Corporate Income Taxation of Multinationals and Fiscal Equalization*

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Abstract: This paper investigates the effect of fiscal equalization on the efficiency properties of corporate income tax rates chosen by symmetric countries in a Nash tax competition game under the taxation principles of Separate Accounting and Formula Apportionment. Fiscal equalization ensures efficiency if the marginal transfer just reflects the fiscal and pecuniary externalities of tax rates. In contrast to previous studies, tax base equalization (Representative Tax System) does not satisfy this condition, but combining tax revenue and private income equalization does, regardless of which taxation principle is implemented. Under Formula Apportionment, tax base equalization is superior to tax revenue equalization if the wage income externality is sufficiently large.

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1 Introduction

Corporate income of multinational enterprises (MNEs) can basically taxed according to two different principles. The principle of Separate Accounting states that corporate income of each subsidiary of a MNE is taxed separately by the host country's tax code. Under the principle of Formula Apportionment, in contrast, corporate income of all subsidiaries is first consolidated and then assigned to the taxing countries according to a formula that usually contains the MNE's capital, payroll and sales shares in the respective countries. Separate Accounting is applied in corporate income taxation at the international level, while some countries like the US, Canada, Germany and Switzerland use Formula Apportionment in taxing firms that operate in several jurisdictions at the national level. Recently, the European Commission (2001, 2007a, 2007b) proposed to replace Separate Accounting by Formula Apportionment within the borders of the European Union. This proposal has led to a heated debate among politicians and researchers on the relative merits of the two taxation principles.

This paper shows that, from a tax competition point of view, it does not matter whether MNEs are taxed according to Separate Accounting or Formula Apportionment, provided the group of countries in which the MNEs operate has implemented the right fiscal equalization system. We employ a multi-country tax competition model with fiscal equalization among countries. In this model, each country hosts a subsidiary of a representative MNE that produces an output with mobile capital and immobile labor. Wage rates and the interest rate are endogenously determined on local labor markets and the capital market. Corporate income of the MNE is taxed according to Separate Accounting or Formula Apportionment. The MNE may reduce tax payments by shifting profits between countries. Each country is populated by a representative household that earns factor income from inelastically supplying capital and labor and profit income from owning a share of the MNE. The household's utility is determined by the consumption of a private good and a public good. The public good is provided by the local government which finances its expenditures by the revenues from the corporate tax. In addition, countries receive or pay transfers within a fiscal equalization system. The transfers depend on the corporate tax rates chosen by the countries.

With the help of this model we investigate the effect of fiscal equalization on the efficiency properties of corporate tax rates chosen by symmetric countries in a non-cooperative (Nash) tax competition game. For both taxation principles we first identify the fiscal and pecuniary externalities caused by changes in tax rates. Fiscal externalities show how the tax rate of one country influences tax revenues in the other countries. Pecuniary externalities describe the effect of one country's tax rate on private income (capital, wage and profit income) in the other countries. In the absence of fiscal equalization, both types of externalities are external to the country's choice of tax rates in a non-cooperative setting and, thus, we can show that they determine the deviation of the non-cooperative tax rates from their Pareto-efficient (cooperative) levels. As a benchmark result we then show that under both Separate Accounting and Formula Apportionment the fiscal equalization system can be used as a Pigouvian instrument: if the marginal transfer of a country, that is the impact of this country's tax rate on its transfer, just reflects all externalities, then the country internalizes the external effects of its tax policy and the non-cooperative tax rates become Pareto-efficient.

Against the background of this benchmark result, we derive three main insights by investigating which type of equalization system satisfies the Pigouvian internalization requirement. The first main result is that under both taxation principles the so-called Representative Tax System (RTS), which basically aims at equalizing tax capacities among countries, does not ensure efficiency of the non-cooperative tax rates. Under Separate Accounting the intuition is that tax base equalization ignores the pecuniary externalities as it is targeted on the public budget only. Moreover, the RTS fails to fully internalize the fiscal externalities. The reason is that a reduction in one country's tax rate reduces the worldwide tax base, since the interest rate goes up. Hence, tax base equalization takes away the increase in the tax base of the tax-reducing country, but this is not enough to compensate the other countries for their reduction in tax bases. Under Formula Apportionment, the story is almost the same except for the reason why fiscal externalities are not fully internalized. For given and symmetric distribution shares of the consolidated tax base, the fall in the worldwide tax base implies that the average tax base falls to the same extent as the part of the consolidated tax base assigned to the tax-reducing country. Hence, this part of the tax-reducing country's change in tax revenues in not redistributed by tax base equalization.

Our second main result shows that non-cooperative tax rates become efficient if tax base equalization is replaced by tax revenue equalization and augmented by private income equalization. This result, too, holds under both Separate Accounting and Formula Apportionment. The rationale is as follows. Tax revenue equalization actually aggravates the incomplete internalization of fiscal externalities, since there is now a direct negative effect of a tax rate reduction in one country on this country's tax revenues and on average tax revenues. Due to averaging, the latter effect is absolutely smaller than the former, so tax revenues redistributed to the other countries fall in comparison to tax base equalization. However, equalizing the households' private income is also not perfect, since it internalizes only a part of the pecuniary externalities. A tax rate reduction in one country leads to the same reduction in capital and profit income in all countries. Hence, private income equalization balances only changes in wage income and thereby reflects only that part of the pecuniary externalities that pertains to wage income (wage income externality), but not those parts that pertain to capital and profit income (capital and profit income externalities). Interestingly, we can show that these deficiencies of tax revenue and private income equalization just offset each other, so a combined system renders non-cooperative tax rates efficient.

The third main result is that under Formula Apportionment the RTS is superior to tax revenue equalization, if the wage income externality is sufficiently large. The latter condition is satisfied, for example, if the apportionment formula uses payroll only. The net effect of tax revenue equalization is that it does not internalize the wage income externality. This externality is positive and points to inefficiently low tax rates. As argued above, the degree of internalization is lower under tax revenue equalization than under the RTS. This difference is reflected by an additional distortion under RTS that points into the other direction than the wage income externality. Hence, if the wage income externality is large enough, tax rates under the RTS are still inefficiently low, but closer to the efficient tax rates than under tax revenue equalization.

Our results have several policy implications. Perhaps most important, the second result may help to mitigate the public debate about the right taxation principle in Europe. It implies that it does not matter whether MNEs are taxed according to Separate Accounting or Formula Apportionment if there is equalization of national income (i.e. private income plus tax revenues). Even though the European Union does not have an explicit equalization system, a part of the EU budget is financed by contributions that are proportional to the national income of the member states (e.g. Fenge and Wrede, 2007). We would not conclude that the implied income redistribution is already enough to ensure efficiency of corporate income taxation, since the EU budget is not an equalization system in the sense of our analysis. But the very existence of income redistribution in Europe might indicate that reforming the member states' contributions to the budget in a suitable way may politically easier to achieve than replacing a whole corporate tax system. With the same caution, a similar argument can be made with respect to corporate income taxation in US states that follows Formula Apportionment. In the US there is no equalization system either, but it is well known that federal taxes and transfers redistribute national income across states (e.g. Bayoumi and Masson, 1995, Mélitz and Zumer, 2002).

The results also have policy implications for corporate taxation and fiscal equalization in Canada and Germany. The Canadian provinces levy a corporate income tax that follows Formula Apportionment (Martens-Weiner, 2005), and there is an equalization scheme that equalizes tax bases of the provinces (Boadway, 2004; Smart, 2007). A similar institutional setting is implemented among municipalities in Germany at the local level (Buettner, 2006; Egger et al., 2007). Our first two main results imply that tax base equalization in Canada and Germany is not the efficient equalization system, since it is dominated by national income equalization. If comprehensive equalization of national income is viewed as politically infeasible, then the Canadian and German cases may be evaluated with the help of our third result. Corporate income taxation of German municipalities uses a pure payroll apportionment formula. Hence, our third result shows that the implemented tax base equalization is superior to the alternative of tax revenue equalization. In Canada, however, apportionment uses payroll and sales with equal weights, so we will show that it is not clear whether the RTS is still superior or whether efficiency gains can be realized by switching to tax revenue equalization.[1]

Our analysis is related to the literature on the relative merits of Separate Accounting and Formula Apportionment (e.g. Gordon and Wilson, 1986; Nielsen et al., 2003; Eggert and Schjelderup, 2003; Sorensen, 2004; Wellisch, 2004; Pethig and Wagener, 2007; Pinto, 2007; Riedel and Runkel, 2007; Eichner and Runkel, 2008, 2009; Nielsen et al., 2009). But in contrast to our analysis, none of these papers take into account fiscal equalization.[2] Without distinguishing different taxation principles, several studies discuss the implications of fiscal equalization for capital tax competition. The seminal paper is Wildasin (1989). Recent contributions are, for example, Dahlby and Warren

[1] Equalization at the state level in Germany ('Länderfinanzausgleich') represents an example for tax revenue equalization (Baretti et al., 2002; Köthenbürger, 2002). Many state taxes use a common tax rate. This would actually imply that tax revenue equalization turns into tax base equalization. But the states are responsible for tax enforcement and so determine the effective tax rates. Hence, we really have tax revenue equalization at the state level in Germany (Stöwhase and Traxler, 2005).

