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Corporate Finance, Capital Market Equilibrium, and International Tax Competition with Capital Income Taxes

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Abstract: We develop a model of capital income tax competition where taxation can discriminate between different kinds of capital income (corporate income, interest income, and dividends) and various rules of international taxation can be applied. The firms' capital structures and the nature of the international capital market equilibrium depend on both the national and the international tax systems. In a fiscal game with revenue maximizing governments it turns out that: (i) Under the source principle, the corporate income tax emerges as the dominant tax form. (ii) Under the residence principle, whole tax blocks are contestable and the Nash equilibrium crucially depends on the technologies employed by the firms. (iii) Tax credits will not survive in international tax competition.

JEL-classification: H87, H25, G32
Key words: Fiscal Competition, Capital Taxation, Financing Policy

1. Introduction

International capital tax competition means the strategic use of taxes on capital and capital income by self-interested national governments in an integrated economic environment with free capital movements. It is a phenonemon whose actual or potential occurrence gives rise to substantial worryings. There may be mainly three reasons for this: Firstly, the amount and the structure of capital invested in a country play a key rôle for its economic standing and prospects. If tax competition brings about changes in the international capital allocation, this may have severe consequences for the international competitiveness of the nations envolved and for the well-being of present and future generations. Secondly, capital (esp. financial capital) is internationally highly mobile and reacts very sensitively to its fiscal treatment. Hence, noticeable changes in the allocation of capital allocation are very likely to happen if tax rates change. This distinguishes capital from, e.g., labour whose relatively low international mobility makes labour income a very inelastic tax base. Thirdly, in all major industrialized countries taxes on capital income form an important source of governments' revenues such that tax competition in this field will also affect other policy areas and thus the fiscal systems as a whole.

The strategic interaction with taxes on capital income is a tricky game of crucial importance for the governments engaged in it. Economic theory has devoted considerable effort to the investigation of this game. However, it has up to now not taken into account the high complexity of real systems of capital income taxation. The standard approach to capital tax competition is a "duopolity" setting (Wildasin (1991)) where each government has at its disposal one tax rate on the capital stock invested in its jurisdiction or on the income that is earned with this capital (source based taxation). Recently, different methods of cross border taxation, which allow for a differential treatment of incomes from different countries, have been incorporated in these models,[1] but still each government is assumed to tax all capital income by the same uniform schedule. In reality, however, capital income tax systems discriminate - already at the national levels - between different kinds of capital income (dividends, interest income, capital gains), between different tax payers (corporate vs. personal taxes) and between different ways of using capital income (retained earnings or distributed profits).

There have been numerous attempts to examine and evaluate the effects of complex national and international tax systems on the allocation of capital.[2] There is, however, hardly any study which analyses the strategic incentives inherent in such complex systems. Complex tax systems offer of course a wider range of taxation strategies than simple ones, and it can be

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1 See e.g. Mintz/Tulkens (1996) or Janeba (1995).

2 King/Fullerton (1984), Alworth (1988) and Sinn (1987) are most seminal studies in this area, which apart from taxes also study the effects of depreciation allowances, cost.deductibilities, loss-offsets, etc.

expected that tax competition will not look alike in both settings. The major obstacle for a theoretical analysis is, however, that even the rudimentary integration of some basic elements of real tax systems results in very complicated capital allocation models. If one builds a fiscal game upon such a model the analysis is very likely to turn untractable very soon.

This paper tries a first step towards a reconciliation of the theory of tax competition with the existing systems of capital income taxation. Its aim is not to give a full theory but rather to develop a simple framework which allows for the analysis both of real tax complexities and of tax competition. We will of course give some first results on tax competition within this approach.

The rest of the paper is organized as follows: Section 2 outlines the model. Sections 3 to 5 discuss capital tax competition under three different international tax rules, namely the source principle, the residence principle and the tax credit method. Section 6 concludes.

Our main findings may be summarized as follows:

- Under the source principle firms, always choose a mixed capital structure (i.e. a combination of debt and equity finance). The corporate income tax will emerge from tax competition as the tax with the highest rate. At the personal level, dividends will be taxed more heavily than interest income. Tax competition induces a tendency towards cash-flow taxation. In general, the equilibria of tax competition are inefficient.
- Under the residence principle, the capital structure of firms in capital importing countries varies with tax rates. Hence, whole tax blocks are contestable. Equilibria in tax competition crucially depend on the firms' technologies. Tax rates may be chosen inefficiently *high*.
- Tax credits will not survive in tax competition. Instead, the source principle will catch on.

2. The model

2.1 General description

Our analysis of capital tax competition is based on a simple, neoclassical two-period-two-country model of a capital market. The first period consists of two stages: In stage I, the national governments choose their tax rates (This is the tax competition game). In stage II, consumers make their savings and portfolio decisions and firms decide on investment and capital structure. The financial instruments available to the firms are debt and equity. Corporate debt is securitized. Hence, consumers' portfolio choices are to be made between

bonds and shares. All private agents incorporate the governments' tax policies in their plans. A Walrasian auctioneer prices assets such as to yield a capital market equilibrium.

In the second period, production takes place. Capital is the only input. The firms sell their output, pay taxes, interests and dividends. Debt is repaid to creditors and the rest of the firm's value accrues to shareholders via liquidation. Capital income net of personal taxes plus repayments form second period disposable income for the consumers. Governments collect taxes.

The two countries are labelled by A and B. We assume that the corporate sector in each country can be represented by a single firm, also labelled by A and B, respectively. Furthermore, we assume that there is only one representative consumer in the world economy. W.l.o.g., this consumer lives in country A. Thus, country A is a capital exporter, while country B is a capital importer. International capital flows only go into one direction.

We assume that national governments aim at maximizing their tax revenues. Although quite limited, this assumption covers a wide range of possible interpretations:[3] With fixed government expenditures revenue maximization is equivalent to budget surplus maximization and thus fits into a Leviathan framework of governments. Furthermore, revenue maximization can be justified from a welfarist perspective when citizens place a high marginal value on public expenditures which tax revenues go to finance. If tax yields are redistributed amongst the population, revenue maximization may as well be seen as the maximization of disposable domestic income. If tax payments are likely to be circumvented (legally or illegally) revenue maximization is equivalent to minimizing tax evasion.

2.2 Capital supply

The representative consumer in our model maximizes an intertemporal utility function $U(C_1, C_2)$, where C_v denotes consumption in period $v = 1,2$ and the function U satisfies the Inada conditions. In period 1 households have an exogenous income $M > 0$. Savings S can be invested in the capital markets, yielding a riskless net return with rate $\rho > 0$. Let $S(\rho)$ be the (unique) solution of the consumer's optimization problem $\max_{S \in \Re} U(M - S, (1+\rho) \cdot S)$. Due to our assumptions, we have $S(\rho) > 0 \quad \forall \rho$. We assume that $S(\rho)$ is non-decreasing and differentiable in ρ; i.e., $S'(\rho) := \frac{d\,S(\rho)}{d\,\rho} \geq 0 \quad \forall \rho > 0$. Savings $S(\rho)$ serve as capital supply in our model. ρ is an endogenous equilibrium net rate of return on international capital markets. Its determination is postponed for a while.

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3 For other tax competition models using this objective function see Bond/Samuelson (1986), Sinn (1992), Kanbur/Keen (1993) or Schulze/Koch (1994).

2.3 Production and capital structure

The corporate sector of each country can be aggregated to one single-output firm. Output serves as numéraire, exchange rates are fixed and set to unity. The only input in each country is capital K^i $(i = A,B)$. Technologies are represented by production functions $F^i(K^i)$ which are thrice differentiable and exhibit strictly positive, but decreasing marginal returns $F^i_K(K^i)$. Furthermore, $F^i(0) = 0$ and $\lim_{K^i \downarrow 0} F^i_K(K^i) = +\infty$.

The employed physical capital can either be equity or debt financed. We assume that it results in a simple additive manner from the monetary terms equity E^i and bonds B^i: $K^i = E^i + B^i$:

- Each unit of debt bears an interest cost of $r^i \geq 0$ $(i = A,B)$. Hence, in period 2 firm i's bondholders receive an amount of $(1+r^i)\cdot B^i$ in exchange for their cash in period 1. Debtholders do not exert any influence on corporate policy.
- Equity holders are claimants to the firms' net wealth, which depends on the profitability of the enterprise. To make notation simple, we assume that equity holders are repaid their invested capital plus a (possibly negative) dividend $d^i \in \Re$ per unit of stock. Hence, shareholders obtain a total amount of $(1+d^i)\cdot E^i$ at the end of period 2. It is the corporation's policy to maximize the dividend on equity, d^i.

2.4 National and international taxation

Taxation in our model is characterized by a separation between corporate and household level. Each government can levy three different taxes: a corporate income tax (labelled by subscript c), a personal tax on interest income (subscript r) and a personal tax on dividend income (subscript d). Tax schedules exhibit constant average rates.

The corporate income tax is a pure source tax. This is not the case for the personal taxes which can be levied both in the source country of the income and the residence country of its claimant. As the consumer lives in country A, this problem is only relevant for capital income from country B. There the effective tax burden for the consumer depends on the method of taxing cross-border income streams applied by the two countries. We use the following notation:

t^i_x denotes the tax rate which is levied by country i on tax base x $(i = A,B;\ x = c,r,d)$. Let $t^i_x \in [0,\bar{t}]\ \forall i \forall x$, where $\bar{t} \in]0,1[$ is an internationally uniform maximum tax rate.[4]

τ^i_x denotes the effective tax rate the consumer has to bear for income of kind $x = r,d$ stemming from country i.

As the fiscal authorities in country B do not have any possibility to tax a resident of country A for her domestic income, we have $\tau^A_x = t^A_x$.[5] For income from country B we assume that the

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4 We use this assumption to hold strategy spaces compact. For a non-technical justification think e.g. of some constitutional property guarantees which forbid expropriation.

effective tax rate for the consumer in A depends in some non-decreasing way on the formal tax rates of the two countries, i.e.: $\tau_x^B = \tau^B(t_x^A, t_x^B)$. The function $\tau^B(\cdot)$ itself does not bear a subscript, indicating that we assume the tax authorities not to discriminate between cross-border incomes of different kinds.[6] If the effective tax rate is τ_x^B the fiscal authorities in B receive a share of t_x^B per revenue dollar, whereas the rest of $(\tau_x^B - t_x^B)$ accrues to country A.

To fully describe the **international tax system** we must of course specify the international tax rule $\tau^B(t_x^A, t_x^B)$. The most prominent methods of taxing cross border income streams used in reality are the following ones ($x = r, d$):[7]

(M1) Source Principle: $\tau_x^B = t_x^B$

Capital income is only taxed in the country of its origin.

(M2) Residence Principle: $\tau_x^B = t_x^A$ and $t_x^B = 0$.

Capital income is only taxed at the residence of its final claimant.

(M3) Tax Credit Method: $\tau_x^B = \max\{t_x^A, t_x^B\}$

Taxes already paid in B can be deducted from the tax shield in country A. The credit is, however, limited from above to country A's own tax rate (no reimbursement of taxes).

(M4) Tax Deduction Method: $\tau_x^B = t_x^B + t_x^A \cdot (1 - t_x^B)$

Both countries tax income from country B, but taxes already paid in B can be deducted from the tax base in country A if income is repatriated.

(M5) (Full) Double Taxation: $\tau_x^B = t_x^A + t_x^B$

Both countries fully tax capital income at their own rate without relief.

