Humanities and Social Sciences
2020; 8(4): 117-125
http://www.sciencepublishinggroup.com/j/hss
doi: 10.11648/j.hss.20200804.13
ISSN: 2330-8176 (Print); ISSN: 2330-8184 (Online)

A Corrective Device for Large Heterogeneous Jurisdictions in a Two-Period Economy with Spillover Effects

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To cite this article:
Tong Yang. A Corrective Device for Large Heterogeneous Jurisdictions in a Two-Period Economy with Spillover Effects. *Humanities and Social Sciences*. Vol. 8, No. 4, 2020, pp. 117-125. doi: 10.11648/j.hss.20200804.13

Received: July 22, 2020; **Accepted**: July 31, 2020; **Published**: August 17, 2020

Abstract: The matching grant (the Pigovian tax) program from a central government to the jurisdictional governments is a strong instrument to solve the problem of an insufficiently provision of local public goods. The under-provision (over-provision) of public goods arises from different kinds of externalities, such as the benefit spillovers and the tax-exporting effect. This study introduces the spillover effect of public goods and the heterogeneity of jurisdictions to the capital tax competition literature using a two-period economy. It is assumed that the central government and the jurisdictional governments play a Stackelberg game with centralised leadership and that there is a unique Stackelberg equilibrium in each period. Meanwhile, the central government and the jurisdictional governments are assumed to be hyperopic and benevolent. A clear result is that the revision of a corrective device used by the central government in the first period to ensure an optimal level of a local public good which is provided by a hyperopic jurisdictional government, significantly depends on the relative size of the income and spill-in effects in the second period. When the income effect is larger than the spill-in effect in the second period, the optimal matching grant rate (the Pigovian tax rate) in the first period from the central government to a more hyperopic jurisdictional government should be increased (decreased). Conversely, when the spill-in effect is larger than the income effect in the second period, the optimal matching grant rate (the Pigovian tax rate) in the first period from the central government to a more hyperopic jurisdictional government should be decreased (increased). The relative size of the two effects, which work in opposite directions, is determined by the tastes and endowments of the jurisdictions, the form of their production functions and the degree of spillovers, among other factors. This result is quite different from the literature.

Keywords: Corrective Device, Spillover, Tax Competition, Heterogeneity

1. Introduction

This study reconsiders the provision of a local public good by a jurisdictional government in a two-period economy with spillover effects when the jurisdictional government is assumed to be hyperopic or farsighted. The corrective device used by the central government to ensure the optimal level of the local public good is provided by the jurisdictional government should be adjusted accordingly.

The literature analysing capital tax competition is relevant to this study (see, for example, [9] and [24]). The basic idea of [24] is that perfect mobility of private capital among small homogeneous jurisdictions results in under-provision of a local public good, which is financed by a distortionary property tax because a lump-sum tax is unavailable. However, [9] demonstrate that the pecuniary externality among large heterogeneous jurisdictions derived from a change in the capital price, which is affected by distortionary capital taxes, should be moderately internalised by a corrective device. In the traditional small-jurisdiction tax competition model, the after-tax return to capital is a parameter for each jurisdiction. In this paper, there are only two jurisdictions, so the after-tax return to capital is endogenous, which, unsurprisingly, leads to tax exporting. There are large-jurisdiction models in the literature, including [10, 13] and many others. This study is based on a large-jurisdiction model that is similar to those in the literature above.

The costs of moving faced by private capital, which are also referred to as transaction costs (see, for example, [16]), should not be ignored in a tax competition model. When the private capital investor has decided to locate in one jurisdiction and invest in some projects, these projects will usually last for a long period of time. Once the private capital is invested, it is usually quite difficult to abandon the projects and leave the jurisdiction because of the large moving costs. Even if the private capital can move freely among the jurisdictions in the initial stage, imperfect mobility is inevitable in the later stages. Therefore, we must consider both transaction costs and inter-temporal effects in a tax competition model. There are several relevant studies that consider such issues. For example, [16] considers the imperfect mobility of private capital arising from transaction costs in a two-period tax competition model. He shows that a jurisdictional government will over-provide local public goods in the second period because of transaction costs and that the jurisdictions may choose a lower capital tax rate than that chosen in a one-period tax competition model to increase capital stock in the first period. Furthermore, by introducing a head tax into the model, [18] confirms that the jurisdictional government may subsidise private capital in the first period to increase capital stock in the second period when a lump-sum tax is available to a hyperopic jurisdictional government. This result is compatible with that of the repeated game explained by [8]. There are also some two-period-model constructions that are relevant to our study (for example, [15]). However, most of the relevant literature analysing the transaction costs and dynamic effects does not clarify the important roles played by the spillover effects of public goods and the heterogeneity of jurisdictions in a repeated-game model. Hence, the focus of this study is to examine these roles.

