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Abstract

The purpose of this paper is to reveal how fiscal policy cooperation can result from repeated interactions in an asymmetric model of capital tax competition. We investigate how regional differences in the per capita capital endowments and/or production technologies affects the willingness of each region to cooperate in achieving tax coordination in a multi-period framework. It is shown not only that there may exist cases where tax coordination is facilitated as regional asymmetries increase but also that the larger the asymmetry in terms of the net capital-exporting positions among regions, the easier is the cooperation to sustain tax coordination.

JEL classification: H73; H77

Keywords: Tax competition; Asymmetric regions; Cooperation; Repeated game; Tax coordination

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1 Introduction

The economic consequences of tax competition have been extensively investigated in a number of literatures. The standard tax competition model reveals that fiscal competition among local governments leads to inefficiently low levels of public services in all jurisdictions and suggests a potential role for tax harmonization to correct this inefficiency. This problem is a typical area for central government intervention; in other words, the central government should provide a Pigouvian subsidy – for instance, via matching grants – to encourage the supply of public goods or it should determine their tax rates directly to achieve the efficient level.

Alternatively, regions may coordinate their tax policies to avoid an underprovision of public goods without the help of the central government. There are several contributions that examine whether there exist Pareto-improving harmonizing reforms of capital income taxes. Zodrow and Mieszkowski (1986) and Wildasin (1989) find that in the setting of identical countries, the welfare of all residents would increase if countries cooperate in coordinating tax increases. In contrast, Edwards and Keen (1996), Fuest and Huber (2001), and Grazzini and van Ypersele (2003) show that coordinated tax increases are more likely to reduce the welfare in a political economy model of tax competition, involving bureaucrats or voters as key decision makers.

Although these papers provide valuable insights into tax coordination, their tax competition models commonly employ a one-shot, static framework despite the obvious fact that in reality, the interaction between local governments does not occur merely once. Furthermore, it is well known that in the theory of repeated games, repeated interactions facilitate cooperation under certain circumstances; hence, a repeated interactions model may provide a more satisfactory explanation of how fiscal cooperation among local governments can be sustained. Despite the importance of this topic, there are a few works that correspond to these motivations. Coates (1993) first deals with the issue of property tax competition in a repeated game setting. However, he analyzes the open-loop equilibrium of a dynamic game and focuses on the intertemporal trade-off between the current and future consumption of private and local public goods. Thus he leaves certain important features that arise from repeated interactions unexplored. Cardarelli et al. (2002) demonstrate that coordinated fiscal policies or tax harmonization can result from repeated interactions between local governments without the intervention of a central authority using a repeated game. Nevertheless, the model they employed differs considerably from a standard tax competition model in the following respects. First, since there is no production activity undertaken by private firms, the representative inhabitant receives the endowment of resources like "manna from heaven" rather than in the form of factor incomes in every period. Moreover, in order to prevent the occurrence of a complete capital flight they introduce a quadratic adjustment (mobility) cost, which is incurred when capital is invested in other regions. Although this simplification allows one to obtain a closed-form solution, it makes it difficult to compare the results with those obtained in the tax competition literature. Second, and more importantly, interest rates are fixed and set equal to zero in capital markets. Although this assumption may be harmless in a "purely competitive" case – including a large number of jurisdictions engaging in tax competition – it would not hold in the context of a small number of jurisdictions where strategic interactions cannot be ignored. To be more specific, the assumption of exogenously fixed interest rates neglects a "pecuniary externality" or the "terms-of-trade effect" that operates through changes in the price of capital in the capital market [see, e.g., DePater and Myers (1994) and Peralta and van Ypersele (2005)]. Consequently, the restrictive assumptions of their model severely limit the validity of their results in assessing the likelihood of fiscal cooperation in more realistic tax competition environments.

This paper aims to reexamine the findings of Cardarelli et al. (2002) under the standard setting of the tax competition literature, which enables us to compare our results directly with those obtained in this literature. In this sense, our analysis complements that of Cardarelli et al.; however, it differs from theirs primarily in the following three respects. First, corresponding to most of the tax competition literature, production is explicitly modeled in a manner such that the return to capital equals its marginal products in each region. This formulation enables us to explicitly derive a demand function for capital and thereby identifies each region's net position in capital, which plays a central role in our subsequent analysis. Second, we assume a capital market wherein the interest rate endogenously responds to fiscal policies, as in the standard tax competition model. This assumption allows each region to undertake non-price-taking behavior and consequently to strategically manipulate the interregional interest rate by choosing its capital tax in their favor.

Third, we analyze how asymmetries between regions affect their willingness to cooperate in implementing tax coordination. In the literature on capital tax competition, the term "asymmetry" has been used in a broad sense. For example, Bucovetsky (1991) and Wilson (1991) use it to reflect the difference in the population size between regions. More recently, Peralta and van Ypersele (2005) enlarge an asymmetrical grade by adding the difference in per capita capital endowment. However, none of these papers analyze the effect of these asymmetries on the likelihood of fiscal cooperation in a repeated game setting. We construct a repeated game version of Peralta and van Ypersele's one-shot asymmetric tax competition model augmented by adding asymmetry in production technologies across regions. Using this extended repeated game model, we demonstrate that whether or not the fiscal cooperation in implementing tax coordination is sustained over time depends crucially on the net capital-exporting position of the respective regions involved, which is jointly determined by the differences in capital endowments and in production technologies. In particular, provided that a region relatively abundant in capital is an exporter of capital, the larger the difference in per capita capital endowments, the easier is the tax coordination; conversely the larger the difference in production technology, the more difficult is the tax coordination. The former result stands in sharp contrast to Cardarelli et al. in that tax coordination is not sustainable even if regions are sufficiently patient, when endowments are sufficiently dissimilar. Based on our results, their finding would not be robust in asymmetric repeated interactions models of tax competition that allow strategic behavior of each region through the terms-of-trade effect.

The rest of the paper is organized in the following manner. Section 2 presents the model structure and derives a one-shot, noncooperative solution. Section 3 conducts the analysis of tax competition in a repeated interactions model, where per capita capital endowments as well as the production technologies are different across regions. Section 4 provides further economic insights into our results. Section 5 concludes the paper with a discussion of extensions.

2 The Model

The economy is composed of two regions that are asymmetric with respect to not only their factor endowments but also their production technologies. There are $\bar{K}_i$ capital and $\bar{N}_i$ labor endowments in region $i = S, L$. For analytical convenience, we express per capita capital endowments for regions S and L, $\bar{k}_i \equiv \bar{K}_i/\bar{N}_i$ for $i = S, L$, as $\bar{k}_S \equiv \overline{k} - \varepsilon$ and $\bar{k}_L \equiv \overline{k} + \varepsilon$, respectively, where $\varepsilon \in \left(0, \bar{k}\right]$ and $\bar{k} \equiv (\bar{k}_S + \bar{k}_L)/2$ is the "average" capital-labor ratio in the whole economy. Regions S and L may alternatively be called "small" and "large" regions, respectively, since it has been assumed that $\bar{k}_S < \bar{k}_L$. Capital is perfectly mobile across regions, while workers are immobile. These factors are used in the production of a homogenous consumption good. Following Bucovetsky (1991), Haufler (1997), and Grazzini and van Ypersele (2003), we assume the following constant-returns-to-scale production function in the capital-intensive form:

$$f^i(k_i) \equiv (A^i - k_i)k_i,\ i = S, L, \tag{1}$$

where $A^i > 0$ is the technology parameter of the region-specific production function and $k_i \equiv K_i/\bar{N}_i$ is the amount of per capita capital invested in region i. Note that higher A^i is associated with higher marginal productivity. Further, we assume that $2k_i < A^i$, which ensures a positive but diminishing marginal productivity of capital.

Public expenditures are financed by a source-based tax on capital. Given the market prices and tax rates, private firms choose the amount of production inputs in order to maximize profits. The first-order conditions are:

$$r = f_k^i - \tau_i = A^i - 2k_i - \tau_i,\ i = S, L, \tag{2}$$

$$w_i = f^i - k_i f_k^i = (k_i)^2,\ i = S, L, \tag{3}$$

where τ_i is the capital tax rate imposed by the government of region i, r is the net return on capital,[1] and w_i is the region-specific wage rate.[2] A capital market equilibrium for the entire

[1] It follows from (2) that a nonnegative constraint on r results in a natural upper bound on the capital tax rate, i.e., $A^i - 2k_i \geq \tau_i, i = S, L$.