Methods (M1) and (M2) are sometimes referred to as tax exemption methods because one of the countries abstains from taxing capital income at the personal level. (M1) and (M2) are seen as the two pure principles of international taxation because only one fiscal authorities has the power to tax capital income. With all other rules, capital income is subject to double taxation of both governments. However, the extent of the double burden widely differs. Methods (M4) and (M5) will not be discussed in this paper with regard to the strategic incentives they offer in a tax competition game. We will, however, state some results concerning their effects on the international capital allocation.

Apart from different methods of international taxation our model allows for different systems of **national capital income taxation**. Country i's system is fully described by the triple (t_c^i, t_d^i, t_r^i). This triple, of course, lacks a very important feature of real systems of capital

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5 The variables τ_r^i may seem superfluous, but their introduction saves some irksome case distinctions.

6 This is not realistic. Alworth (1988, p. 75) shows for the OECD-countries that double taxation relief varies across different kinds of taxable income.

7 See Findlay (1986, p. 209) or Mintz/Tulkens (1996).

income taxation, namely the taxation of retained earnings. In our two-period model retentions are not an available form of corporate finance. We distinguish different national tax systems by the extent to which they discriminate against different forms of capital income.

(S1) Equal treatment of interest income and dividends: $t_r^i = t_d^i$

This procedure is the actual legal norm in all OECD-countries. Real tax systems, however, differ in their use of corporate income tax:

$t_c^i = 0$: This coincides with the full-imputation system of capital income taxation, which is actually applied by (among others) Germany, Greece, Italy and Norway.[8]

$t_c^i > 0$: Dividend payouts are taxed twice, first at the corporate level and then at the shareholders' level. This results in a higher marginal tax burden on dividends than on interest payments, an effect which in reality occurs with the partial imputation and the classical systems of corporate income taxation.[9]

(S2) Unequal treatment of interest income and dividends: $t_r^i \neq t_d^i$

Several non-OECD countries run this system as a legal norm. If the t_x^i are understood as the *de facto* marginal personal tax rate on the respective kinds of income, then (S2)-type taxation is actually at work in the OECD, namely if capital income is not only subject to personal income taxation, but also to some other taxes which discriminate between dividends and interest income, or if the chances for illegal tax evasion are unequally distributed for interest income and dividends. The dominant constellation in reality is a higher *de facto* tax on dividends than on interest income, i.e., $t_r^i < t_d^i$.

A stylized fact in capital income taxation is that the total tax burden on dividend payouts is higher than on interest income. We will restrict our analysis to this empirically dominant case:

Definition: A triple (t_c^i, t_d^i, t_r^i) is a *feasible* national system of capital income taxation in country i if it satisfies $1 - t_r^i \geq (1 - t_c^i) \cdot (1 - t_d^i)$.

All (S1)-type systems and all (S2)-type systems with $t_r^i < t_d^i$ are feasible. As most real tax systems are feasible, the restriction is merely technical. Its purpose will become clear later.

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8 In reality, there is a corporate income tax in these countries, but it is fully credited to the shareholders with the effect that dividends only are subject to the personal income tax.

9 These two systems differ in the treatment of retentions. See Sinn (1987, p. 50 ff.) for details.

2.5 The investment and financial decisions of the firms

Firms choose that combination of equity and bonds which allows for the maximum dividend payments to shareholders. The dividend d^i which accrues to the shareholders of firm i per unit of stock amounts to:

$$d^i = (1-t_c^i)\cdot\frac{1}{E^i}\cdot\left[F^i(E^i+B^i)-r^i\cdot B^i-B^i-E^i\right],$$

where the terms in brackets describe the value of the firm after reimbursing the firm's capital donors. Maximizing d^i is equivalent to maximizing the return on equity.

The financial decisions are made subject to a constraint which prevents too high leverage of the firm: At most a share of $\sigma^i \in]0,1]$ of the firms investments can be debt financed, i.e.:

$$B^i \le \sigma^i \cdot K^i = \frac{\sigma^i}{1-\sigma^i}\cdot E^i .$$

A "real" constraint $\sigma^i < 1$ can be motivated in several ways: Firstly, legal restrictions may impose minimum requirements on equity capital in order to ensure the firm's liability and solvency towards creditors. Secondly, usually debt contracts with banks cannot be signed unless some underlying securities are provided by the borrower. Credit costs are the higher the smaller is the borrower's amount of liable capital and they may become prohibitively high. Thirdly, unwritten, but nevertheless widely accepted laws of solid finance among businessmen may *de facto* demand for a limitation of the debt-asset ratio. The violation of these rules would be interpreted as a signal of unsound management.

The assumption of a financial restriction follows Sinn (1987) and drives a number of our results. Without this assumption it cannot be explained why under certainty firms choose a mixed capital structure. Firm i's optimization problem reads (i=A,B):

$$\max_{E^i,B^i\ge 0} d^i \qquad \text{s.t.} \qquad B^i \le \frac{\sigma^i}{1-\sigma^i}\cdot E^i .$$

Solving a Kuhn-Tucker approach we can characterize the optimal investment and finance decisions as follows:[10]

LEMMA 1:

a) If $r^i > \dfrac{d^i}{1-t_c^i}$, then $B^i = 0$, $K^i = E^i$ and K^i satisfies $\dfrac{d^i}{1-t_c^i} = F_K^i - 1$.

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10 Two remarks: (i) An implicit assumption we make is that firms really enter in the markets. A sufficient condition for this is $F^i(K^i) > K^i$ for all $K^i > 0$, since then a completely equity financed firm is able to pay out a positive dividend. (ii) It may seem odd that the maximand itself (more exactly: its optimum value) appears in Lemma 1. This should be understood in the sense that the lemma allows us to conclude from the realized values of d on the optimal capital structure of the firm.

b) If $r^i = \frac{d^i}{1-t_c^i}$, then K^i satisfies $\frac{d^i}{1-t_c^i} = r^i = F_K^i - 1$ and the firm is indifferent between all capital structures satisfying $B^i = K^i - E^i \leq \sigma^i \cdot K^i$.

c) If $r^i < \frac{d^i}{1-t_c^i}$, then $B^i = \sigma^i \cdot K^i$ where K^i satisfies $\sigma^i \cdot r^i + (1-\sigma^i) \cdot \frac{d^i}{1-t_c^i} = F_K^i - 1$.

In Lemma 1 the rôle of the financial restriction σ^i becomes obvious. Without this constraint the firm would follow a bang-bang strategy of finance: either completely equity or completely credit financed. For the special case b) in Lemma 1 we assume that the firm chooses a capital structure with $B^i = \sigma^i \cdot K^i$. Then, in its financial optimum, firm i either is completely equity financed or has a leveraged capital structure:

$$r^i \begin{bmatrix} > \\ \leq \end{bmatrix} \frac{d^i}{1-t_c^i} \Leftrightarrow \begin{cases} B^i = 0, \; E^i = K^i > 0 \\ B^i = \sigma^i \cdot K^i = \dfrac{\sigma^i}{1-\sigma^i} \cdot E^i \end{cases}.$$

2.6 Portfolio choices and capital market equilibrium

In Section 2.2 we described how the representative consumer chooses her optimum level of savings $S(\rho)$, taking the net return of ρ as given. Now we turn to the allocation of S on the different assets in our model. The household can choose among four different securities: stock of firms A and B and bonds of the two firms. A share in company i yields a net return of $d^i \cdot (1-\tau_d^i)$, whereas per unit of bonds the household earns $r^i \cdot (1-\tau_r^i)$ (i=A,B). Having the choice between several assets a consumer will select that (those) with the highest after tax return(s). Therefore, the relevant net rate of return is $\rho = \max\left\{d^i \cdot (1-\tau_d^i), r^i \cdot (1-\tau_r^i);\; i = A,B\right\}$. ρ determines S and the portfolio decisions follow the rule never to buy any asset whose net return is smaller than ρ.[11]

Informally, a situation is an *equilibrium in the capital markets* (CME) if demand and supply for all assets are equal, i.e., if the optimal amounts of equity and loan capital of the two firms are compatible with the utility maximizing saving and portfolio decisions of the consumers. To formalize this we proceed in two steps. We first focus on a single country $i \in \{A,B\}$. Assume that we are in a CME. Then for any i=A,B either of the following two cases must hold:

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11 This is a typical condition for a Miller-equilibrium in capital markets (named after Miller (1977)), where every single household selects only one specific asset for her portfolio. The emergence of a mixed market portfolio in a Miller-setting is usually explained by the aggregation of the consumers to a representative agent (See Sinn (1987, p. 98 ff.) or for an international model Hodder/Senbet (1990)).

Case I: Firm i is completely equity financed ($B^i = 0$). Applying Lemma 1, part a), this requires $d^i < (1-t_c^i)\cdot r^i$. Seen from the consumer's perspective, $B^i = 0$ is only optimal if $d^i \geq \frac{1-\tau_r^i}{1-\tau_d^i}\cdot r^i$. Combining both conditions, it must be true that $\frac{1-\tau_r^i}{1-\tau_d^i} < 1-t_c^i$. For the net rate of return we get $\rho = d^i\cdot(1-\tau_d^i)$. Inserting this into the corresponding marginal condition of Lemma 1, part a), we obtain:

$$\rho = (1-t_c^i)\cdot(1-\tau_d^i)\cdot\left[F_K^i - 1\right].$$

Case II: Firm i is leveraged. Following Lemma 1, part c), we thus must have $d^i \geq (1-t_c^i)\cdot r^i$. For consumers to hold both equity and bonds of a firm it is necessary that $d^i = \frac{1-\tau_r^i}{1-\tau_d^i}\cdot r^i$. Together, $\frac{1-\tau_r^i}{1-\tau_d^i} \geq 1-t_c^i$. The rate of return then is $\rho = d^i\cdot(1-\tau_d^i) = r^i\cdot(1-\tau_r^i)$.

Integrating this in the marginal condition of Lemma 1, part c), we end up with:

$$\rho = \frac{F_K^i - 1}{\frac{\sigma^i}{1-\tau_r^i} + \frac{1-\sigma^i}{(1-t_c^i)\cdot(1-\tau_d^i)}}.$$

With $\mathbf{t} := \left((t_x^i)_{x=c,d,r}\right)_{i=A,B} \in [0,\bar{t}]^6$ our considerations are summarized in the following[12]

LEMMA 2: Define:

$$\bar{\sigma}^i := \begin{cases} \sigma^i & \text{iff } 1-t_c^i \leq \frac{1-\tau_r^i}{1-\tau_d^i} \\ 0 & \text{otherwise} \end{cases} \qquad \text{for } i=A,B.$$

In a CME we have $B^i = \bar{\sigma}^i\cdot\tilde{K}^i(\rho,\mathbf{t})$ and $E^i = (1-\bar{\sigma}^i)\cdot\tilde{K}^i(\rho,\mathbf{t})$ where $\tilde{K}^i(\rho,\mathbf{t})$ uniquely solves

$$\rho = \frac{F_K^i - 1}{\frac{\bar{\sigma}^i}{1-\tau_r^i} + \frac{1-\bar{\sigma}^i}{(1-t_c^i)\cdot(1-\tau_d^i)}}. \qquad (1)$$

The functions $\tilde{K}^i(\rho,\mathbf{t})$ describe equilibrium values for capital to be dependent on the market return ρ and on the tax system $\mathbf{t}$. The implicit presumption behind this is that ρ is exogenous. This is not the case, however: ρ is an equilibrium rate which is endogenously determined on the world capital market. This leads us to the second step of our CME determination. To have a simple mechanism which solves the problem of price determination in the asset markets, we assume that the world capital market is operated without frictions by a Walrasian auctioneer who runs the following procedure: He (arbitrarily) announces a certain rate ρ. Then the consumer can immediately calculate her capital supply $S(\rho)$. Given a tax system $\mathbf{t}$, firms know that they must pay an interest rate of (at least) $r^i = \frac{\rho}{1-\tau_r^i}$ on loans and a

