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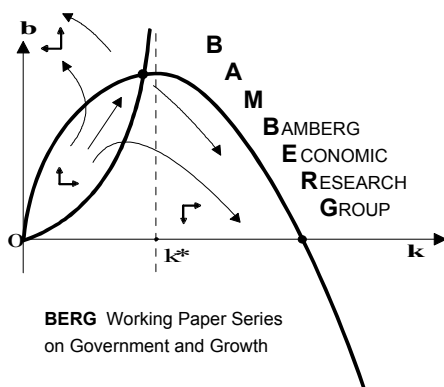
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# Capital Tax Competition and Partial Cooperation: Welfare Enhancing or not?

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## Abstract

The paper analyzes under which conditions a partial tax cooperation will be welfare enhancing within the cooperating regions. Starting from the standard symmetric tax competition model, subgroups of regions can form tax cooperations and thereby increase their relevant market share. As the non-cooperation regions react to the tax change in the bloc, the welfare outcome relative to the symmetric case is ambiguous. Complementary to a more general theoretical approach, a simulation is also used to clarify the limits of welfare enhancing partial tax coordination of a subgroup of regions. In the used structure, only if regions are very large, tax rates are complements. However, the case of welfare loss due to a partial tax harmonization is mainly limited to the case of a single cooperation.

### *Key words:*

Capital Tax Competition, Tax Harmonization, Asymmetric Tax Competition

*JEL Classification:* H25, H26, F21

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# Capital Tax Competition and Partial Cooperation: Welfare Enhancing or not?

## 1 Introduction

Literature on fiscal competition is manifold. One of its key results is the under-supply of publicly provided goods resulting from limited tax instruments and uncoordinated action of decentralized governments. With the intention to attract mobile factors of production, each local government has an incentive to reduce its related tax rate under the efficient level. However, as all governments act in the same manner, no region is able to gain an advantage in production or income of immobile factors, only a loss of tax income arises for each region. Based on the more intuitive approach of Oates (1972), Zodrow and Mieszkowski (1986) as well as Wilson (1986) reproduced his conclusion in the context of formal models. Since then, several aspects have been added to the basic structure of fiscal competition models, giving a more detailed view on the problem of fiscal competition.<sup>1</sup> According to Gordon (1986) and Razin and Sadka (1991), due to the global market integration, countries will finally abolish the taxation of mobile capital at the source, switching to the residence principle or taxing only immobile factors. Therefore, Sinn (1997) and Arnold (2000) pronounce the increasing inequality of tax burden between factor owners and also the arising problems for the existing system of welfare state, as perfect mobile factors can avoid any taxation.

In principle, there are three possibilities to solve the prisoners' dilemma caused by positive fiscal externality of source-based tax competition.

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<sup>1</sup> An overview on fiscal competition literature give e.g.: Wilson (1999), Zodrow (2003) and Wilson and Wildasin (2004). For an introduction in the theory of fiscal competition see e.g. Wellisch (2000).

Firstly, in line with Bucovetsky and Wilson (1991), the taxing system may be changed by enforcing the residence principle. Secondly, as the *race to the bottom* arises due to a positive externality, a system of matching grants could be introduced for internalizing this positive externality. And finally, following Hoyt (1991) the relevant market share could be increased by reducing the number of regions or binding contracts on tax harmonization.

Concerning the implementation of the residence principle for capital taxation, Tanzi (1995) highlights the administrative infeasibility. If tax authorities are not able to monitor foreign source capital income, a high risk of tax evasion and tax avoidance emerges especially in a globalized economy. As a solution, Razin and Sadka (1991) advocate the cooperation of countries via information sharing about foreign capital income.<sup>2</sup> In the context of capital tax competition, the alternative solution of a grant system, which was firstly proposed by Wildasin (1989) and later on extend in several ways,<sup>3</sup> involves a high degree of complexity especially in case of asymmetric regions. Finally, concerning a tax harmonization, all countries should cooperate. Although the latter approach leads towards the first-best solution, a common increase of capital tax rates in all regions may not be feasible. Denying to cooperate creates an ever higher advantage than being part of the cooperation as shown by Bucovetsky (1991) and Wilson (1991). The advantage of relatively small regions is well known in the literature on capital tax competition. However, the impact of a partial cooperation on the welfare level within the subgroup of tax harmonizing regions is widely neglected. As an exception, Konrad and Schjelderup (1999) present clear cut results of a welfare increase within the cooperation by setting tax rates as strategic complements. Although there is empirical evidence to suggest a positive sign of the reaction function implying that tax rates

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<sup>2</sup> Concerning the rationality of information sharing, see e.g. Bacchetta and Espinosa (1995) and Eggert and Kolmar (2002).

<sup>3</sup> E.g. DePater and Myers (1994), Dillén (1995), and Sato (2000).

are complements,<sup>4</sup> in theory the sign is ambiguous. Therefore, the paper gives more insights under which conditions a partial cooperation in capital tax rates is not welfare enhancing within the cooperating regions, subject to endogen tax reaction. This approach is highly related to Beaudry, Cahuc, and Kempf (2000) who analyze in general terms the impact of simultaneous strategic spill-overs on the preferability of partial cooperation. However, concluding a possible welfare loss due to partial cooperations, the mentioned authors concentrate on a symmetric structure. In contrast, the present approach includes an asymmetry in capital market share after bloc building process. Complementary to the more general theoretical approach, a simulation is also used to clarify the limits of tax coordination in a subgroup of regions. The used simulation model, which is quite rudimentary compared to reality, incorporates the advantage of getting clear linkages between stimulus and results. This is not the case for more sophisticated models as used by Sørensen (2000, 2004).

After introducing in the next part the basic model of capital tax competition, the third part analyzes the theoretical impact of capital tax collusion between a subgroup of regions on the choice of the tax rate. The fourth part discusses the welfare effects if only a small market-share is not included in the cooperation activity. In contrast, the fifth section extends the setting for a increased number of non-cooperating regions. The sixth section highlights results of a numerical simulation and the last section concludes the paper.

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<sup>4</sup> See e.g. Brueckner and Saavedra (2001), Buettner (2001), Devereux, Lockwood, and Redoano (2002), Altshuler and Goodspeed (2003).



## 2 Setup of the Model

In most aspects, the setup of the model is identical to Wildasin (1988), since the utility at the symmetric Nash-equilibrium is used as point of reference. However, considering the partial tax cooperation, the structure is close to Bucovetsky (1991) and Wilson (1991), except for the number of regions which is no longer limited to the two region case.

