's consumption possibility frontier.

At first glance, this result may be surprising because it seems to be in sharp contrast to the intuition stemming from the inverse elasticity rule of optimal taxation, which suggests the source-based capital tax to be levied at some positive rate since the own tax elasticity of international movements is finite for a large country. Hence, one would possibly predict 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 actually is that the government voluntarily abstains from taxing capital at source and this is in fact closely related to the Diamond-Mirrlees (1971) Production Efficiency lemma that aggregate consumption optimally 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 labor 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 keep valid in an international context. Moreover, there is no scope for an international income tax harmonization program aiming at increasing efficiency worldwide by coordinating decentralized fiscal policies.

The absence of the source-based capital tax in the three tax equilibrium also has some implications on the sequence of the tax competition games with two tax instruments that have been previously considered. The result that the source-based tax is not levied in the optimum with an unconstrained set of fiscal instruments reveals for the equilibria with a constrained tax instrument set that although both tax combinations enure efficiency, the tax mix of a labor 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 figure 1, the theoretical results of the second-best optimal direct tax problem can be summarized diagrammatically. The figure stylizes the situation of a single country. In figure 1 the horizontal axis measures composite private consumption and the vertical axis public good supply from the viewpoint of a single country. The shaded area below $\overline{T^o T^o}$ is the world's production set under second-best optimal taxation. In all situations where we proved efficiency of decentralized fiscal policies, the production possibility frontier of an open economy coincidences with the the closed economy's. This is due to our assumption of identical countries leading to the absence of a motive for trade in the model, except for differences in tax rates. The curve $\overline{T^n T^n}$ stylizes the production possibility frontier as being *perceived* by a typical government in the inefficient situations where the residence-

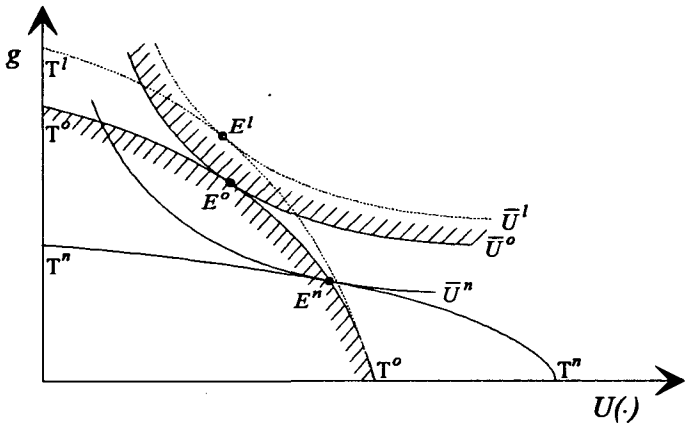

Figure 1: Constrained efficiency with a complete tax instrument set

based capital tax is not available. 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 own tax changes [see equations (3.2)] resulting in an increase of marginal costs for all available tax instruments [see equations (2.11)]. To see the consequences on the level of public good supply consider first-order condition (2.10d). 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 costs of an additional unit of public spending are perceived to be higher and this explains the flatter gradient of $\overline{T^nT^n}$ in the absence of residence-based capital taxes.

Curves $\overline{U}$ denote the representative household's indifference loci. From standard microeconomic theory, the optimal tax equilibrium is given by the highest indifference curve that is also 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 an higher indifference locus in the constrained efficient Nash equilibrium denoted by point E^o, compared to the inefficient equilibrium in point E^n. Notice that $\overline{T^nT^n}$ crosses $\overline{T^oT^o}$ in E^n, since the international allocation of capital is undistorted in a symmetric Nash equilibrium.

Finally, notice that even in the presence of residence-based capital taxes Nash equilibria, E^o, are only efficient in a third-best sense. A first-best allocation, represented by point E^l, could be established in the presence of a lump-sum tax, and the second-best public-good supply is optimal when no lump-sum but only distorting income taxes are available. The third-best public good supply is optimal under the additional constraint that the scheme of income taxation chosen in an internationally well integrated country

is identical to that chosen in the closed economy benchmark.