The problem of capital tax competition may be solved by making a transfer from one jurisdiction to another jurisdiction when a lump-sum tax is not available in a capital tax competition model with imperfect population mobility among large heterogeneous jurisdictions (see [7]). [7] find that the pecuniary externality and the fiscal externality, which work in opposite directions, can be cancelled out if the capital importer subsidises capital, while the capital exporter taxes capital. Conversely, [9] confirm that the capital importer taxes capital while the capital exporter provides a subsidy on capital if a lump-sum tax is available for the jurisdictions. In this study, we follow [9] because the strategy of manipulating the terms of trade is incentive compatible for the jurisdictions.

In the discussion on the spillover effects of local public goods among different jurisdictions, the prevailing view is that such spillover effects will aggravate the under-provision of local public goods (see, for example, [5]). However, another quite different view is that the spillover effects of local public goods may alleviate the under-provision of local public goods in some situations. In a repeated-game model with large homogeneous jurisdictions, [14] find that the jurisdictional governments are more inclined to provide an efficient level of local public goods when the degree of the spillover effects is sufficient. Furthermore, [20] confirms that, in a tax competition model with large heterogeneous jurisdictions, the jurisdiction with less efficient production technology is likely to increase its capital tax rate to drive out private capital and obtain substantial spill-in effects from the other jurisdiction with more efficient production technology. This means that a distortional capital tax may lead to a more efficient level of local public goods funding. This finding is a key motivation and implication for the current study.

This study is closely related to the literature on fiscal federalism. It has been considered that the voluntary provision of public goods and the provision of local public goods with spillovers are insufficient even when using the 'Lindhal mechanism' because of the existence of free-riders and, therefore, that a matching grant from a central government to persons or to local governments for (local) public goods is required to solve the problem. Matching grants are a very particular policy device and this is relevant in the context of the vast literature. The seminal article by [5] shows the relationship between the efficient provision of public goods and an optimal matching grant rate. [21] uses the same model and analyses issues including the efficiency of subsidies. [1] replace individuals with local governments and examine the welfare effects of the central government's subsidies for local public goods in a Nash equilibrium model with two types of public goods, local and central. Furthermore, [19] argues that the matching grant rate may decrease with spillover effects if the elasticity of capital with respect to the capital tax rate is significant in a tax competition model. Additionally, the role of matching grants as a commitment device has been considered in recent research (see [2]). Most of the key assumptions of this study correspond with the conventional wisdom presented in the studies above. Finally, we note that matching grants are especially empirically relevant for China and Japan.

By introducing spillover effects into our analysis, we verify that the jurisdiction with the less efficient production technology may choose to tax private capital in the first period, assuming that a lump-sum tax is available to it, and receive substantial spillover benefits from the other jurisdiction with more efficient production technology in the second period when the jurisdiction is hyperopic and benevolent, which is quite different from [18]. In other words, these constructions are put together to model an interesting phenomenon and not simply to arrive at predetermined results.

The remainder of the paper is organised as follows. The basic model is set out in section 2, in which we introduce the spillover effects of public goods and the heterogeneity of jurisdictions into a two-period economy. In section 3, we show the Stackelberg equilibria by employing backward induction to obtain the optimal corrective device to be employed by the central government in the two periods. In section 4, we discuss our findings based on the derived optimal corrective device. Section 5 draws conclusions.