[2] There is a paper by Traxler and Reutter (2008) on Formula Apportionment and fiscal equalization. But they model Formula Apportionment as a means to redistribute tax revenues and compare the resulting effects on the countries' tax enforcement policy with those of fiscal equalization. In contrast to our paper, they do not address the question how fiscal equalization can be used to internalize externalities of corporate tax rates under Formula Apportionment and Separate Accounting.

(2003), Buettner (2006), Smart (2007) and Egger et al. (2007).[3] Our analysis is closest to DePater and Myers (1994), Köthenbürger (2002) and Bucovetsky and Smart (2006). Under the conditions of our analysis, i.e. symmetric countries and fixed capital supply, these authors show that the RTS ensures efficiency of non-cooperative tax rates.[4] The difference to our results is due to the different modeling of corporate taxation. While we consider a tax on corporate income, defined as the difference between sales and deductible factor costs, previous studies assume a unit (wealth) tax on capital. Hence, in their framework there is no interest effect on the worldwide tax base, which is one of the driving forces behind our results.[5] Moreover, with symmetric countries and fixed capital supply, pecuniary externalities sum up to zero in previous studies, whereas a non-zero sum of pecuniary externalities is another driving force of our results.

The paper is organized as follows. Section 2 describes the basic framework. In Section 3 and Section 4 we examine tax competition and fiscal equalization under Separate Accounting and Formula Apportionment, respectively. Section 5 concludes.

2 Basic Framework

Consider an economy consisting of $n \geq 2$ identical countries. There is a large number of MNEs with subsidaries in each country. We suppose all MNEs are identical and, without loss of generality, focus on the representative MNE. In country i the MNE produces a (numeraire) good with the help of k_i units of the mobile input capital and ℓ_i units of the immobile input labor. The production function reads $F(k_i, \ell_i)$. It exhibits positive and decreasing marginal returns with respect to the two inputs, i.e. $F_k > 0$, $F_{kk} < 0$, $F_\ell > 0$ and $F_{\ell\ell} < 0$. Furthermore, the cross derivative of the production function satisfies $F_{k\ell} = F_{\ell k} > 0$, so increasing the quantity of one input raises the marginal return to the other input. The production function is homogeneous of degree $m \in]0,1[$, i.e. $F(\lambda k_i, \lambda \ell_i) = \lambda^m F(k_i, \ell_i)$ for all $\lambda > 0$. Assuming $m \in]0,1[$ means that we have decreasing returns to scale. Hence, there is a fixed third production factor like

[3] There is also a literature discussing incentive effects of fiscal equalization in the presence of labor mobility, in contrast to capital mobility. A survey is given in Boadway (2004).

[4] For the case of asymmetric countries and/or an endogenous capital supply (savings), these studies also come to the conclusion that a pure RTS does not ensure efficiency.

[5] In an extension, Smart (1998) discusses a (pure) profit tax. However, in his approach the tax rate is always 100% and he does not explicitly account for capital mobility and different taxation principles. More important, and related to this, in his model the worldwide (and average) profit tax base is exogenously given, so he too does not obtain the results derived by our analysis.

e.g. land or entrepreneurial services that gives rise to positive economic rents.[6]

The MNE may shift profits between its subsidiaries by, for example, manipulating transfer prices of intermediate goods and services or by reallocating overhead costs (Devereux, 2006). In an abstract way, profit shifting can be modeled by introducing the variable s_i. If $s_i < 0$, the MNE shifts profits from the subsidiary in country i to the subsidiaries in the other countries. For $s_i > 0$, profits are shifted to the subsidiary in country i. Profit shifting has to satisfy $\sum_{j=1}^{n} s_j = 0$. This condition ensures that profit shifting does not influence the MNE's overall profits. Profit shifting is not costless to the MNE since, e.g., the MNE has to pay tax consultants or may face the risk of being detected and penalized when its profit shifting strategy violates tax law. We assume that the concealment costs of the subsidiary in country i are represented by $C(s_i)$. This function is supposed to satisfy $C(0) = 0$, $\text{sgn}\{C'(s_i)\} = \text{sgn}\{s_i\}$ and $C''(s_i) > 0$ for all s_i. That means, concealment costs are U-shaped with a minimum at the point where the MNE does not shift profits. Note that our modeling implicity assumes that profit shifting between two subsidiaries is associated with concealment costs in both subsidiaries. Though we think that this is a realistic assumption, since each country has its own tax rules that the MNE has to satisfy, all our results would qualitatively remain true when we assume concealment costs to accrue only once.

In most tax systems, labor costs are fully deductible from the corporate tax base, while capital costs are only partially deductible. For example, debt financing costs usually reduce the tax base, while equity financing costs cannot be deducted. We therefore assume that the MNE is allowed to deduct the share $\rho \in [0, 1[$ of capital costs from the tax base. The deductibility parameter ρ is the same for all countries and exogenously given. This is a realistic assumption for many Formula Apportionment systems, like the one in Germany and Canada or the proposed system in Europe, since these systems use a common tax base definition.[7] Denoting the wage rate in country i by w_i and the world interest rate by r, the MNE's tax base in country i reads

$$\phi_i = F(k_i, \ell_i) - \rho r k_i - w_i \ell_i + s_i. \tag{1}$$

The tax base of the MNE equals revenues reduced by the partially deductible capital costs and the fully deductible labor costs and adjusted by profit shifting.

[6] This is a typical assumption in the above-mentioned literature on Separate Accounting versus Formula Apportionment. All our main results also hold for the case of constant returns to scale ($m = 1$), with slight changes in the notation of our analysis.

[7] An exception is Formula Apportionment in the US where each state uses its own tax base definition. But even in this system the definitions are not that different (e.g. Martens-Weiner, 2005).

Each country is populated by a representative household who owns a fixed capital endowment $\overline{k}$ and a fixed labor endowment $\overline{\ell}$. The household earns income from inelastically supplying these factor endowments on the world capital market and the local labor market, respectively. Moreover, the household in country i owns a share $\theta_i = 1/n$ of the MNE and, thus, receives the share $1/n$ of the MNE's after-tax profits π as profit income. The household uses its total income to buy the numeraire good. Denoting by c_i the quantity consumed, the budget constraint of the household in country i reads

$$c_i = r\overline{k} + w_i\overline{\ell} + \theta_i\pi. \tag{2}$$

In addition to the numeraire good, the household consumes the quantity g_i of a (local) public good provided by the local government. The utility of the household in country i is represented by the quasi-concave utility function $U(c_i, g_i)$.

The equilibrium on the world capital market requires that the MNE's aggregate capital demand has to be equal to the households' aggregate capital supply, i.e.

$$\sum_{j=1}^{n} k_j = n\overline{k}. \tag{3}$$

The local labor market in country i is in equilibrium if the MNE's labor demand in this country equals the household's labor supply. Formally, we obtain

$$\ell_i = \overline{\ell}. \tag{4}$$

Capital demand k_i and labor demand ℓ_i *inter alia* depend on the factor prices r and w_i according the MNE's profit-maximization that we consider in detail below. Hence, the factor prices r and w_i are endogenously determined by the equations (3) and (4).