4 Tax policy in the small country case

As already noticed, a big part of the early literature on capital tax competition is concerned with the welfare effects of decentralized fiscal policies in a static framework with small countries [cf. Wilson (1986); Zodrow and Mieszkowski (1986)]. These articles have been set into a more realistic environment by the work of Frenkel, Razin and Sadka (1991). However the latter does not provide an analysis of a tax competition game with three taxes. This section about small countries is primarily aiming at catching up on work about the efficiency properties and the second-best optimal tax structure in a decentralized equilibrium with an unconstrained set of fiscal instruments. Secondary, it serves to relate the results of a small country's tax policy analysis to the large country case discussed above. While it is well understood by now that there are many parallels between the results obtained in the small and large country case, almost no work has been provided that contrasts these results. As far as we replicate results that already exist in the literature, this is an attempt to bridge this gap. As a side-effect, some results we derived in the more general framework become intuitively reasonable because the small country is by definition confronted with a fixed interest rate and an infinite elasticity of capital supply. Therefore the intuition from the inverse elasticity rule of optimal taxation theory can be applied to substitute to a large extent the reasoning of the more general but less intuitive concept of the Production Efficiency lemma.

Consider the case of a small country i without influence on world market's prices which has to compete for mobile capital against a world consisting of identical small countries. The following equations system describes the market reactions of the economic agents:

$$-U_l - (w-z)U_x = 0 \quad , \tag{4.1a}$$

$$-U_s - (r-v)U_x = 0 \quad , \tag{4.1b}$$

$$f_l - w = 0 \quad , \tag{4.1c}$$

$$f_k - (r+u) = 0 \quad , \tag{4.1d}$$

$$l - L = 0 \quad , \tag{4.1e}$$

which are in pairs the first-order conditions of households, firms and the market clearing condition for the home labor market. The apparent difference to (3.1) is that the small country faces a fixed world interest rate determined by the rest of the world.

Solving the system (4.1) for the tax induced changes in k, s, l yields for the derivatives

of the capital balance:

$$M_u = \frac{k_r\left(kL_w - ls_w\right)|\mathcal{U}| - k}{k\left(L_w - l_w\right)|\mathcal{U}|} \quad , \tag{4.2a}$$

$$M_v = \frac{lk_rL_r - kl_ws_r}{k\left(L_w - l_w\right)} \quad , \tag{4.2b}$$

$$M_z = \frac{lk_rL_w - kl_ws_w}{k\left(L_w - l_w\right)} \quad . \tag{4.2c}$$

Notice, that equations (4.2) are identical to (3.2) except for that the number of countries, n, plays no role in (4.2).[13]

Analogous to the procedure in the previous section we insert the comparative statics of differentiating system (4.1) into the relevant first-order conditions in (2.11) to obtain the second-best optimal tax structure for a small open economy. Before analyzing the outcome of a Nash tax competition game in all three taxes, consider first three cases in which governments are constrained in the set of second-best tax instruments available to them because of some exogenous reason.

No wage taxes: In the absence of a wage tax (2.11c) does not hold with equality, and the optimal tax structure emerges from equality of (2.11a) and (2.11b) alone. Solving for the two remaining tax instruments and inserting the market responses gives:

$$\frac{u}{v} = -\frac{lk_r\psi}{k\left(k - k_r\phi|\mathcal{U}|\right)}|\mathcal{U}| \quad , \tag{4.3}$$

which is identical to condition (3.3) and strictly positive under our assumptions. The number of countries, n, plays no role in condition (4.3). As a result decentralized fiscal policies lead to a Pareto efficient tax structure. The reasoning behind (4.3) is that the source-based capital tax is an incomplete substitute for the lacking wage tax and allows the government to absorb in part the rents accruing to labor which optimally should be taxed. Equation (4.2a) indicates that a small source-based capital tax worsens the country's net capital balance, thereby raising the level of domestic saving by increasing the before-tax rate of capital return. For a small source-based capital tax rate, the loss in production efficiency will be sufficiently small and dominated by the additional tax revenue generated.

No residence-based taxes: Here equation (2.11b) does not hold with equality and the conditions of interest are (2.11a) and (2.11c) in which the market reactions are inserted

[13] It is recorded that n vanishes in equation (4.2) since $\lim_{n\to\infty}\frac{n-1}{n} = 1$. In analogy to equations (3.2), the derivatives of the net capital balance are $M_u < 0$, $M_v = 0$ and $M_z = 0$ if factor supply is exogenous.