Consider a world economy consisting of  $I \geq 3$  regions, each inhabited by  $\bar{N}$  immobile households. Concentrating on efficiency and Pareto-improvements, the regions are identical in per-capita endowments, technologies, preferences and number of immobile households. The representative individual's preferences corresponds to a strictly quasi-concave function  $u^i = u(x_i, z_i)$ , whereby  $x_i$  denotes the consumption of a private (numeraire) good at the region  $i$  and  $z_i$  the per-capita level of a publicly provided good which can only be consumed by individuals residing in  $i$ . Note that the publicly provided good is completely rival in consumption. Each household has two potential sources of income: wage income from an inelastic supply of one unit of an immobile factor called labor and a mobile factor called capital  $\bar{k}$ . The factors are used to produce a homogeneous private good, using a constant return to scale production technology. Considering the inelastic supply of labor in each region and the linear homogeneity of the production function, the latter can also be represented in intensive form as  $f(k^i)$ . Note that  $k^i$  represents the capital-labor ratio used for the production process in the region  $i$  while  $\bar{k}$  corresponds to the capital endowment of each inhabitant which is independent of the region. The per-capita production function is triple continuously differentiable, whereby the marginal product of each factor is positive and diminishing and  $f'''(k) \geq 0$  holds.<sup>5</sup> Supposing profit maximization in the production and compet-

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<sup>5</sup> See Laussel and Le Breton (1998) and Bayindir-Upmann and Ziad (2003 forthcoming), concerning the relevance of a non-negative third derivation of  $f(k^i)$  to ensure the existence of an equilibrium in tax competition.

itive factor markets, gross return to capital is equal to its marginal product while local wages obey as residual  $f(k^i) - k^i f'(k^i)$ . Given the interregional net return of capital  $r$ , private consumption is given by

$$x_i = f(k^i) - k^i f'(k^i) + r\bar{k}. \quad (1)$$

Instead of being used for private consumption, one unit of the produced homogeneous good can also be transformed into one unit of the publicly provided good. Thus, the marginal rate of transformation is always equal to one,  $MRT_{zx} = 1$ . For financing the provision of the impure public good, the regions are limited to a source-based per unit tax on capital  $\tau_i$ .<sup>6</sup> Thus, the budget restraint of the benevolent regional government follows immediately as

$$z_i = \tau_i k^i. \quad (2)$$

The capital market is in equilibrium, if the total fixed supply equals the global capital input

$$\sum_{i=1}^I N_i k^i = \sum_{i=1}^I N_i \bar{k}. \quad (3)$$

Taking into account the global capital market, the regional gross return to capital reduced for regional tax rate must be equal to the uniform net return to capital

$$f'(k^i) - \tau_i = r. \quad (4)$$

Furthermore, equation (3) together with equation (4) implies that the tax rate is bounded to a upper limit of  $\tau_i \leq f'(k^i)$ , otherwise the house-

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<sup>6</sup> The assumption of a unit tax is not innocent. As shown by Lockwood (2004), the intensity of the tax competition may be higher and therefore, the state activity lower in the case of ad valorem taxes instead of a unit tax. However, since in case of an ad valorem tax system the analysis becomes more complicated and less tractable, we abstain from the more realistic assumption.

holds would not behave rational since  $\bar{\tau}_i > f'(k^i)$  implies a negative net return to capital, called an excess supply of capital.<sup>7</sup>

Globally, the capital supply is fixed, hence, the capital tax is lump-sum taxation. Thus, a global planner would set the tax rates in order that the marginal rate of substitution of a representative household with

$$MRS_{zx}^i := \frac{u_{z_i}^i}{u_{x_i}^i}$$

is equal to the marginal rate of transformation for all regions. Considering the one-to-one technology with  $MRT_{zx} = 1$ , an efficient choice of the tax rate implies  $MRS_{zx}^i = 1, \forall i$ . Excluding an excess-supply, the efficient tax rate chosen by a central planner is also upper-bounded. Therefore, the efficient amount of publicly provided goods  $z^*$  cannot be higher than gross capital income  $f'(k^*)k^*$  otherwise the households would have to pay for supplying capital. Hence, in an economy of rational households the efficient share of public activity cannot be higher than the partial output elasticity for capital  $\alpha$

$$\frac{z^*}{f(k^*)} \leq \alpha. \quad (5)$$

If (5) did not hold, even the central planner would fail in efficiently providing the publicly provided good.

From the perspective of a single region, the capital supply is not fixed. Therefore, each regional government will take into account an outflow of capital as reaction on a marginal increase of the tax rate. Formally,

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<sup>7</sup> Bucovetsky (1991) presents conditions for ruling out an excess supply in the Nash-equilibrium.

by implicitly differentiating (4) we get

$$\begin{aligned} \frac{dk^i}{d\tau_i} &= \frac{1}{f''(k^i)} \left( \frac{dr}{d\tau_i} + 1 \right) \\ \frac{dk^j}{d\tau_i} &= \frac{1}{f''(k^j)} \frac{dr}{d\tau_i}, j \neq i \end{aligned} \quad (6)$$

while the condition for the cleared capital market implies

$$0 = \bar{N}_i \frac{dk^i}{d\tau_i} + \sum_{j=1}^I \bar{N}_j \frac{dk^j}{d\tau_i}, j \neq i. \quad (7)$$

Inserting (6) in (7), while considering the symmetric set-up with identical regions  $\bar{N}_i = \bar{N}_j$ ,  $f''(k^i) = f''(k^j) = f''(k)$  and defining  $\theta \equiv \frac{1}{I}$  as the capital market share of a region, the expected inflow into another region simplifies to

$$k_{\tau_i}^j := \frac{dk^j}{d\tau_i} = -\frac{\theta}{f''(k)} > 0,$$

which leads together with (6) to

$$\begin{aligned} r_{\tau_i} &:= \frac{dr}{d\tau_i} = -\theta < 0, \\ k_{\tau_i}^i &:= \frac{dk^i}{d\tau_i} = \frac{1-\theta}{f''(k)} < 0. \end{aligned} \quad (8)$$

Each regional government wants to maximize the utility of a representative household  $u^i = u(x_i, z_i)$  by choosing the tax rate. Thereby, the private consumption  $x_i$  and the public consumption  $z_i$  are defined by (1) and (2) respectively. However, in their decision the governments also consider the conjectured reaction of the regional capital supply  $k_{\tau_i}^i$  and the interest rate  $r_{\tau_i}$  defined by (8). Thus, the first-order condition

yields the best reply function for given tax rates in all other regions.

$$0 = MR_{S_{zx}}(1 - \epsilon_{k\tau}) - 1 \quad (9)$$

with  $\epsilon_{k\tau} := -\frac{\tau}{k}k_{\tau}$ .

As well-known, the source-based capital tax provokes an under-supply of the publicly provided good,  $MR_{S_{zx}}^i > 1$ , since all regional governments take a potential outflow of capital into account.

### 3 The choice of the tax rate in the case of partial integration

Since we want to focus on a partial cooperation, we assume that  $\Psi$  regions decide commonly about their tax rate. Thus, they harmonize their tax rates by a constitutional act, whereas the identical tax rates in the Nash-equilibrium of the symmetric setting are the consequence of the identical endowment. Furthermore, as in the moment of the group-building process the partial cooperation is seen as welfare enhancing, several coalitions may build simultaneously. In order to maintain the structure tractable, all  $I^l$  coalitions will have the same size of  $\Psi$ . To assure the existence of at least one non-cooperation region,

$$2 \leq \Psi I^l \leq (I - 1)$$

must hold.