3 Separate Accounting

Behavior of the MNE. Under Separate Accounting, the MNE's profits are subject to taxation in the country where they are declared. Denoting country j's statutory tax rate by t_j, after-tax profits of the MNE under Separate Accounting can be written as

$$\pi = \sum_{j=1}^{n}(1-t_j)\phi_j - (1-\rho)r\sum_{j=1}^{n} k_j - \sum_{j=1}^{n} C(s_j). \tag{5}$$

The MNE maximizes its after-tax profits with respect to capital demand, labor demand and profit shifting, taking as given the tax rates and the factor prices. In solving its maximization problem, the MNE takes into account the profit shifting constraint $\sum_{j=1}^{n} s_j = 0$. Denoting the Lagrange multiplier associated with this constraint by μ, the first-order conditions of profit maximization are

$$(1-t_i)[F_k(k_i,\ell_i) - \rho r] - (1-\rho)r = 0, \tag{6}$$

$$F_\ell(k_i,\ell_i) - w_i = 0, \tag{7}$$

$$(1-t_i) - C'(s_i) + \mu = 0, \tag{8}$$

with $i \in \{1,\ldots,n\}$. Due to (6), capital is invested in country i up to the point where the after-tax marginal returns equal marginal costs, taking into account deductibility of capital costs. Equation (7) shows that the same is true with respect to labor input, except for replacing the after-tax marginal returns by the before-tax marginal returns since payroll is fully tax deductible. Finally, profits are shifted up to the point where the marginal benefits from saving taxes equal the marginal concealment costs, as shown in (8). This condition together with $\sum_{j=1}^{n} s_j = 0$ implies that the MNE shifts profits from countries with above average tax rates to countries with below average tax rates.

The first-order conditions (6)–(8) together with the market clearing conditions (3) and (4) determine capital input, labor input, wage rates and the interest rate in the equilibrium of the factor markets. For later purposes, we have to identify the comparative static effects of tax rate changes on the equilibrium values. We follow previous studies on Separate Accounting versus Formula Apportionment and focus on the case of full symmetry where countries impose the same tax rate $t_i = t$ for all $i \in \{1,\ldots,n\}$.[8] With identical tax rates in all countries we obtain $k_i = \overline{k}$, $\ell_i = \overline{\ell}$, $w_i = w$, $s_i = 0$ and $\phi_i = \phi$ for all $i \in \{1,\ldots,n\}$. Totally differentiating (6)–(8) and then applying the symmetry assumption, the appendix proves

$$\frac{\partial r}{\partial t_i} = -\frac{(F_k - \rho r)}{n(1-t\rho)} < 0, \tag{9}$$

$$\frac{\partial k_i}{\partial t_i} = -(n-1)\frac{\partial k_j}{\partial t_i} = \frac{n-1}{n}\frac{F_k - \rho r}{(1-t)F_{kk}} < 0, \tag{10}$$

$$\frac{\partial w_i}{\partial t_i} = -(n-1)\frac{\partial w_j}{\partial t_i} = \frac{n-1}{n}\frac{(F_k - \rho r)F_{k\ell}}{(1-t)F_{kk}} < 0, \tag{11}$$

[8] It may be argued that this is a restrictive assumption when discussing the implications of fiscal equalization. But the basic *incentive* effects of equalization can be investigated also under symmetry. Moreover, equalization with asymmetric countries has already been studied by DePater and Myers (1994), Köthenbürger (2002) and Bucovetsky and Smart (2006). Hence, assuming symmetry helps to work out the effects that the modeling of corporate taxation has for the incentive effects of equalization.

$$\frac{\partial s_i}{\partial t_i} = -(n-1)\frac{\partial s_j}{\partial t_i} = -\frac{n-1}{n}\frac{1}{C''} < 0, \tag{12}$$

with $i, j \in \{1, \ldots, n\}$ and $i \neq j$. Reducing the tax rate in country i lowers capital costs in this country. Hence, the MNE reallocates capital away from all other countries to country i, as shown in equation (10). According to (9), the reallocation of capital comes along with an increase in the interest rate. Because of the complementarity of capital and labor ($F_{k\ell} > 0$), an increase (decline) in capital input increases (lowers) the marginal returns to labor. Thus, the MNE has an incentive to raise labor demand in country i and decrease labor demand in all other countries. Since labor input is fixed due to the labor market equilibrium condition (4), these changes in labor demand are transformed into corresponding changes in the wage rates, as shown in (11). Finally, equation (12) states that the fall in country i's tax rate induces the MNE to shift more profits from the other countries to country i.

Tax competition. Having investigated the behavior of the MNE, we can now turn to tax competition among the countries. The public budget constraint of country i contains public expenditures g_i, on the one hand, and corporate tax revenues $t_i\phi_i$, on the other hand. In addition, we introduce a fiscal equalization system that influences the public budget constraint. More specific, country i's budget constraint contains the expression $T^i(\mathbf{t})$ where $\mathbf{t} := (t_1, \ldots, t_n)$ is the vector of corporate tax rates of all countries. If $T^i(\mathbf{t})$ is positive, it represents a transfer that country i receives. For negative values of $T^i(\mathbf{t})$, country i has to pay a contribution. We assume $\sum_{j=1}^{n} T^j(\mathbf{t}) = 0$, so resources collected from one country are fully redistributed to other countries. Taking into account the equalization system, country i's budget constraint reads

$$g_i = t_i\phi_i + T^i(\mathbf{t}). \tag{13}$$

Country i sets its tax rate t_i in order to maximize the utility of its representative household, $U(c_i, g_i)$, subject to the private and public budget constraints (2) and (13). Moreover, it takes into account the effect of its tax rate on the factor market equilibrium captured by (9)–(12), but it takes as given the tax policy of all other countries. Hence, we have a non-cooperative tax competition game among the n countries. The Nash equilibrium of this game is determined by $\partial U(c_i, g_i)/\partial t_i = 0$ for all $i \in \{1, \ldots, n\}$.

As already mentioned above, we focus on a symmetric equilibrium with $t_i = t$, $k_i = \overline{k}$, $\ell_i = \overline{\ell}$, $w_i = w$, $s_i = 0$ and $\phi_i = \phi$ for all $i \in \{1, \ldots, n\}$. Using (9)–(12), it is straightforward to show that in the symmetric equilibrium the condition

$\partial U(c_i, g_i)/\partial t_i = 0$ can be rewritten as

$$\frac{U_g}{U_c} = \frac{\phi - n\rho t\overline{k}\dfrac{\partial r}{\partial t_i} + (n-1)(\mathrm{CE} + \mathrm{WE} + \mathrm{PE})}{\phi - n\rho t\overline{k}\dfrac{\partial r}{\partial t_i} - (n-1)(\mathrm{TE} + \mathrm{SE}) + T^i_{t_i}}, \tag{14}$$

with

$$\mathrm{CE} = \overline{k}\frac{\partial r}{\partial t_i} < 0,\ \mathrm{WE} = \overline{\ell}\frac{\partial w_j}{\partial t_i} > 0,\ \mathrm{PE} = \frac{1}{n}\frac{\partial \pi}{\partial t_i} = \frac{1}{n}\left[-\phi - n(1-\rho t)\overline{k}\frac{\partial r}{\partial t_i}\right] < 0, \tag{15}$$

$$\mathrm{TE} = t\left[(F_k - \rho r)\frac{\partial k_j}{\partial t_i} - \rho\overline{k}\frac{\partial r}{\partial t_i} - \overline{\ell}\frac{\partial w_j}{\partial t_i}\right] \gtreqless 0, \quad \mathrm{SE} = t\frac{\partial s_j}{\partial t_i} > 0, \tag{16}$$

for $i \neq j$. The expressions in (15) are the pecuniary externalities caused by corporate income taxation. They represent the effect of country i's tax rate on private income in country j. A decrease in country i's tax rate raises capital and profit income in country j (negative capital and profit income externalities CE and PE)[9] and lowers wage income in country j (positive wage income externality WE). Equation (16) contains the fiscal externalities, i.e. the effect of country i's tax rate on country j's tax revenues. A decrease in country i's tax rate changes the tax base net of profit shifting in country j (positive or negative tax base externality TE) and reduces the tax base in country j via a fall in profit shifting (positive profit shifting externality SE). In the absence of fiscal equalization, the pecuniary and fiscal externalities determine the deviation of the equilibrium tax rates from their Pareto-efficient (cooperative) level. Formally, this can be seen by setting all externalities and $T^i_{t_i}$ equal to zero in (14). We then obtain $U_g/U_c = 1$ which is the Samuelson rule for the Pareto-efficient supply of the local public good.[10] It can be shown that the sign of the sum of all externalities is indeterminate. Hence, it is not clear whether tax competition leads to inefficient undertaxtion (sum of externalities is positive) or inefficient overtaxation (sum of externalities is negative). In any case, the sum of externalities is zero only by chance and, thus, it can be expected that without fiscal equalization tax competition leads to inefficient tax rates.