[2] Derivatives are indicated by subscripts, e.g., $f_k^i \equiv \partial f^i(k_i)/\partial k_i$.

economy is achieved when the demand for per capita capital, $k_i(r+\tau_i)$ for $i = S, L$, is equal to the exogenously fixed capital stock per capita:

$$k_S(r+\tau_S) + k_L(r+\tau_S) = 2\overline{k}, \tag{4}$$

where it follows from (2) that $k_i(r+\tau_i) \equiv [A - (r+\tau_i)]/2$, $i = S, L$. Summing (2) over i and substituting (4) for $k_S + k_L$ into the resultant expression, yields the following equilibrium interest rate:

$$r^* = \frac{1}{2}\left[A^S + A^L - (\tau_S + \tau_L)\right] - 2\overline{k}. \tag{5}$$

Equating (2) with (5) and rearranging, we can obtain the equilibrium amount of per capita capital demanded in each region:

$$k_S^* = \overline{k} + \frac{1}{4}\left[(\tau_L - \tau_S) - \left(A^L - A^S\right)\right], \tag{6}$$

$$k_L^* = \overline{k} + \frac{1}{4}\left[(\tau_S - \tau_L) - \left(A^S - A^L\right)\right]. \tag{7}$$

An examination of (6) and (7) reveals that the allocation of capital across regions depends on the differences in their tax rates as well as in their production technologies. The equilibrium amounts of per capita capital demanded in both regions will be equalized, i.e., $k_S^* = k_L^*$, when the difference in capital tax rates, $\tau_L - \tau_S$, happens to be equal to that in technologies, $A^L - A^S$. In what follows, we assume that the marginal product of the capital in region L is higher than or equal to that in region S, i.e., $A^L - A^S \equiv \theta \geq 0$.

The inhabitants of each region posses identical preferences and inelastically supply one unit of labor to regional firms. Moreover, since they also invest their capital endowment on the regional firm that pays the highest after-tax return, the inhabitants of all regions eventually receive a common net return on capital r^*.

By inserting (2) and (3) into the budget constraint of a representative inhabitant in region i, $c_i = w_i^* + r^*\overline{k}_i$, it can be expressed in the following manner:

$$c_i = f^i(k_i^*) - (r^* + \tau_i)k_i^* + r^*\overline{k}_i, \;\; i = S, L. \tag{8}$$

Taking the other governmental policy as given, each regional government supplies a publicly provided private good $g_i \equiv G_i/\bar{N}_i$ to all residents in each region by levying a source-based tax on capital, i.e., $G_i = \tau_i k_i^* \bar{N}_i$. For analytical simplicity and to focus on the present problem, we assume that the utility function of the representative inhabitant is linear in private consumption, c_i, and in a local public good, g_i.[3] Accordingly, each local government chooses the capital tax rate in order to maximize the representative inhabitant's utility function, which is equivalent to the gross income he or she receives:

$$u_i(c_i, g_i) \equiv c_i + g_i = f^i(k_i^*) - r^*(k_i^* - \bar{k}_i), \ i = S, L, \tag{9}$$

where the second equality follows from the substitution of (8) and the per capita government budget constraint $g_i = \tau_i k_i^*$. In other words, the governments are assumed to behave as per capita Gross National Product (GNP) maximizers. Assuming interior solutions and taking into account (1), (5), (6), and (7), the best reaction functions of the respective regions are derived by solving the first-order conditions for the regional maximization of (9) as follows:

$$-3\tau_S + \tau_L = \theta - 4\varepsilon, \tag{10}$$

$$-3\tau_L + \tau_S = -\theta + 4\varepsilon. \tag{11}$$

By solving (10) and (11), we can obtain the following Nash equilibrium tax rates in the one-shot tax competition game:

$$\tau_S^N = \varepsilon - \frac{1}{4}\theta \ \text{ and } \ \tau_L^N = -\left(\varepsilon - \frac{1}{4}\theta\right). \tag{12}$$

Substituting (12) into (5), (6), and (7), together with $\bar{k} = \bar{k}_S + \varepsilon = \bar{k}_L - \varepsilon$ and $\theta \equiv A^L - A^S \geq 0$, yields the following Nash equilibrium interest rate, r^N, and the corresponding demand for per

[3]In addition to the fact that several authors such as Cardarelli et al. (2002), Grazzini and van Ypersele (2003), and Peralta and van Ypersele (2005) have also employed a linear utility function, this rather restrictive utility function is required to obtain a closed-form solution for the minimum values of the regional discount factors; these discount factors consist of several utility components associated with different phases of the repeated game described in the next section.

capita capital in each region, k_i^N, $i = S, L$, respectively:

$$
\begin{aligned}
r^N &= \frac{1}{2}\left(A^S + A^L\right) - 2\bar{k}, && (13) \\
k_S^N &= \bar{k}_S + \frac{1}{2}\left(\varepsilon - \frac{1}{4}\theta\right), && (14) \\
k_L^N &= \bar{k}_L - \frac{1}{2}\left(\varepsilon - \frac{1}{4}\theta\right). && (15)
\end{aligned}
$$

A comparison of (5) and (13) reveals that the Nash equilibrium interest rate is equal to the remuneration of capital without capital taxation, $\tau_S = \tau_L = 0$ in (5).

It is instructive to first analyze the case where $\theta = 0$, i.e., both the regions share the same production technology. In this case, it follows from (12), (14), and (15), coupled with $\theta = 0$, that the small region imports capital with taxation (i.e., $\tau_S^N > 0$) and the large region exports capital with subsidy (i.e., $\tau_L^N < 0$). This result coincides with that of Peralta and van Ypersele (2005), which only allows for the difference in capital endowments. Employing their exposition, this result can be attributed to the fact that a capital importer taxes capital; this is because imposing the tax causes the equilibrium interest rate of the capital to fall according to (5), thus reducing their capital payments. On the other hand, an exporter subsidizes capital in order to stimulate the demand for capital and to thereby raise the price of capital, which in turn increases the number of capital payments from the other region. These effects are known as the *terms-of-trade* effect. In equilibrium, these conflicting effects caused by the opposite signs of the taxes nullify each other accurately according to (13).

Adding the technological difference $\theta > 0$ may reverse the abovementioned relationship between the net exporting position of each region and the distribution of per capita capital endowments. More specifically, manipulating (14) and (15) yields the following:

$$
\begin{aligned}
k_L^N - k_S^N &= \varepsilon + (\theta/4) > 0, && (16) \\
k_L^N - \bar{k}_L &= -(1/2)\left[\varepsilon - (\theta/4)\right] \lesseqgtr 0 \text{ if and only if } \varepsilon - (\theta/4) \gtreqless 0, && (17) \\
k_S^N - \bar{k}_S &= (1/2)\left[\varepsilon - (\theta/4)\right] \gtreqless 0 \text{ if and only if } \varepsilon - (\theta/4) \gtreqless 0. && (18)
\end{aligned}
$$

In other words, the per capita capital of the large (small) region becomes an exporter (importer) of capital if $\varepsilon - (\theta/4) > 0$ and vice versa if $\varepsilon - (\theta/4) < 0$. Alternatively, if the technology of the large region is sufficiently more efficient than that of the small region (i.e., $\varepsilon - (\theta/4) < 0$), then the large region turns into an importer. This reversion stems from the fact that the great capital demand of the large region caused by its higher marginal product of capital (i.e., a higher A^L) exceeds its large capital endowment. In sum, we have the following proposition:

Proposition 1 *Assume that a region with a large per capita capital endowment possesses more efficient production technology than a region with a small per capita capital endowment does. If the difference in per capita capital endowments across regions is sufficiently larger than that in the production technologies, then the large (small) region becomes a capital exporter (importer). Conversely, if the difference in the production technologies across regions is sufficiently larger than that in per capita capital endowments, then the small (large) region becomes a capital exporter (importer).*

The abovementioned proposition is a straightforward generalization of Proposition 1 in Peralta and van Ypersele (2005), involving only asymmetric per capita capital endowments to the case where differences in both capital endowments and technologies are present. In their model, only the capital-labor ratio is required to determine whether a region becomes an exporter or importer of capital, in order to maintain the large region as an exporter in their model. However, in our model, the technological differences among regions also matters in determining whether a region becomes an importer or an exporter, as indicated by (17) and (18).

Substituting (14) and (15) into (9) and using (13), we obtain the utility levels of the respective regions at the Nash equilibrium, denoted by u_i^N, $i = S, L$ as follows:

$$u_S^N = \left[\overline{k} + \frac{1}{2}\left(\varepsilon - \frac{3}{4}\theta\right)\right]\left[\overline{k} - \frac{1}{2}\left(\varepsilon + \frac{1}{4}\theta\right)\right] + r^N\left(\overline{k} - \varepsilon\right), \tag{19}$$

$$u_L^N = \left[\overline{k} - \frac{1}{2}\left(\varepsilon - \frac{3}{4}\theta\right)\right]\left[\overline{k} + \frac{1}{2}\left(\varepsilon + \frac{1}{4}\theta\right)\right] + r^N\left(\overline{k} + \varepsilon\right). \tag{20}$$

Subtracting (19) from (20) yields the following:

$$u_L^N - u_S^N = \theta\overline{k} + 2\varepsilon r^N > 0.$$

This outcome implies that the more abundant the per capita capital endowment of the large region and/or the more efficient its production technology, the higher is the welfare of the large region, regardless of whether it is an exporter or importer. Thus, the technological advantage of the large region further enhances its welfare advantage.