Since the governments of a cooperation set their tax rates jointly, each fortress can be treated as one single large region. By choosing jointly the tax rate  $\tau_l$ , they determine the supply of the public activity  $z_l$  and also the private consumption possibilities  $x_l$  within the cooperation. Since the public activity is rival in consumption, we need not to puzzle about possible inconsistencies concerning the accessibility to public activity or existing positive spill-overs which would be internalized by

the coalition process.<sup>8</sup> While indexing all the variables of a cooperation by  $l$ , we will use  $s$  for the non-cooperating regions. Compared to the symmetric setting or a non-cooperation region, the individual endowment has not changed. However, the share and therefore the power on the capital market within a coalition is increased to  $\theta^l = \Psi/I$  while the market share of a non-cooperating region remains unchanged at  $\theta^s = 1/I$ . Although the equations (6) and (7) still hold, there is no longer an equivalence in the number of inhabitants as  $\bar{N}_l = \Psi\bar{N}_s$ . For the modified setting, a change in the tax rate  $\tau_i$  implies

$$0 = \bar{N}_i \frac{dk^i}{d(r + \tau_i)} + \sum_{j=1}^I \bar{N}_j \frac{dk^j}{d(r + \tau_i)} r_{\tau_i} \Leftrightarrow$$

$$r_{\tau_i} = - \frac{\theta^i f''(k^j)}{\Theta f''(k^s) + (1 - \Theta) f''(k^l)} \quad i, j = s, l; i \neq j \quad (10)$$

$$k_{\tau_i}^i = \frac{1}{f''(k^i)} \left( 1 - \frac{\theta^i f''(k^j)}{\Theta f''(k^l) + (1 - \Theta) f''(k^s)} \right) \quad i, j = s, l; i \neq j \quad (11)$$

whereby  $\Theta$  represents the aggregated market share of all cooperating regions and  $(1 - \Theta)$  for all non-cooperating regions  $I^s$ :

$$I = I^s + \Psi I^l$$

$$\Theta := \frac{\Psi I^l}{I} \quad (12)$$

$$1 - \Theta = \frac{I^s}{I} \quad (13)$$

The Entscheidungsproblem of each region remains unchanged compared to the symmetric case. Thus, the first-order condition is given as

$$\frac{\partial u^i}{\partial \tau_i} \stackrel{!}{=} 0 \Leftrightarrow MRS_{zx}^i \frac{dz_i}{d\tau_i} + \frac{dx_i}{d\tau_i} = 0.$$

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<sup>8</sup> See Bjorvatn and Schjelderup (2002) for a capital tax competition model with international public goods.

After implicitly differentiating the private budget (1) as well as the public budget restrictions (2) and inserting them into the preceding equation, the optimal reply in the region  $i$  for given tax rates in the other regions follows as

$$MRS_{zx}^i = \frac{1 - r_{\tau_i} \left( \frac{\bar{k}}{k^i} - 1 \right)}{1 - \epsilon_{k^i \tau_i}} \quad (14)$$

with  $\epsilon_{k^i \tau_i} = -\frac{\tau_i}{k^i f''(k^i)} (1 + r_{\tau_i})$ .

Starting from the symmetric case at which all countries set an equal tax rate, the marginal costs of public funds differ only in the elasticity of the capital supply with respect to the own tax rate  $\epsilon_{k^i \tau_i}$ , since  $\frac{\bar{k}}{k^i} - 1 = 0$  holds. Furthermore, as the symmetric capital input implies also  $f''(k^i) = f''(k^j)$ , the only argument differing in the case of a cooperating to a non-cooperation region, is the marginal variation of the interest rate for changing the local tax rate  $r_{\tau_i}$ . From the point of view of a very large cooperation, (10) indicates, that a change in the tax rate reduces the interest rate for the same amount, and no capital flight will arise,

$$\lim_{\theta^i \rightarrow 1} r_{\tau_i} = 1 \Rightarrow \lim_{\theta^i \rightarrow 1} k_{\tau_i}^i = 0. \quad (15)$$

Meanwhile, a very small, non-cooperating region takes the interest rate as given, and conjectures an enormous outflow of capital in reaction to a marginal increase of its tax rate,

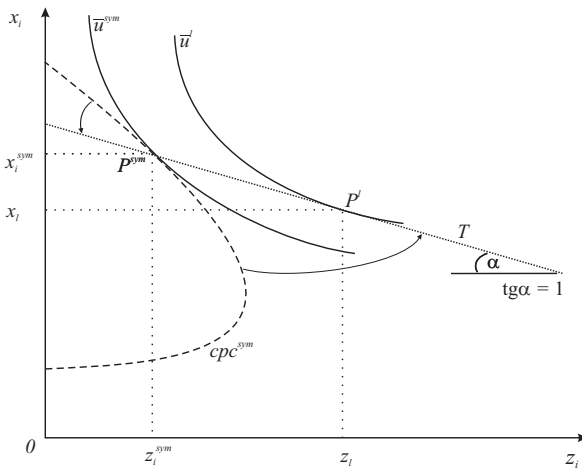
$$\lim_{\theta^i \rightarrow 0} r_{\tau_i} = 0 \Rightarrow \lim_{\theta^i \rightarrow 0} k_{\tau_i}^i = \frac{1}{f''(k^i)}. \quad (16)$$

#### 4 Welfare effects for a small market share not included in any cooperation

In a first step, the situation of a nearly global cooperation activity is analyzed. In this case, only a very small market share is excluded

from the harmonization activity, however, this does not mean that all cooperating regions are engaged in the same bloc. It includes also the possibility that several sub-groups of regions simultaneously form a cooperation.

Given the unchanged tax rate of the non-cooperation regions, the increased influence on the capital market within each fortress also implies a reduction of the considered excess burden of taxation. Figure 1 depicts the extreme case of one very large cooperation. As indicated, the considered outflow of capital will decline with an increased market share and in this extreme case reach zero. Thus, with a market share close to one, the consumption possibility curve (*cpc*) of the cooperation is very close to the transformation curve *T*, at which  $\frac{dx}{dz} = -1$  holds.<sup>9</sup>



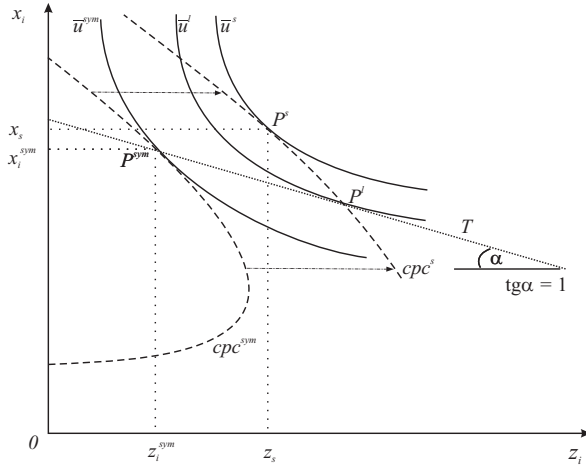
**Figure 1.** Welfare effects in a large cooperation with  $\theta^l \rightarrow 1$

Therefore, the optimal consumption bundle within the cooperation shifts from the symmetric point  $P^{sym}$  to  $P^l$ , implying an increase in the level of publicly provided goods, while the amount of disposable

<sup>9</sup> Note, that for the purpose of visibility, the axes are **not** scaled identically.



income and therefore private consumption is reduced. In the case of one very large cooperation, the tax rate will draw level with the efficient tax rate, and therefore, the inhabitants reach an utility level that is close to but lower than the efficient level, as figured in Fig. 1. If there are more than one cooperation, nevertheless with an aggregate market share still close to one  $\Theta \rightarrow 1$ , the new tax rate is also increased compared to the symmetric setting but just for a lower amount than with one large cooperation. Without a reaction of the non-cooperating regions, the consumption possibility curve stays unchanged and the welfare is increased within the cooperation. Even if the non-cooperating regions change their tax rates, this will not influence the welfare level within a cooperation, since the non-included market share is neglectable small and therefore, the change in the tax rate remains irrelevant within the cooperation.



**Figure 2.** Welfare effects outside of the cooperation

As highlighted in figure 2, the increased tax rates within the cooperation imply an enormous inflow of capital to the small non-cooperating region and moves the consumption possibility curve to the right  $cpc^s$ .