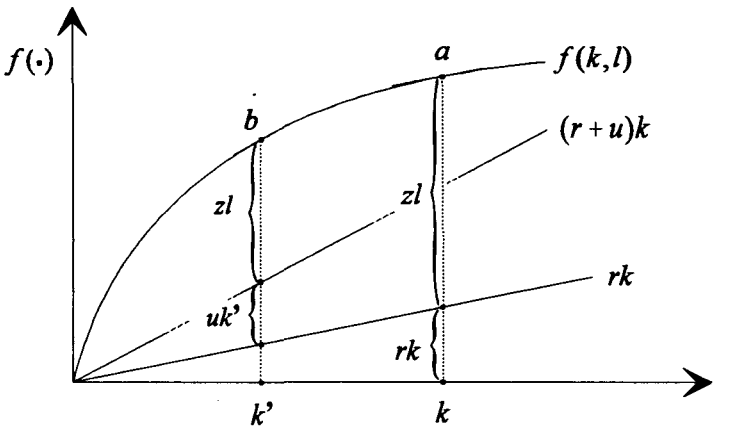

Figure 2: Optimal tax mix without residence-based capital taxes

to obtain:

$$\frac{u}{z} = 0 \quad . \tag{4.4}$$

The absence of source-based capital taxes is absolutely reasonable. The small country perceives an high tax base elasticity and expects an enormous tax base loss that is incurred by a given rise in the domestic source-based tax rate. In contrast the elasticity of labor supply is finite. The inverse elasticity rule from optimal tax theory then suggests that a small country refrains from taxing capital at source. This leads to the question whether the tax instruments are set efficiently from the world's perspective. It can be reported that the outcome of a tax competition game in wage taxes is not second-best efficient since the benchmark of (3.5) is not replicated by (4.4). A global optimum is clearly not attainable. In contrast to the closed economy, where the tax burden is distributed over all factor incomes to minimize the overall excess burden, the whole tax burden falls on labor income in a small open economy.

The high rivalry amongst small countries for mobile factor reduces the tax burden which capital has to bear to equal zero. This result is related to the Diamond-Mirrlees (1971) Production Efficiency lemma of optimal commodity taxation. Despite the absence of an optimal commodity tax system, which would generally imply a tax on labor and a residence-based capital tax, the result is that a small country does not tax capital at source in order to leave the international allocation of capital undistorted. It solely uses the tax revenue coming from labor taxation to finance the provision of the local public good.

Figure 2 illustrates the crucial effects in a partial equilibrium framework. It represents the productive sector of a typical region. The curve $f(k, l)$ denotes the concave production technology of the representative firm. When no source-based capital taxes are levied, the

line rk indicates the cost of capital. The profit maximizing capital demand, k, is yielded at a point on the abscissa where the vertical distance between both curves is maximized. Point a denotes such a place in which the slope of the production function equals r, the cost of a marginal unit of capital. With $(w = z)$, the government obtains wage tax revenues, zl, equal to the rents otherwise accruing to labor. If the government now introduces a source-based capital tax the cost of capital schedule moves up to $(r+u)k$. Firms optimally adjust their capital demand to $(k' < k)$, which is given by the new tangency solution at point b. Although total tax revenue now consists of the revenue of two taxes at lower rates, every advantage is exhausted by a large loss in production efficiency. A direct comparison of total tax revenues in both situations supports the result of (4.4) which implies that the source-based capital tax should not be used. This suggests what is noted above: Small regions offer a 'tax holiday' for internationally mobile capital.

No source-based taxes: In this case (2.11a) is not fulfilled with equality. Solving for the rates of the remaining tax instruments yields:

$$\frac{v}{z} = \frac{\phi}{\psi} \quad . \tag{4.5}$$

According to (4.5) both taxes are to be levied with positive rates. The government has the necessary set of instruments to effectively control tax induced distortions on labor and capital supply. A comparison of (4.5) with the benchmark case of a closed economy (3.6) directly suggests that the decentralized equilibrium is second-best efficient in the absence of source-based capital taxes. This conclusion together with (4.4) corresponds to Frenkel, Razin and Sadka (1991), stating that the outcome of a non-cooperative tax competition equilibrium in source-based taxes is Pareto inferior to an equilibrium in residence-based taxes.

Unconstrained set of fiscal instruments: Finally, we portray the outcome of the tax competition game with an unrestricted set of fiscal instruments. Since all conditions in (2.11) now hold with strict equality we get:

$$\frac{u_i}{v_i} = 0 \quad , \tag{4.6a}$$

$$\frac{u_i}{z_i} = 0 \quad , \tag{4.6b}$$

$$\frac{v_i}{z_i} = \frac{\phi}{\psi} \quad . \tag{4.6c}$$

In an environment with an unconstrained set of fiscal instruments the small country's optimal tax structure is identical to a globally efficient tax relationship. Moreover the source-based capital tax is not part of the tax mix, which is due to the high elasticity of international capital movements a small country is faced with.