3 A Repeated Game

In this section, we construct a simple repeated tax game with different regional discount factors indexed by $\delta_i \in [0, 1)$. In every period, each government sets its capital tax rate at some prescribed value, denoted by τ_i^C, on condition that the other government follows it in the previous period. If a region deviates from it, then their cooperation collapses, triggering the punishment phase that results in a Nash equilibrium, which persist forever. In other words, both the governments utilize grim trigger strategies. Accordingly, the conditions to sustain cooperation in region $i = S,\ L$ are given by

$$\frac{1}{1-\delta_i}u_i^C \geq u_i^D + \frac{\delta_i}{1-\delta_i}u_i^N,\ i = S,\ L, \tag{21}$$

where u_i^h for $h = C,\ D$, and N represent the utility levels associated with the cooperation, deviation, and punishment (i.e., the Nash equilibrium) phases, respectively. The left-hand side of (21) is the discounted total utility for inhabitants in region i, when the fiscal cooperation of both regions that imposes τ_i^C on the capital is infinitely sustained. The right-hand side represents the sum of the current period's utility resulting from the best-deviation tax rate τ_i^D and the total discounted utility resulting from the Nash phase in all subsequent periods.

The prescribed tax rates under fiscal cooperation are aimed to maximize the following utilitarian social welfare function:

$$V \equiv u_S + u_L = f^S(k_S) + f^L(k_L).$$

The first-order conditions for the optimal choices of τ_S and τ_L are as follows:

$$\tau^C \equiv \tau_S = \tau_L. \tag{22}$$

In other words, the first-best tax rates must be equalized across regions such that $f_k^S(k_S) = f_k^L(k_L)$. Moreover, (22) implies not only that this tax rate is independent of the differences in their production technologies and per capita capital endowments but also that τ^C itself is indeterminate.[4] This indeterminacy property has also been identified by Peralta and van Ypersele (2005) since they have also assumed that the linear utility functions are common to all regions. In addition, they also found that the first-best capital demands of both the regions coincide; however, this feature no longer holds in the present model because of the difference in technologies between the two regions. On comparing (22) with (12), it is revealed that the Nash equilibrium allocation of the capital between the two regions is not the first-best, unless all regions have the same per capita capital endowment as well as identical technology, leading to $\tau_S^N = \tau_L^N = \tau^C$.

Substituting (1), (5), (6), and (7) into (9), coupled with (22), the resulting utility levels of the respective regions are as follows:

$$u_S^C = \left(\overline{k} + \tau^C - \frac{1}{4}\theta\right)\left(\overline{k} - \frac{1}{4}\theta\right) + r^C\left(\overline{k} - \varepsilon\right), \tag{23}$$

$$u_L^C = \left(\overline{k} + \tau^C + \frac{1}{4}\theta\right)\left(\overline{k} + \frac{1}{4}\theta\right) + r^C\left(\overline{k} + \varepsilon\right), \tag{24}$$

[4] However, it should be noted that the per capita capital demands of both regions, k_i, $i = S, L$, associated with the cooperative phase are uniquely determined as follows:

$$k_S^C = \overline{k}_S + \left(\varepsilon - \frac{1}{4}\theta\right) \text{ and } k_L^C = \overline{k}_L - \left(\varepsilon - \frac{1}{4}\theta\right),$$

which are obtained from setting $\tau^C \equiv \tau_S = \tau_L$ in (6) and (7), respectively. These unique values in turn determine the values of $f^i(k_i)$, $i = S, L$, respectively; thus, the social welfare $V \equiv f^S(k_S) + f^L(k_L)$.

where $r^C = [(A^S + A^L)/2] - \tau^C - 2\overline{k}$ is the prevailing interest rate at the cooperative phase. Although the first-best can be realized with any tax rate provided that the same tax rate is imposed on every region, the conditions to ensure that cooperation is possible, i.e., $u_i^C \geq u_i^N$, $i = S, L$, will limit the range of the first-best tax rates:[5]

$$\tau^C \leq \frac{1}{4}\left|\varepsilon - \frac{1}{4}\theta\right|. \tag{25}$$

The best-deviation tax rate τ_i^D should maximize the utility of inhabitants in region i, provided the rival region follows the prescribed tax rate τ^C. The best-deviation tax rates τ_i^D, $i = S,\ L$, are obtained by solving for τ_S – the small region's best reaction function (10) (replacing τ^C with τ_L) – and for τ_L, the large region's best reaction function (11) (replacing τ^C with τ_S):

$$\tau_S^D = \frac{1}{3}\tau^C + \frac{4}{3}\left(\varepsilon - \frac{1}{4}\theta\right), \tag{26}$$

$$\tau_L^D = \frac{1}{3}\tau^C - \frac{4}{3}\left(\varepsilon - \frac{1}{4}\theta\right). \tag{27}$$

When region S deviates from τ^C by choosing τ_S^D, while region L follows τ^C, we obtain the following:

$$r_S^D = \frac{A^S + 2A^L}{3} - 2\overline{k} - \frac{2}{3}\left(\tau^C + \varepsilon\right), \tag{28}$$

$$k_S^D = \overline{k} - \frac{1}{6}\left(\theta - \tau^C + 2\varepsilon\right), \tag{29}$$

$$u_S^D = \left[\overline{k} - \frac{1}{2}\left(\theta - \tau^C - 2\varepsilon\right)\right]\left[\overline{k} - \frac{1}{6}\left(\theta - \tau^C + 2\varepsilon\right)\right] + r_S^D\left(\overline{k} - \varepsilon\right), \tag{30}$$

[5] Using (19), (20), (23), and (24), the so-called "participation constraints" for the respective regions, $u_i^C \geq u_i^N$, $i = S, L$, can be expressed as follows:

$$u_S^C - u_S^N = \tau^C\left(\varepsilon - \frac{1}{4}\theta\right) + \frac{1}{4}\left(\varepsilon - \frac{1}{4}\theta\right)^2 \geq 0,$$

$$u_L^C - u_L^N = -\tau^C\left(\varepsilon - \frac{1}{4}\theta\right) + \frac{1}{4}\left(\varepsilon - \frac{1}{4}\theta\right)^2 \geq 0.$$

These two inequalities simplify to (25). Moreover, note that condition (25) is a necessary condition but not a sufficient condition to sustain fiscal cooperation.

where the interest rate, r_S^D, and the small region's demand for per capita capital, k_S^D, follow from substituting (26) and τ^C into τ_S and τ_L in (5) and (6), respectively. Further, the associated utility level, u_S^D, is obtained by substituting (28) and (29) into (9).

In an analogous manner, when region L deviates from τ^C by choosing τ_L^D, while region S follows τ^C, we obtain the following:

$$\begin{aligned} r_L^D &= \frac{2A^S + A^L}{3} - 2\overline{k} - \frac{2}{3}\left(\tau^C - \varepsilon\right), \\ k_L^D &= \overline{k} + \frac{1}{6}\left(\theta + \tau^C + 2\varepsilon\right), \\ u_L^D &= \left[\overline{k} + \frac{1}{2}\left(\theta + \tau^C - 2\varepsilon\right)\right]\left[\overline{k} + \frac{1}{6}\left(\theta + \tau^C + 2\varepsilon\right)\right] + r_L^D\left(\overline{k} + \varepsilon\right). \end{aligned} \tag{31}$$

By substituting (19), (20), (23), (24), (30), and (31) into the equality expressed in (21) and rearranging, we can compute the threshold (or minimum) values of the regional discount factors, $\tilde{\delta}_i$, $i = S, L$ as follows:

$$\tilde{\delta}_S \equiv \frac{u_S^D - u_S^C}{u_S^D - u_S^N} = \frac{\left(\tau^C - 2\varepsilon\right)^2 - \left[2\left(\varepsilon - \frac{1}{8}\theta\right) - \tau^C\right]\theta}{\left(\tau^C + 7\varepsilon\right)\left(\tau^C + \varepsilon\right) - \left[\frac{7}{2}\left(\varepsilon - \frac{1}{8}\theta\right) + 2\tau^C\right]\theta}, \tag{32}$$

$$\tilde{\delta}_L \equiv \frac{u_L^D - u_L^C}{u_L^D - u_L^N} = \frac{\left(\tau^C + 2\varepsilon\right)^2 - \left[2\left(\varepsilon - \frac{1}{8}\theta\right) + \tau^C\right]\theta}{\left(\tau^C - 7\varepsilon\right)\left(\tau^C - \varepsilon\right) - \left[\frac{7}{2}\left(\varepsilon - \frac{1}{8}\theta\right) - 2\tau^C\right]\theta}. \tag{33}$$

Moreover, only when the actual discount factors of both the regions are greater than the critical discount factor defined by $\delta^* = max[\tilde{\delta}_S,\ \tilde{\delta}_L]$, then the first-best tax rate τ^C can be sustainable as a subgame perfect Nash equilibrium of the repeated game.