Fiscal equalization. This inefficiency result holds in the absence of fiscal equalization. However, from (14) it becomes obvious that the equilibrium condition of the tax

[9]The sign of PE follows from using (7), (9) and the Euler Theorem $mF = kF_k + \ell F_\ell$ in the definition of PE in (15), so we obtain $\mathrm{PE} = -(1-m)F/n < 0$.

[10]The appendix shows that the Samuelson rule really characterizes the Pareto-efficient (cooperative) solution in our model.

competition game coincides with the Samuleson rule if and only if

$$T^i_{t_i} = (n-1)(\mathrm{CE} + \mathrm{WE} + \mathrm{PE} + \mathrm{TE} + \mathrm{SE}). \tag{17}$$

Hence, the fiscal equalization system can be used as a Pigouvian instrument to correct for the inefficiency caused by the non-cooperative tax policy. If the marginal transfer of country i reflects all externalities caused by country i's tax rate, then country i internalizes the effects of its tax policy on all other countries. As a consequence, the tax policy in the non-cooperative tax competition game is identical to the Pareto-efficient (cooperative) tax policy characterized by the Samuelson rule.

This is qualitatively the same insight as the previous literature obtained in the standard tax competition model with a unit tax on capital (e.g. DePater and Myers, 1994, Köthenbürger, 2002, Bucovetsky and Smart, 2006). An important difference is, however, that the nature of externalities in our framework is different from that in previous studies. This raises the question which type of equalization system satisfies (17) and, thus, ensures that the non-cooperative tax policy becomes Pareto-efficient. One candidate considered in the previous literature is the so-called Representative Tax System (RTS) that aims at equalizing the difference in a region's tax base relative to that of a representative tax system. Under the RTS the transfer of country i reads

$$T^{iB}(\mathbf{t}) = \bar{t}(\bar{\phi} - \phi_i), \tag{18}$$

where $\bar{\phi} = \sum_{j=1}^{n} \phi_j / n$ is the average tax base and $\bar{t} = \sum_{j=1}^{n} t_j \phi_j / \sum_{j=1}^{n} \phi_j$ is the representative tax rate, i.e. the tax rate that yields the same tax revenues when applied to the world tax base as the sum of regional tax revenues. The RTS is a central element in the fiscal equalization system in Canada (Boadway, 2004; Smart, 2007), and also equalization at the local level in Germany aims at equalizing tax bases (Buettner, 2006; Egger et al., 2007). To illustrate the basic working of the RTS, it is useful to consider a symmetric situation with identical tax bases. If country i tries to improve its tax base by reducing its tax rate and if this reduction in the tax rate leaves unaltered the average tax base, then the fiscal equalization system fully redistributes the increase in country i's tax revenues back to the other countries. Hence, the net effect is zero and country i looses the incentive to lower its tax rate.

Exactly for that reason, the RTS renders the non-cooperative tax policy in the standard tax competition framework with symmetric countries and a fixed capital supply efficient (Köthenbürger, 2002, Bucovetsky and Smart, 2006).[11] In contrast,

[11] Formally, in this type of model the RTS reads $T^{iB}(\mathbf{t}) = \bar{t}(\sum_{j=1}^{n} k_j/n - k_i)$. From $\sum_{j=1}^{n} \partial k_j / \partial t_i = 0$

in our framework the RTS is not able to restore efficiency. Differentiating (18) with respect to t_i, taking into account (1), (10)–(12) and (16) and applying symmetry yields

$$T^{iB}_{t_i} = -\rho t \bar{k} \frac{\partial r}{\partial t_i} - t \frac{\partial \phi_i}{\partial t_i} = (n-1)(\mathrm{TE} + \mathrm{SE}) + (n-1)\rho t \bar{k} \frac{\partial r}{\partial t_i}. \tag{19}$$

Comparing (19) with (17) immediately proves

Proposition 1. *Suppose the non-cooperative tax competition game under Separate Accounting attains a symmetric Nash equilibrium. Then, implementing a fiscal equalization system of the RTS type [$T^i(\mathbf{t}) = T^{iB}(\mathbf{t})$ for $i = 1, \ldots, n$] does not ensure Pareto-efficiency of the non-cooperative tax rates.*

The intuition of this result can best be explained with the help of (19). This equation shows that the RTS does not internalize the pecuniary externalities CE, WE and PE. The reason is obvious, since the RTS aims at equalizing the countries' tax bases, not their private income. But even if we ignore this deficiency, (19) reveals a further reason for the failure of the RTS. Tax base equalization does not fully internalize the fiscal externalities TE and SE. To understand this, suppose we start in a fully symmetric situation where all countries have the same tax base. If country i now tries to improve its tax base by reducing its tax rate, the transfer system redistributes the corresponding increase in country i's tax revenues back to the other countries, see the expression $-t(\partial \phi_i / \partial t_i)$ in (19). In contrast to the standard tax competition model, however, the worldwide tax base $\sum_{j=1}^{n} \phi_j$ falls, since the interest rate and thereby capital costs go up in response to the tax rate decrease in country i.[12] As a consequence, the average tax base $\bar{\phi}$ falls and, thus, the redistribution system takes away from country i more than the additional tax revenues. This effect is represented by the expression $-\rho t \bar{k}(\partial r / \partial t_i)$ in (19). But even the increased transfer of country i is not enough to compensate the other countries for their loss in tax revenues, since averaging implies that the fall in the average tax base is smaller than the fall in the worldwide tax base. In sum, the RTS internalizes only a part of the fiscal externalities as shown in (19).

At this point a remark on the countries' impact on the interest rate is in order. As argued above, the RTS fails to fully internalize fiscal externalities because a decline in country i's tax rate influences the interest rate. One might therefore conjecture that this failure of the RTS vanishes when countries are small so that their impact on the

follows $T^{iB}_{t_i} = -t(\partial k_i / \partial t_i) = (n-1)t(\partial k_j / \partial t_i)$. The latter expression reflects the fiscal externality. As the pecuniary externalities sum up to zero, the RTS renders the non-cooperative tax policy efficient.

[12]Formally, using equations (10)–(12) we obtain $\sum_{j=1}^{n}(\partial \phi_j / \partial t_i) = -n\rho \bar{k}(\partial r / \partial t_i) > 0$.

interest rate is negligible. But this is not true. Formally, the case of small countries is reflected by our model if the number of countries is large. If we let n converge to infinity, equation (9) shows that country i's impact on the interest rate really tends to zero. However, the failure of the RTS to fully internalize fiscal externalities still remains as shown by using $n \to \infty$ in (19). Intuitively, the reason is that a decline in country i's tax rate still lowers the worldwide tax base. For large n, country i's impact on the interest rate and on the tax base of a single other country is small. But the aggregate number of countries is large and, thus, the sum of tax bases of the other countries still decreases. Hence, Proposition 1 and its interpretation also hold for the case of small countries. The same will be true for all results derived below.

The failure of the RTS stated in Proposition 1 raises the question how to modify the fiscal equalization system in order to ensure that the non-cooperative tax policy becomes efficient. We discuss two modifications. As the RTS fails to fully internalize the fiscal externalities, we take a look at tax revenue equalization represented by

$$T^{iR}(\mathbf{t}) = \overline{t\phi} - t_i\phi_i, \tag{20}$$

where $\overline{t\phi} = \sum_{j=1}^{n} t_j\phi_j/n$ equals average tax revenues. Since the RTS ignores pecuniary externalities, we additionally consider private income equalization given by

$$T^{iP}(\mathbf{t}) = \bar{c} - c_i, \tag{21}$$

where $\bar{c} = \sum_{j=1}^{n} c_j/n$ represents average private income. Note that according to (2), private income in country i equals private consumption c_i.