2. The Model

The model that we use is similar to that used in [18]. There are two heterogeneous jurisdictions in a two-period game[1]

[1] The model can be written in a simpler way using only one period (see, for example, [20]). However, as this paper focuses on how the degree of governmental hyperopia and asymmetry in capital ownership affect the optimal redistribution mechanism, the dynamic effects must be considered.

and, in each jurisdiction i (i=1, 2)[2], the immobile resident is normalised to unity, with preferences defined by a strictly quasi-concave utility function[3] $U_p^i(x_p^i, G_p^i)$, where x_p^i is the consumption of a private numeraire good in period p(p=1,2) and G_p^i is the consumption of a local public good in period p. The local public good G_p^i is defined by:

$$G_p^i = g_p^i + \beta_{ji} g_p^j, \tag{1}$$

where g_p^i is the provision of the local public good by jurisdictional government i and β_{ji} ($0 \leqq \beta_{ji} \leqq 1$) is a parameter indicating the degree of spillover benefits from jurisdiction j to jurisdiction i.

We assume that the well-behaved aggregate production function in jurisdiction i is $f_i(k_p^i)$, and that $\frac{df_i(k_p^i)}{dk_p^i}$ and $\frac{d^2 f_i(k_p^i)}{d(k_p^i)^2}$ can be rewritten as $f_{kp}^i(k_p^i)$ and $f_{kkp}^i(k_p^i)$, respectively, where k_p^i is the private capital employed by jurisdiction i in period p. The production function can be assumed to take the quadratic form, for example, $f^i(\mathrm{k}_p^i) = a_i k_i - 0.5 b_i k_i^2$, which is also used by [22] and [20] in their numerical analyses, because the marginal productivity of private capital can take a linear and concise form, that is, $f_{kp}^i(k_p^i) = a_i - b_i k_i$. The production technology in the jurisdiction depends on the parameters a_i and b_i. The private capital is perfectly mobile in the first period and perfectly immobile in the second period. We assume that the private capital is myopic, following [18]. The reason behind this is that the jurisdictional governments cannot commit to second-period taxes given the immobility of private capital in the second period. Even if the private tax rate was 100% in the second period, the private capital could not move to another jurisdiction. Thus, the private capital providers consider the tax rate only in the first period when making the location decision because they do not believe in the jurisdictional government's commitment to the tax rate in the second period. In other words, the capital owners do not take into account second-period taxation in their location decision.

The total supply of private capital in the country is fixed at $\bar{k}$ such that:

$$\bar{k} = \mathrm{k}_p^i + \mathrm{k}_p^j. \tag{2}$$

In equilibrium, therefore, the after-tax return to capital in the first period is equalised across jurisdictions as follows:

$$f_{k1}^i(\mathrm{k}_1^i) - t_1^i = f_{k1}^j(\mathrm{k}_1^j) - t_1^j = r, \ (j \neq i) \tag{3}$$

where t_1^i is the tax rate per unit of capital employed by jurisdiction i and r is the after-tax return to private capital in the country in the first period. Based on the established conventions, for example, see [6] and [20], we obtain the effect of changes in the first-period tax rate on the after-tax return to private capital and the location of private capital by taking total derivatives of (2) and (3), as follows:

$$\frac{\partial k_1^i}{\partial t_1^i} = \frac{1}{f_{kk1}^i + f_{kk1}^j} < 0 \tag{4}$$

$$\frac{\partial k_1^j}{\partial t_1^i} = -\frac{1}{f_{kk1}^i + f_{kk1}^j} > 0 \tag{5}$$

$$\frac{\partial r}{\partial t_1^i} = -\frac{f_{kk1}^j}{f_{kk1}^i + f_{kk1}^j} < 0 \tag{6}$$

The budget constraint of the resident in the first period requires that:

$$x_1^i = f_i(k_1^i) - f_{k1}^i(k_1^i)\,\mathrm{k}_1^i + r\overline{k_1^i} - h_1^i, \tag{7}$$

where $\overline{k_1^i}$ is the initial endowment of private capital in jurisdiction i with $\overline{k_1^i} = \alpha^i \bar{k}$ and h_1^i is the uniform lump-sum tax that the central government has imposed. Following [18], we postulate that α^i is a fraction of the capital stock owned by the resident in jurisdiction i and that it does not change with time, where $\alpha^i + \alpha^j$=1. Local and central governments can change the tax rate, but cannot impose a discriminatory tax rate. Moreover, it is required that the revenue from the national and local forest environmental taxes must be used for environmental policies. Therefore, these taxes and policies can be viewed as similar to the lump-sum taxes and the local public goods that we analyse in this article.