Since the expected capital outflow is higher, the  $cpc^s$  must be steeper than the  $cpc^l$ . Consequently, the point  $P^l$ , that is feasible for the same tax rate as in the cooperation cannot be optimal. Choosing the point  $P^s$ , a non-cooperating region reaches a higher welfare level than within the cooperation.

In that extreme case, the result concerning the utility level is quite clear. The non-cooperating regions, each on its own as well as aggregated with an infinitively small market share, will always choose a lower tax rate than a region within the cooperation. The tax differential implies an inflow of capital  $k^s > k^{sym}$ . Accordingly, the consumption level is increased in the non-cooperation regions compared to the symmetric level. Even if an undersupply of publicly provided goods arises, the reachable utility level is always higher than within the cooperating group and at the efficient solution (Bucovetsky, 1991: 180). Thus, we can conclude:

**Proposition 1** *If the aggregated market share of all cooperating regions approaches one  $\Theta \rightarrow 1$ , a partial tax harmonization increases always the welfare level in all regions. Furthermore, acceding also the fortress is not useful for the new member. Staying outside of the cooperation involves an advantage, compared to the reachable efficient utility level inside the cooperation.*

**PROOF:** Follows directly from the preceding discussion.

Note, since the tax rates within and outside a cooperation no longer coincide, capital is not be allocated efficiently. Hence, the global level of production and therefore the aggregated consumption could be increased by reallocating the mobile factor. Nevertheless, in the asymmetric case the welfare level in all regions is increased compared to the symmetric setting, even though the latter involves an efficient production level on the transformation curve. Thus, partial cooperations involving a very large market share are Pareto-superior to the symmet-

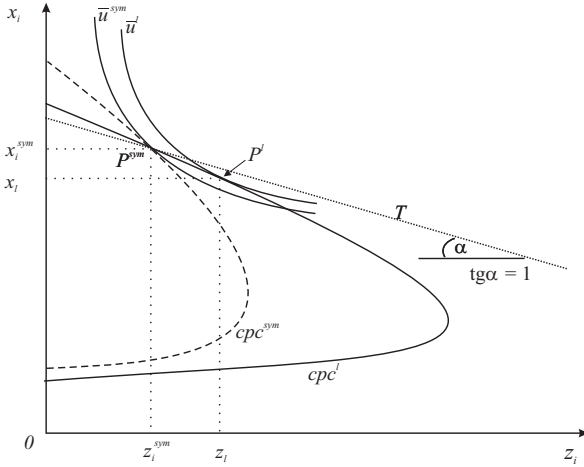
ric case and can be seen as a second-best solution if the tax instrument are limited to a source-based capital tax.

## **5 Impact of a Sizable Market Share of the Non-Cooperating Regions**

A neglectable small aggregated market share of all non-cooperating regions was crucial to obtain the unambiguous result of a global welfare increase in the previous section. Extending for a remarkable market share outside of any cooperation, the inner-relation between the utility level of cooperating and non-cooperating regions remains unchanged. As shown by Wilson (1991), the relative small region, which is equal with a non-cooperating region in our context, will always reach a higher utility level than the large region, in the given context any region involved in the harmonization process. One possible extension would focus on the second second part of proposition 1, by searching for the critical cooperation size out of the view of a newcomer. Starting from the symmetric point, acceding the fortress is welfare increasing. Meanwhile, being the last small non-member of the economy, the region would not enter the cooperation. Thus, there must be a critical group size until which entering the fortress is advantageous. However, the following part will not further investigate this critical cooperation size.

Instead, we will concentrate on the welfare effects for the cooperating regions. The assumption of a very small market share outside of the cooperations has prevented any repercussion of a tax change outside of the fortress on the consumption possibility curve of the cooperating regions. Allowing a remarkable market share being outside of the cooperations, the result may change significantly. Since a Nash-behavior is assumed, the first step of a tax increase inside the cooperation is not determined. Thus, taking the tax rates outside of the own cooperation as given, the increased market power, compared to the symmetric case,

implies a higher taxation and therefore a higher utility level. Out of the view of a region within a fortress, the decision of tax harmonization is always seen as welfare increasing, since any tax reactions of regions outside the own cooperation are neglected. As indicated in Figure 3, any region within a coalition could also remain with the symmetric tax rate and its related consumption bundle.



**Figure 3.** Considered welfare effect within a tax cooperation,  $\theta^l < 1$

Since the market share of each fortress is increased, compared to the share of a single region, the coalition consumption possibility curve  $cpc^l$  is absolutely flatter in the relevant area. As the market share is lower than 1, the slope must stay smaller than  $-1$ . The preferred point  $P^l$  involves an increased public activity and therefore a higher tax rate than in the symmetric setting on the costs of a reduced level of private consumption. However, until now, the non-cooperating regions have not reacted on the new tax policy of the tax harmonization area.

The crucial question is, how the non-cooperating regions react on the increased tax rate within the cooperating regions. Konrad and Schjelderup (1999) just set a positive response function by assuming

$\frac{\partial \tau_s}{\partial \tau_l} > 0$ . As such a direct reaction involves an inconsistency,<sup>10</sup> the standard Cournot-Nash approach of given tax rates in the other regions is kept further on. Nevertheless, there is an indirect connection between the tax rates. A partial tax increase involves an outflow of capital in direction of any non-cooperating region and therefore  $\frac{d\tau_s}{dk^s} \frac{dk^s}{d\tau_l}$  applies. Since  $k_{\tau_l}^s > 0$  always holds, the sign of  $\frac{d\tau_s}{d\tau_l}$  is only determined by the sign of  $\frac{d\tau_s}{dk^s}$ . Concentrating on Nash-equilibria and the optimal reply for given tax rates outside the region (14), we know that for an optimum

$$MRS_{zx}^i - \frac{\widetilde{EE}}{1 - \epsilon_{k^i \tau}} = 0 \quad (17)$$

always holds.

$$\widetilde{EE} := 1 - r_{\tau_i} \left( \frac{\bar{k}}{k^i} - 1 \right) \quad (18)$$

represents the impact on private consumption in the region  $i$  of a marginal change in taxation, related to the per-capita capital input:  $-\frac{dx_i}{d\tau_i} (k^i)^{-1}$ , the observed income effect of taxation per used capital unit. Nevertheless we could state directly the regional reaction for a marginal change of the capital input, it is more useful to derive the elasticity of taxation for a change of the capital input  $\epsilon_{\tau, k}$ , whereby  $\frac{d\tau_s}{d\tau_l} \geq 0 \Leftrightarrow \epsilon_{\tau, k} \geq 0$ . Suppressing the indices, the impact on the capital elasticity of taxation can be stated as follows:<sup>11</sup>

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<sup>10</sup> Given the reaction of the non-cooperating regions for a tax change within *one* cooperation, the cooperating regions are in a first mover position. Thus, they can behave as a Stackelberg-leader. With the knowledge about the reaction of the non-cooperating regions, they will directly choose their optimal point on the reaction function of the non-cooperating regions.