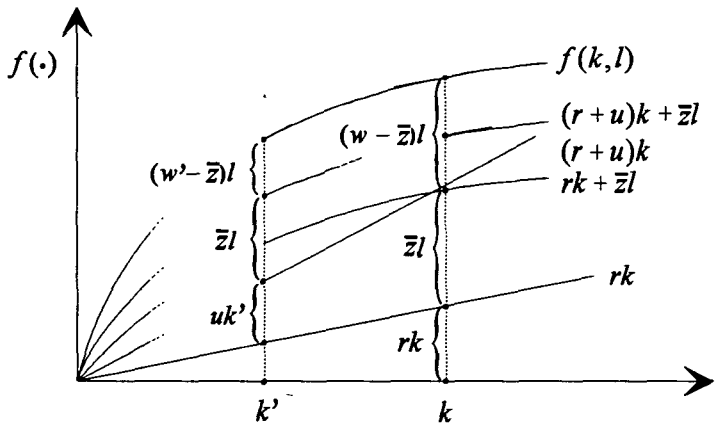

Figure 3: No residence-based capital taxes and only bounded wage taxes available

Somewhat more puzzling than the absence of source-based capital taxes in the small country's optimal tax mix is the observation that the governments' use of labor and residence-based capital taxes results in an efficient Nash equilibrium. To provide an intuitive explanation for that result, we have to remind ourself that equation (4.2) shows that both taxes exert an influence on the home capital stock. Whereas the labor tax tends to a rise in capital exports through the process of factor substitution in private production, the residence-based capital tax tends to increase capital imports due to the reduction in saving. Therefore the small country has in principle the possibility to act strategically in order to attract capital. According to (4.6) the government does not use this potential and sets tax rates efficiently, even from the world's view. The conclusion therefore is that the wage tax externality and the effects on international capital movements induced by the residence-based capital tax are directly competing. In equilibrium, the effects on the net capital balance are offset and no international distortions are induced. Thus the overall conclusion is that decentralized fiscal decisions lead to an efficient outcome and can do without an intervention of a supranational organization or harmonization of national tax rates.

A simple model modification

The results noted have determined some relations between income taxes. However, the model can be approached from a number of alternative perspectives which prevent any simple statement being given. Lastly to show how results may change if additional, sensible restrictions are introduced, reconsider the case of an absent residence-based capital tax in a partial equilibrium framework where factors are in fixed supply within a country.

Figure 3 captures the main effects of introducing an upper bound, $\overline{z}$, on labor taxation when additionally only source-based and no residence-based capital taxes are available.

The justification for the introduction of such an upper bound may arise out of legal restrictions that ban confiscatory taxes. Figure 3 tallies with figure 2 except for the consequences of the model extension. In the following, we show by contradiction that both taxes, the source-based capital and the labor tax are used by a government. For this purpose, assume that the wage tax is set according to its upper bound and the government refrains from using the source-based capital tax. Total tax revenue results in $\overline{z}l$. Introducing a non-zero source-based capital tax may well increase total tax revenues, hence $\overline{z}l < \overline{z}l' + uk'$, despite the loss in production efficiency attributed to the source-based capital tax. The source-based capital tax is part of the tax scheme. The interpretation is that the tax serves to shift labor rents to the public sector which otherwise would be tax-exempted. The present discussion clearly extends the previous result of (4.4), although it puts aside the fact that factor supplies might react.[14]

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 tax instruments. Due to the existence of international fiscal externalities, the opening of a country's borders not necessarily expands a country's consumption possibilities. It has been shown that generally all three direct taxes being considered exert an influence on the tax bases of foreign countries. Aside from the usual spillovers provoked by the source-based capital tax, we identified a negative wage tax externality and a positive fiscal externality induced by the residence-based capital tax. As has been emphasized throughout our analysis, all international effects are of particular relevance under global efficiency considerations.

The conclusions that can be drawn from the present analysis are many and diverse. First of all the analysis proved that a necessary and sufficient condition for efficiency of decentralized fiscal policies is that governments have access to residence-based capital taxes. Independently of countries' size, efficiency of decentralized fiscal decisions can be established regardless of combining residence-based capital taxes with either source-based or else labor taxes. We hence conclude that it is the absence of residence-based capital taxes and not the presence of positive source-based tax rates that causes inefficiency of decentralized fiscal decisions. Therefore the straightforward policy advice that may be drawn from the present analysis is to abolish the obstacles to tax residents on their income

[14] Wage income can also be re-interpreted as profits accruing to all other non-capital factors of production not being owned by foreigners. Huizinga and Nielsen (1995), section three, provide a general equilibrium analysis of the consequences putting upper bounds on profit taxes in a small country when profits are only domestically owned. Essentially, the effects resemble the ones yielded in the presented graphical analysis. However, Huizinga and Nielsen (1995) expand their framework to the case of foreign ownership of firms.

from capital invested in other countries. As it has already been portrayed, we consciously state this advice being difficult to implement in the real world due to the enforcement problem that fiscal authorities are faced with. Further, it has been shown in the analysis that although both tax combinations establish efficiency, a mix of a residence-based with source-based capital taxes is Pareto inferior to a situation in which only residence-based capital and labor taxes are available.