12 Note the similarity of (1) wih the optimum condition in Sinn (1987, p. 106).

(minimum) dividend of $d^i = \frac{\rho}{1-\tau_d^i}$ per stock to cover their needs in the respective kinds of finance. Via Lemma 2 they can give their capital demands and capital structures. If it accidentally happens that

$$S(\rho) = \tilde{K}^A(\rho,\mathbf{t}) + \tilde{K}^B(\rho,\mathbf{t}), \tag{2}$$

then the auctioneer collects savings and allocates them to the assets and firms. If capital supply and demand differ, he starts another trial with a different ρ. Using Lemma 2, the auctioneer can calculate the effects of changing ρ on the firms' behaviour. By implicit differentiation of (1) we obtain that capital demand (c.p.) decreases with the "price" of capital:

$$\tilde{K}_\rho^i := \frac{\partial \tilde{K}^i}{\partial \rho} = \left[\frac{\bar{\sigma}^i}{1-\tau_r^i} + \frac{1-\bar{\sigma}^i}{(1-t_c^i)\cdot(1-\tau_d^i)}\right]\cdot(F_{KK}^i)^{-1} < 0. \tag{3}$$

Together with $S'(\rho) \geq 0$ this implies that the capital market satisfies the condition of Walras stability. Of course, the equilibrium rate implicitly defined by (2) depends on the tax system, i.e.: $\rho = \rho(\mathbf{t})$. Next define for any tax system $\mathbf{t}$ the equilibrium value of the capital stock in country i=A,B as

$$K^i(\mathbf{t}) := \tilde{K}^i(\rho(\mathbf{t}),\mathbf{t}).$$

2.7 Comparative statics

We have just traced back a CME to the taxation decisions of the national governments. Using (1) to (3) we now calculate the comparative statics of marginal tax changes on the CME:[13]

LEMMA 3: Let x be a component of $\mathbf{t}$.

a) Define $\tilde{K}_x^i := \frac{\partial \tilde{K}^i}{\partial x}$ and $\bar{\Phi}^i := \frac{\bar{\sigma}^i}{1-\tau_r^i} + \frac{1-\bar{\sigma}^i}{(1-t_c^i)(1-\tau_d^i)} \geq 1$. Then:[14]

$$\tilde{K}_{t_c^i}^i \equiv 0$$

$$\tilde{K}_{t_c^j}^i = \frac{F_K^i}{F_{KK}^i \cdot \bar{\Phi}^i} \cdot \frac{1-\bar{\sigma}^i}{(1-\tau_d^i)\cdot(1-t_c^i)^2} < 0$$

$$\tilde{K}_{t_d^j}^i = \frac{F_K^i}{F_{KK}^i \cdot \bar{\Phi}^i} \cdot \frac{\partial \tau_d^i}{\partial t_d^j} \cdot \frac{1-\bar{\sigma}^i}{(1-\tau_d^i)^2\cdot(1-t_c^i)} \leq 0 \qquad i,j = A,B$$

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13 Whenever in the sequel the superscripts i and j occur in the same expression, we assume that $i \neq j$, unless explicitly stated otherwise.

14 Two remarks concerning the $\frac{\partial \tau_x^i}{\partial t_x^i}$: (i) For country A we clearly have $\frac{\partial \tau_x^i}{\partial t_x^i} \equiv 1$ and $\frac{\partial \tau_x^i}{\partial t_x^B} \equiv 0$. (ii) Under (M3) the partials $\frac{\partial \tau_x^B}{\partial t_x^i}$ are only well-defined if $t_x^i \neq t_x^B$.

$$\tilde{K}^i_{t^j_r} = \frac{F^i_K}{F^i_{KK}\cdot\overline{\Phi}^i}\cdot\frac{\partial\tau^i_r}{\partial t^j_r}\cdot\frac{\overline{\sigma}^i}{(1-\tau^i_r)^2}\le 0 \qquad i,j = A,B\,.$$

b) Define $D := S' - \tilde{K}^A_\rho - \tilde{K}^B_\rho > 0$. Then:

$$\frac{\partial\rho}{\partial x} = \frac{1}{D}\cdot\left[\tilde{K}^A_x + \tilde{K}^B_x\right]\le 0\,.$$

c) $$K^i_x := \frac{d\,K^i}{d\,x} = \tilde{K}^i_\rho\cdot\frac{\partial\rho}{\partial x} + \tilde{K}^i_x = \frac{1}{D}\cdot\left[\tilde{K}^i_x\cdot(S' - \tilde{K}^j_\rho) + \tilde{K}^j_x\cdot\tilde{K}^i_\rho\right].$$

d) $$K^A_x + K^B_x = \frac{S'}{D}\cdot\left[\tilde{K}^A_x + \tilde{K}^B_x\right]\le 0\,.$$

Some comments: Part a) contains the (partial) effects of tax changes on the capital allocation under the assumption that ρ is constant. They are obtained from implicitly differentiating (1). It can be seen that increasing a tax rate will never lead to an increase in the employment of capital. If the derivatives $\frac{\partial\tau^i_x}{\partial t^j_x}$ are positive (which is, e.g., the case if $i = j = A$) then higher tax rates t^j_x will drive capital out of country i. Part b) shows the effect of tax increases on the equilibrium net rate of return to be non-positive. In most cases, it will be strictly negative. This result is obtained from implicit differentiation of (2). Part c) gives the *total* effect of a marginal tax change on the capital stocks in each country which stems from three distinct sources: the two direct "partial" effects $\tilde{K}^A_x$ and $\tilde{K}^B_x$ and the indirect (price) effect via the change in the equilibrium net rate of return. Part d), finally, gives the effect on the total amount of capital employed in the world. It is obtained from (2), using part b) of Lemma 3.

At this point, the advantages of our somehow long-winded two step procedure for the determination of a CME might be obvious: Firstly, introducing a Walrasian auctioneer allows us to model household behaviour independently of tax rates. Capital supply depends on ρ only. The fact that ρ is tax determined is irrelevant for the consumers. The analysis can thus be held simple. Secondly, the two-step approach clearly separates direct and indirect effects of taxation on the capital allocation. In the discussion of tax competition it will later turn out that the direct effects (as given by the partials $\tilde{K}^i_x$) are innocent of the efficiency failures of fiscal competition. The whole blame for the shortcomings of tax competition rests with the indirect price effects. They are the source of externalities between the governments.

Our model comprises as special cases two scenarios often discussed in the tax competition literature: the case of an inelastic capital supply (fixed capital stock, $S'(\rho)\equiv 0$ and $K^A_x + K^B_x = 0$ for all x) and the case of price-taking countries (perfectly elastic capital supply, $\rho = \overline{\rho}$ and $K^i_x = \tilde{K}^i_x$ for all x).[15]

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15 Bond/Samuelson (1989), Wildasin (1989, 1991), or Wilson (1987) are examples for the first case, Gordon (1986), Giovannini (1991), Razin/Sadka (1991) or Mintz/Tulkens (1996) examples for the second.

2.8 Corporate capital structure and tax systems

We now state some relationships between tax systems and the optimal corporate capital structure in a CME:

LEMMA 4: Assume that both countries apply a feasible national tax system.

a) Firm A always chooses a mixed capital structure.

b) Under the source principle (M1) firm B has a mixed capital structure.

c) If country A runs a (S1)-type tax system and one of the methods (M2), (M3) or (M4) is applied, then firm B has a mixed capital structure.

d) Assume, country A runs a (S1)-type system and (M5) is applied. Then firm B has a mixed capital structure if $t_r^B \le t_d^B$ (i.e., esp. under (S1) in B).

Proof: Firm i has a mixed capital structure iff $\frac{1-\tau_r^i}{1-\tau_d^i} \ge 1-t_c^i$ (cf. case II in the discussion preceeding Lemma 2). Feasibility of the national tax systems requires $\frac{1-t_r^i}{1-t_d^i} \ge 1-t_c^i$. For country A we have $\tau_x^A = t_x^A$ $(x = r,d)$, which proves part a). Under (M1) we have $\tau_x^B = t_x^B$ $(x = r,d)$, which proves part b). Parts c) and d) follow from straightforward calculations.

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For the scenarios not mentioned in Lemma 4 we cannot give a general rule concerning the capital structure of firms in the capital importing country B.

Lemma 4 shows that a combination of equity and loan capital is the dominant financial pattern of firms in our model. This observation is mainly driven by two assumptions: First, our restriction to feasible tax systems only allows for tax systems which make equity the more expensive form of finance relative to bonds. Tax systems in our model (and in reality) discriminate against equity finance. Second, the financial constraint $B^i \le \sigma^i \cdot K^i$ forces firms to issue some minimum portion of shares. Without this restriction, firms would prefer a 100% credit finance. Hence, the mixed capital structure of firms may be interpreted as the maximum avoidance of expensive equity finance.

Interestingly, this general financial pattern may be distorted by international taxation: There are cases where the firm in the capital importing country is fully equity financed.[16] Thus, international tax rules may have quite severe effects.

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16 Consider, e.g., the following scenario: The residence principle (M1b) is applied, country A chooses $t_c^A = 0.5$, $t_d^A = 0.1$ and $t_r^A = 0.3$. Country B sets $t_c^B = 0.2$. Both countries' systems are feasible. We have: $\frac{1-\tau_r^B}{1-\tau_d^B} = 0.\overline{7} < 0.8 = 1-t_c^B$. According to Lemma 2, firm B is fully equity financed.

2.9 Tax revenues

By $T^i(\mathbf{t})$ we denote the tax revenue of country i=A,B when the tax parameters are given by the vector $\mathbf{t}$ (and a specific international tax rule is in application). In calculating tax revenues we must distinguish between capital im- and -exporting countries.

a) Tax revenues of the capital importing country B consist of all source based taxes levied in that country, i.e.:

$$T^B(\mathbf{t}) = \frac{t_c^B}{1-t_c^B}\cdot d^B\cdot E^B + t_d^B\cdot d^B\cdot E^B + t_r^B\cdot r^B\cdot B^B.$$

Using the properties of a CME this can equivalently be written as:

$$T^B(\mathbf{t}) = \rho\cdot K^B\cdot\left[\frac{1-\bar{\sigma}^B}{1-\tau_d^B}\cdot\left(\frac{t_c^B}{1-t_c^B}+t_d^B\right)+\bar{\sigma}^B\cdot\frac{t_r^B}{1-\tau_r^B}\right]. \tag{5}$$

b) A capital exporter's tax revenues stem both from taxes on domestic source income and on repatriated interest and dividend earnings. Hence, for country A we get:

$$T^A(\mathbf{t}) = \frac{t_c^A}{1-t_c^A}\cdot d^A\cdot E^A + t_d^A\cdot d^A\cdot E^A + t_r^A\cdot r^A\cdot B^A + (\tau_d^B - t_d^B)\cdot d^B\cdot E^B + (\tau_r^B - t_r^B)\cdot r^B\cdot B^B.$$

Again using CME properties and the fact that firms in country A always have a mixed capital structure (cf. Lemma 4, part a)) we obtain:

$$\begin{aligned} T^A(\mathbf{t}) = {} & \rho\cdot K^A\cdot\left[\frac{1-\sigma^A}{1-t_d^A}\cdot\left(\frac{t_c^A}{1-t_c^A}+t_d^A\right)+\sigma^A\cdot\frac{t_r^A}{1-t_r^A}\right] \\ & + \rho\cdot K^B\cdot\left[(1-\bar{\sigma}^B)\cdot\frac{\tau_d^B-t_d^B}{1-\tau_d^B}+\bar{\sigma}^B\cdot\frac{\tau_r^B-t_r^B}{1-\tau_r^B}\right] \end{aligned} \tag{6}$$

2.10 The tax competition game

We assume that the national governments in our model aim at maximizing their tax revenues. Their strategy variables are the tax rates. In deciding on tax rates, each government anticipates the changes its policies will induce in the international allocation of capital (i.e., it will incorporate the comparative static results of Section 2.8 in its behaviour). It will take for given the international tax system (i.e., the function τ) and the taxation decisions of the other government. More formally, let S^i be the strategy set of government i (i=A, B). S^i contains all tax rates that are at the disposal of government i. As we model several kinds of taxes, strategies can be multidimensional them by vectors $\mathbf{t}^i$. In its most general form the strategy set of government i is given by $S^i = \left\{\mathbf{t}^i = (t_c^i, t_d^i, t_r^i) \in [0,\bar{t}]^3 \,\middle|\, 1-t_r^i \geq (1-t_c^i)\cdot(1-t_d^i)\right\}$, where the restriction reflects the feasibility constraint. We will, however, often use strategy sets that are smaller than the one just presented. $S := S^A \times S^B$ is the strategy space of the fiscal game. Tax revenues T^i serve as payoff-functions for the players i=A, B. They clearly depend on both the own and the foreign strategy vector. The natural candidate for a solution of the tax

competition game is the Nash equilibrium, which we sometimes also call "revenue equilibrium".