Differentiating equation (20) with respect to t_i and taking into account (1), (10)–(12) and (16) yields

$$T^{iR}_{t_i} = -\rho t\bar{k}\frac{\partial r}{\partial t_i} - t\frac{\partial \phi_i}{\partial t_i} - \phi\frac{n-1}{n} = (n-1)(\mathrm{TE}+\mathrm{SE}) + \frac{n-1}{n}\left(-\phi + n\rho t\bar{k}\frac{\partial r}{\partial t_i}\right). \tag{22}$$

Comparing (22) with (19) shows that tax revenue equalization triggers the same effects as the RTS and is thereby characterized by the same deficiencies as the RTS. But there is now an additional effect reflected by the expression $-\phi(n-1)/n$ in (22). To understand this additional effect note that under tax revenue equalization the reduction in country i's tax rate has a direct negative impact on country i's tax revenues and on average tax revenues. Because of averaging, the loss in country i's tax revenues is larger in absolute terms than the loss in average tax revenues. Hence, the direct effect further reduces the net transfer of country i to the other countries and aggravates this deficiency of the RTS. In terms of externalities, tax revenue equalization decreases the part of fiscal externalities that is internalized, compared to the RTS.

Similarly, from (1), (2), (10)–(12), (16) and (21) we obtain

$$\begin{aligned} T^{iP}_{t_i} &= \bar{k}\frac{\partial r}{\partial t_i} + \frac{1}{n}\frac{\partial \pi}{\partial t_i} - \frac{\partial c_i}{\partial t_i} \quad = \quad -\bar{\ell}\frac{\partial w_i}{\partial t_i} \\ &= (n-1)\mathrm{WE} \quad = \quad (n-1)(\mathrm{CE} + \mathrm{WE} + \mathrm{PE}) - \frac{n-1}{n}\left(-\phi + n\rho t\bar{k}\frac{\partial r}{\partial t_i}\right). \end{aligned} \tag{23}$$

If country i reduces its tax rate, its private income is raised by an increase in capital, wage and profit income. This increase in private income is reflected by the term $\partial c_i/\partial t_i$ in the first line of (23). However, the increase via capital and profit income is fully compensated by an equal increase in average private income reflected by the terms $\bar{k}(\partial r/\partial t_i)$ and $(\partial \pi/\partial t_i)/n$ in the first line of (23). What remains is the effect via country i's wage income that the income equalization system redistributes to the other countries and that is enough to compensate the other countries for the decline in their wage income. But the other countries also benefit from an increase in capital and profit income and the income equalization system does not compensate for these changes. In terms of externalities this means that private income equalization internalizes the positive wage income externality but not the negative capital and profit income externalities, as shown in the second line of (23).

To sum up, implementing tax revenue equalization or private income equalization separately does not remove the deficiencies of the RTS. Private income equalization internalizes only a part of the pecuniary externalities and tax revenue equalization even worsens the internalization of fiscal externalities. An open question is, however, whether combinations of the different equalization systems render the non-cooperative tax policy Pareto-efficient. Combining private income equalization with tax revenue equalization and the RTS, respectively, yields

$$T^{iP}_{t_i} + T^{iR}_{t_i} = (n-1)(\mathrm{CE} + \mathrm{WE} + \mathrm{PE} + \mathrm{TE} + \mathrm{SE}), \tag{24}$$

$$T^{iP}_{t_i} + T^{iB}_{t_i} = (n-1)(\mathrm{CE} + \mathrm{WE} + \mathrm{PE} + \mathrm{TE} + \mathrm{SE}) + \phi\frac{n-1}{n}. \tag{25}$$

Comparing with (17) immediately proves

Proposition 2. *Suppose the non-cooperative tax competition game under Separate Accounting attains a symmetric Nash equilibrium. Then,*
(i) implementing private income equalization and tax revenue equalization $[T^i(\mathbf{t}) =$

$T^{iP}(\mathbf{t}) + T^{iR}(\mathbf{t})$ for all $i = 1, \ldots, n$] renders the non-cooperative tax rates efficient, (ii) implementing private income equalization and the RTS [$T^i(\mathbf{t}) = T^{iP}(\mathbf{t}) + T^{iB}(\mathbf{t})$ for all $i = 1, \ldots, n$] leads to inefficiently high equilibrium tax rates.

The problem of income equalization is that it does not internalize the capital and profit income externalities. Interestingly, these externalities just equal the part of the fiscal externalities that is not internalized by tax revenue equalization.[13] Hence, the deficiency of one of these equalization systems offsets the deficiency of the other system and combining both systems renders the equilibrium tax rates Pareto-efficient, as states in Proposition 2 (i). Under the RTS, in contrast, the deficiency regarding the internalization of fiscal externalities is not as severe as under tax revenue equalization. Hence, combining RTS with the private income equalization redistributes too much resources between the countries and thereby yields the countries an incentive to raise the corporate tax rates above their efficient levels, as proven by Proposition 2 (ii).

4 Formula Apportionment

Behavior of the MNE. Under Formula Apportionment the tax bases of the MNE's subsidiaries are consolidated. This gives the consolidated tax base $\sum_{j=1}^{n} \phi_j$ which is apportioned to the countries according to a certain formula. We consider the general case in which the formula contains all three apportionment factors usually employed in practice, that are the MNE's capital, sales and payroll shares. Denoting the weights attached to these factors by γ, σ and φ with $(\gamma, \sigma, \varphi) \in [0,1]^3$ and $\gamma + \sigma + \varphi = 1$, the share of the consolidated tax base apportioned to country i can be written as

$$A^i(k_i, k_{-i}, \ell_i, \ell_{-i}, w_i, w_{-i}) = \gamma \frac{k_i}{\sum_{j=1}^{n} k_j} + \sigma \frac{F(k_i, \ell_i)}{\sum_{j=1}^{n} F(k_j, \ell_j)} + \varphi \frac{w_i \ell_i}{\sum_{j=1}^{n} w_j \ell_j}, \tag{26}$$

where $x_{-i} := (x_1, ..., x_{i-1}, x_{i+1}, ..., x_n)$ for $x \in \{k, \ell, w\}$. The MNE's tax liability in country i is $t_i A^i(\cdot) \sum_{j=1}^{n} \phi_j$ and its after-tax profits read

$$\pi = (1-\tau) \sum_{j=1}^{n} \phi_j - (1-\rho) r \sum_{j=1}^{n} k_j - \sum_{j=1}^{n} C(s_j), \tag{27}$$

where

$$\tau = \sum_{j=1}^{n} t_j A^j = t_i + \sum_{j \neq i}^{n} (t_j - t_i) A^j \tag{28}$$

[13] Formally, the term $(n-1)[-\phi + n\rho t \bar{k}(\partial r/\partial t_i)]/n$ in equations (22) and (23) is equal to $(n-1)(\mathrm{CE} + \mathrm{PE})$. This is straightforward to show by using equation (15).

is the MNE's effective tax rate equal to the weighted average of all national tax rates.

The MNE maximizes after-tax profits (27). Since tax bases are consolidated, it is not possible to lower the tax liability by shifting profits. For this reason the optimal amount of profit shifting is zero in all countries, i.e. $s_i = 0$ for all $i = 1, \ldots, n$. The first-order conditions with respect to capital and labor input are given by

$$\sum_{j=1}^{n} \phi_j \cdot \sum_{j \neq i}^{n} (t_i - t_j) A^j_{k_i} + (1-\tau)[F_k(k_i, \ell_i) - \rho r] - (1-\rho) r = 0, \tag{29}$$

$$\sum_{j=1}^{n} \phi_j \cdot \sum_{j \neq i}^{n} (t_i - t_j) A^j_{\ell_i} + (1-\tau)[F_\ell(k_i, \ell_i) - w_i] = 0, \tag{30}$$

for $i = 1, \ldots, n$. As under Separate Accounting, these conditions contain the after-tax marginal returns to the input factors and the factor costs. But due to consolidation and apportionment the after-tax marginal returns are now computed not with the help of the national tax rates, but with the help of the effective tax rate τ. Moreover, (29) and (30) are characterized by additional terms containing the derivatives of the apportionment formula. These terms reflect the MNE's formula manipulation incentive, i.e. the incentive to increase investment and labor demand in low-tax countries in order to increase the share of the consolidated tax base assigned to these countries.