<sup>11</sup> See Appendix A.1 for the derivation in detail.

$$\epsilon_{\tau,k} = 1 + \underbrace{\epsilon_{EE,k} + \epsilon_{EE,\tau}}_{>0} + \underbrace{\epsilon_{MRS_{z_x},k}}_{?} \underbrace{(\epsilon_{k,\tau}^{-1} - 1)}_{>0} - \underbrace{\epsilon_{k_\tau,k}}_{?} \quad (19)$$

$$\epsilon_{\tau,k} := \frac{d\tau}{dk} \frac{k}{\tau}; \quad \epsilon_{k,\tau} := -k_\tau \frac{\tau}{k};$$

$$\epsilon_{EE,\tau} := \frac{d\widetilde{EE}}{d\tau} \frac{\tau}{EE}; \quad \epsilon_{EE,k} := \frac{d\widetilde{EE}}{dk} \frac{k}{EE};$$

$$\epsilon_{k_\tau,k} := \frac{dk_\tau}{dk} \frac{k}{k_\tau}; \quad \epsilon_{MRS_{z_x},k} := \frac{dMRS_{z_x}}{dk} \frac{k}{MRS_{z_x}}.$$

First of all, an inflow of capital widens the tax base and therefore, c.p. the tax rate will be changed at the same percentage as the regional capital supply varies.

The first and second elasticities are related to the change of the income effect of taxation. Since an inflow of capital is advantageous for the *factor terms of trade effect*, the elasticities related to the conjectured income effect of taxation are in sum always positive.<sup>12</sup> As pronounced by DePater and Myers (1994), the effect incorporates a pecuniary externality. Thus, in the case of small non-cooperating regions, the factor terms of trade effect becomes irrelevant, since the interest rate is seen as exogenously given.

The third elasticity is related to the individual preferences concerning the optimal allocation between private and publicly provided consumption. As shown by Wilson (1991: 430f.), an inflow of capital increases the level of publicly provided consumption  $\frac{dz_s}{d\tau_l} > 0$  as well as the private consumption possibilities  $\frac{dx_s}{d\tau_l} > 0$ . Therefore, only if the private good had the property of an inferior good or the level of private consumption was independent of the income,  $\epsilon_{MRS_{z_x},k} > 0$  would always hold, implying a positive impact on  $\epsilon_{\tau,k}$ . However, estimations give some evidence on a constant amount of public activity independent of income (e.g. Rubinfeld, 1987; Oates, 1996). Therefore, with an utility

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<sup>12</sup> See Appendix A.2.

function quasi-linear in the publicly provided good,  $\epsilon_{MRS_{z,x},k} < 0$  gives an negative impact on  $\epsilon_{\tau,k}$ .

Finally, the fourth term incorporates the change of the "capital movement effect" (Peralta and van Ypersele, 2003: 7) for a marginal change in the regional capital input  $\epsilon_{k\tau,k}$ . If  $f'''(k) = 0$  held,<sup>13</sup> the fourth effect would be nil. In the standard case of a convex capital demand curve with  $f'''(k) > 0$ ,<sup>14</sup> the sign is ambiguous. However, as a special case we can state:

**Proposition 2** *If the market share of each non-cooperation region is small  $\theta \rightarrow 0$ , but not the aggregated market share of the non-cooperating regions  $\Theta < 1$ ,  $\epsilon_{k\tau,k} \geq 0$ .*

**PROOF.** Implicitly differentiating (6), a change in the capital input implies

$$\frac{dk_{\tau}^s}{dk^s} = -\frac{f'''(k^s)}{(f''(k^s))^2} (1 + r_{\tau_s}) + \frac{1}{f''(k^s)} \frac{dr_{\tau_s}}{dk^s}.$$

In the case of small non-cooperating regions,  $\lim_{\theta \rightarrow 0} r_{\tau_s} = 0$  which will not be changed if the variation of the regional capital supply is not large. Since the aggregated market share of the non-cooperating regions is not neglectable small, the inflow of capital into each non-cooperating regions is limited. Therefore, with  $\lim_{\theta \rightarrow 0} \frac{dr_{\tau_s}}{dk^s} = 0$ , the second term vanishes and  $\frac{dk_{\tau}^s}{dk^s} = -\frac{f'''(k^s)}{(f''(k^s))^2} \leq 0$  must hold. Taking into account that  $\frac{dk_{\tau}}{dk} \leq 0 \Leftrightarrow \epsilon_{k\tau,k} \geq 0, \Rightarrow \epsilon_{k\tau,k} \geq 0$ .  $\square$

In sum, the exemplified relation between the tax setting decisions is not as clear as pronounced by Konrad and Schjelderup (1999: 162). Furthermore, a negative slope of the reaction function need not be caused

<sup>13</sup> E.g. Wildasin (1991) and Bucovetsky (1991) assume a linear-quadratic production function implying  $f'''(k) = 0$ .

<sup>14</sup> This is typically the case for CES production functions, at least those exhibiting an elasticity of substitution between capital and labor exceeding 1/2, including the case of a Cobb-Douglas production function.

by the preferences structure.<sup>15</sup> Even if the marginal rate of substitution stays unchanged for an increased capital supply  $\epsilon_{MRS_{z,x},k} = 0$ , a tax reduction in the non-cooperating regions may arise.

**Proposition 3** *In the case of a CES production function, small non-cooperating regions with a significant aggregated market share, and preferences implying at the optimum  $\epsilon_{MRS_{z,x},k} = 0$ , tax rates are substitutes  $\frac{d\tau_s}{d\tau} < 0$  if for the elasticity of factor substitution  $1 \leq \sigma \leq 2$  holds.*

**PROOF:** See appendix A.3.

The logic of the result is simple; starting from equation (17), for the case of a small non-cooperating region, the factor terms of trade effect are fixed. Assuming furthermore an unchanged  $MRS_{z,x}$ , the tax elasticity of capital  $\epsilon_{k,\tau} = -k_{\tau} \frac{\tau}{k}$  must also remain unchanged within the new optimum. Besides the own tax rate, the tax elasticity of capital of a small region is reciprocally related to the capital input multiplied with  $f''(k)$ . In the case of a quadratic production function,  $f'''(k) = 0$  holds and therefore, an increased capital input reduces the tax elasticity of capital for an unchanged tax rate. Since the tax elasticity of capital should not be changed for obtaining an optimum, the tax rate must be increased. However, if  $f'''(k) > 0$  holds, the impact of the increased tax base is reduced. Thus, if the regional capital demand curve is sufficiently convex to the origin, the tax elasticity of capital would increase with an unchanged tax rate under a higher capital supply; subsequently the tax rate will be reduced to hold  $\epsilon_{k,\tau}$  constant.

Nevertheless, proposition 3 comprises two shortcomings. Firstly, in the case of small non-cooperating regions, the total number of regions must be large. However, Razin and Sadka (1991) lay stress on the limited

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<sup>15</sup> Brueckner and Saavedra (2001) lay stress on the impact of the preferences and consider a quadratic production function to highlight a possible negative sign of the tax reaction.



gains of a small cooperation even without any tax reaction. Secondly, even if tax rates are substitutes,  $\frac{d\tau_s}{d\tau_l} < 0$ , the impact on the welfare level within a cooperation stays ambiguous. Referring back to figure 3, a tax-cut in the non-cooperating regions shifts the  $cpc^l$  of the cooperating regions backwards to the left and reduces the absolute value of the slope. However, in sum, the decision for cooperating may still be welfare enhancing. The limits of welfare increasing partial cooperations we will be clarified through numerical analysis in the next section.