Finally and as far as the comparison of inefficient equilibria in which government only have access to an incomplete tax instruments set is concerned, the model predicts that positive source-based taxes are optimally levied in a large country even in the absence of terms of trade considerations, whereas the small country abstains from taxing capital at source. This model prediction should be related to the empirical observation that a majority of countries levies positive source-based capital taxes. As the EU example demonstrates, countries which offer a 'tax holiday' are mostly the smaller ones. Hence we showed that the patterns observed in the data can arise even in a simple theoretical model.

The paper analyzed an economy which was, by necessity, highly stylized. Only some of the shortcomings to mention shall be outlined here. Firstly the interactions between factor and commodity taxation have been neglected in the present paper. The unique private consumption good has been chosen as numéraire. There was no room for a meaningful analysis of commodity taxes. As far as factor taxation is concerned we left out any kind of tax credits for source-based capital taxes. Secondly, the preferences of the households have been taken as identical. Hence differences in preferences do not arise. Furthermore the household has been viewed as supplying an homogeneous form of labor but in practice the total labor supply is often the sum of male and female components. The nature of these is often very different and empirical evidence suggests that they have markedly different responses to taxation. We abstracted from underemployment whereas a realistic analysis for many countries would incorporate underemployment. In the complex real world, countries' incentives to attract capital possibly are even stronger than in the theoretical model. Governments may strive for boosting national incomes in order to relieve their social security systems. We hope to integrate some of these aspects in future research.

A Appendix

The basic purpose of the appendix is to derive the expressions in 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:

$$\mathcal{L} \equiv U\left(y-s, x, T-L\right) - \lambda\left(x-(w-z)L-(r-v)s\right) \quad . \tag{A.1}$$

The first-order conditions are:

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

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

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

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

Simple manipulations give (2.3) in the main text. Using the Implicit Functions theorem on (2.3) yields:

$$L_w = -\frac{\mathrm{E}}{\mathrm{B}} \quad , \qquad L_r = -\frac{\mathrm{G}}{\mathrm{B}} \quad , \qquad s_w = -\frac{\mathrm{H}}{\mathrm{A}} \quad , \qquad s_r = -\frac{\mathrm{F}}{\mathrm{A}} \quad , \tag{A.3}$$

where:

$$\mathrm{A} \equiv U_{ss} - 2(r-v)U_{sx} + (r-v)^2 U_{xx} \quad , \qquad \mathrm{B} \equiv U_{ll} - 2(w-z)U_{xl} + (w-z)^2 U_{xx} \quad ,$$

$$\mathrm{E} \equiv U_x + L\left((w-z)U_{xx} - U_{xl}\right) \quad , \qquad \mathrm{F} \equiv U_x + s\left((r-v)U_{xx} - U_{sx}\right) \quad ,$$

$$\mathrm{G} \equiv s\left((w-z)U_{xx} - U_{xl}\right) \quad , \qquad \mathrm{H} \equiv L\left((r-v)U_{xx} - U_{sx}\right) \quad ,$$

and $\mathrm{A} < 0$, $\mathrm{B} < 0$ must hold for a maximum. In order to prove this we totally differentiate the first-order conditions (A.2):

$$\begin{pmatrix} 0 & r-v & -1 & w-z \\ r-v & U_{ss} & -U_{sx} & U_{sl} \\ -1 & -U_{sx} & U_{xx} & -U_{xl} \\ w-z & U_{sl} & -U_{xl} & U_{ll} \end{pmatrix} \begin{pmatrix} d\lambda \\ ds \\ dx \\ dL \end{pmatrix} = \begin{pmatrix} -s & -L \\ -\lambda & 0 \\ 0 & 0 \\ 0 & -\lambda \end{pmatrix} \begin{pmatrix} dr-v \\ dw-z \end{pmatrix} \quad . \tag{A.4}$$

Hence, $-\mathrm{A}$ and $-\mathrm{B}$ denote the determinants of the 3 by 3 principal minors of the Hessian, $\mathcal{H}$. Symmetry of $\mathcal{H}$ implies that the determinants of these principal minors have to be positive for a maximum, i.e. $\mathrm{A} < 0, \mathrm{B} < 0$, and that $|\mathcal{H}| < 0$.