To derive the comparative static effects of tax rate changes, we again focus on a symmetric situation with $t_i = t$, $k_i = \bar{k}$, $\ell_i = \bar{\ell}$, $w_i = w$ and $\phi_i = \phi$ for all $i = 1, \ldots, n$. Moreover, symmetry implies $A^i = 1/n$ and

$$A^i_{k_i} = -(n-1) A^j_{k_i} = \frac{n-1}{n^2} \left(\frac{\gamma}{\bar{k}} + \frac{\sigma F_k}{F} \right), \tag{31}$$

$$A^i_{\ell_i} = -(n-1) A^j_{\ell_i} = \frac{n-1}{n^2} \left(\frac{\varphi}{\bar{\ell}} + \frac{\sigma F_\ell}{F} \right), \tag{32}$$

$$A^i_{w_i} = -(n-1) A^j_{w_i} = \frac{n-1}{n^2} \frac{\varphi}{w}. \tag{33}$$

Using these expressions, the Appendix proves

$$\frac{\partial r}{\partial t_i} = -\frac{F_k - \rho r}{n(1 - t\rho)} < 0, \tag{34}$$

$$\frac{\partial k_i}{\partial t_i} = -(n-1) \frac{\partial k_j}{\partial t_i} = \frac{(n-1)\phi}{n(1-t) F_{kk}} \left(\frac{\gamma}{\bar{k}} + \frac{\sigma F_k}{F} \right) < 0, \tag{35}$$

$$\frac{dw_i}{dt_i} = -(n-1) \frac{\partial w_j}{\partial t_i} = \frac{(n-1)\phi}{n(1-t) F_{kk}} \left(\frac{\gamma F_{k\ell}}{\bar{k}} + \frac{\sigma (F_k F_{k\ell} - F_\ell F_{kk})}{F} - \frac{\varphi F_{kk}}{\bar{\ell}} \right) < 0, \tag{36}$$

for $i, j = 1, \ldots, n$ and $i \neq j$. These results are qualitatively the same as under Separate Accounting, but the intuition is different. Under Separate Accounting the MNE reallocates factor inputs to the tax-reducing country because this raises the tax base in this country and lowers the tax bases in the other countries. Due to tax base consolidation, this incentive is not present under Formula Apportionment. However, the tax rate reduction in country i now induces the MNE to raise investment in country i and to lower investment in all other countries since, by doing so, the MNE increases the share of the consolidated tax base assigned to country i. The same is true with respect to labor demand and, because labor supply in each country is fixed, with respect to wage rates. Formally, this intuition is confirmed by the fact that the effects in (35) and (36) are non-zero only if one of the formula weights γ, σ or φ is positive.

Tax Competition. Under Formula Apportionment, tax revenues of country i read $t_i A^i(\cdot) \sum_{j=1}^n \phi_j$. Adding the transfer $T^i(\mathbf{t})$ of the fiscal equalization system, the public budget constraint of country i can be written as

$$g_i = t_i A^i(k_i, k_{-i}, \ell_i, \ell_{-i}, w_i, w_{-i}) \sum_{j=1}^n \phi_j + T^i(\mathbf{t}). \tag{37}$$

The government of country i chooses its tax rate t_i in order to maximize its resident's utility $U(c_i, g_i)$ subject to the private and public budget constraints (2) and (37). With the help of (1), (27), (28) and (31)–(36), it is straightforward to show that the Nash equilibrium of the resulting tax competition game is characterized by

$$\frac{U_g}{U_c} = \frac{\phi - n\rho t\bar{k}\dfrac{\partial r}{\partial t_i} + (n-1)(\mathrm{CE} + \mathrm{WE} + \mathrm{PE})}{\phi - n\rho t\bar{k}\dfrac{\partial r}{\partial t_i} - (n-1)(\mathrm{TE} + \mathrm{FE}) + T^i_{t_i}}. \tag{38}$$

with

$$\mathrm{CE} = \bar{k}\frac{\partial r}{\partial t_i} < 0,\ \mathrm{WE} = \bar{\ell}\frac{\partial w_j}{\partial t_i} > 0,\ \mathrm{PE} = \frac{1}{n}\frac{\partial \pi}{\partial t_i} = \frac{1}{n}\left[-\phi - n(1-\rho t)\bar{k}\frac{\partial r}{\partial t_i}\right] < 0, \tag{39}$$

$$\mathrm{TE} = \frac{t}{n}\sum_{j=1}^n \frac{\partial \phi_j}{\partial t_i} = -\rho t\bar{k}\frac{\partial r}{\partial t_i} > 0, \tag{40}$$

$$\mathrm{FE} = tn\phi\frac{\partial A^j}{\partial t_i} = t\phi\left[\left(\frac{\gamma}{\bar{k}} + \frac{\sigma F_k}{F}\right)\frac{\partial k_j}{\partial t_i} + \frac{\varphi}{w}\frac{\partial w_j}{\partial t_i}\right] > 0. \tag{41}$$

According to (38), the deviation of the non-cooperative tax policy from the Pareto-efficient solution is again determined by the pecuniary and fiscal externalities. The pecuniary externalities in (39) are basically the same as under Separate Accounting. The only difference is that the wage income externality WE is now influenced by the formula, as can be seen by using (36) in WE. The fiscal externalities under Formula Apportionment are represented by (40) and (41). In contrast to Separate Accounting, the tax base externality TE is now unambiguously positive since it reflects the effect on the consolidated tax base, so changes in capital and wage rates cancel out and only the change via the interest rate remains. Moreover, the profit shifting externality is replaced by the formula externality FE, since under Formula Apportionment the MNE shifts profits by manipulating apportionment shares instead of paper profits.

Fiscal Equalization. From (38) we see that the Nash equilibrium of the tax competition game under Formula Apportionment is efficient if and only if

$$T^i_{t_i} = (n-1)(\mathrm{CE} + \mathrm{WE} + \mathrm{PE} + \mathrm{TE} + \mathrm{FE}). \tag{42}$$

As under Separate Accounting, the transfer system under Formula Apportionment plays a Pigouvian role. In order to render tax rates efficient, the marginal transfer of country i has to internalize the externalities caused by this country's tax rate.

We start again by investigating whether the RTS satisfies this condition. Under Formula Apportionment the relevant tax base of country i is given by $\phi^c_i = A^i \sum_{j=1}^n \phi_j$. The average tax base is the same as under Separate Accounting since $\sum_{j=1}^n A^i = 1$ implies $\bar{\phi} = \sum_{j=1}^n \phi^c_j/n = \sum_{j=1}^n \phi_j/n$. The representative tax rate reads $\bar{t} = \sum_{j=1}^n t_j\phi^c_j / \sum_{j=1}^n \phi^c_j$. Under the RTS, the transfer of country i equals

$$T^{iB}(\mathbf{t}) = \bar{t}(\bar{\phi} - \phi^c_i). \tag{43}$$

From (1), (35), (36), (40), (41), (43) and $\partial A^i/\partial t_i = -(n-1)(\partial A^j/\partial t_i)$ follows

$$T^{iB}_{t_i} = -\rho t\bar{k}\frac{\partial r}{\partial t_i} - t\frac{\partial \phi^c_i}{\partial t_i} = (n-1)\mathrm{FE} = (n-1)(\mathrm{FE} + \mathrm{TE}) + (n-1)\rho t\bar{k}\frac{\partial r}{\partial t_i}. \tag{44}$$

Comparing (44) with (42) immediately proves

Proposition 3. *Suppose the non-cooperative tax competition game under Formula Apportionment attains a symmetric Nash equilibrium. Then, implementing a fiscal equalization system of the RTS type* $[T^i(\mathbf{t}) = T^{iB}(\mathbf{t})$ *for* $i = 1, \ldots, n]$ *does not ensure Pareto-efficiency of the non-cooperative tax rates.*

The RTS ignores the pecuniary externalities and fails to fully internalize the fiscal externalities. This is the same reasoning as for the failure of the RTS under Separate

Accounting, but the story for the partial internalization of the fiscal externalities is now different. Suppose country i reduces its tax rate and, by doing so, changes its tax revenues. This change is represented by $-t(\partial\phi_i^c/\partial t_i)$ in the first part of (44), and it is caused by a reduction in the consolidated tax base and an increase in the share of the consolidated tax base assigned to country i. In the RTS, the former effect is neutralized by an equal fall in the average tax base, which is reflected by $-\rho t\bar{k}(\partial r/\partial t_i)$ in the first part of (44). What remains is the increase in country i's share of the consolidated tax base. This increase is fully redistributed to the other countries, so the other countries are compensated for the decline in their shares of the consolidated tax base. But the other countries also suffer from the reduction in the consolidated tax base for which the RTS does not compensate. Hence, the transfer taken from country i is too low, i.e. the RTS reflects the formula externality, but not the tax base externality.