## 6 Numerical Simulation

For the purpose of the numerical analysis, the following specifications will be taken into account. The production technology takes the form of a Cobb-Douglas function

$$f(k^i) = k^{i\alpha}.$$

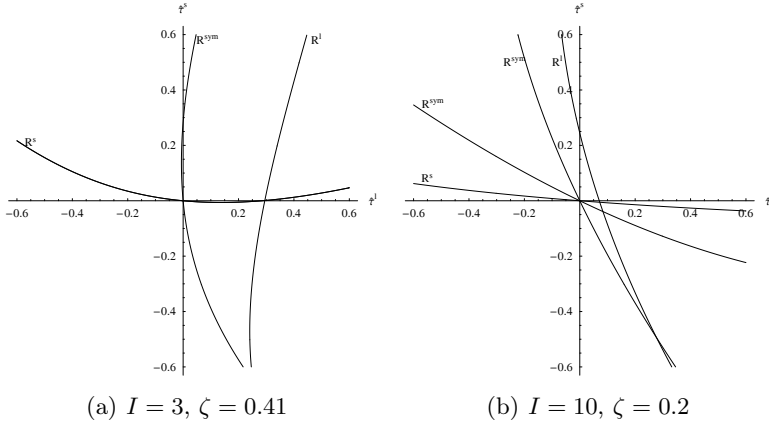
The partial output elasticity for capital will be fixed at  $\alpha = 0.3$ , which can be justified by empirical observations on the capital income share of domestic net income. The utility of a representative individual is also given by a Cobb-Douglas function

$$u(x_i, z_i) = x_i^\xi z_i^\zeta.$$

The values of  $\xi$  and  $\zeta$  are set that  $\xi + \zeta = 1$  holds. Since therefore the utility function is homogenous of degree one, a change of utility induced by the tax harmonization reflects the equivalent variation both measured as a relative change.

In the first step, we will search for conditions, implying tax rates are complements. Therefore, we take the number of regions and cooperation size as given and increase the optimal share of public activity  $\zeta$  until  $\frac{d\tau_s}{d\tau_l} > 0$  arises. In the smallest possible setting of  $I = 3$  and the

corresponding cooperation size of  $\Psi = 2$  the critical share of public activity is reached at  $\zeta = 41$  percent and the corresponding reaction curves are given in figure 4(a), whereby the changes of the tax rates on the axis are set in relation to the symmetric tax rate  $\hat{\tau}^i = \frac{\tau^i}{\tau_{sym}} - 1$ .

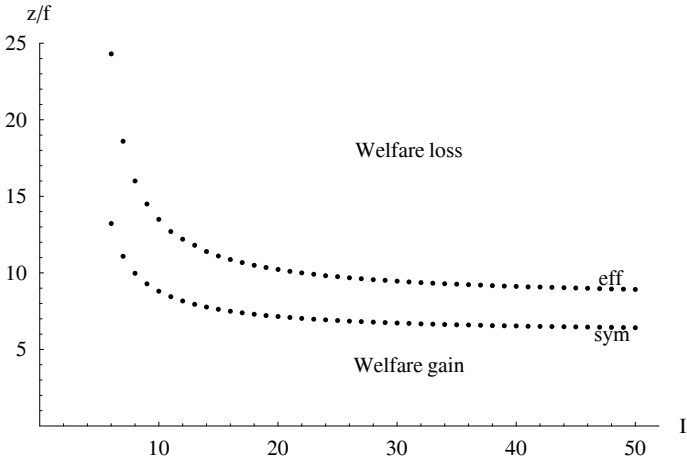


**Figure 4.** Reaction curves,  $\Psi = 2$

For an efficient share of public activity of  $\zeta = 40$  percent and lower, the non-cooperating region will reduce the tax rate as reaction on an increase in the harmonization area. However, as  $\zeta > \alpha$  must hold for  $\frac{d\tau_s}{d\tau_l} > 0$ , the setting always conflicts with equation (5). Thus, at a complementarity in tax rates the single instrument of a capital tax is insufficient inducing always an undersupply of the publicly provided good even in case of global tax harmonization. Assuming more than three regions, no constellation could be found, at which  $\frac{d\tau_s}{d\tau_l} > 0$  holds. Thus, the relevant case should be  $\frac{d\tau_s}{d\tau_l} < 0$ . Figure 4(b) shows as an example the reaction curves for the parameters  $I = 10, \zeta = 0.2$  and  $\Psi = 2$ . Due to the fortress building process, the relevant reaction curve of the cooperation regions is shifted to the right from  $R^{sym}$  to  $R^l$ . Note, the reaction curve of the non-cooperating regions only pivots from  $R^{sym}$  to  $R^s$  as in the asymmetric setting is a fewer number of regions which

give the impulse by changing their tax rate. While in the symmetric setting the change of the tax rate in  $(I - 1)$  regions must be considered, in the asymmetric setting  $(\Psi I^l)$  regions give an impulse by changing the tax rate and  $(I - \Psi I^l)$  regions outside of a fortress react. Only in case of one single non-cooperating region  $I^s = 1$ , the reaction curves of the non-cooperating region coincides.

Likewise as a complementarity in tax rates is rare, the probability of a potential welfare loss due to the integration  $u^{sym} > u^l$  is also limited, given that the cooperation is not small or that more than one cooperation are simultaneously build. Nevertheless, in the case of one single fortress incorporating two regions only, the risk of a welfare loss is quite remarkable.



**Figure 5.** *Public activity frontier and economy size for  $\Psi = 2$*

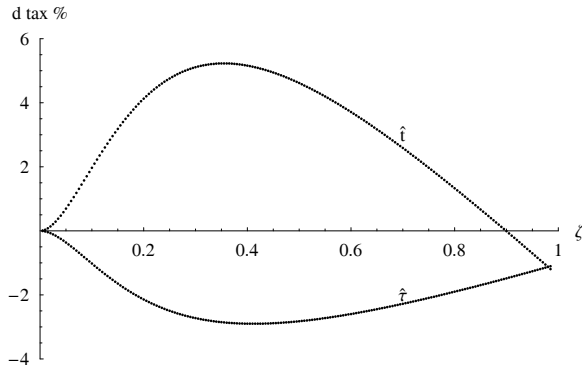
Figure 5 presents the related frontier of state activity at which the welfare level within the cooperation does not change due to the fortress building process. Thus, for a higher share of public activity, given the economy size  $I$ , a partial tax harmonization of two regions causes a welfare loss within the fortress. In contrast, for any lower level of state

activity, the partial tax harmonization is welfare enhancing. The upper dots indicate the related efficient share of publicly provided good of total production  $\zeta$ , while the lower level, relates to the share of public activity in the symmetric setting before cooperating.

For the case of a quite small economy with  $I < 6$  and therefore a high market share of the cooperation, a partial tax harmonization of two regions is always welfare increasing for all regions. However, in an economy of six and more regions, a small tax cooperation may also induce a welfare loss for the inhabitants of the fortress. For six regions, a welfare loss due to the partial tax harmonization arises if the efficient share of public activity counts a quarter of total output ( $\zeta = 0.243$ ). By increasing the size of the economy the limit is reduced to e.g. 10 percent in the case of 20 non-cooperating regions ( $I = 22$ ). For the case of 50 regions and a small two region fortress, a welfare loss would arise if a global planer provided more than 9 percent ( $\zeta = 0.0892$ ) of total production as public activity.

Turning to the second curve, the share of public consumption out of total production before the building of the fortress is easier to estimate than the efficient share. Again, for the example of a small bloc of two regions, figure 5 indicates, that the risk is quite high to suffer a welfare loss due to the own harmonization activity. This will be the case, if there are more than 6 regions within the capital market area and a quite modest state activity of 13,5 percent before cooperating. For a lower market share within the fortress of 10 percent ( $I = 20$ ), a share of about 7 percent of publicly provided good out of total production is enough, for causing a reduction of the welfare level.