In a next step (A.4) can be used to decompose the uncompensated effects in Hicksian price effects and income effects. Applying Cramer's rule to (A.4) yields:

$$s_r = \lambda \, \mathrm{B} \, |\mathcal{H}|^{-1} + s \, \frac{\partial s}{\partial x} \quad , \qquad s_w = \lambda \, \mathrm{C} \, |\mathcal{H}|^{-1} + L \, \frac{\partial s}{\partial x} \quad ,$$
$$L_w = \lambda \, \mathrm{A} \, |\mathcal{H}|^{-1} + L \, \frac{\partial L}{\partial x} \quad , \qquad L_r = \lambda \, \mathrm{D} \, |\mathcal{H}|^{-1} + s \, \frac{\partial L}{\partial x} \quad .$$

These Slutsky decompositions together with the second-order conditions and the definitions used in (A.3) directly imply that:

$$\mathfrak{s}_r \equiv \lambda \frac{\mathrm{B}}{|\mathcal{H}|} > 0 \quad , \qquad \mathfrak{L}_w \equiv \lambda \frac{\mathrm{A}}{|\mathcal{H}|} > 0 \quad , \qquad \mathfrak{s}_w \equiv \lambda \frac{\mathrm{C}}{|\mathcal{H}|} = \lambda \frac{\mathrm{D}}{|\mathcal{H}|} \equiv \mathfrak{L}_r \quad .$$

A.2 Firms

Normalizing the price of output to equal one, profit maximization on the part of the firms:

$$\pi = f(k, l) - (r + u)k - wl \quad , \tag{A.5}$$

implies:

$$\frac{\partial \pi}{\partial l} = f_l - w = 0 \quad , \tag{A.6}$$
$$\frac{\partial \pi}{\partial k} = f_k - (r + u) = 0 \quad . \tag{A.7}$$

Total differentiation of the first-order conditions gives:

$$\begin{pmatrix} f_{ll} & f_{lk} \\ f_{kl} & f_{kk} \end{pmatrix} \begin{pmatrix} dl \\ dk \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} dw \\ dr + u \end{pmatrix} \tag{A.8}$$

Next, we apply Cramer's rule to (A.8) and use the second-order conditions. This yields:

$$l_w = \frac{f_{kk}}{|\mathcal{U}|} < 0 \quad , \qquad k_w = \frac{f_{kl}}{|\mathcal{U}|} \gtreqless 0 \quad ,$$
$$l_r = \frac{f_{lk}}{|\mathcal{U}|} \gtreqless 0 \quad , \qquad k_r = \frac{f_{ll}}{|\mathcal{U}|} < 0 \quad . \tag{A.9}$$

where $|\mathcal{U}|$ denotes the determinant of the substitution matrix. From symmetry, a maximum requires that $f_{ll} < 0$ holds and $|\mathcal{U}|$ must be strictly positive. Assuming then a linear-homogeneous production technology, using Euler's theorem and inserting the resulting expressions into (A.9) gives (2.6) in the main text.

A.3 Governments

The first-order conditions of (2.9) are given by (2.10) and (A.2). The requirement that profits – defined by (A.5) – equal zero in equilibrium defines a negatively-sloped factor-price frontier $(\partial w / \partial r) = -k/L$. This and the labor market clearing condition, $(L = l)$,

are used after total differentiation of (A.2) to get:

$$k = -x_u + (w - z)L_u + (r - v)s_u \quad , \tag{A.10a}$$

$$s = -x_v + (w - z)L_v + (r - v)s_v \quad , \tag{A.10b}$$

$$L = -x_z + (w - z)L_z + (r - v)s_z \quad . \tag{A.10c}$$

Inserting (A.10) into (2.10) yields (2.11) in the main text.

Only two tax instruments available: If the government only has two of the three tax instruments at its disposal, the second-best optimal tax structure is yielded by solving two first-order conditions of (2.11) simultaneously. The condition for the unused tax instrument is redundant. The optimal tax structures for all three possible combinations of taxes are:

$$\frac{u}{v} = \frac{s_v k - s_u s}{k_u s - k_v k} \qquad \wedge \qquad z = 0 \quad , \tag{A.11}$$

$$\frac{u}{z} = \frac{l_z k - l_u l}{k_u l - k_z k} \qquad \wedge \qquad v = 0 \quad , \tag{A.12}$$

$$\frac{v}{z} = \frac{l_v l - l_z s}{s_z s - s_v l} \qquad \wedge \qquad u = 0 \quad . \tag{A.13}$$