As an alternative equalization system we again consider tax revenue equalization and private income equalization. Average tax revenues can be written as $\overline{t\phi^c} = \sum_{j=1}^n t_j\phi_j^c/n$. Country i's transfer under tax revenue equalization therefore reads

$$T^{iR}(\mathbf{t}) = \overline{t\phi^c} - t_i\phi_i^c. \tag{45}$$

Differentiating (45) in the same way as (43) gives

$$T_{t_i}^{iR} = -\rho t\bar{k}\frac{\partial r}{\partial t_i} - t\frac{\partial\phi_i^c}{\partial t_i} - \phi\frac{n-1}{n} = (n-1)(\mathrm{FE}+\mathrm{TE}) + \frac{n-1}{n}\left(-\phi + n\rho t\bar{k}\frac{\partial r}{\partial t_i}\right). \tag{46}$$

Compared to the RTS, under tax revenue equalization a tax rate decrease in country i additionally has a direct negative effect on average tax revenues and on tax revenues of country i. This effect is represented by the term $-\phi(n-1)/n$ in (46). It is the reason why the internalization of the fiscal externalities under tax revenue equalization is less complete than under the RTS, as becomes obvious by comparing (44) and (46).

Private income is defined in the same way as under Separate Accounting, so the transfer paid or received by country i under private income equalization is given by the same expression as in (21). Moreover, the definitions of the private income externalities under Formula Apportionment and Separate Accounting are also the same, as can be seen from comparing equation (15) with equation (39). Hence, the analysis of private income equalization under Formula Apportionment is qualitatively the same as under Separate Accounting. That means, analogous to (23), we can show that private income equalization internalizes the wage income externality WE, but fails to correct for the capital and profit income externalities CE and PE, respectively.

Combing the different types of equalization systems, we obtain

$$T_{t_i}^{iP} + T_{t_i}^{iR} = (n-1)(\mathrm{CE} + \mathrm{WE} + \mathrm{PE} + \mathrm{TE} + \mathrm{FE}), \tag{47}$$

$$T_{t_i}^{iP} + T_{t_i}^{iB} = (n-1)(\mathrm{CE} + \mathrm{WE} + \mathrm{PE} + \mathrm{TE} + \mathrm{FE}) + \phi\frac{n-1}{n}. \tag{48}$$

Comparing with (42) proves

Proposition 4. *Suppose the non-cooperative tax competition game under Formula Apportionment attains a symmetric Nash equilibrium. Then,*
(i) implementing private income equalization and tax revenue equalization $[T^i(\mathbf{t}) = T^{iP}(\mathbf{t}) + T^{iR}(\mathbf{t})$ *for all* $i = 1, \dots, n]$ *renders the non-cooperative tax rates efficient,*
(ii) implementing private income equalization and the RTS $[T^i(\mathbf{t}) = T^{iP}(\mathbf{t}) + T^{iB}(\mathbf{t})$ *for all* $i = 1, \dots, n]$ *leads to inefficiently high equilibrium tax rates.*

Private income equalization ignores the capital and profit income externalities. These externalities are also the reason why tax revenue equalization does not fully internalize the fiscal externalities. Hence, the drawbacks of both equalization systems just offset each other and a combined private income and tax revenue equalization system ensures the efficient corporate tax policy under Formula Apportionment, as stated by Proposition 4 (i). The degree of internalization of the fiscal externalities is larger under the RTS than under tax revenue equalization. Combining the RTS with private income equalization therefore implies too much internalization, so the non-cooperative tax rates are inefficiently high as shown by Proposition 4 (ii).

Comparing Proposition 4 with Proposition 2, we see that a combination of private income and tax revenue equalization ensures efficiency, regardless of whether corporate income taxation follows Separate Accounting or Formula Apportionment. As already discussed in the Introduction, this result may help to mitigate the discussion on the right taxation principle in the European Union. To see this, we have to take into account that the combination of private income and tax revenue equalization is the same as national income equalization and that there is already some redistribution of national income in Europe via the EU budget. Of course, the EU budget does not represent an equalization system as modeled in our formal analysis. But with some caution we may at least argue that the existing income redistribution provides a good basis for implementing an equalization system that *inter alia* accounts for externalities caused by corporate income taxation in Europe. Perhaps a reform of income redistribution is even easier to implement than a reform of the corporate tax system, since the former does not directly affect firms and households. In the same sense we may argue that income redistribution in the US contributes to internalization of externalities arising from corporate income taxation at the state level.

If national income equalization is not feasible, for example due to political reasons, the question arises whether the RTS or tax revenue equalization performs better in terms of efficiency. This question is of particular importance under Formula Apportionment since in Canada and Germany we observe the combination of Formula Apportionment taxation and tax base equalization. Rewriting (44) and (46) to

$$T^{iB}_{t_i} = (n-1)(\mathrm{FE}+\mathrm{TE}+\mathrm{CE}+\mathrm{PE}) + \phi\frac{n-1}{n}, \tag{49}$$

$$T^{iR}_{t_i} = (n-1)(\mathrm{FE}+\mathrm{TE}+\mathrm{CE}+\mathrm{PE}), \tag{50}$$

and inserting into (38), it immediately follows

Proposition 5. *Suppose the non-cooperative tax competition game under Formula Apportionment attains a symmetric Nash equilibrium. Then, implementing a RTS* $[T^i(\mathbf{t}) = T^{iB}(\mathbf{t})$ *for all* $i = 1, \ldots, n]$ *is superior to implementing tax revenue equalization* $[T^i(\mathbf{t}) = T^{iR}(\mathbf{t})$ *for all* $i = 1, \ldots, n]$*, if* $\mathrm{WE} > \phi/n$.

Proposition 5 identifies $\mathrm{WE} > \phi/n$ as a sufficient condition for the superiority of the RTS over tax revenue equalization under Formula Apportionment. As can be seen from (49) and (50), both the RTS and tax revenue equalization do not internalize the wage income externality represented by $(n-1)\mathrm{WE}$. This externality is positive and points to inefficiently low tax rates in the equilibrium of the tax competition game. But the RTS is characterized by a further distortion. It fails to exactly internalize the other externalities. This failure is reflected by the expression $\phi(n-1)/n > 0$ in (49) and points to too much internalization and too high equilibrium tax rates. Hence, it goes into the other direction than the missing wage income externality. If $\mathrm{WE} > \phi/n$, the wage income externality is the more severe distortion and the countries end up with inefficient undertaxation under both equalization systems. But the tax rates under the RTS are then closer to their efficient levels than with tax revenue equalization.

Whether the condition $\mathrm{WE} > \phi/n$ is satisfied depends *inter alia* on the shape of the apportionment formula. Under a pure payroll formula we have $\gamma = \sigma = 0$ and $\varphi = 1$. Inserting into (36) and (39) implies $\mathrm{WE} > \phi/n$ if and only if $1/(1-t) > 1$. The latter condition is always satisfied since $t < 1$. Hence, with a pure payroll formula the wage income externality is sufficiently large and, in terms of efficiency, the RTS always outperforms tax revenue equalization. This insight supports the institutional setting at the local level in Germany where Formula Apportionment taxation of corporate income employs a pure payroll formula. Hence, the implemented tax base equalization is really more efficient than the alternative of tax revenue equalization

The implications for the Canadian case are less clear-cut. Corporate income taxation at the province level in Canada employs the Formula Apportionment principle with a formula that uses payroll and sales with equal weights. For $\gamma = 0$ and $\sigma = \varphi = 1/2$ the condition WE $> \phi/n$ may or may not be satisfied. To illustrate, consider the special case of a Cobb-Douglas production function $F(k_i, \ell_i) = k_i^{\alpha} \ell_i^{\beta}$ with $\alpha, \beta \in]0, 1[$. Inserting into (36) and (39) implies WE $> \phi/n$ if and only if $1+\beta-\alpha > 2(1-t)(1-\alpha)$. Whether this latter condition is satisfied or not depends on the properties of the production function and the equilibrium tax rate. The growth literature often supposes constant returns to scale with $\alpha = 0.3$ and $\beta = 0.7$ (e.g. Ortigueira and Santos, 1997, Steger, 2005). The above condition is then equivalent to $1.4 > 1.4(1-t)$ and, thus, always satisfied according to $t < 1$. However, if we assume a fixed production factor (like land or natural resources) with a production share of $1 - \alpha - \beta = 0.2$ (e.g. Nordhaus et al., 1992) and keep the assumption of $\alpha = 0.3$, then the above condition becomes $t > 14.29\%$. As the corporate income tax rates of Canadian provinces currently lie between 10% and 16%,[14] it is no longer clear whether the condition WE $> \phi/n$ is satisfied and the RTS is superior to tax revenue equalization. This problem becomes the more severe the lower the production share of labor represented by β.