Quite puzzling seems the impact of higher preferences for the publicly provided good. In a setting of large regions ( $I = 3$ ), the feasibility of a complementarity in tax rates increases in  $\zeta$ . However, cutting the capital market share of each region by half or more ( $I > 6$ ), high preferences for the publicly provided good may imply welfare losses due to partially harmonizing the tax on capital. An explanation may give figure 6, presenting the change of the optimal tax burden in a non-cooperating region. The curve  $\hat{\tau}$  represents the relative change of the unit tax rate for a non-cooperating region  $\frac{\tau_s}{\tau_s^{ym}} - 1$  in percent depending on the efficient share of public activity.



**Figure 6.** Change of the tax burden for different  $\zeta$ ,  $I = 4$ ,  $\Psi = 2$

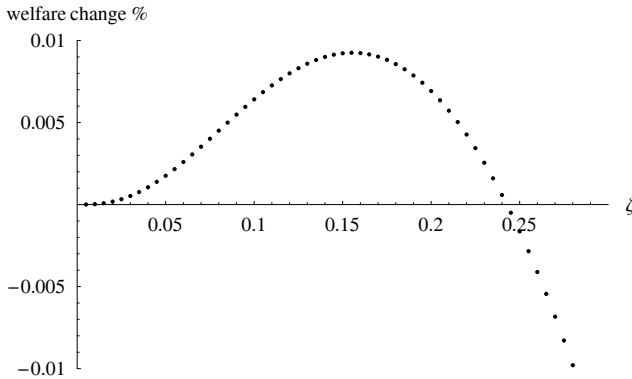
While for small values of  $\zeta$  the reduction of tax rate increases, at a value of  $\zeta > 41$  percent the direction changes. In the case of more regions in the economy, the minimum of the  $\hat{\tau}$  curve is shifted to the right. Thus, we can not generally conclude that a higher share of public activity also implies a higher risk for a welfare loss.

The second curve in figure 6 represents the alternative concept of tax burden in the sense of an ad valorem tax with  $t = \frac{\tau_s}{f'(k^s)}$ . Thus, the curve  $\hat{t}$  shows the change of the tax share out of pretax rate of return. Hence, the presented results concerning the sign of the reaction  $\frac{d\tau_s}{d\tau_l}$  may

not conflict with a positive sign of the reaction function measured as an add valorem tax rate, if the harmonization activity implies a markable change in the interest rate. More formally, the relation between the change in the unit tax rate and the change of the relative tax burden can be stated as

$$\frac{dt}{dk} = \frac{1}{(f'(k))^2} \left( f'(k) \frac{d\tau}{dk} - \tau f''(k) \right).$$

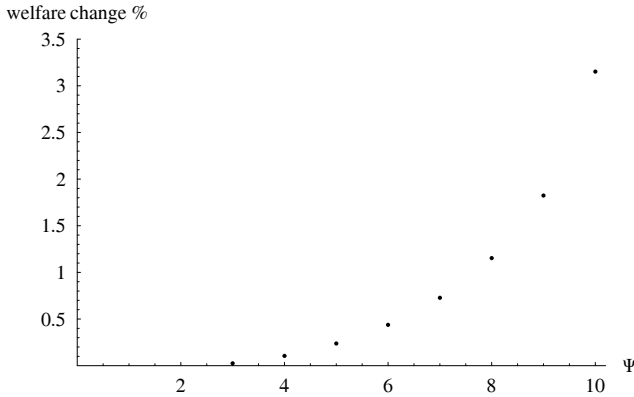
Hence, if  $\frac{d\tau}{dk} > 0$  holds,  $\frac{dt}{dk} > 0$  follows directly, however not always in the other direction.



**Figure 7.** Welfare effect of a partial cooperation  $I = 6$ ,  $\Psi = 2$

Concerning the impact of the partial cooperation on the welfare level, the change of the utility level are not quantitative significant. Even in the setting of quite large regions the welfare effects of a tax harmonization are low, as the figure 7 indicates. For low efficient public activity levels, a higher preference for the publicly provided good implies also an increased welfare gain due to the tax harmonization. However, at an efficient share of about 16 percent, welfare gains decline for a further increased efficient share of public activity. In the case of six regions an efficient  $z$  exists at which the inhabitants are indifferent between an integration and the symmetric setting, however, it does not exist for

smaller economies  $I < 6$ .



**Figure 8.** *Welfare effect of a partial cooperation for  $I = 10$ ,  $\zeta = 0.2$*

The result of a moderate welfare gain due to a partial cooperation still holds if the size of the cooperation is increased as indicated in figure 8. For the case of a global cooperation, a welfare increase of 3.15 percent, measured as equivalent variation, would be possible. Even if eight out of ten regions take part in the tax harmonization cooperation, a welfare increase of 1.15 percent will not reach half of the possible welfare gain. If the subgroup consists of six regions, the possible welfare gain does not reach a half percent.

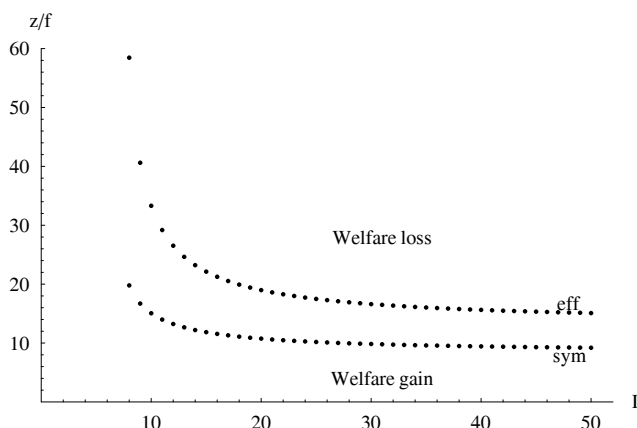
The results are highly sensitive to the number of cooperations. If simultaneously two cooperations are formed, each consisting of two regions, a welfare loss becomes rare. Even in a setting of 100 regions, the efficient share of private good consumption might be lower than one third ( $\zeta > 0.71$ ), in order that a welfare loss would arise.

Lowering the share of capital income by 5 percentage points to  $\alpha = 0.25$ ,<sup>16</sup> implies an increase in the potential of welfare losses. As an

<sup>16</sup> Eggert and Haufler (1998) assume a share of 25 percent, based on United Nations (1996).

example, in the case of 10 regions, the efficient share of public activity only needs to be greater than 11.5 percent, compared to 13.5 percent in the basic setting.

As shown in Kächelein (2004 forthcoming) the results are also sensitive to changes in the price elasticity of the public good. For an utility function quasi-linear in the publicly provided good, a change from  $\eta = -0.4$  to  $\eta = -0.2$  nearly has the same consequences as the upper change of the partial production elasticity for capital.



**Figure 9.** Public activity frontier and economy size for  $\Psi = 3$

As predictable, increasing the cooperation size reduces the risk of a welfare loss due to the partial tax harmonization. As figure 9 indicates, a subgroup of three cooperating regions only suffers a welfare loss for an economy size of eight and more regions,  $I \geq 8$ . Furthermore, the frontier is shifted upward, implying for  $\Psi = 3$  and 20 non-cooperating regions  $I = 23$ , that a welfare loss within the fortress arises only if the efficient share is higher than 18 percent; in case of 50 regions, the limit is still at 15.1 percent.