As a yardstick for the evaluation of the outcomes of tax competition we use the concept of strict efficiency. A strictly efficient solution would emerge if the governments colluded. Formally, a pair $(\hat{\mathbf{t}}^A, \hat{\mathbf{t}}^B) \in S$ is strictly efficient in S under τ^B if there exists no other pair $(\mathbf{t}^A, \mathbf{t}^B) \in S$ with $(\mathbf{t}^A, \mathbf{t}^B) \neq (\hat{\mathbf{t}}^A, \hat{\mathbf{t}}^B)$ such that $T^A(\mathbf{t}^A, \mathbf{t}^B) + T^B(\mathbf{t}^A, \mathbf{t}^B) > T^A(\hat{\mathbf{t}}^A, \hat{\mathbf{t}}^B) + T^B(\hat{\mathbf{t}}^A, \hat{\mathbf{t}}^B)$.

3. Competition with tax systems under the source principle

3.1 General description

In this section we examine which national tax systems will emerge if the governments engage in revenue maximizing international tax competition. Governments are allowed to use the full range of tax instruments. This is new in the literature on tax competition with capital taxes, where it is assumed that governments use only one tax instrument. To start, we assume that the international tax rule follows the source principle (M1), i.e.: $\tau_x^B(t_x^A, t_x^B) = t_x^B$.

The consequences of this assumption are: First, the firms in both countries have a mixed capital structure (cf. Lemma 4) and thus all sources of finance are really employed and taxable. Second, we can abstract from all effects of international double taxation which may otherwise overlie the strategic situation. Third, the situation is essentially symmetric.

The strategy spaces are the S^i as given above. Thus, we endow governments with the widest range of instruments possible in our model. Using Lemma 2, a CME is characterized by:

$$\rho = \frac{1}{\Phi^A} \cdot \left[F_K^A - 1\right] = \frac{1}{\Phi^B} \cdot \left[F_K^B - 1\right] \tag{7}$$

where we defined $\Phi^i := \frac{\sigma^i}{1-\tau_r^i} + \frac{1-\sigma^i}{(1-t_c^i)(1-\tau_d^i)}$ $(i=A,B)$. Equation (3) becomes to:

$$\tilde{K}_\rho^i = \frac{\Phi^i}{F_{KK}^i} < 0.$$

Applying Lemma 3, part a), we can establish that foreign tax changes do not have direct effects on domestic capital allocation, which is simply a consequence of the source principle:

$$\tilde{K}_{t_c^j}^i = \tilde{K}_{t_d^j}^i = \tilde{K}_{t_r^j}^i \equiv 0.$$

Next define:

$$\beta^i := \frac{\sigma^i}{1-t_r^i} \cdot \frac{1}{\Phi^i}.$$

Observe that, since $\sigma^i \in]0,1[$, $\beta^i \in]0,1[$ as soon as at least one tax rate is strictly positive. Furthermore, $1-\beta^i = \frac{1-\sigma^i}{(1-t_c^i)\cdot(1-t_d^i)} \cdot \frac{1}{\Phi^i}$. Using these definitions and (7), we can, via Lemma 3, part a), calculate the direct effects of tax changes on the amount of domestic capital:

$$\tilde{K}^i_{t_r^i} = \frac{\rho}{F^i_{KK}} \cdot \frac{\sigma^i}{(1-t_r^i)^2} = \frac{\rho}{1-t_r^i} \cdot \frac{1}{\Phi^i} \cdot \frac{\sigma^i}{1-t_r^i} \cdot \tilde{K}^i_\rho = \frac{\rho}{1-t_r^i} \cdot \beta^i \cdot \tilde{K}^i_\rho,$$

and, similarly,

$$\tilde{K}^i_{t_d^i} = \frac{\rho}{1-t_d^i} \cdot (1-\beta^i) \cdot \tilde{K}^i_\rho \qquad \text{and} \qquad \tilde{K}^i_{t_c^i} = \frac{\rho}{1-t_c^i} \cdot (1-\beta^i) \cdot \tilde{K}^i_\rho.$$

These expressions simplify the analysis significantly as they allow us to work with the partial $\tilde{K}^i_\rho$ only. The price effects of tax changes according to Lemma 3, part b), are obtained as:

$$\frac{\partial \rho}{\partial t_r^i} = \frac{\tilde{K}^i_{t_r^i}}{D} = e^i \cdot \beta^i \cdot \frac{\rho}{1-t_r^i},$$

and, similarly,

$$\frac{\partial \rho}{\partial t_d^i} = e^i \cdot (1-\beta^i) \cdot \frac{\rho}{1-t_d^i} \qquad \text{and} \qquad \frac{\partial \rho}{\partial t_c^i} = e^i \cdot (1-\beta^i) \cdot \frac{\rho}{1-t_c^i},$$

where $e^i := \frac{\tilde{K}^i_\rho}{D} \in [-1,0]$ is a measure for the tax reagibility of the equilibrium rate of return. All effects are non-positive.

Under the source principle the tax revenues of capital importing and exporting countries are of the same structure. Using (6) and (7), respectively, we obtain:

$$T^i(\mathbf{t}) = z^i \cdot \rho \cdot K^i,$$

where $z^i := \frac{1-\sigma^i}{1-t_d^i} \cdot \left[\frac{t_c^i}{1-t_c^i} + t_d^i \right] + \sigma^i \cdot \frac{t_r^i}{1-t_r^i}$ can be interpreted as a kind of overall effective tax rate on the capital returns in country *i*. The functions $T^i(\mathbf{t})$ are continuous and differentiable in $\mathbf{t}$. Using the above expressions, we can calculate the marginal revenue effects of tax changes:

$$\begin{aligned} \frac{\partial T^i}{\partial t_r^i} &= z^i \cdot \left[\frac{\partial \rho}{\partial t_r^i} \cdot K^i + \rho \cdot \left[\tilde{K}^i_\rho \cdot \frac{\partial \rho}{\partial t_r^i} + \tilde{K}^i_{t_r^i} \right] \right] + \rho \cdot K^i \cdot \frac{\sigma^i}{(1-t_r^i)^2} \\ &= \frac{\rho \cdot K^i \cdot \beta^i}{1-t_r^i} \cdot \left[z^i \cdot \left[e^i \cdot (1+\varepsilon^i_\rho) + \varepsilon^i_\rho \right] + \frac{\sigma^i}{1-t_r^i} \cdot \frac{1}{\beta^i} \right] = \frac{\rho \cdot K^i \cdot \beta^i}{1-t_r^i} \cdot \left[z^i \cdot \left[e^i \cdot (1+\varepsilon^i_\rho) + \varepsilon^i_\rho \right] + \Phi^i \right], \end{aligned} \tag{8a}$$

where we introduced the elasticity of the equilibrium amount of capital in country *i* with respect to the net rate of return:

$$\varepsilon^i_\rho := \tilde{K}^i_\rho \cdot \frac{\rho}{K^i} = \frac{F^i_K - 1}{K^i \cdot F^i_{KK}}.$$

Note that ε^i_ρ is purely technologically determined. Completely analogously we obtain:

$$\frac{\partial T^i}{\partial t_d^i} = \frac{\rho \cdot K^i \cdot (1-\beta^i)}{1-t_d^i} \cdot \left[z^i \cdot \left[e^i \cdot (1+\varepsilon^i_\rho) + \varepsilon^i_\rho \right] + t_c^i \cdot \Phi^i \right] \tag{8b}$$

$$\frac{\partial T^i}{\partial t_c^i} = \frac{\rho \cdot K^i \cdot (1-\beta^i)}{1-t_c^i} \cdot \left[z^i \cdot \left[e^i \cdot (1+\varepsilon_\rho^i) + \varepsilon_\rho^i \right] + \Phi^i \right]. \tag{8c}$$

A glance at these expressions exhibits close relations between the different kinds of taxes. The most important observation is that for $t_c^i > 0$:

$$\frac{\partial T^i}{\partial t_r^i} \leq 0 \Leftrightarrow \frac{\partial T^i}{\partial t_c^i} \leq 0 \Rightarrow \frac{\partial T^i}{\partial t_d^i} < 0. \tag{9}$$

I.e., if an increase in the tax on dividends leads to an increase in tax revenues, this is also true for increases in the taxes on interest and corporate income. The converse is not true, however.

3.2 Characterization of Nash equilibria

If we try to establish results on the outcome of fiscal competition in the scenario just designed we face two difficulties: First, our knowledge of the properties (say, monotonicity and curvature) of the tax revenue functions is quite limited. Second, the governments' strategy sets are not convex. Convexity of the strategy sets is, however, a necessary condition in almost all existence theorems for Nash equilibria. The first of these two problems can only be overcome by additional assumptions, giving more structure on the game. The second problem then can be solved via the small detour of convexifying the strategy space. We eventually can establish an interesting result on the properties of an equilibrium, whose **proof** is relegated to Appendix A.

RESULT 1: Assume, that for $i=A, B$ tax revenue functions $T^i(\mathbf{t}^i, \mathbf{t}^j)$ under the source principle are quasi-concave in the (own) strategy variables $\mathbf{t}^i$. Then a revenue equilibrium exists. The equilibrium tax rates of country i ($i=A, B$) satisfy either of the following conditions:

a) $0 = t_d^i = t_r^i < t_c^i$;

b) $0 = t_d^i < t_r^i \leq t_c^i$;

c) $t_r^i = t_c^i = \bar{t}$.

There is an imprecision in this statement which lies in the notion of quasi-concavity. This property is well-defined on convex sets only and thus can - strictly speaking - not be applied here. What we essentially require is that the payoffs are quasi-concave on every convex subset of the strategy sets. This is a strong assumption, but still compatible with a wide range of revenue structures, encompassing, e.g., strictly increasing revenue functions or Laffer curves.