All tax instruments available: If the set of fiscal instruments is unconstrained the first-order conditions of all tax instruments in (2.11) have to be fulfilled with strict equality. Hence:

$$\frac{u}{v} = \frac{k\,(l_z s_v - l_v s_z) + l\,(l_v s_u - l_u s_v) + s\,(l_u s_z - l_z s_u)}{k\,(k_z l_v - k_v l_z) + l\,(k_v l_u - k_u l_v) + s\,(k_u l_z - k_z l_u)} \quad , \tag{A.14a}$$

$$\frac{u}{z} = \frac{k\,(l_v s_z - l_z s_v) + l\,(l_u s_v - l_v s_u) + s\,(l_z s_u - l_u s_z)}{k\,(k_z s_v - k_v s_z) + l\,(k_v s_u - k_u s_v) + s\,(k_u s_z - k_z s_u)} \quad , \tag{A.14b}$$

$$\frac{v}{z} = \frac{k\,(k_v l_z - k_z l_v) + l\,(k_u l_v - k_v l_u) + s\,(k_z l_u - k_u l_z)}{k\,(k_z s_v - k_v s_z) + l\,(k_v s_u - k_u s_v) + s\,(k_u s_z - k_z s_u)} \quad . \tag{A.14c}$$

A.4 Identical countries case

The market responses of households and firms must be derived from (3.1). Taking the initial situation as an equilibrium starting-point, eliminating the wage rates in system (3.1) by inserting (3.1c) everywhere and totally differentiating (3.1) yields for identical

countries:

$$
\begin{aligned}
(\mathrm{B}+\mathrm{E}f_{ll})\,dl^i + \mathrm{E}f_{kl}dk^i + \mathrm{G}dr - \mathrm{G}dv_i - \mathrm{E}dz_i &= 0 \quad , \\
(\mathrm{B}+\mathrm{E}f_{ll})\,dl^a + \mathrm{E}f_{kl}dk^a + \mathrm{G}dr - \mathrm{G}dv_a - \mathrm{E}dz_a &= 0 \quad , \\
\mathrm{H}f_{ll}dl^i + \mathrm{H}f_{kl}dk^i + \mathrm{A}ds^i + \mathrm{F}dr - \mathrm{F}dv_i - \mathrm{H}dz_i &= 0 \quad , \\
\mathrm{H}f_{ll}dl^a + \mathrm{H}f_{kl}dk^a + \mathrm{A}ds^a + \mathrm{F}dr - \mathrm{F}dv_a - \mathrm{H}dz_a &= 0 \quad , \\
f_{kl}dl^i + f_{kk}dk^i - dr - du_i &= 0 \quad , \\
f_{kl}dl^a + f_{kk}dk^a - dr - du_a &= 0 \quad , \\
dk^i - ds^i + (n-1)\,(dk^a - ds^a) &= 0 \quad .
\end{aligned}
$$

In matrices:

$$
\begin{pmatrix}
\mathrm{I} & 0 & \mathrm{II} & 0 & 0 & 0 & \mathrm{G} \\
0 & \mathrm{I} & 0 & \mathrm{II} & 0 & 0 & \mathrm{G} \\
\mathrm{III} & 0 & \mathrm{IV} & 0 & \mathrm{A} & 0 & \mathrm{F} \\
0 & \mathrm{III} & 0 & \mathrm{IV} & 0 & \mathrm{A} & \mathrm{F} \\
f_{kl} & 0 & f_{kk} & 0 & 0 & 0 & -1 \\
0 & f_{kl} & 0 & f_{kk} & 0 & 0 & -1 \\
0 & 0 & 1 & n-1 & 1-n & 1 & 0
\end{pmatrix}
\begin{pmatrix} dl^i \\ dl^a \\ dk^i \\ dk^a \\ ds^i \\ ds^a \\ dr \end{pmatrix}
=
\begin{pmatrix}
0 & \mathrm{G} & \mathrm{E} & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & \mathrm{G} & \mathrm{E} \\
0 & \mathrm{F} & \mathrm{H} & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & \mathrm{F} & \mathrm{H} \\
1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
\begin{pmatrix} du_i \\ dv_i \\ dz_i \\ du_a \\ dv_a \\ dz_a \end{pmatrix}
\quad , \tag{A.15}
$$

where

$$
\begin{aligned}
&\mathrm{I} \equiv \mathrm{B} + \mathrm{E}f_{ll} = \mathrm{B}\,(1 - k_r L_w |\mathcal{U}|) \quad , \quad \mathrm{II} \equiv \mathrm{E}f_{kl} = -\mathrm{B}k_w L_w |\mathcal{U}| \quad , \\
&\mathrm{III} \equiv f_{ll}\mathrm{H} = -\mathrm{A}k_r s_w |\mathcal{U}| \quad , \qquad \mathrm{IV} \equiv f_{kl}\mathrm{H} = -\mathrm{A}k_w s_w |\mathcal{U}| \quad .
\end{aligned}
$$

Applying Cramer's rule to (A.15) we solve for the own-tax induced market reactions. Dropping indices, using (2.6) and (A.3) everywhere and inserting the resulting expressions into equations (A.11)-(A.14) yields the optimal tax structures for the home country being well integrated in a world consisting of identically large countries.