As is evident from (32) and (33), the minimum discount factors of both the regions depend only on the three principal parameters of the model, i.e., τ^C, ε, and θ. Since our main focus is to understand how the degree of asymmetries affects the likelihood of tax coordination, it amounts to performing comparative statics exercises with respect to those parameters. For this purpose, first, we need to identify the precise ranges of both $\tilde{\delta}_S$ and $\tilde{\delta}_L$, when τ^C varies over the range given by (25). It follows from (A1), (A2), (A3), and (A4) in Appendix A that both $\tilde{\delta}_L$ and $\tilde{\delta}_S$ vary over the same range given by $[49/145,\ 1]$.

Although any tax rate τ^C over the range (25) is socially efficient, each region's incentive to cooperate is critically influenced by the size of τ^C. Clearly, it is straightforward to demonstrate that the minimum discount factor of the small region, $\tilde{\delta}_S$, is decreasing in τ^C, while $\tilde{\delta}_L$ is increasing in τ^C if $\varepsilon - (\theta/4) > 0$ [see (A5) and (A6) in Appendix A]. The minimum discount factors of both these regions coincide with each other at $\tau^C = 0$, for $\tilde{\delta}_S = \tilde{\delta}_L = 4/7$. Figures 1 and 3 plot $\tilde{\delta}_S$ and $\tilde{\delta}_L$ as decreasing and increasing functions of τ^C, respectively, when $\varepsilon - (\theta/4) > 0$. On the contrary, when $\varepsilon - (\theta/4) < 0$, $\tilde{\delta}_S$ and $\tilde{\delta}_L$ are increasing and decreasing functions of τ^C, respectively [see (A5) and (A6) in Appendix A], as illustrated in Figures 2 and 4.

Furthermore, it follows from the definition of δ^* and Figures 1 - 4 that if $\varepsilon - (\theta/4) > 0$, then $\delta^* = \tilde{\delta}_L$ for $\tau^C \in [0, (1/4)(\varepsilon - (\theta/4))]$, while $\delta^* = \tilde{\delta}_S$ for $\tau^C \in [-(1/4)(\varepsilon - (\theta/4)), 0]$ and vice versa if $\varepsilon - (\theta/4) < 0$. We can further identify two features that hold regardless of whether $\varepsilon - (\theta/4)$ R 0: first, $\delta^* \in [4/7,\ 1]$, second, and more importantly, the closer the absolute value of τ^C is to zero, the easier is the cooperation to sustain tax coordination.

These lead to the following proposition:

Proposition 2

(i) If the discount factors of both the regions are sufficiently close to 1*, tax coordination can be sustained as a subgame perfect Nash equilibrium of the repeated game;*

(ii) if the discount factors of both the regions are less than $4/7$*, tax coordination is impossible;*

(iii) the larger (smaller) the absolute value of the first-best capital tax, the more difficult is (easier) the tax coordination;

(iv) if the difference in per capita capital endowments across regions is sufficiently large as compared to the technological difference, i.e., $\varepsilon - (\theta/4) > 0$*, then the large (small) region has a stronger incentive to deviate from the coordinated first-best tax rate when this tax rate is positive (negative) and vice versa if* $\varepsilon - (\theta/4) < 0$*; and*

(v) when the capital tax rate is set equal to zero, it is most likely that the tax coordination will be sustained.

Suppose that $\varepsilon - (\theta/4) > 0$, i.e., the large (small) region is a capital exporter (importer). In such a case, higher coordinated capital tax rates imply lower after-tax interest rates that prevail in the capital market, thereby reducing the utility (= GNP) of the large region (i.e., an exporter) and strengthening the incentive to deviate. Accordingly, the threshold value of the discount factor $\tilde{\delta}_L$ is increasing with τ^C [see (A6)]. Simultaneously, the lower after-tax interest rate will raise the utility (= GNP) of the small region (i.e., an importer), thereby strengthening the incentive to cooperate. As a result, $\tilde{\delta}_S$ is decreasing with τ^C [see (A5)], as shown in Figures 1 and 3.

On the other hand, if $\varepsilon-(\theta/4) < 0$, then the net capital-exporting positions of the respective regions are reversed, and hence, the small (large) region becomes a capital exporter (importer). For the same reason stated above, the threshold value of the small region's discount factor $\tilde{\delta}_S$ increases with the coordinated tax rate τ^C, whereas that of the large region's discount factor $\tilde{\delta}_L$ decreases with τ^C, as indicated in Figures 2 and 4.

It is important to note that when the coordinated tax rate τ^C is positive (negative), the exporter (importer) of capital tends to have a strong incentive to deviate. It is the sign of $\varepsilon - (\theta/4)$ that determines which region becomes an exporter or importer. As a result, there are four possibilities; these correspond to Figures 1-4, respectively.

Subsequently, we consider the effects of increasing the degree of asymmetry in capital endowments ε or in the production technology θ on each region's incentive of cooperation. When $\varepsilon - (\theta/4) > 0$, higher values of ε cause a counter clockwise turn of locus $\tilde{\delta}_S$ and a clockwise turn of locus $\tilde{\delta}_L$ around the intersection point $(0, 4/7)$ [see (B5) and (B6) in Appendix B]. These movements have been illustrated in Figure 1. As is evident from Figure 1, locus δ^* shifts downwards with ε over the whole range of the sustainable first-best tax rate τ^C, with the exception of $\tau^C = 0$. Hence, a higher ε results in widening the range of τ^C, thus facilitating tax coordination.

On the other hand, given a value of ε and the assumption $\varepsilon - (\theta/4) > 0$, increasing the technological gap θ narrows the range of τ^C, as is indicated in Figure 2; this is because higher values of θ cause a counter clockwise turn of locus $\tilde{\delta}_S$ and a clockwise turn of locus $\tilde{\delta}_L$ around the intersection point $(0, 4/7)$ [see also (B5) and (B6) in Appendix B]. Consequently, the locus of the critical rate δ^* shifts upwards over the whole range of the sustainable first-best tax rate τ^C, with the exception of $\tau^C = 0$. This implies that a higher θ hampers cooperation.

When $\varepsilon - (\theta/4) < 0$, the net positions of the respective regions are reversed [i.e., the small (large) region becomes an exporter (importer) of capital]. Loci $\tilde{\delta}_S$ and $\tilde{\delta}_L$ rotate around the point $(0, 4/7)$ with ε in the directions opposite to those indicated in Figure 1 and with θ in the directions opposite to those indicated in Figure 3. These movements have been illustrated in Figures 2 and 4. In sum, we obtain the following:

Proposition 3

(i) If $\varepsilon - (\theta/4) > 0$ and $\tau^C \neq 0$, increasing ε facilitates tax coordination, while increasing θ hampers tax coordination;
(ii) if $\varepsilon - (\theta/4) < 0$ and $\tau^C \neq 0$, increasing ε hampers tax coordination, while increasing θ facilitates tax coordination; and
(iii) when $\tau^C = 0$, the willingness of tax coordination is unaffected by the changes in ε or θ.

Furthermore, considering Figures 1-4 and using Proposition 3, we can identify the simple relationship between the net capital positions of the respective regions and the likelihood of cooperation (i.e., tax coordination) as follows:

Corollary 1 *The larger the difference in the net position of capital between the two regions, the more cooperative they are to implement tax coordination.*

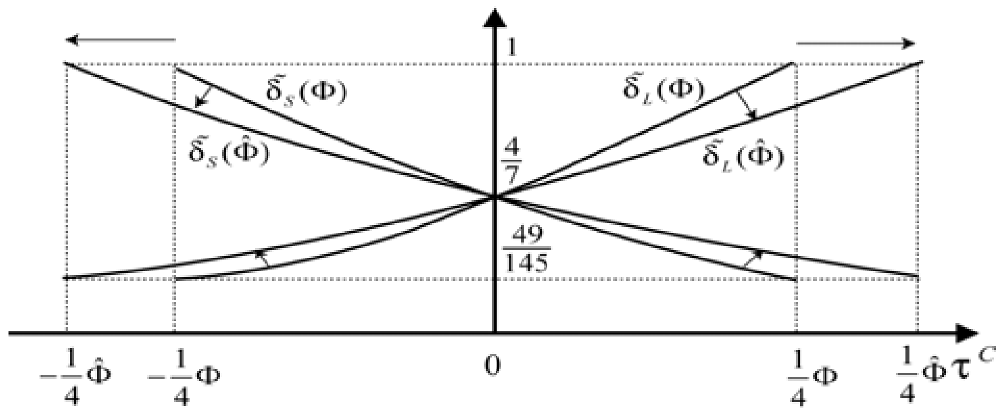

Figure 1. The effects of an increase in ε on $\tilde{\delta}_i$, $i = S, L$, when $\Phi \equiv \varepsilon - (\theta/4) > 0$ and $\hat{\Phi} \equiv \hat{\varepsilon} - (\theta/4) > 0$ with $\hat{\varepsilon} > \varepsilon$