Under the source principle, tax competition with different kinds of capital income taxes will result in national tax systems of type (S2) which discriminate at the personal level between interest and dividend incomes. This discrimination is, as long as the governments do not use

their maximum tax rates $\bar{t}$, extreme in the sense that dividends will be tax free. The tax exemption of dividends. however, is accompanied by a corporate tax on payouts that is higher than the personal income tax on interest income. Altogether, we end up with tax systems in either of the two countries which taxes income that stems from bonds finance (only) at the personal level, and income that originates from equity finance (only) at the firm's level. The driving force behind this structure is condition (9). Taxes on interest income and corporate payouts never yield a lower marginal revenue than taxes on dividends. Therefore they should be exploited in the first place (so-called "Principle of Targeting" (Dixit (1985, p. 314))). The fact that, in total, equity income is taxed more heavily than interest income, can be traced back to our restriction to feasible tax systems. There we excluded *a priori* that interest income is taxed at a smaller rate than equity income. As a consequence, firms hold equity only to obey their financial constraints. Corporate payouts are a less elastic tax base than interest payments and therefore the natural candidate for higher taxes.

Result 1 identifies the constellation $0 = t_d^i = t_r^i < t_c^i$ (i=A,B) as a possible equilibrium structure. In such a (S1)-type system capital income is tax exempt at the personal level; there is only a corporate income tax on payouts. These properties are characteristic for the so-called cash-flow taxation as it has been proposed in the late seventies for Great Britain, esp. in the forms of S-Base- and R-Base-taxation. These proposals have, although attributed with a number of positive features, never been realised, most probably because they are quite radical. Seen against this background, it is interesting that tax competition may be a mechanism which Nash-implements cash-flow taxation which otherwise would fail due to political obstacles.
The efficiency properties of revenue equilibria are summarized in the next assertion:

RESULT 2: If $\rho(\mathbf{t}) = \bar{\rho}$, revenue equilibria in the tax competition game under the source principle are strictly efficient. If $\rho(\mathbf{t}) \neq \bar{\rho}$, revenue equilibria are in general not strictly efficient.

Proof: For $x = c,d,r$ we have $\dfrac{\partial T^j}{\partial t_x^i} = z^j \cdot \dfrac{\partial \rho}{\partial t_x^i} \cdot \left[K^j + \tilde{K}_\rho^j\right]$.

a) If $\rho(\mathbf{t}) = \bar{\rho}$, then $\dfrac{\partial T^i}{\partial t_x^j} \equiv 0$. A country's tax revenues do not depend on the other country's tax rates. Therefore, separately solving $\max_{t^i \in S^i} T^i(\mathbf{t})$ for i=A,B is equivalent to jointly solving $\max_{(t^A, t^B) \in S^A \times S^B} \left[T^A(\mathbf{t}) + T^B(\mathbf{t})\right]$.

b) Consider a "typical" interior Nash equilibrium with $0 = t_d^i < t_r^i < t_c^i < \bar{t}$ for i=A,B. In such a situation $\dfrac{\partial T^i}{\partial t_c^i} = 0$ holds and the feasibility constraint does not bite. If this situation

were strictly efficient. we should also have $\frac{\partial T^A}{\partial t_c^i}+\frac{\partial T^B}{\partial t_c^i}=0$, or: $\frac{\partial T^I}{\partial t_c^i}=0$. For $\frac{\partial \rho}{\partial t_c^i}\neq 0$ there is no hint why this is the case.

Result 2 is the restatement of a standard result on decentralized decision making:[17] If there are no externalities between the agents (or if they are not perceived), then decentralized optimization will result in a Pareto optimum. If externalities prevail, this is not the case. In our model the externalities are given by the "indirect" price effects of taxation as represented by the partials $\frac{\partial \rho}{\partial t_x^i}$. These price effects are induced by national tax changes, but they affect the international system as a whole. Uncoordinated maximization of tax revenues does not recognize these effects and thus leads to outcomes that cooperation can improve upon.

There is a widespread view that capital tax competition is (in general) inefficient because the governments ignore the fact that, by changing their tax rates, they cause international capital movements which (also) change the tax bases of other governments.[18] Note that this view is not the full truth: It is not the fact that capital must go anywhere which is responsible for the efficiency failures of decentralized maximization - these capital movements are the standard reactions to relative price changes. It is the ignored fact that the disturbance of the equilibrium price ρ itself causes a further reallocation of international capital. This (and not the direct tax base effect) is the relevant externality.[19] If the pecuniary externalities do not occur (i.e., if $\rho=\bar{\rho}$) there is no need for correcting the outcome of tax competition.[20,21]

Observe that we cannot decide whether governments choose too high or too low tax rates in a Nash equilibrium. The direction of the inefficiency depends on the signs of the cross tax effects $\frac{\partial T^I}{\partial t_x^i}$ which are indeterminate. Intuition tells us that tax competition exerts a downward pressure on tax rates ("The taming of Leviathan" (Sinn (1992)) and that collusive governments (a tax cartel) thus would levy higher taxes. This expectation, however, may be flawed.

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17 For the field of fiscal federalism and tax competition this *decentralization theorem* was first (although not formally) established by Oates (1972, p. 33 ff.).

18 See, e.g., Oates/Schwab (1988, p. 343), Wilson (1987, p. 837) or Wildasin (1989, p. 196).

19 This is most clearly elaborated in DePater/Myers (1992).

20 It is this absence of price effects (or: the assumption of price-taking governments) that drives the efficiency results in Oates/Schwab (1988) or Razin/Sadka(1991).

21 The structure of the Nash equilibrium as described by Result 1 does not depend on the existence or non-existence of variations in ρ. If ρ is constant, we would have $e^i=0$ in the marginal revenue effects $\frac{\partial T^i}{\partial t_r^i}$. This does not affect (9) which is the driving force behind Result 1.

3.3 Tax competition in (S1)-type tax systems

De lege, all OECD countries apply national tax systems of the (S1)-type, which do not discriminate between dividends and interest income on the personal level. Recurring on the previous sections we can easily model tax competition in (S1)-type systems. By $t^i := t^i_r \equiv t^i_d$ we denote the uniform tax rate on dividends and interest income in country i (i=A, B) which we will refer to as the "personal income tax rate". The strategy set of each government is now given by $S^i = [0,\bar{t}]^2$, which is convex. By

$$\hat{\Phi}^i := \frac{\sigma^i}{1-t^i} + \frac{1-\sigma^i}{(1-t^i_c)\cdot(1-t^i)}$$

we denote the analogon to the variable Φ^i from above for the case $t^i = t^i_r = t^i_d$. Similarly, we define $\hat{\beta}^i$ and $\hat{z}^i$ (always for i=A, B). Set:

$$\hat{T}^i(t^i_c,t^i,t^j_c,t^j) := T^i(t^i_c,t^i,t^i,t^j_c,t^j,t^j). \tag{10}$$

In a CME the condition

$$\rho = \frac{1}{\hat{\Phi}^A}\cdot\left[F^A_K - 1\right] = \frac{1}{\hat{\Phi}^B}\cdot\left[F^B_K - 1\right]$$

holds. Hence, with respect to t^i_c all partial derivatives of section 3.1 remain valid if the variables Φ^i, β^i and z^i are replaced by the corresponding hat-values. Furthermore:

$$\tilde{K}^i_{t^j} = \left[\tilde{K}^i_{t^i_r} + \tilde{K}^i_{t^i_d}\right]_{t^i_r = t^i_d = t^j} = \begin{cases} \dfrac{\rho}{1-t^i}\cdot\tilde{K}^i_\rho & \text{if } i=j \\ 0 & \text{if } i\neq j \end{cases}$$

$$\frac{\partial\rho}{\partial t^i} = \left[\frac{\partial\rho}{\partial t^i_r} + \frac{\partial\rho}{\partial t^i_d}\right]_{t^i_r = t^i_d = t^i} = e^i\cdot\frac{\rho}{1-t^i}.$$

The marginal revenue effects of tax changes are given by:

$$\frac{\partial\hat{T}^i}{\partial t^i} = \left[\frac{\partial T^i}{\partial t^i_r} + \frac{\partial T^i}{\partial t^i_d}\right]_{t^i_r = t^i_d = t^i} = \frac{\rho\cdot K^i}{1-t^i}\cdot\left[\hat{z}^i\cdot\left[e^i\cdot(1+\varepsilon^i_\rho)+\varepsilon^i_\rho\right] + \hat{\Phi}^i\cdot\left[\hat{\beta}^i + t^i_c\cdot(1-\hat{\beta}^i)\right]\right].$$

and, parallel to the version without hat,

$$\frac{\partial\hat{T}^i}{\partial t^i_c} = \frac{\rho\cdot K^i\cdot(1-\hat{\beta}^i)}{1-t^i_c}\cdot\left[\hat{z}^i\cdot\left[e^i\cdot(1+\varepsilon^i_\rho)+\varepsilon^i_\rho\right] + \hat{\Phi}^i\right].$$

As the coefficient of $\hat{\Phi}^i$ in the first of these expressions is smaller than one, we obtain:

$$\frac{\partial\hat{T}^i}{\partial t^i_c} \leq 0 \Rightarrow \frac{\partial\hat{T}^i}{\partial t^i} < 0. \tag{11}$$

RESULT 3: Suppose, for i=A, B the functions $\hat{T}^i$ are on $[0,\bar{t}]^2$ quasi-concave in (t^i_c,t^i). Then a revenue equilibrium exists. For each country $i \in \{A,B\}$ one of the following two cases holds in the equilibrium:

a) $t^i = 0$ and $0 < t^i_c < \bar{t}$;

b) $t^i_c = \bar{t}$.

Proof (sketch): Existence follows from the Debreu-Fan-Glicksberg-Theorem. Properties a) and b) are easily derived from the (constrained)[22] maximization problems of each player.

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Result 3 claims that revenue maximizing governments will at best levy a personal income tax when their corporate income tax rate has reached its upper bound. Otherwise they will tax capital income only at the firms' level. The reason why governments do without personal taxation is that it has lower marginal revenue effects than corporate taxation (cf. (11)).

Starting from Result 1, the new result could not have been foreseen. There the taxes on corporate and income interest had essentially the same marginal revenue effects, both higher than that of the dividend tax. This made governments do without the latter tax (at least in general). The actual scenario emerged by packing the personal taxes into one. For this package it was by no means clear that it would yield smaller marginal returns than the corporate income tax does; after all, we only sum up the single effects.

Under the source principle tax competition with OECD-type tax systems Nash-implements a cash-flow system (at least unless the upper bound for the corporate tax is exploited). We have had the possibility of cash-flow systems in Result 1 already, but now it becomes the rule.[23]

3.4 Tax competition without the corporate income tax

We now briefly discuss the outcomes of tax competition if the corporate income tax t_c' does not belong to the set of strategy variables, i.e., if governments only compete with their personal income taxes. We can easily do this within the framework of Section 3.4, just setting $t_c^A = t_c^B \equiv 0$. From (8b) and (8c) we can derive the following implication (i=A, B):

$$\frac{\partial T^i}{\partial t_d'} \leq 0 \Rightarrow \frac{\partial T^i}{\partial t_r'} < 0 \qquad (12)$$

which directly implies

RESULT 4: With $t_c' \equiv 0$ a revenue maximizing government of country i (i=A, B) will in general not tax interest income, i.e., $t_r' = 0$. A positive tax rate on interest income can only be optimal if $t_d' = \bar{t}$.[24]

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22 The constraints are that none of the tax rates may exceed $\bar{t}$.