Finally notice that:

$$
r_u = \frac{k\,(k_r\,(kL_w - ls_w)\,|\mathcal{U}| - k)}{n\,(k^2 - kk_r\phi|\mathcal{U}| - lk_r\psi|\mathcal{U}|)} \tag{A.16a}
$$

$$
r_v = \frac{lk_r\,(kL_r - ls_r)}{n\,(k^2 - kk_r\phi|\mathcal{U}| - lk_r\psi|\mathcal{U}|)} \tag{A.16b}
$$

$$
r_z = \frac{lk_r\,(kL_w - ls_w)}{n\,(k^2 - kk_r\phi|\mathcal{U}| - lk_r\psi|\mathcal{U}|)} \tag{A.16c}
$$

Equations (A.16a) and (A.16c) correspond to equations (16) and (17) in Bucovetsky and Wilson (1991).

A.5 Small countries case

The market responses of households and firms must be derived from (4.1). Taking the initial situation as an equilibrium starting-point, eliminating the wage rate in system (4.1) by inserting (4.1c) everywhere and totally differentiating (4.1) yields for a system of identical small countries:

$$(\mathrm{B}+\mathrm{E}f_{ll})\,dl+\mathrm{E}f_{kl}dk-\mathrm{G}dv-\mathrm{E}dz=0 \quad , \tag{A.17}$$

$$\mathrm{H}f_{ll}dl+\mathrm{H}f_{kl}dk+\mathrm{A}ds-\mathrm{F}dv-\mathrm{H}dz=0 \quad , \tag{A.18}$$

$$f_{kl}dl+f_{kk}dk-du=0 \quad . \tag{A.19}$$

Firstly using (A.19) to eliminate dl everywhere in (A.17) and (A.18), then multiplying both equations by f_{kl} gives:

$$\begin{pmatrix} -\mathrm{B}f_{kk}-\mathrm{E}|\mathcal{U}| & 0 \\ \mathrm{D}f_{kk}-\mathrm{H}|\mathcal{U}| & \mathrm{A}f_{kl} \end{pmatrix}\begin{pmatrix} dk \\ ds \end{pmatrix}=\begin{pmatrix} -\mathrm{B}-\mathrm{E}f_{ll} & \mathrm{G}f_{kl} & \mathrm{E}f_{kl} \\ \mathrm{D}-\mathrm{H}f_{ll} & \mathrm{F}f_{kl} & \mathrm{H}f_{kl} \end{pmatrix}\begin{pmatrix} du \\ dv \\ dz \end{pmatrix} \quad . \tag{A.20}$$

Let $\mathcal{S}$ denote the matrix on the left side of (A.20). Local stability requires $|\mathcal{S}|$ to be negative. Applying Cramer's rule to (A.15), using (2.6) and (A.3) everywhere we derive the tax induced market reactions:

$$k_u=-k^2\left(1-k_rL_w|\mathcal{U}|\right)/(N|\mathcal{U}|) \quad , \tag{A.21a}$$

$$k_v=klk_rL_r/N \quad , \tag{A.21b}$$

$$k_z=klk_rL_w/N \quad , \tag{A.21c}$$

$$s_u=klk_rs_w/N \quad , \tag{A.21d}$$

$$s_v=l^2k_rs_r/N \quad , \tag{A.21e}$$

$$s_z=l^2k_rs_w/N \quad , \tag{A.21f}$$

$$l_u=lkk_rL_w/N \quad , \tag{A.21g}$$

$$l_v=l^2k_rL_r/N \quad , \tag{A.21h}$$

$$l_z=l^2k_rL_w/N \quad , \tag{A.21i}$$

where $N=k^2L_w-l^2k_r$ is strictly positive for ($|\mathcal{S}|<0$). Notice that labor market responses are derived by inserting (A.21a)-(A.21f) into (A.19).

Inserting expressions (A.21) into equations (A.11)-(A.14) yields the optimal tax structures for the home country being well integrated in a world consisting of identically small countries.

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