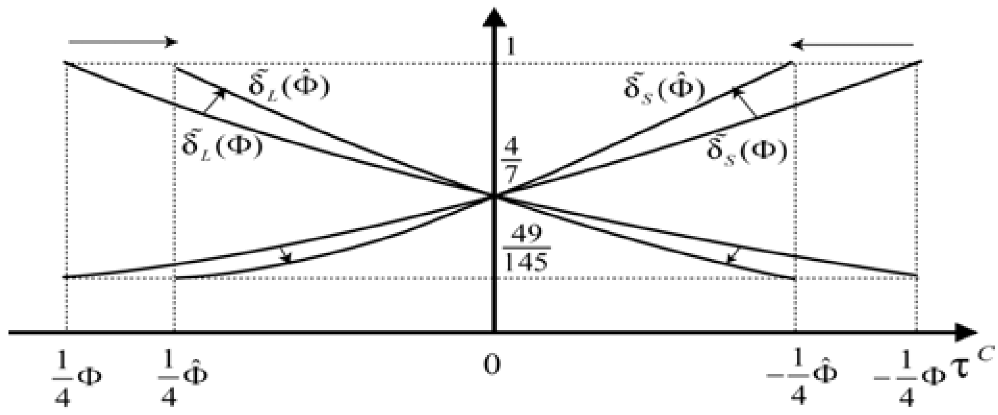

Figure 2. The effects of an increase in ε on $\tilde{\delta}_i$, $i = S, L$, when $\Phi \equiv \varepsilon - (\theta/4) < 0$ and $\hat{\Phi} \equiv \hat{\varepsilon} - (\theta/4) < 0$ with $\hat{\varepsilon} > \varepsilon$

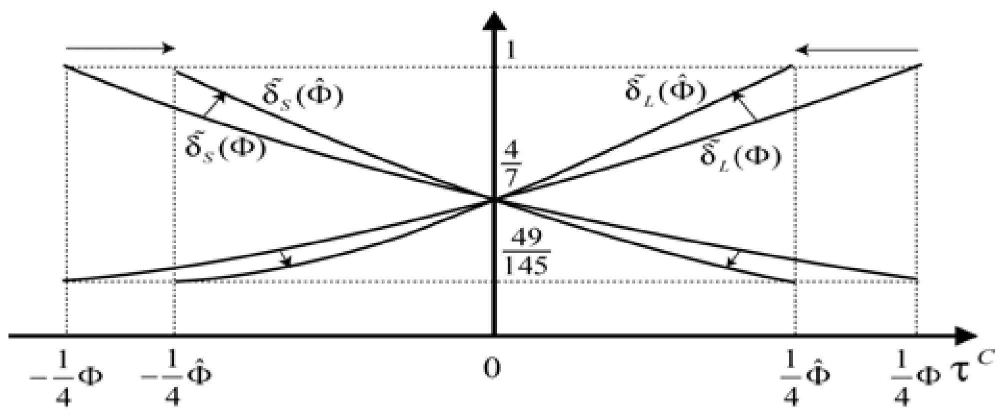

Figure 3. The effects of an increase in θ on $\tilde{\delta}_i$, $i = S, L$, when $\Phi \equiv \varepsilon - (\theta/4) > 0$ and $\hat{\Phi} \equiv \varepsilon - (\hat{\theta}/4) > 0$ with $\hat{\theta} > \theta$

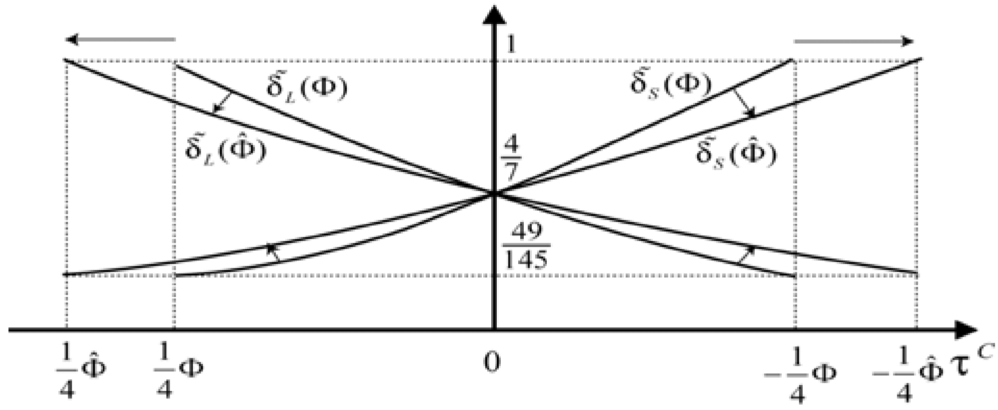

Figure 4. The effects of an increase in θ on $\tilde{\delta}_i$, $i = S, L$, when $\Phi \equiv \varepsilon - (\theta/4) < 0$ and $\hat{\Phi} \equiv \varepsilon - (\hat{\theta}/4) < 0$ with $\hat{\theta} > \theta$

4 Discussion

In order to gain further insight underlying Proposition 3 and Corollary 1, we first need to precisely know how increasing ε or θ affects the utility levels of the respective regions associated with each phase of the repeated game. For this purpose, we decompose the marginal impacts of a change in ε on the utilities of the respective regions into three effects. First, we differentiate u_i^D with respect to ε to yield the following:

$$\frac{\partial u_i^D}{\partial \varepsilon} = \tau_i^D \frac{\partial k_i^D}{\partial \varepsilon} + r_i^D \frac{\partial \bar{k}_i}{\partial \varepsilon} - \frac{\partial r_i^D}{\partial \varepsilon} \left(k_i^D - \bar{k}_i\right), \; i = S, L. \tag{34}$$

The first and second terms on the right-hand side of (34) represent the "capital movement effect" caused by a change in the difference in per capita capital endowments, which is negative, and the "direct endowment effect", which is negative for the small region and positive for the large region, respectively (recall the definition of ε). The third term represents the "terms-of-trade effect" caused by a change in the difference in per capita capital endowments, which is nonnegative for both regions.[6]

[6] Note that we have used the terms "capital movement effect" and "terms-of-trade effect" in a manner that is different from that used in the literature on asymmetric tax competition, such as Granzzini and van Ypersele

Differentiating (30) and (31) with respect to ε results in a negative "capital movement effect" and a positive "terms-of-trade effect", both of which completely cancel each other out. As a result, only the second term on the right-hand side of (34), which corresponds to the "direct endowment effect", remains and can be represented as follows:

$$\frac{\partial u_S^D}{\partial \varepsilon} = -r_S^D < 0 \text{ and } \frac{\partial u_L^D}{\partial \varepsilon} = r_L^D > 0. \tag{35}$$

In other words, while a larger dissimilarity in per capita capital endowments discourages the small region to deviate, it encourages the large region to deviate.

Similarly, one can observe the effects of a change in ε on the utility levels of the respective regions at the cooperative and Nash equilibrium phases. In the cooperative phase, since k_i^C and r^C are independent of ε owing to the property that the coordinated tax rate is exogenously fixed at the agreed first-best one, only the "direct endowment effect" is of consequence. Bearing this fact in mind, we differentiate (23) and (24) with respect to ε, to obtain the following:

$$\frac{\partial u_S^C}{\partial \varepsilon} = -r^C < 0 \text{ and } \frac{\partial u_L^C}{\partial \varepsilon} = r^C > 0. \tag{36}$$

Hence, at the cooperative phase a greater diversity in per capita capital endowments harms the willingness of the small region to cooperate, whereas it enhances that of the large region.

On the other hand, the effects of a change in ε on the utilities of the respective regions at the Nash equilibrium are given by differentiating (19) and (20) with respect to ε:

$$\frac{\partial u_S^N}{\partial \varepsilon} = -\frac{1}{2}\left(\varepsilon - \frac{\theta}{4}\right) - r^N < 0 \text{ and } \frac{\partial u_L^N}{\partial \varepsilon} = -\frac{1}{2}\left(\varepsilon - \frac{\theta}{4}\right) + r^N \;\; \mathsf{R} \; 0 \text{ if } \varepsilon - \frac{\theta}{4} > 0, \tag{37}$$

while the opposite holds if $\varepsilon - (\theta/4) < 0$. As a result of (37) the "terms-of-trade effect" ceases since the interest rate is determined by (13) independent of ε, while the "capital movement effect" and the "direct endowment effect" remain. Therefore, at the Nash equilibrium, the utility of the small region falls with ε, which in turn enhances the effectiveness of punishment

(2003), and Peralta and van Ypersele (2005). Their capital movement and terms-of-trade effects are caused by changes in the capital income tax, and therefore, the sources of generating these effects differ between their models and ours. In order to distinguish our terminology from theirs, we have used expressions in quotation marks, for example, the "terms-of-trade effect".

and thus strengthens an incentive to cooperate. However, the effect on the utility of the large region is ambiguous, since the "capital movement effect" and the "direct endowment effect" operate in opposite directions.