23 With regard to the efficiency properties of the (S1)-equilibria we refer to Result 2, which is still true.

24 Two remarks concerning the feasibility constraint, which in the actual scenario requires $t_r' \leq t_d'$ to hold: First, this restriction is not *explicitly* used in the derivation of Result 4. It is, however, implicitly

Implication (12) and thus Result 4 are immediate consequences of our assumptions: By the restrictions on the corporate capital structure (i.e., by $B^i \leq \sigma^i \cdot K^i$) we force firms into a - in a sense - suboptimal financial pattern: If they were allowed to, they would, under any feasibile tax structure, choose a full credit finance. Governments now exploit the firms' financial inflexibility by levying higher taxes on the less elastic part of their tax base. As governments pursue only one objective (maximizing tax revenues), but are endowed with two policy instruments (t_c^i and t_d^i), the tax discrimination between equity and bonds is extreme in the sense that, in general, the less profitable tax on interest income is not used.

From the viewpoint of tax competition, the source principle of international taxation is rather unattractive. Hardly anything in the preceeding discussion indicates that the governments face a strategic situation. Each government's optimization could be seen as if it were the only government and the use of elements from game theory (such as best responses, etc.) could be avoided. Nevertheless, unless we assume that the equilibrium net rate of return ρ is exogenous and constant, there is a strategic interdependence between the governments: They both determine the value of ρ by their tax choices and thereby inflict externalities on each other. In the next section, however, the strategic situation of capital income taxation will hopefully become clearer and more exciting.

4. Tax competition and variable corporate capital structure: The case of the residence principle

Lemma 4 indicates that, in contrast to the source principle of international taxation, the capital structure of firms in a capital importing country is not *a priori* clear if the residence principle is applied. Some constellations of tax rates make firms choose a pure equity finance, others induce a mixed capital structure. This makes the examination of the effects of tax competition in such a scenario quite interesting, because tax induced changes in the capital structure lead to discontinuous jumps in tax revenues and their distribution amongst the fiscal authorities.

This exercise seems even more worthwile as the residence principle is one of the most prominent international income tax rules. The OECD double taxation convention favours this rule (most probably because it protects the mainly capital exporting OECD members from fiscal losses[25]) and the Ruding committee, which was in charge of reform proposals for the EU capi-

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contained because we assume a mixed capital structure in both firms which is only optimal if interest income is taxed less heavily than dividends. Second, governments' best choices satisfy this restriction.

25 The United Nations double tax convention proposes the source principle to leave some fiscal returns to the mainly capital importing developing and emerging countries.

tal income taxation, recommends to abstain from source based taxes and to rely on the residence principle. Alworth (1988) shows that the residence principle reduces the incentives for harmful tax arbitrage and, in the same line, Giovannini/Hines (1991) argue for the residence principle in order to fight tax evasion.

Unfortunately, the results of tax competition under the residence principle are all but crystal clear. This can be seen already in a boilt-down version of our model. Therefore assume:

$$\sigma^A = 1,\ t_d^A \equiv 0 \text{ and } t_c^A \equiv \bar{t}\,.$$

In country A the financial choices of firms are unrestricted. Government A does not levy a tax on dividends, but instead taxes corporate income at the highest admissable rate. The assumptions ensure that the firm in country A is fully debt financed. The only policy instrument of A's government is the tax rate on interest income t_r^A.

In the capital importing country B, where we assume a real financial constraint $\sigma^B \in]0,1[$ to prevail, the residence principle restricts policy choices of the government to the corporate income tax t_c^B. Under these assumptions, in a CME the following arbitrage condition holds:

$$\rho = (1-t_r^A)\cdot\left[F_K^A - 1\right] = \frac{F_K^B - 1}{\dfrac{\bar{\sigma}^B}{1-t_r^A} + \dfrac{1-\bar{\sigma}^B}{1-t_c^B}},$$

where

$$\bar{\sigma}^B = \begin{cases} \sigma^B & \text{if } t_r^A \le t_c^B \\ 0 & \text{if } t_r^A > t_c^B \end{cases}$$

characterizes the optimal capital structure of firm B: If the corporate income tax in country B is lower than the income tax in country A, the firm decides to be purely equity financed. Otherwise, it chooses a mixed capital structure.

The change in the capital structure of firm B at $t_r^A = t_c^B$ causes the functions $K^A(\mathbf{t})$, $K^B(\mathbf{t})$ and $\rho(\mathbf{t})$ to be non-differentiable at these places (yet they are still continuous). For $t_r^A \neq t_c^B$, however, the partial effects given in Lemma 3 can be applied.

The governments' tax revenue functions are of course affected by the financial variability of firm B. The host country of that firm only collects the corporate income tax, i.e. (with $\mathbf{t} = (t_r^A, t_c^B)$):

$$T^B(\mathbf{t}) = \frac{t_c^B}{1-t_c^B}\cdot\rho(\mathbf{t})\cdot(1-\bar{\sigma}^B)\cdot K^B(\mathbf{t}).$$

The residence country collects taxes on interest income, which accrues to its inhabitant from country B only if firm B has a mixed financial structure:

$$T^A(\mathbf{t}) = \frac{t_r^A}{1-t_r^A}\cdot\rho\cdot\left[K^A(\mathbf{t}) + \bar{\sigma}^B\cdot K^B(\mathbf{t})\right].$$

Both revenue functions are discontinuous at $t_r^A = t_c^B$. Each government's revenues consist of a safe (*inside option*) and a contestable (*outside option*) part. Government A's safe tax base is the domestic interest income, for government B it is firm B's corporate income which comes

from the minimum share $(1-\sigma^B)$ of equity finance this firm must use. The contestable tax base is the income earned by the rest of σ^B of firm B's capital. If $t_r^A \le t_c^B$, it is interest income and tax revenues from it accrue to government A. Otherwise it is equity income whose tax reve-nues go to government B. In this case, we only have source based taxes. Check that:

$$\lim_{t_r^A \downarrow t_c^B} T^A(\mathbf{t}) = \frac{t_r^A}{1-t_r^A} \cdot \rho \cdot K^A < \frac{t_r^A}{1-t_r^A} \cdot \rho \cdot \left[K^A + \sigma^B \cdot K^B\right] = T^A(\mathbf{t})\big|_{t_r^A = t_c^B}$$

$$\lim_{t_c^B \uparrow t_r^A} T^B(\mathbf{t}) = \frac{t_c^B}{1-t_c^B} \cdot \rho \cdot K^B > (1-\sigma^B) \cdot \frac{t_c^B}{1-t_c^B} \cdot K^B = T^B(\mathbf{t})\big|_{t_c^B = t_r^A}.$$

I.e., if $t_r^A = t_c^B$, government B should better lower its tax rate whereas for government A should avoid an increase in its tax rate. These relations have some important implications:

a) T^A is not upper semi-continuous. Hence, Theorem 2 in Dasgupta/Maskin (1986) cannot be applied to ensure the existence of a pure strategy equilibrium in our game.[26,27]

b) A situation with $t_r^A = t_c^B$ can never be a Nash equilibrium.

c) If both firms employ identical technologies, we must have $t_r^A < t_c^B$ in an equilibrium.

General results for the existence, the number and the location of Nash equilibria can generically not be derived. We demonstrate this in Appendix B by means of an example which exhibits a great variety of possible equilibrium features. It becomes obvious that the equilibrium features crucially depend on the technologies of the two firms: Some slight change in a technological parameter may induce severe consequences for the outcome of the fiscal game.

Inspite of this apparently chaotic structure we can give some interesting results on the efficiency properties of Nash equilibria in our setting (existence of equilibria provided):

RESULT 5: Assume, that the strictly efficient solution $\tilde{\mathbf{t}}$ of the revenue game is unique and belongs to the interior of the strategy space ($\tilde{\mathbf{t}} \in]0,\bar{t}[^2$) with $\tilde{t}_r^A \neq \tilde{t}_c^B$.

a) Let $\frac{\partial \rho}{\partial x} \neq 0$ for $x = t_r^A, t_c^B$. Then revenue equilibria are in general not strictly efficient.

b) Let $\frac{\partial \rho}{\partial x} \equiv 0$ for $x = t_r^A, t_c^B$ and assume that $\hat{\mathbf{t}} = (\hat{t}_r^A, \hat{t}_c^B) \in]0,\bar{t}[^2$ is the unique Nash equilibrium of the tax competition game.

b1) If $\hat{t}_r^A > \hat{t}_c^B$ and $\tilde{t}_r^A > \tilde{t}_c^B$, then $\hat{\mathbf{t}} = \tilde{\mathbf{t}}$.

b2) If $\hat{t}_r^A < \hat{t}_c^B$ and $\tilde{t}_r^A < \tilde{t}_c^B$, then $\hat{\mathbf{t}} > \tilde{\mathbf{t}}$.

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26 The Debreu-Fan-Glicksberg Theorem cannot be applied either, because payoffs are not contiuous.

27 Note that both revenue functions are weakly lower semi-continuous, that they are bounded, that their discontinuties only occur in a set with (Lebesgue-)measure of zero and that their sum is continuous. By Theorem 5 in Dasgupta/Maskin (1986) a *mixed* equilibrium exists. This is (if at all) of merely technical interest, as we cannot give any reasonable interpretation for randomized tax decisions.

Proof: By assumption, the unique efficient tax vector solves

$$\frac{\partial (T^A + T^B)}{\partial t_r^A} = \frac{\partial (T^A + T^B)}{\partial t_c^B} = 0.$$

(Note that we assume $\tilde{t}_r^A \neq \tilde{t}_c^B$). Calculate that

$$\frac{\partial T^A}{\partial t_c^B} = \rho \cdot \frac{t_r^A}{1 - t_r^A} \cdot \left[\left[\frac{1}{\rho} + \tilde{K}_\rho^A + \bar{\sigma}^B \cdot \tilde{K}_\rho^B \right] \cdot \frac{\partial \rho}{\partial t_c^B} + \bar{\sigma}^B \cdot \tilde{K}_{t_c^B}^B \right]$$

and

$$\frac{\partial T^B}{\partial t_r^A} = \rho \cdot (1 - \bar{\sigma}^B) \cdot \frac{t_c^B}{1 - t_c^B} \cdot \left[\frac{K^B}{\rho} \cdot \frac{\partial \rho}{\partial t_r^A} + \tilde{K}_\rho^B \cdot \frac{\partial \rho}{\partial t_r^A} + \tilde{K}_{t_r^A}^B \right].$$

Next verify that $\tilde{K}_{t_r^A}^B = \frac{\rho}{(1 - t_r^A)^2} \cdot \frac{\bar{\sigma}^B}{\bar{\Phi}^B} \cdot \tilde{K}_\rho^B$.

a) If $\operatorname{sgn}\left[\tilde{t}_r^A - \tilde{t}_c^B\right] \neq \operatorname{sgn}\left[\hat{t}_r^A - \hat{t}_c^B\right]$, then Nash equilibria are inefficient in any way. Now assume $0 \neq \operatorname{sgn}\left[\tilde{t}_r^A - \tilde{t}_c^B\right] = \operatorname{sgn}\left[\hat{t}_r^A - \hat{t}_c^B\right]$. In a Nash equilibrium we have: $\frac{\partial T^A}{\partial t_r^A} = \frac{\partial T^B}{\partial t_c^B} = 0$. If this were an efficient solution, we should in addition have $\frac{\partial T^A}{\partial t_c^B} = \frac{\partial T^B}{\partial t_r^A} = 0$. For $\frac{\partial \rho}{\partial x} \not\equiv 0$ ($x = t_r^A, t_c^B$) there is no hint that this is the case.

b) Now let $\frac{\partial \rho}{\partial x} \equiv 0$ für $x = t_r^A, t_c^B$.

b1) For $\operatorname{sgn}\left[\tilde{t}_r^A - \tilde{t}_c^B\right] = \operatorname{sgn}\left[\hat{t}_r^A - \hat{t}_c^B\right] = 1$ we have $\bar{\sigma}^B = 0$ and hence $\frac{\partial T^A}{\partial t_c^B} = \frac{\partial T^B}{\partial t_r^A} = 0$ and strict efficiency. Uniqueness implies $\hat{\mathbf{t}} = \tilde{\mathbf{t}}$.

b2) For $\operatorname{sgn}\left[\tilde{t}_r^A - \tilde{t}_c^B\right] = \operatorname{sgn}\left[\hat{t}_r^A - \hat{t}_c^B\right] = -1$ we have $\bar{\sigma}^B = \sigma^B \in]0,1[$. Hence:

$$\frac{\partial T^A}{\partial t_c^B} = \rho \cdot \frac{t_r^A}{1 - t_r^A} \cdot \sigma^B \cdot \tilde{K}_{t_c^B}^B < 0 \text{ and } \quad \frac{\partial T^B}{\partial t_r^A} = \rho \cdot (1 - \sigma^B) \cdot \frac{t_c^B}{1 - t_c^B} \cdot \tilde{K}_{t_r^A}^B < 0.$$

Therefore, in a Nash equilibrium:

$$\frac{\partial (T^A + T^B)}{\partial t_r^A} < 0 \quad \text{and} \quad \frac{\partial (T^A + T^B)}{\partial t_c^B} < 0,$$

which upon uniqueness of the efficient solution implies $\hat{\mathbf{t}} > \tilde{\mathbf{t}}$.