5 Conclusion

This paper addresses the question whether pecuniary and fiscal externalities arising in tax competition among countries can be internalized by fiscal equalization. The main innovation of the analysis is that it explicitly models a corporate income tax and distinguishs different taxation principles, whereas previous studies interpreted corporate taxation as a unit (wealth) tax on capital. In contrast to the previous literature, we can show that, with symmetric countries and an exogenously given capital supply, tax base equalization is not suitable to render non-cooperative tax rates Pareto-efficient. The reason is that tax base equalization does not internalize the pecuniary externalities, which in our framework are usually different from zero, and only partially internalizes the fiscal externalities since a tax rate reduction in one country lowers the worldwide

[14] See http://www.kpmg.ca/en/services/tax/taxrates.html.

tax base. Tax revenue equalization aggravates the latter problem, but combined with private income equalization it just internalizes all externalities and ensures efficient tax rates. These results hold for both taxation principles. If private income equalization is not feasible under Formula Apportionment, then tax base equalization may be superior to tax revenue equalization depending on the apportionment formula used.

Appendix

Proof of equations (9)–(12). Totally differentiating (6), taking into account (4) and then applying the symmetry assumption yields

$$(1-t)F_{kk}\mathrm{d}k_i - (F_k - \rho r)\mathrm{d}t_i - (1-\rho t)\mathrm{d}r = 0. \tag{51}$$

From (3) we obtain $\sum_{i=1}^{n} \mathrm{d}k_i = 0$. Hence, summing (51) over all countries gives

$$-(F_k - \rho r)\sum_{i=1}^{n} \mathrm{d}t_i - n(1-\rho t)\mathrm{d}r = 0. \tag{52}$$

To identify the comparative static effects of tax rates changes, we have to set all but one $\mathrm{d}t_i$ equal to zero. This immediately proves (9). Using (9) in (51) and doing the same for j instead of i yields (10). Form (7) and $\ell_i = \bar{\ell}$, we obtain $\mathrm{d}w_i = F_{k\ell}\mathrm{d}k_i$. Using (10) in this relation proves (11). Finally, differentiating (8) yields

$$-\mathrm{d}t_i - C''\mathrm{d}s_i + \mathrm{d}\mu = 0. \tag{53}$$

Summing (53) over all countries and setting all but one $\mathrm{d}t_i$ equal to zero implies $\mathrm{d}\mu = 1/(n\mathrm{d}t_i)$ since $\sum_{i=1}^{n} s_i = 0$ yields $\sum_{i=1}^{n} \mathrm{d}s_i = 0$. Using the expression for $\mathrm{d}\mu$ in (53) and taking into account $\sum_{i=1}^{n} \mathrm{d}s_i = 0$ proves (12). ■

Pareto-efficient (cooperative) solution. We derive the Pareto-efficient (cooperative) solution only for the tax regime of Separate Accounting. Since there are no regime specific costs in our model, it follows from Coasean economics that the Pareto-efficient solution under Formula Apportionment is exactly the same.

To characterize the cooperative solution, consider a social planner (e.g. a supranational government) that maximizes the countries' joint welfare given by

$$\sum_{j=1}^{n} U(c_j, g_j) = \sum_{j=1}^{n} U(r\bar{k} + w_j\bar{\ell} + \pi/n, t_j\phi_j), \tag{54}$$

where ϕ_j, π, r, k_j and w_j depend on the tax rates according to (1), (5) and (9)–(12). Maximizing (54) with respect to t_i and applying the symmetry property yields the first-order condition

$$U_c\left(n\bar{k}\frac{\partial r}{\partial t_i}+\bar{\ell}\sum_{j=1}^{n}\frac{\partial w_j}{\partial t_i}+\frac{\mathrm{d}\pi}{\mathrm{d}t_i}\right)+U_g\left(\phi+t\sum_{j=1}^{n}\frac{\partial\phi_j}{\partial t_i}\right)=0. \tag{55}$$

From (1), (5) and (9)–(12) we obtain $\sum_{j=1}^{n}\partial w_j/\partial t_i=0$, $\partial\pi/\partial t_i=-\phi-n(1-\rho t)\bar{k}(\partial r/\partial t_i)$ and $\sum_{j=1}^{n}\partial\phi_j/\partial t_i=-n\rho\bar{k}(\partial r/\partial t_i)$. Inserting into (55) gives

$$U_c\left(-\phi+n\rho t\bar{k}\frac{\partial r}{\partial t_i}\right)+U_g\left(\phi-n\rho t\bar{k}\frac{\partial r}{\partial t_i}\right)=0, \tag{56}$$

and, thus, the Samuelson rule $U_g/U_c=1$. ■

Proof of equations (34)–(36). Totally differentiating (29) and (30), taking into account $\mathrm{d}\ell_i=0$ from (4) and applying the symmetry property yields

$$n\phi\sum_{j\neq i}^{n}(\mathrm{d}t_i-\mathrm{d}t_j)A^j_{k_i}+(1-t)F_{kk}\mathrm{d}k_i-(F_k-\rho r)\mathrm{d}\tau-(1-t\rho)\mathrm{d}r=0, \tag{57}$$

$$n\phi\sum_{j\neq i}^{n}(\mathrm{d}t_i-\mathrm{d}t_j)A^j_{\ell_i}+(1-t)F_{k\ell}\mathrm{d}k_i-(1-t)\mathrm{d}w_i=0. \tag{58}$$

Equation (28) and the symmetry assumption implies $\mathrm{d}\tau=\sum_{j=1}^{n}\mathrm{d}t_j/n$. Inserting into (57) and solving for k_i gives

$$\mathrm{d}k_i=\frac{1}{(1-t)F_{kk}}\left\{\frac{F_k-\rho r}{n}\sum_{j=1}^{n}\mathrm{d}t_j-n\phi A^j_{k_i}\left[(n-1)\mathrm{d}t_i-\sum_{j\neq i}^{n}\mathrm{d}t_j\right]+(1-t\rho)\mathrm{d}r\right\}. \tag{59}$$

If we sum up (59) over all $i=1,\dots,n$ and take into account $\sum_{i=1}^{n}\mathrm{d}k_i=0$ from (3) as well as $\sum_{i=1}^{n}[(n-1)\mathrm{d}t_i-\sum_{j\neq i}^{n}\mathrm{d}t_j]=0$, equation (59) simplifies to

$$\mathrm{d}r=-\frac{F_k-\rho r}{n(1-t\rho)}\sum_{j}\mathrm{d}t_j. \tag{60}$$

Equation (34) follows from (60), if we set one $\mathrm{d}t_j\neq 0$ and all others equal to zero. Inserting (60) back into (59) implies

$$\frac{\partial k_i}{\partial t_i}=-(n-1)\frac{\partial k_i}{\partial t_j}=-\frac{n(n-1)\phi A^j_{k_i}}{(1-t)F_{kk}}. \tag{61}$$

Using (31) proves (35). Finally, from (58) we obtain

$$\mathrm{d}w_i=F_{k\ell}\mathrm{d}k_i+\frac{n\phi}{1-t}\sum_{j\neq i}(\mathrm{d}t_i-\mathrm{d}t_j)A^j_{\ell_i}, \tag{62}$$

and, thus,

$$\frac{\partial w_i}{\partial t_i} = F_{k\ell}\frac{\partial k_i}{\partial t_i} + \frac{n(n-1)\phi}{1-t}A^j_{\ell_i}, \qquad \frac{\partial w_i}{\partial t_j} = F_{k\ell}\frac{\partial k_i}{\partial t_j} - \frac{n\phi}{1-t}A^j_{\ell_i}. \tag{63}$$

Using (61) and (32) proves (36). ■

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