At this point, we can proceed to investigate how these effects together influence the minimum discount factors of the respective regions. In order to do so, we need to compare the following two impacts (see Appendix C for details). First, we observe how the short-run utility gains of the respective regions from the current period's deviation are affected by a change in ε. Subtracting (36) from (35) yields

$$\frac{\partial u_S^D}{\partial \varepsilon} - \frac{\partial u_S^C}{\partial \varepsilon} = -r_S^D + r^C = \frac{1}{3}\left[-\tau^C + 2\left(\varepsilon - \frac{\theta}{4}\right)\right] \mathsf{R}\ 0 \Longleftrightarrow \varepsilon - \frac{\theta}{4} \mathsf{R}\ 0, \tag{38}$$

$$\frac{\partial u_L^D}{\partial \varepsilon} - \frac{\partial u_L^C}{\partial \varepsilon} = r_L^D - r^C = \frac{1}{3}\left[\tau^C + 2\left(\varepsilon - \frac{\theta}{4}\right)\right] \mathsf{R}\ 0 \Longleftrightarrow \varepsilon - \frac{\theta}{4} \mathsf{R}\ 0. \tag{39}$$

Taken together, in order to observe how the discounted future utility losses (abbreviate the long-run losses) from the deviation of the respective regions from the next period are affected by a change in ε, we bring (36) and (37) together to obtain

$$\frac{\delta_S}{1-\delta_S}\left[\frac{\partial u_S^C}{\partial \varepsilon} - \frac{\partial u_S^N}{\partial \varepsilon}\right] = \frac{\delta_S}{1-\delta_S}\left[\tau^C + \frac{1}{2}\left(\varepsilon - \frac{\theta}{4}\right)\right] \mathsf{R}\ 0 \Longleftrightarrow \varepsilon - \frac{\theta}{4} \mathsf{R}\ 0, \tag{40}$$

$$\frac{\delta_L}{1-\delta_L}\left[\frac{\partial u_L^C}{\partial \varepsilon} - \frac{d u_L^N}{\partial \varepsilon}\right] = \frac{\delta_L}{1-\delta_L}\left[-\tau^C + \frac{1}{2}\left(\varepsilon - \frac{\theta}{4}\right)\right] \mathsf{R}\ 0 \Longleftrightarrow \varepsilon - \frac{\theta}{4} \mathsf{R}\ 0. \tag{41}$$

Nevertheless, if $\varepsilon - (\theta/4) > 0$ ($\varepsilon - (\theta/4) < 0$), a higher ε simultaneously increases (decreases) the short-run gains of both the regions as well as the long-run losses; hence, the net effects on the incentives for both the regions to cooperate are still unclear.

In order to unambiguously sign the net effects, we need to directly subtract (38) from (40) and (39) from (41) as follows:

$$\begin{aligned}
&\frac{\partial u_S^D}{\partial \varepsilon} - \frac{\partial u_S^C}{\partial \varepsilon} - \frac{\delta_S}{1-\delta_S}\left[\frac{\partial u_S^C}{\partial \varepsilon} - \frac{\partial u_S^N}{\partial \varepsilon}\right] \\
&= \frac{1}{3\left(1-\delta_S\right)}\left[-\tau^C + 2\left(\varepsilon - \frac{\theta}{4}\right) - 2\tau^C\delta_S - \frac{7}{2}\left(\varepsilon - \frac{\theta}{4}\right)\delta_S\right] \mathsf{R}\ 0 \\
&\Longleftrightarrow \delta_S\ \mathsf{Q}\ \bar{\delta}_S \equiv \frac{-\left[\tau^C - 2\left(\varepsilon - \frac{\theta}{4}\right)\right]}{2\left[\tau^C + \frac{7}{4}\left(\varepsilon - \frac{\theta}{4}\right)\right]},
\end{aligned} \tag{42}$$

$$
\begin{aligned}
&\frac{\partial u_L^D}{\partial \varepsilon} - \frac{\partial u_L^C}{\partial \varepsilon} - \frac{\delta_L}{1-\delta_L}\left[\frac{\partial u_L^C}{\partial \varepsilon} - \frac{\partial u_L^N}{\partial \varepsilon}\right] \\
&= \frac{1}{3\left(1-\delta_L\right)}\left[\tau^C + 2\left(\varepsilon - \frac{\theta}{4}\right) + 2\tau^C\delta_L - \frac{7}{2}\left(\varepsilon - \frac{\theta}{4}\right)\delta_L\right] \gtreqless 0 \\
&\Longleftrightarrow \delta_L \lesseqgtr \bar{\delta}_L \equiv \frac{-\left[\tau^C + 2\left(\varepsilon - \frac{\theta}{4}\right)\right]}{2\left[\tau^C - \frac{7}{4}\left(\varepsilon - \frac{\theta}{4}\right)\right]}. \qquad (43)
\end{aligned}
$$

From these subtractions, it is immediately evident that $\bar{\delta}_S = \bar{\delta}_L = 4/7$ when $\tau^C = 0$ and that $\bar{\delta}_S = 3/4$ and $\bar{\delta}_L = 7/16$ when $\tau^C = -\left(1/4\right)\left(\varepsilon - \left(\theta/4\right)\right)$, while $\bar{\delta}_S = 7/16$ and $\bar{\delta}_S = 3/4$ when $\tau^C = \left(1/4\right)\left(\varepsilon - \left(\theta/4\right)\right)$. Moreover, since it is verified by straightforward calculation that loci $\bar{\delta}_S$ and $\bar{\delta}_L$ are downward and upward sloping in τ^C, respectively, these two loci will pass through the two loci $\tilde{\delta}_S$ and $\tilde{\delta}_L$, as illustrated in Figure 5.

As is evident from Figure 5, locus $\tilde{\delta}_L$ is located above locus $\bar{\delta}_L$ provided that τ^C is positive. Keeping (43) in mind, it is observed that the marginal long-run gain from cooperation in response to a larger ε will dominate the marginal short-run gain from deviation. This is mainly because the discount factor $\tilde{\delta}_L$ is initially relatively large, which places greater weight on the long-run gain. This in turn strengthens the incentive to cooperate, thereby reducing the threshold value $\tilde{\delta}_L$. In contrast, since locus $\tilde{\delta}_S$ is located below locus $\bar{\delta}_S$ when $\tau^C > 0$, taking into account (42), it is observed that the short-run gain from deviation will dominate the long-run gain from cooperation because of the initial relatively small discount factor $\tilde{\delta}_S$. This in turn discourages the willingness of cooperation, thereby raising $\tilde{\delta}_S$.

On the other hand, as illustrated in Figure 5, $\tilde{\delta}_S > \bar{\delta}_S$ and $\tilde{\delta}_L < \bar{\delta}_L$ when $\tau^C < 0$. It follows from (42) and (43) that the short-run gain from deviation will dominate the long-run gain from cooperation for the large region, whereas the opposite holds for the small region. As a result, $\tilde{\delta}_L$ should rise, whereas $\tilde{\delta}_S$ should fall in response to a larger ε.