Some remarks concerning this result:

a) First look at part b): With the assumption of an exogenous net rate of return we eliminate the source for the inefficiency of Nash equilibria under the source principle (cf. Result 2). Consequently, if only source based taxes are employed, Nash equilibria are strictly efficient in the actual scenario as well ($\hat{\mathbf{t}} = \tilde{\mathbf{t}}$; cf. part b1)). This is, however, no longer the case, if both governments tax income that originates from country *B* (see part b2)). Here, Nash equilibria are inefficient ($\hat{\mathbf{t}} \neq \tilde{\mathbf{t}}$) although price externalities via the net rate of return cannot occur. The reason for this failure is that the amount of capital invested in *B* depends on the ef-

fective tax rate which is $1-\left[\frac{\sigma^B}{1-t_r^A}+\frac{1-\sigma^B}{1-t_c^B}\right]^{-1}$ and thus depends on both governments' choices. If one government changes its tax rate it changes the tax base for the other government even though it does not influence ρ. This is a non internalized externality and thus efficiency fails.

b) The direction of the inefficiency stated in part b2) of Result 5 is remarkable: Nash tax rates are too high as compared to the strictly efficient rates. Collusive governments would agree on lower tax rates. In tax competition governments operate in the decreasing part of the Laffer curve. This observation gives rise to the warning not to overhastily interpret the empirical phenonemon of falling capital income tax rates in the last fifteen years as an indicator of tax competition. It may as well hint at a tax cartel of Leviathan governments.

c) The general inefficiency of Nash equilibria (part a)) is not very astounding, but offers a nice contrast to an efficiency theorem developed by Janeba/Peters (1995, Proposition 1) in a similar tax competition setting. Like here, in the Janeba/Peters model the two revenue maximizing governments each have a safe inside option of taxation and they compete for a mobile outside option which will fall to the government with the lower tax rate. Unlike here, the inside options in Janeba/Peters (1995) are independent of the other government's fiscal decisions. Hence, in the Janeba/Peters framework there are no externalities between the governments which distort equilibrium outcomes away from efficiency.

In summary, this section gives a rather diffuse picture of tax competition. Counter-intuitive results are likely to emerge. This calls for a careful and case specific approach in the political discussion about the merits and flaws of fiscal competition.

5. Fiscal competition under a tax credit rule

The most common international tax rule to alleviate double taxation is the tax credit method (M3). Almost all OECD countries apply this rule for some kind of foreign capital income.[28] In our model, where capital flows only go one direction (namely from A to B), the tax credit rule can easily be described by:

$$\tau_x^B = \max\left\{t_x^A, t_x^B\right\}.$$

Despite their widespread acceptance it is a straightforward exercise to show that tax credits cannot be persistent in an international tax competition between revenue maximizing

28 See OECD (1991, p. 36 f.). Note that the tax credit method is a unilateral measure of double taxation relief. On the contrary, the residence principle, e.g., requires a bilateral agreement to be implemented.

governments. For this purpose it is sufficient to have a look at the incentives of government *B*. Tax revenues are given by (5):

$$T^B(\mathbf{t}) = \rho \cdot K^B \cdot \left[\frac{1-\bar{\sigma}^B}{1-\tau_d^B} \cdot \left(\frac{t_c^B}{1-t_c^B} + t_d^B \right) + \bar{\sigma}^B \cdot \frac{t_r^B}{1-\tau_r^B} \right],$$

where:

$$\bar{\sigma}^B = \begin{cases} \sigma^B & \text{if } 1-t_c^B \le \dfrac{1-\max\{t_r^A, t_r^B\}}{1-\max\{t_d^A, t_d^B\}} \\ 0 & \text{otherwise} \end{cases}$$

A situation with $0 \le t_x^B < \tau_x^B = t_x^A$ (x=r,d) cannot constitute a Nash equilibrium. To see this, consider an increase in government *B*'s tax rate. As long as we still have $t_x^B \le t_x^A = \tau_x^B$, this does not change τ_x^B, $\bar{\sigma}^B$ and thus K^A, K^B and S. For government *B*'s tax revenues this implies that the worst thing that can happen is that revenues remain unchanged, namely if we are in a situation with $\bar{\sigma}^B = 0$ and t_r^B is increased. (In such a setting the tax credit does not make sense anyway: there is nothing to be credited.) In all other situations *B*'s tax revenues will strictly increase. To undercut a given tax rate t_x^A hence cannot be a best reponse of government *B*:

RESULT 6: In a Nash equilibrium under the tax credit method $\tau_x^B = t_x^B$ holds for $x = d,r$.

The intuition behind this result is simple: A revenue maximizing government of a capital importing country either tries to exploit the capital exporting country as far as possible without affecting the international capital allocation (and sets $t_x^B = t_x^A$), or it ignores that its taxes will be credited in the foreign country and acts as if the source principle were at work (and chooses $t_x^B > t_x^A$). In the former case the capital importer in a sense does not tax firms or capital owners, but the foreign government.[29] In none of the cases the capital exporting country *A* yields any revenue from its taxation of foreign source income.[30] Tax credits do not make any sense. If in a Nash equilibrium under the tax credit rule capital income is taxed at the personal level with a positive rate, then the capital importing country never chooses a lower tax rate than the capital exporter does. *De facto*, the source principle (M1) is at work:

RESULT 7: Denote by $\mathbf{N}$ the set of revenue equilibria under the source principle (M1). Let $(\hat{t}_c^A, \hat{t}^A, \hat{t}_c^B, \hat{t}^B) \in [0,\bar{t}]^4$ be a Nash equilibrium of tax competition under the tax credit method (M3). Then: $(\hat{t}_c^A, \hat{t}^A, \hat{t}_c^B, \hat{t}^B) \in \mathbf{N}$.

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29 Summers (1988, p. 150) comments on this as follows: "[The] observation is essentially that foreign governments are the best candidates for taxation. There is a very general principle that it is good to tax things that are in inelastic supply. The government of France is presumably in inelastic supply, though perhaps no current government is likely to remain in office forever."

30 The same mechanism has been discovered by Slemrod (1988, p. 150) and Bond/Samuelson (1989).

Hence, the efficiency properties of tax competition under a tax credit rule are known already from our discussion of the source principle in Chapter 3. Note that Result 7 does neither make any assertion concerning the existence of revenue equilibria for the source principle nor for the tax credit method. The existence of equilibria with the source principle does not imply the same for the tax credit rule for we must additionally have that the capital importer's tax rate is not lower than the capital exporter's one.

All above arguments remain of course valid if we restrict ourselves to tax systems of type (S1), where $t_r^i = t_d^i =: t^i$ for $i=A,B$. Furthermore, we can show that in such a scenario a situation with identical positive personal income tax rates cannot be a Nash equilibrium either.

Lemma 5: If both countries apply tax systems of type (S1), then a situation with $0 < t^A = t^B$ cannot be a revenue equilibrium under the tax credit.

Proof: First note that with (S1)-type tax systems both firms choose a mixed capital structure (cf. Lemma 4).[31] This implies that the CME values of K^A, K^B and ρ are overall differentiable in all tax rates.[32] Using definition (10), government A's tax revenues amount to:

$$\hat{T}^A(t_c^A,t^A,t_c^B,t^B) = \rho\cdot K^A\cdot\left[\frac{t^A}{1-t^A}+(1-\sigma^A)\cdot\frac{t_c^A}{(1-t_c^A)\cdot(1-t^A)}\right]+\rho\cdot K^B\cdot\frac{\tau^B-t^B}{1-\tau^B}.$$

This function is continuous, but at $t^A = t^B$ non-differentiable. Assume $t^B > 0$. Taking limits, we obtain:

$$\lim_{t^A\downarrow t^B}\frac{\partial\hat{T}^A}{\partial t^A} = \lim_{t^A\downarrow t^B}\left(\frac{\partial}{\partial t^A}\left[\rho\cdot K^A\cdot\left[\frac{t^A}{1-t^A}+(1-\sigma^A)\cdot\frac{t_c^A}{(1-t_c^A)\cdot(1-t^A)}\right]\right]\right)+\frac{\rho\cdot K^B}{1-t^A}$$

$$> \frac{\partial}{\partial t^A}\left[\rho\cdot K^A\cdot\left[\frac{t^A}{1-t^A}+(1-\sigma^A)\cdot\frac{t_c^A}{(1-t_c^A)\cdot(1-t^A)}\right]\right] = \lim_{t^A\uparrow t^B}\frac{\partial\hat{T}^A}{\partial t^A}.$$

Hence, due to the continuity of $\hat{T}^A$ the best response of government A to a given $t^B > 0$ can never be $t^A = t^B$.

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Lemma 5 sheds some light on the severe existence problems of revenue equilibria with tax credits for it implies the following

Corollary: Assume that both firms employ the same production functions, i.e., $F^A(K) = F^B(K)\ \forall K \geq 0$, that tax systems are of type (S1) and that the functions

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31 For the mixed capital structure it is sufficient that country A runs a (S1)-type system.

32 This is not the case if the firms' financial patterns can vary with across tax rates. Due to discontinuities in the functions $\bar{\sigma}$ the functions K^{-1}, K^B and ρ lack differentiability (but are still continuous).

$$\tilde{T}^i(\mathbf{t}) := \rho \cdot K^i \cdot \left[(1-\sigma^i) \cdot \frac{t_c^i}{(1-t^i)\cdot(1-t_c^i)} + \frac{t^i}{1-t^i} \right]$$

are strictly quasi-concave in (t_c^i, t^i) for $i=A, B$.

a) Assume that the corporate income tax is not available, i.e., $t_c^A = t_c^B \equiv 0$. Then, under (M3) there is no revenue equilibrium.

b) Assume that the corporate income tax is among the disposable policy instruments. Then in a revenue equilibrium it holds that $0 = t^A = t^B$.