## **7 Conclusion**

Based on a very simple model of tax competition, we illustrated the limits of a welfare enhancing partial tax harmonization. Admittedly, the framework is relative restrictive by incorporating only one tax instrument, one source-based capital tax for financing a publicly provided good, homogenous individuals and therefore no distribution aspects, and finally a fixed supply of production factors. Therefore, we should not over-interpret the derived results. Nevertheless, the results indicate that a partial capital tax harmonization may involve the risk of welfare loss, especially if the fortress incorporates only a small capital market share. Meanwhile, taking up the results of a setting with more than one fortress, the risk of a welfare loss is neglectable.

## A Appendix

### A.1 Derivation of Equation 19

Rearranging (17), the optimal choice of the tax rate for given tax rates outside of region  $i$ , results in

$$\tau = \frac{k}{k_\tau} \left( \frac{\widetilde{EE}}{MRS_{zx} - 1} \right), \quad (\text{A.1})$$

whereby we have suppressed the regional indices. Therefore, the variation of the regional tax rate for a marginal change of the capital intensity is given as

$$\begin{aligned} \frac{d\tau}{dk} = & \frac{1}{k_\tau} \left( \frac{\widetilde{EE}}{MRS_{zx} - 1} \right) \left( 1 - \frac{dk_\tau}{dk} \frac{k}{k_\tau} \right) \\ & - \frac{\widetilde{EE}}{k_\tau MRS_{zx}} \left( \frac{k}{MRS_{zx}} \frac{dMRS_{zx}}{dk} - \frac{k}{\widetilde{EE}} \frac{d\widetilde{EE}}{dk} \right). \end{aligned}$$

Using the equivalence of

$$\frac{\widetilde{EE}}{k_\tau MRS_{zx}} \Leftrightarrow \frac{\tau}{k} \left[ \frac{k}{\tau k_\tau} \left( \frac{\widetilde{EE}}{MRS_{zx} - 1} \right) + \frac{k}{\tau k_\tau} \right]$$

and (A.1) leads together with the definitions of the elasticities

$$\begin{aligned} \epsilon_{\tau,k} &:= \frac{d\tau}{dk} \frac{k}{\tau}; & \epsilon_{k,\tau} &:= -k_\tau \frac{\tau}{k} > 0; & \epsilon_{\widetilde{EE},k} &:= \frac{d\widetilde{EE}}{dk} \frac{k}{\widetilde{EE}}; \\ \epsilon_{\widetilde{EE},\tau} &:= \frac{d\widetilde{EE}}{d\tau} \frac{\tau}{\widetilde{EE}}; & \epsilon_{k_\tau,k} &:= \frac{dk_\tau}{dk} \frac{k}{k_\tau}; & \epsilon_{MRS_{zx},k} &:= \frac{dMRS_{zx}}{dk} \frac{k}{MRS_{zx}}, \end{aligned}$$

and

$$\epsilon_{\widetilde{EE},k} \left( 1 - \frac{1}{\epsilon_{k,\tau}} \right) = \epsilon_{\widetilde{EE},k} + \epsilon_{\widetilde{EE},\tau} \quad (\text{A.2})$$

to

$$\epsilon_{\tau,k} = 1 + \epsilon_{\widetilde{EE},k} + \epsilon_{\widetilde{EE},\tau} + \epsilon_{MRS_{zx},k} (\epsilon_{k,\tau}^{-1} - 1) - \epsilon_{k_\tau,k}. \quad (\text{A.3})$$

## A.2 Sign of the elasticities concerning the factor terms of trade effect

From (A.2), it is known that

$$\epsilon_{\widetilde{EE},k} \left( \frac{1 - \epsilon_{k,\tau}}{\epsilon_{k,\tau}} \right) < 0 \Leftrightarrow \epsilon_{\widetilde{EE},k} + \epsilon_{\widetilde{EE},\tau} > 0.$$

Thus, we have to proof that  $\epsilon_{\widetilde{EE},k} < 0$ , since  $0 < \epsilon_{k,\tau} < 1$ . Since the capital input and  $\widetilde{EE}$  are always positive, the sign of  $\epsilon_{\widetilde{EE},k}$  is equal to the sign of  $\frac{d\widetilde{EE}}{dk}$ . Using the total differential, (18) implies

$$\frac{d\widetilde{EE}}{dk} = \frac{dr_\tau}{dk} \left( 1 - \frac{\bar{k}}{k} \right) + r_\tau \frac{\bar{k}}{k^2}, \quad (\text{A.4})$$

Since  $r_\tau < 0$  the second term is negative and for a non-cooperation region  $k > \bar{k}$  holds, we need only to proof that  $\frac{dr_\tau}{dk} \leq 0$  holds. The capital market clearing condition (3) implies together with (12), (13)

$$\frac{dk^l}{dk^s} = \frac{1 - \Theta}{\Theta}. \quad (\text{A.5})$$

Building the total differential of (10), while using (A.5),

$$\begin{aligned} \frac{dr_{\tau_s}}{dk^s} &= - \frac{\theta^s f'''(k^l) \frac{dk^l}{dk^s}}{\Theta f''(k^s) + (1 - \Theta) f''(k^l)} \\ &+ \theta^s f''(k^l) \frac{\Theta f'''(k^s) + (1 - \Theta) f'''(k^l) \frac{dk^l}{dk^s}}{[\Theta f''(k^s) + (1 - \Theta) f''(k^l)]^2} \Leftrightarrow \\ &= \theta^s \frac{f'''(k^s)}{f''(k^s)} \frac{(1 - \Theta) \frac{f'''(k^l)}{f''(k^s)} + \Theta \frac{f'''(k^l)}{f''(k^s)}}{\left[ \Theta + (1 - \Theta) \frac{f''(k^l)}{f''(k^s)} \right]^2} \leq 0 \\ &\Rightarrow \epsilon_{\widetilde{EE},k} < 0. \quad \square \end{aligned}$$

### A.3 Proof of Proposition 3

The assumption concerning the preferences implies  $\epsilon_{MR_{S_x}, k} = 0$ . In the case of small non-cooperating regions, the interest rate for capital is seen as given,  $r_{\tau_s} = 0$ , and therefore,  $\epsilon_{EE, k}^{\sim} + \epsilon_{EE, \tau}^{\sim} \approx 0$ . Thus, we have to proof the sign of  $1 - \epsilon_{k_\tau}$ , since

$$1 - \epsilon_{k_\tau} \gtrless 0 \Rightarrow \frac{d\tau_s}{d\eta} \gtrless 0.$$

Using (16), for a small region  $\epsilon_{k_\tau, k}$  is given as

$$\left. \frac{k^s}{k_{\tau_s}} \frac{dk_{\tau_s}}{dk^s} \right|_{\theta \rightarrow 0} = -k^s \frac{f'''(k^s)}{f''(k^s)}.$$

For the case of a CES production function, with

$$f(k^i) = [\alpha k^\rho + (1 - \alpha)]^{\frac{1}{\rho}},$$

after simplifying and suppressing the indices, we derive

$$\begin{aligned} 1 - \epsilon_{k_\tau, k} &\stackrel{\text{CES}}{=} \frac{\rho - 1 - \alpha(\rho - 1 + \rho k^\rho)}{f^\rho} \\ &\stackrel{\text{CES}}{=} (2\rho - 1)(1 - \alpha)f^{-\rho} - \rho. \end{aligned} \tag{A.6}$$

Thus, for the case of  $(0 \leq \rho \leq \frac{1}{2})$ , equation (A.6) is always negative. Using the definition of the elasticity of factor substitution

$$\sigma := \frac{1}{1 - \rho},$$

at  $1 \leq \sigma \leq 2$ ,  $\epsilon_{k_\tau, k} > 1$  always holds.  $\square$

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