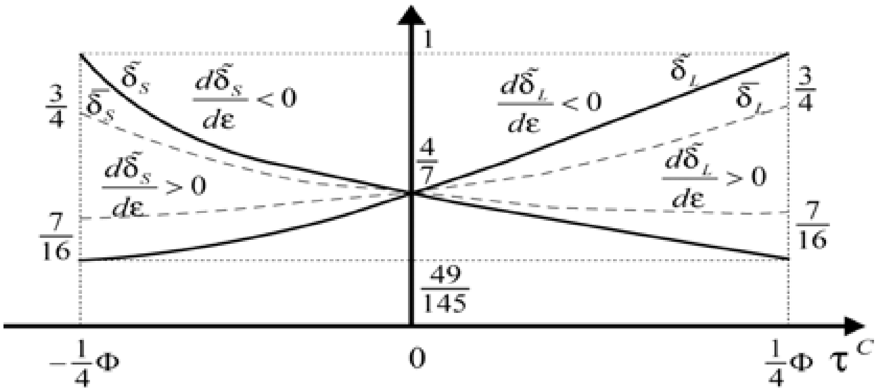

Figure 5. Loci $\bar{\delta}_i$, $i = S, L$, lie between loci $\tilde{\delta}_i$, $i = S, L$, when $\Phi \equiv \varepsilon - (\theta/4) > 0$

When $\varepsilon - (\theta/4) < 0$, the positions of loci $\tilde{\delta}_i$ for $i = S, L$, as well as loci $\bar{\delta}_i$ for $i = S, L$, are reversed as compared to those of Figure 5. Moreover, locus $\tilde{\delta}_S$ ($\tilde{\delta}_L$) is located above (below) locus $\bar{\delta}_S$ ($\bar{\delta}_L$) when $\tau^C > 0$ and vice versa when $\tau^C < 0$, as shown in Figure 6. For the same reason as mentioned before, both loci $\tilde{\delta}_i$ for $i = S, L$, should rise over the range indicated by by (25) such that the range of the sustainable first-best tax rate τ^C will shrink in response to a larger ε.[7]

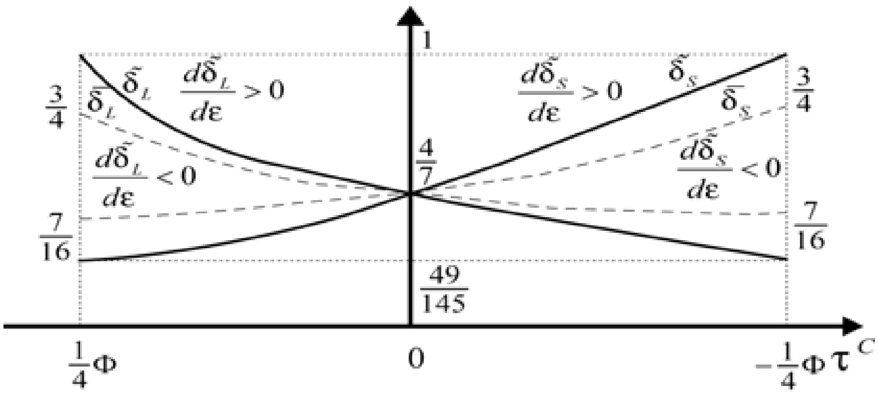

Figure 6. Loci $\bar{\delta}_i$, $i = S, L$, lie between loci $\tilde{\delta}_i$, $i = S, L$, when $\Phi \equiv \varepsilon - (\theta/4) < 0$

Not only do Cardarelli et al. (2002) claim that if the difference in endowments is sufficiently large, then the tax harmonization may not be sustainable but also that the small region always

[7] Using the diagrams similar to Figures 5 and 6, we can also explain how an increase in θ affects loci $\tilde{\delta}_i$, $i = S, L$, and thus the incentives of the respective regions to cooperate.

has a stronger incentive to deviate as compared to the large region. However, these results apparently contradict ours. These differences stem from the fact that in their model, the after-tax interest rate is set equal to zero, which is eventually equivalent to the "small country assumption" under which every region is unable to influence the rate of interest prevailing in the capital market. With this assumption, the regions can manipulate the price of capital only through the "capital movement effect", and as a result, the small region (i.e., importer) always has a stronger incentive to undercut (positive) capital taxes in order to attract a larger tax base (i.e., capital). In contrast, in our model, the large region has a stronger incentive to cut down the positive capital tax rate in order to boost the price of capital, *provided it is an exporter*. Therefore, the region that has a stronger incentive to deviate from the agreed first-best tax rate crucially depends on which region becomes an exporter or an importer of capital, i.e., on the sign of $\varepsilon - (\theta/4)$.

5 Concluding Remarks

Cardarelli et al. (2002) argue that even if regions are sufficiently patient, tax coordination cannot be sustained provided that endowments across regions are sufficiently dissimilar. However, this is not always the case. Our analysis reveals a seemingly opposite possibility in which an increasing asymmetry in per capita capital endowments makes both the regions more cooperative towards achieving tax coordination. Further, our analysis reveals an even more striking result: the larger the asymmetry in terms of the net capital-exporting positions among regions, the easier is the cooperation to sustain tax coordination. The main driving force behind this difference is the absence of the terms-of-trade effect due to the assumption of exogenously fixed interest rates in the model of Cardarelli et al., which is essentially equivalent to assuming the "small country assumption". Nevertheless, since fiscal cooperation or tax coordination among a small number of regions is more likely to arise and since it appears that the strategic behavior of regions through changes in the price of capital would be more relevant in the context of a small number of regions, the result of Cardarelli et al. needs to be qualified in the "large country" or "two-country" case. The second conclusion deduced from the present analysis is that the net capital-exporting position plays a more essential role in the establishment of tax coordination in the presence of asymmetric technologies rather than in the presence of asymmetric capital endowments or production technologies. Therefore, policymakers who are interested in implementing tax coordination should pay more attention to the net capital-exporting position of the respective regions (or countries) involved rather than to the size of the population and the distribution of capital endowments across regions. The third conclusion is as follows. Bucovetsky (1991) and Wilson (1991) as well as Cardarelli et al. (2002), find that small regions have stronger incentives to undercut tax rates. In other words, small regions will play a pivotal role in successfully implementing coordinated tax policies in their models. In contrast, since our paper indicates that large regions have a stronger incentive to cut down the capital tax provided that they are capital exporters, the conclusion of the abovementioned authors should be also qualified.

Recently, a variety of capital tax coordination proposals have been discussed in the European Union (EU) [see, e.g., Zodrow (2003)]. Among these, the introduction of a minimum capital tax may be the most realistic resolution to realize coordinated tax harmonization under the EU's institutional requirement whereby fiscal policy reforms are decided by the unanimity rule. Clearly, the minimum tax rate agreement is considerably consistent with the prediction of our repeated interactions model with inhabitants possessing long-term foresight in which the closer the first-best tax rate is to zero, the greater are the chance of tax coordination being sustained.

We conclude that the results obtained in this paper rely heavily on several very restrictive assumptions, in particular, with respect to the forms of regional utility and production functions in the present model. In order to construct a more realistic model, we should conduct the analysis under more general forms of these functions. For this purpose, a numerical analysis may be conducted in order to characterize how cooperation (i.e., a critical rate of the discount factor) is affected by changes in the degree of asymmetries.

Another natural generalization of the present analysis is to allow for asymmetric preferences, and, in particular, to investigate how the difference of preferences towards a public good across regions affects the likelihood of tax coordination. Further, varying the number of regions is also one possible extension. Although one may infer that increasing the number of regions would hamper fiscal cooperation in general, we are ignorant as to the actual outcome that emerges in the limiting case of the asymmetric tax competition model presented in this paper. A comprehensive study of such a limiting model is an interesting subject for future research.

Appendix A

In order to draw the graphs of $\tilde{\delta}_i$, $i = S, L$, first, we need to identify the range of these graphs in τ^C, which is given by (25). For this purpose, we express $\tilde{\delta}_i$ as a function of τ^C, i.e., $\tilde{\delta}_i(\tau^C)$, $i = S, L$. We substitute the upper- and lower-bound values of τ^C in (25), i.e., $-(1/4)[\varepsilon - (\theta/4)]$ and $(1/4)[\varepsilon - (\theta/4)]$, respectively, into τ^C in (32) and (33) to yield

$$\tilde{\delta}_S\left(-\frac{1}{4}\left(\varepsilon - \frac{1}{4}\theta\right)\right) = 1, \tag{A1}$$

$$\tilde{\delta}_S\left(\frac{1}{4}\left(\varepsilon - \frac{1}{4}\theta\right)\right) = \frac{49}{145}, \tag{A2}$$

$$\tilde{\delta}_L\left(-\frac{1}{4}\left(\varepsilon - \frac{1}{4}\theta\right)\right) = \frac{49}{145}, \tag{A3}$$

$$\tilde{\delta}_L\left(\frac{1}{4}\left(\varepsilon - \frac{1}{4}\theta\right)\right) = 1. \tag{A4}$$

In addition, we can verify that $\tilde{\delta}_S(0) = \tilde{\delta}_L(0) = 4/7$.