Proof: Note first that under the assumption of strict quasi-concavity of the $\tilde{T}^i(\mathbf{t})$ Nash equilibria under the source principle (M1) exist and are symmetric, i.e., $(t_c^A, t^A) = (t_c^B, t^B)$.

a) Let $t_c^A = t_c^B \equiv 0$. On the one hand revenue equilibria under (M3) should be non-symmetric (Lemma 5) if $t^A, t^B \neq 0$. On the other hand they should be symmetric (because they also are revenue equilibria under (M1); Result 7). This is a contradiction. Furthermore observe that a situation where $t^i = 0$ (and hence $T^i = 0$) for some $i=A, B$ cannot be a revenue equilibrium as the respective government(s) could improve upon this situation by choosing a small, but strictly positive rate (yielding some positive return). Therefore, revenue equilibria do not exist.

b) Now allow for $t_c^i > 0$. With the same argument as above we can exclude revenue equilibria where (at least) one of the t^i is positive. However, we cannot exclude a situation with $0 = t^i < t_c^i \leq \bar{t}$ for both i to be a Nash equilibrium. In fact, from Result 3 this is very likely.

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Observe that the assumptions in this corollary offer best chances for the existence of a Nash equilibrium (symmetry, convex strategy sets, continuity of the payoffs, (strict) quasi-concavity of the payoffs over a wide range). Nevertheless, no equilibrium exists. The reason is that a symmetric situation can be improved from the view of the capital exporting country.

6. Concluding remarks

This paper analyses international capital tax competition when taxation can discriminate between different kinds of capital income. It is designed as a first step towards the integration of the characteristics of real systems of national and international capital taxation into the fiscal game approach. The model contains as special cases a number of approaches known from the literature. The analysis given in this paper is incomplete in three respects: Firstly, we did not discuss all scenarios which are possible in the present version of the model (e.g., tax competition under the tax deduction method or under full double taxation). Secondly, our model offers a wide range of straightforward extensions and variations which we did not

address in this paper (e.g., taxes on the capital stock or tax competition among national income maximizing governments). Thirdly, and most seriously, the model still suffers from plenty of shortcomings and fails to incorporate very important features of (tax) reality: There is only one consumer, capital flows only go one direction, taxes on retained earnings are not feasible, there is no commodity trade, etc. These elements cannot be embedded into the model without difficulties, but leave of course a lot of space for further reserach.

Appendix A: Proof of Result 1

Define for $i=A,B$: $\tilde{S}^i := \left\{(t_c^i, t_d^i, t_r^i) \in [0,\bar{t}]^3 \middle| t_r^i \le t_d^i + t_c^i\right\}$. $\tilde{S}^i$ is the convex hull of S^i. Clearly, $\tilde{S} := \tilde{S}^A \times \tilde{S}^B \supset S$. Now let $(\mathbf{t}^A, \mathbf{t}^B) \in \tilde{S}$ and define $(k^A(\mathbf{t}), k^B(\mathbf{t}), \tilde{\rho}(\mathbf{t}))$ as the unique solution of the following set of equations:

$$\tilde{\rho}(\mathbf{t}) = \frac{F_K^A(k^A(\mathbf{t}))-1}{\frac{\sigma^A}{1-t_r^A} + \frac{1-\sigma^A}{(1-t_c^A)\cdot(1-t_d^A)}} = \frac{F_K^B(k^B(\mathbf{t}))-1}{\frac{\sigma^B}{1-t_r^B} + \frac{1-\sigma^B}{(1-t_c^B)\cdot(1-t_d^B)}}$$

and

$$k^A(\mathbf{t}) + k^B(\mathbf{t}) = S(\tilde{\rho}(\mathbf{t})).$$

$(k^A(\mathbf{t}), k^B(\mathbf{t}), \tilde{\rho}(\mathbf{t}))$ should merely be interpreted as a mathematical construction which for $(\mathbf{t}^A, \mathbf{t}^B) \in S$ accidentally coincides with $(K^A(\mathbf{t}), K^B(\mathbf{t}), \rho(\mathbf{t}))$. Define for $\mathbf{t} \in \tilde{S}$ and for $i=A,B$:

$$\tilde{T}^i(\mathbf{t}) = \left[\frac{1-\sigma^i}{1-t_d^i}\cdot\left[\frac{t_c^i}{1-t_c^i} + t_d^i\right] + \sigma^i \cdot \frac{t_r^i}{1-t_r^i}\right]\cdot\tilde{\rho}(\mathbf{t})\cdot k^i(\mathbf{t}),$$

which for $(\mathbf{t}^A, \mathbf{t}^B) \in S$ equals $T^i(\mathbf{t})$. By construction the partial derivatives of $T^i(\mathbf{t})$ remain valid for $\tilde{T}^i(\mathbf{t})$ if the K^i and ρ are replaced by k^i and $\tilde{\rho}$, respectively. We thus constructed an artificial, "extended" game with convex strategy sets $\tilde{S}^i$ and payoffs $\tilde{T}^i(\mathbf{t})$ $(i=A,B)$.

Assumption: For $i=A,B$ the functions $\tilde{T}^i(\mathbf{t})$ are on $\tilde{S}^i$ quasi-concave in (t_c^i, t_d^i, t_r^i).

Then, due to the Debreu-Fan-Glicksberg-Theorem (see Dasgupta/Maskin (1986, Theorem 1)) the extended game has the nice property to possess a Nash equilibrium. In the extended game, each player $i=A,B$ solves the following problem:

$$\max_{t_c^i, t_d^i, t_r^i \in \Re_+^3} \tilde{T}^i(\mathbf{t}) \quad \text{s.t.} \quad t_c^i + t_d^i - t_r^i \ge 0 \quad \text{and} \quad \bar{t} \ge t_x^i \text{ for } x=c,d,r.$$

It is a lengthy but straightforward Kuhn-Tucker exercise (available by the author upon request) to show that under our assumptions the optimal solution has either of the properties a) to c) given in Result 1.[33]

Even though not visible, the solution of the Kuhn-Tucker problem describes player *i*'s reaction correspondence (best response), for the analysis is carried out under the implicit assumption of given (t_c^j, t_d^j, t_r^j). This is of course true for both players. Now note that all three tax constellations a) to c) belong to the original strategy sets S^i for both players. Hence, the Nash equilibrium of the extended game lies in the original strategy space. As the extended game contains the original game, any Nash equilibrium of the extended game must also be a Nash equilibrium of the original game.

Appendix B: A numerical example

In this appendix we demonstrate by means of an example that in fact we cannot yield any general results concerning the existence, the number and the location of Nash equilibria in the setting of Section 4. Assume that the net rate of return ρ is exogenous and constant. The firms in the two countries use the technologies $F^i(K^i) = (\gamma_i + 1) \cdot K^i - (K^i)^2$ where $\gamma_i > 0$ and $i=A, B$. These functions are strictly increasing and concave as long as $K^i < (\gamma_i + 1)/2$, which will always be the case.[34] Using the CME conditions, we calculate the equilibrium values for capital in the two countries as:

$$K^A(\mathbf{t}) = \frac{1}{2} \cdot \left[\gamma_A - \frac{\rho}{1 - t_r^A} \right]$$

and

$$K^B(\mathbf{t}) = \begin{cases} \frac{1}{2} \cdot \left[\gamma_B - \frac{\rho}{1 - t_c^B} \right] =: K_1^B(\mathbf{t}) & \text{if} \quad t_r^A > t_c^B \\ \frac{\gamma_B}{2} - \frac{\rho \cdot \left[\sigma^B \cdot t_c^B + (1 - \sigma^B) \cdot t_r^A \right]}{2 \cdot (1 - t_r^A) \cdot (1 - t_c^B)} =: K_2^B(\mathbf{t}) & \text{if} \quad t_r^A \leq t_c^B \end{cases}$$

Now define:

$$T_1^A(\mathbf{t}) := \frac{t_r^A}{1 - t_r^A} \cdot \rho \cdot K^A(\mathbf{t}) \text{ and } T_1^B(\mathbf{t}) := \frac{t_c^B}{1 - t_c^B} \cdot \rho \cdot K_1^B(\mathbf{t})$$

$$T_2^A(\mathbf{t}) := \frac{t_r^A}{1 - t_r^A} \cdot \rho \cdot \left[K^A(\mathbf{t}) + \sigma^B \cdot K_2^B(\mathbf{t}) \right] \text{ and } T_2^B(\mathbf{t}) := \frac{t_c^B}{1 - t_c^B} \cdot \rho \cdot (1 - \sigma^B) \cdot K_2^B(\mathbf{t})$$

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33 It can be shown that all requirements of the Arrow-Enthoven-Theorem (see Takayama (1985, Theorem 1.E.2)) are satisfied and that hence these properties are both necessary and sufficient.

34 The F^i violate, however, the Inada condition $\lim_{K^i \downarrow 0} F_K^i(K^i) = +\infty$, which ensures a strictly positive capital demand in any situation. In all what follows in this appendix a non-zero amount of capital will be employed, so that the Inada condition can be dropped for the moment without danger.

Revenue equilibria then can be of two types, depending on which government gains the contestable tax base:

Type I: $$\frac{\partial T_1^A}{\partial t_r^A} = \frac{\partial T_1^B}{\partial t_c^B} = 0 \quad \wedge \quad t_r^A > t_c^B$$

Type II: $$\frac{\partial T_2^A}{\partial t_r^A} = \frac{\partial T_2^B}{\partial t_c^B} = 0 \quad \wedge \quad t_r^A < t_c^B .$$

We can express this equivalently by calculating the best response functions:

Type I: $$t_r^A = \frac{\gamma_A - \rho}{\gamma_A + \rho} \quad \wedge \quad t_c^B = \frac{\gamma_B - \rho}{\gamma_B + \rho} \quad \wedge \quad t_r^A > t_c^B$$

Type II: $$t_r^A(t_c^B) = \frac{(\gamma_A - \rho + \sigma^B \cdot \gamma_B - \rho \cdot \sigma^B) \cdot (1 - t_c^B) - \rho \cdot \sigma^B \cdot t_c^B \cdot (1 - \sigma^B)}{(\gamma_A + \rho + \sigma^B \cdot \gamma_B - \rho \cdot \sigma^B) \cdot (1 - t_c^B) - \rho \cdot \sigma^B \cdot t_c^B \cdot (1 + \sigma^B) - 2 \cdot \rho \cdot (\sigma^B)^2}$$

$$\wedge \quad t_c^B(t_r^A) = \frac{(\gamma_B - \rho) \cdot (1 - t_r^A) - \rho \cdot \sigma^B \cdot t_r^A}{(\gamma_B + \rho) \cdot (1 - t_r^A) + \rho \cdot \sigma^B \cdot t_r^A - 2 \cdot \rho \cdot \sigma^B} \quad \wedge \quad t_r^A < t_c^B .$$

Type I-equilibria are equilibria in dominant strategies. This reflects that only source based taxes are used and price effects do not occur.
Now take a situation with $\sigma^B = 0.75$ and $\rho = 0.5$ and consider the following four cases which (only) differ in the values of γ_A and γ_B:

Case 1: $\gamma_A = \gamma_B = 1$
A unique Nash equilibrium of type II exists with $t_r^A = 0.326$ and $t_c^B = 0.560$.[35]

Case 2: $\gamma_A = 2$ and $\gamma_B = 1$
A unique Nash equilibrium of type I exists with $t_r^A = 3/5$ and $t_c^B = 1/3$.

Case 3: $\gamma_A = 1$ and $\gamma_B = 3$
There is no Nash equilibrium.

Case 4: $\gamma_A = 1.25$ and $\gamma_B = 1$
Two Nash equilibria exist, one of type I with $t_r^A = 3/7$ and $t_c^B = 1/3$ and a second one of type II with $t_r^A = 0.397$ and $t_c^B = 0.502$.

These four cases have been chosen as to yield four different equilibrium outcomes. This may suffice as a proof that general results are impossible to obtain.

35 This corresponds with our observation in the main text that with symmetric production functions revenue equilibria can only have the form $t_r^i < t_c^i$.

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