Subsequently, in order to determine whether the functions $\tilde{\delta}_i(\tau^C)$, $i = S, L$, are increasing or decreasing in τ^C over the range given by (25), we differentiate (32) and (33) with respect to τ^C to obtain the following:

$$\frac{\partial \tilde{\delta}_S}{\partial \tau^C} = \frac{6}{\Gamma_S^2}\left(\varepsilon - \frac{1}{4}\theta\right)\left[\tau^C - 2\left(\varepsilon - \frac{1}{4}\theta\right)\right]\left[2\tau^C + 5\left(\varepsilon - \frac{1}{4}\theta\right)\right], \tag{A5}$$

$$\frac{\partial \tilde{\delta}_L}{\partial \tau^C} = \frac{6}{\Gamma_L^2}\left(\varepsilon - \frac{1}{4}\theta\right)\left[\tau^C + 2\left(\varepsilon - \frac{1}{4}\theta\right)\right]\left[5\left(\varepsilon - \frac{1}{4}\theta\right) - 2\tau^C\right], \tag{A6}$$

where

$$\Gamma_S \equiv \left(\tau^C + 7\varepsilon\right)\left(\tau^C + \varepsilon\right) - \left[\frac{7}{2}\left(\varepsilon - \frac{1}{8}\theta\right) + 2\tau^C\right]\theta \text{ and}$$
$$\Gamma_L \equiv \left(\tau^C - 7\varepsilon\right)\left(\tau^C - \varepsilon\right) - \left[\frac{7}{2}\left(\varepsilon - \frac{1}{8}\theta\right) - 2\tau^C\right]\theta.$$

Assume first that $\varepsilon - (\theta/4) > 0$. Since $\tau^C \leq (1/4)\left|\varepsilon - (\theta/4)\right|$, the sign of $\partial\tilde{\delta}_S/\partial\tau^C$ in (A5) depends only on the sign of

$$\left[\tau^C - 2\left(\varepsilon - \frac{1}{4}\theta\right)\right]\left[2\tau^C + 5\left(\varepsilon - \frac{1}{4}\theta\right)\right], \tag{A7}$$

which is eventually negative, because the second term in (A7) is positive, while the first term in (A7) can be rewritten as follows:

$$\tau^C - 2\left(\varepsilon - \frac{1}{4}\theta\right) < \tau^C - \frac{1}{4}\left(\varepsilon - \frac{1}{4}\theta\right) \leq 0, \tag{A8}$$

where the last inequality follows from (25). This implies that $\partial\tilde{\delta}_S/\partial\tau^C < 0$.

The sign of $\partial\tilde{\delta}_L/\partial\tau^C$ in (A6) also depends only on the sign of

$$\left[\tau^C + 2\left(\varepsilon - \frac{1}{4}\theta\right)\right]\left[5\left(\varepsilon - \frac{1}{4}\theta\right) - 2\tau^C\right], \tag{A9}$$

which is eventually positive, because the first term in (A9) is positive, while the second term in (A9) can be rewritten as follows:

$$5\left(\varepsilon - \frac{1}{4}\theta\right) - 2\tau^C = 2\left[\frac{5}{2}\left(\varepsilon - \frac{1}{4}\theta\right) - \tau^C\right] > 2\left[\frac{1}{4}\left(\varepsilon - \frac{1}{4}\theta\right) - \tau^C\right] \geq 0.$$

Similarly, we can prove that when $\varepsilon - (\theta/4) < 0$, $\partial\tilde{\delta}_S/\partial\tau^C > 0$ and $\partial\tilde{\delta}_L/\partial\tau^C < 0$ over the range indicated by (25).

Appendix B

We differentiate the critical rates of the regional discount factors given by (32) and (33) with respect to ε and θ to yield the following:

$$\frac{\partial \tilde{\delta}_S}{\partial \varepsilon} = \frac{6\tau^C}{\Gamma_S^2}\left[\tau^C + 2\left(\varepsilon - \frac{1}{4}\theta\right)\right]\left[5\left(\varepsilon - \frac{1}{4}\theta\right) - 2\tau^C\right], \tag{B1}$$

$$\frac{\partial \tilde{\delta}_L}{\partial \varepsilon} = \frac{6\tau^C}{\Gamma_L^2}\left[\tau^C + 2\left(\varepsilon - \frac{1}{4}\theta\right)\right]\left[2\tau^C - 5\left(\varepsilon - \frac{1}{4}\theta\right)\right], \tag{B2}$$

$$\frac{\partial \tilde{\delta}_S}{\partial \theta} = \frac{3\tau^C}{2\Gamma_S^2}\left[\tau^C - 2\left(\varepsilon - \frac{1}{4}\theta\right)\right]\left[2\tau^C + 5\left(\varepsilon - \frac{1}{4}\theta\right)\right], \tag{B3}$$

$$\frac{\partial \tilde{\delta}_L}{\partial \theta} = \frac{3\tau^C}{2\Gamma_L^2}\left[\tau^C + 2\left(\varepsilon - \frac{1}{4}\theta\right)\right]\left[5\left(\varepsilon - \frac{1}{4}\theta\right) - 2\tau^C\right]. \tag{B4}$$

Combining (A7) and (A9) with (B1) - (B4), we obtain the following:

$$\frac{\partial \tilde{\delta}_S}{\partial \varepsilon} \geq 0,\ \frac{\partial \tilde{\delta}_L}{\partial \varepsilon} \leq 0,\ \frac{\partial \tilde{\delta}_S}{\partial \theta} \leq 0,\ \frac{\partial \tilde{\delta}_L}{\partial \theta} \geq 0 \text{ if } \tau^C \in \left[0, \frac{1}{4}\left(\varepsilon - \frac{1}{4}\theta\right)\right], \tag{B5}$$

$$\frac{\partial \tilde{\delta}_S}{\partial \varepsilon} < 0,\ \frac{\partial \tilde{\delta}_L}{\partial \varepsilon} > 0,\ \frac{\partial \tilde{\delta}_S}{\partial \theta} > 0,\ \frac{\partial \tilde{\delta}_L}{\partial \theta} < 0 \text{ if } \tau^C \in \left[-\frac{1}{4}\left(\varepsilon - \frac{1}{4}\theta\right), 0\right), \tag{B6}$$

provided $\varepsilon - (\theta/4) > 0$, while

$$\frac{\partial \tilde{\delta}_S}{\partial \varepsilon} \geq 0,\ \frac{\partial \tilde{\delta}_L}{\partial \varepsilon} \leq 0,\ \frac{\partial \tilde{\delta}_S}{\partial \theta} \leq 0,\ \frac{\partial \tilde{\delta}_L}{\partial \theta} \geq 0 \text{ if } \tau^C \in \left[0, -\frac{1}{4}\left(\varepsilon - \frac{1}{4}\theta\right)\right], \tag{B7}$$

$$\frac{\partial \tilde{\delta}_S}{\partial \varepsilon} < 0,\ \frac{\partial \tilde{\delta}_L}{\partial \varepsilon} > 0,\ \frac{\partial \tilde{\delta}_S}{\partial \theta} > 0,\ \frac{\partial \tilde{\delta}_L}{\partial \theta} < 0 \text{ if } \tau^C \in \left[\frac{1}{4}\left(\varepsilon - \frac{1}{4}\theta\right), 0\right), \tag{B8}$$

provided $\varepsilon - (\theta/4) < 0$.

Appendix C

Differentiating (32) and (33) with respect to ε yields

$$\frac{d\tilde{\delta}_i}{d\varepsilon} = \frac{\left(\frac{du_i^D}{d\varepsilon} - \frac{du_i^C}{d\varepsilon}\right)\left(u_i^D - u_i^N\right) - \left(u_i^D - u_i^C\right)\left(\frac{du_i^D}{d\varepsilon} - \frac{du_i^N}{d\varepsilon}\right)}{\left(u_i^D - u_i^N\right)^2},\ i = S, L. \tag{C1}$$

Further, the manipulation of (C1) yields

$$\frac{u_i^D - u_i^N}{1-\tilde{\delta}_i}\frac{d\tilde{\delta}_i}{d\varepsilon} = \left(\frac{du_i^D}{d\varepsilon} - \frac{du_i^C}{d\varepsilon}\right) - \frac{\tilde{\delta}_i}{1-\tilde{\delta}_i}\left(\frac{du_i^C}{d\varepsilon} - \frac{du_i^N}{d\varepsilon}\right), \; i = S, L. \tag{C2}$$

Using (C2) and taking into account the fact that $u_i^D - u_i^N > 0$ and $1 - \tilde{\delta}_i > 0$, we can establish the following relationship:

$$\frac{d\tilde{\delta}_i}{d\varepsilon} \; \mathsf{R} \; 0 \Longleftrightarrow \left(\frac{du_i^D}{d\varepsilon} - \frac{du_i^C}{d\varepsilon}\right) - \frac{\tilde{\delta}_i}{1-\tilde{\delta}_i}\left(\frac{du_i^C}{d\varepsilon} - \frac{du_i^N}{d\varepsilon}\right) \; \mathsf{R} \; 0, \; i = S, \, L. \tag{C3}$$

Thus, in an analogous manner, we can establish as follows:

$$\frac{d\tilde{\delta}_i}{d\theta} \; \mathsf{R} \; 0 \Longleftrightarrow \left(\frac{du_i^D}{d\theta} - \frac{du_i^C}{d\theta}\right) - \frac{\tilde{\delta}_i}{1-\tilde{\delta}_i}\left(\frac{du_i^C}{d\theta} - \frac{du_i^N}{d\theta}\right) \; \mathsf{R} \; 0, \; i = S, \, L. \tag{C4}$$

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