Substituting (3) into (7), (7) can be rewritten as:

$$x_1^i = f_i(k_1^i) - t_1^i \mathrm{k}_1^i + r\left(\overline{k_1^i} - k_1^i\right) - h_1^i. \tag{8}$$

During the second period, the after-tax return to capital may differ between the two jurisdictions because of the immobility of private capital. Therefore, the budget constraint of the resident in the second period requires that:

$$x_2^i = f_i(k_2^i) - f_{k2}^i(k_2^i)\,\mathrm{k}_2^i + \alpha^i\left\{\left[f_{k2}^i(k_2^i) - t_2^i\right]k_2^i + \left[f_{k2}^j(k_2^j) - t_2^j\right]k_2^j\right\} - h_2^i. \tag{9}$$

The jurisdictional government budget constraint is given by:

$$g_p^i = t_p^i k_p^i + s_p^i. \tag{10}$$

The central government establishes a corrective device to encourage the jurisdictional government i to provide the local public good. Hence, the following condition holds:

$$s_p^i = m_p^i g_p^i, \tag{11}$$

where s_p^i is the matching grant received by the jurisdictional government i from the central government in period p and m_p^i is the rate of the matching grant received by the jurisdictional government i from the central government in period p.

The lump-sum tax (subsidy) imposed (offered) by the central government h_p^i will be chosen to satisfy the following budget constraint of that central government:

[2] For simplicity, we assume that there are only two jurisdictions in the model. It can be confirmed that most of the results in this paper will not change qualitatively even if there are more than two jurisdictions.

[3] The properties of the utility functions are similar to those in the extant literature (for example, [18]).

$$s_p^i + s_p^j = h_p^i + h_p^j = m_p^i g_p^i + m_p^j g_p^j. \quad (12)$$

Modelling intergovernmental transfer/taxes in such a way is well-established in the literature (see, for example, [19] and [5]).

3. The Stackelberg Equilibria

We assume that the central government and the jurisdictional governments play a Stackelberg game with centralised leadership and that there is a unique Stackelberg equilibrium in each period. As this two-period game is a subgame perfect equilibrium, we employ backward induction to solve the problem for each jurisdictional government.

3.1. The Second Period

In the second period, there are two stages:

In stage 1, the central government chooses the national lump-sum tax (subsidy) h_2^i and the matching grant rate (the Pigovian tax rate) m_2^i as a Stackelberg leader.

In stage 2, the jurisdictional government i chooses the capital tax rate t_2^i, and the local public good g_2^i as a Stackelberg follower, taking h_2^i and m_2^i as given.

In the second period, the jurisdictional government i maximises the utility of the residents by choosing t_2^i and g_2^i, given t_2^j and g_2^j. Although the jurisdictional governments cannot commit to second-period taxes, some facts (for example, the laws and policies in the jurisdictions) stop the capital-importing country from taxing away all capital and redistributing it to its citizens. Therefore, the capital owners would foresee this in their location decision. Following [18], the optimisation problem for jurisdictional government i can be written as:

$$\max_{t_2^i, g_2^i} U_i(x_2^i, G_2^i)$$

$$\text{s.t. } x_2^i = f_i(k_2^i) - f_{k2}^i(k_2^i)k_2^i + \alpha^i\{[f_{k2}^i(k_2^i) - t_2^i]k_2^i + [f_{k2}^j(k_2^j) - t_2^j]k_2^j\} - h_2^i$$

$$G_2^i = g_2^i + \beta_{ji} g_2^j$$

$$g_2^i = t_2^i k_2^i + s_2^i$$

$$s_2^i = m_2^i g_2^i$$

The first-order condition for jurisdictional government i is given by:

$$\frac{\partial u_2^i}{\partial t_2^i} = U_{G2}^i\left[\frac{k_2^i}{1-m_2^i}\right] + U_{x2}^i(-\alpha^i k_2^i) = 0, \quad (13)$$

where the jurisdictional government i takes k_2^i as k_1^i in the first period. It can be derived that the second-order condition is satisfied under some realistic functional assumptions and the properties of the equilibria are fully determined (see [20]). Rearranging (13), we have:

$$\frac{U_{G2}^i}{U_{x2}^i} = \alpha^i(1 - m_2^i). \quad (14)$$

The optimal corrective device that the central government should choose is given by:

$$m_2^i = 1 - \frac{1}{\alpha^i}\frac{U_{G2}^i}{U_{x2}^i}. \quad (15)$$

The Pareto-optimal condition is derived by:

$$\max_{x_2^i, g_2^i} U_2^i(x_2^i, G_2^i) + U_2^j(x_2^j, G_2^j)$$

$$\text{s.t. } x_2^i + x_2^j + g_2^i + g_2^j = f_i(k_2^i) + f_j(k_2^j).$$

The Lagrange function is given by:

$$\mathrm{L}(x_2^i, g_2^i) = U_2^i + U_2^j + \lambda[x_2^i + x_2^j + g_2^i + g_2^j - f_i(k_2^i) - f_j(k_2^j)].$$

Differentiating $L(x_2^i, g_2^i)$ with respect to x_2^i, g_2^i, and λ, yields:

$$\frac{\partial L}{\partial g_2^i} = U_{G2}^i + \beta_{ij} U_{G2}^j + \lambda = 0,$$

$$\frac{\partial L}{\partial x_2^i} = U_{x2}^i + \lambda = 0,$$

$$\frac{\partial L}{\partial \lambda} = x_2^i + x_2^j + g_2^i + g_2^j - f_i(k_2^i) - f_j(k_2^j) = 0,$$

which can be rewritten as:

$$U_{G2}^i + \beta_{ij} U_{G2}^j = U_{x2}^i. \quad (16)$$

A comparison of (15) and (16) shows that the optimal matching grant rate (the Pigovian tax rate) that the central government should choose is given by:

$$m_2^i = 1 - \frac{1}{\alpha^i}\left(1 - \beta_{ij}\frac{U_{G2}^j}{U_{x2}^i}\right). \quad (17)$$

This finding corresponds with the conclusions from the existing literature (for example, see [4]). Notably, this result is an extension of [18] with reference to a particular case.

The inefficiency here arises first from the under-provision of local public goods resulting from the spillover effects. This is determined by the number of jurisdictions and the degree of spillovers. The larger are the numbers of jurisdictions and the degree of spillovers, the larger is the positive externality. In addition, inefficiency arises from the over-provision of local public goods resulting from tax exporting [1]. This effect is determined by the proportion of the capital stock owned by the jurisdiction's residents. The larger this proportion is, the larger is the negative fiscal externality ignored by the jurisdictional government. If the former positive externality is larger than the latter negative fiscal externality, the net effect is that local public goods are under-provided by the jurisdictional

[1] See [17].

government in the second period, which means that the optimal corrective device provided by the central government is a matching grant. Conversely, if the former positive externality is smaller than the latter negative fiscal externality, the net effect is that local public goods are over-provided by the jurisdictional government in the second period, which means that the optimal corrective device that the central government should provide is a Pigovian tax. This finding may be summarised in the following proposition.

Proposition 1: If the spillover effect is larger than the tax-exporting effect in the second period, the central government should choose the matching grant as a corrective device. In this sense, the local public good is under-provided. On the contrary, if the spillover effect is smaller than the tax-exporting effect in the second period, the central government should choose the Pigovian tax as a corrective device. In this case, the local public good is over-provided.

This proposition mainly restates what the prior literature has found in similar contexts (see, for example, [4]).

3.2. The First Period

In the first period, there are two stages:

In stage 1, the central government chooses the national lump-sum tax (subsidy) h_1^i and the matching grant rate (the Pigovian tax rate) m_1^i as a Stackelberg leader.

In stage 2, the jurisdictional government i chooses the capital tax rate t_1^i and the local public good g_1^i as a Stackelberg follower, taking h_1^i, h_2^i, m_1^i and m_2^i as given.

The capital tax rate in the second period depends on the amount of private capital located in jurisdiction i in the second period. Owing to the immobility of private capital in the second period, the amount of private capital located in jurisdiction i in the second period is equal to the amount in the first period, that is, $k_1^i = k_2^i$. At the same time, the amount of private capital located in jurisdiction i in the first period depends on the capital tax rate, which is chosen by the jurisdictional government in the first period. Therefore, following [18], we assume that $t_2^i = q(t_1^i)$, where t_2^i is expressed as a function of t_1^i. This means that how the jurisdictional government i chooses the optimal capital tax rate in the second period is significantly determined by the capital tax rate that it chose in the first period. Note that this does not mean that t_2^i is predetermined. The jurisdictional government chooses t_1^i to maximise the discounted sum of the utilities in the two periods, given the variables for jurisdictional government j. If the jurisdictional government is hyperopic, the maximisation problem for jurisdictional government i in the first period can be written as:

$$\max_{t_1^i, g_1^i} u_1^i = U_i(x_1^i, G_1^i) + \delta^i U_i(x_2^i, G_2^i)$$

s.t. $x_1^i = f_i(k_1^i) - f_{k1}^i(k_1^i)k_1^i + r_1\overline{k_1^i} - h_1^i x_2^i = f_i(k_2^i) - f_{k2}^i(k_2^i)k_2^i + \alpha^i\{[f_{k2}^i(k_2^i) - t_2^i]k_2^i + [f_{k2}^j(k_2^j) - t_2^j]k_2^j\} - h_2^i$

$$G_1^i = g_1^i + \beta_{ji} g_1^j$$

$$G_2^i = g_2^i + \beta_{ji} g_2^j$$

$$g_1^i = t_1^i k_1^i + s_1^i$$

$$g_2^i = t_2^i k_2^i + s_2^i$$

$$s_1^i = m_1^i g_1^i$$

$$s_2^i = m_2^i g_2^i$$

$$k_1^i = k_2^i$$

$$t_2^i = q(t_1^i)$$

by assuming that the discount factor for the jurisdictional government is $\delta^i \geq 0$. To derive the first-order condition, we use the substitution method and differentiate u_1^i with respect to t_1^i. Substituting (1), (3), (7), (9), (10) and (11) into the objective function, we obtain:

$$\frac{\partial u_1^i}{\partial t_1^i} = U_{G1}^i\left[\frac{1}{1-m_1^i}\left(k_1^i + t_1^i\frac{\partial k_1^i}{\partial t_1^i}\right) + \frac{1}{1-m_1^j}\beta_{ji}t_1^j\frac{\partial k_1^j}{\partial t_1^i}\right] + U_{x1}^i\left[\left(\overline{k_1^i} - k_1^i\right)\frac{\partial r_1}{\partial t_1^i} - k_1^i\right]$$

$$+\delta^i U_{x2}^i\left\{\left[\alpha^i\left(f_{k2}^i - t_2^i\right) - (1-\alpha^i)k_2^i f_{kk2}^i\right]\frac{\partial k_2^i}{\partial t_1^i} - \alpha^i k_2^i\frac{\partial t_2^i}{\partial t_1^i}\right\} + \delta^i U_{G2}^i\left[\frac{1}{1-m_2^i}\left(t_1^i\frac{\partial k_2^i}{\partial t_1^i} + k_2^i\frac{\partial t_2^i}{\partial t_1^i}\right) + \frac{1}{1-m_2^j}\beta_{ji}t_2^j\frac{\partial k_2^j}{\partial t_1^i}\right]. \quad (18)$$

Substituting (14) into (18), (18) can be rewritten as:

$$\frac{\partial u_1^i}{\partial t_1^i} = U_{G1}^i\left[\frac{1}{1-m_1^i}\left(k_1^i + t_1^i\frac{\partial k_1^i}{\partial t_1^i}\right) + \frac{1}{1-m_1^j}\left(\beta_{ji}t_1^j\frac{\partial k_1^j}{\partial t_1^i}\right)\right] + U_{x1}^i\left[\left(\overline{k_1^i} - k_1^i\right)\frac{\partial r_1}{\partial t_1^i} - k_1^i\right]$$

$$+\delta^i U_{G2}^i\left\{\frac{1}{1-m_2^i}\left[\left(f_{k2}^i - t_2^i\right) - \frac{1-\alpha^i}{\alpha^i}k_2^i f_{kk2}^i\right]\frac{\partial k_2^i}{\partial t_1^i} - \frac{1}{1-m_2^i}k_2^i\frac{\partial t_2^i}{\partial t_1^i}\right\} + \delta^i U_{G2}^i\left[\frac{1}{1-m_2^i}\left(t_1^i\frac{\partial k_2^i}{\partial t_1^i} + k_2^i\frac{\partial t_2^i}{\partial t_1^i}\right) + \frac{1}{1-m_2^j}\beta_{ji}t_2^j\frac{\partial k_2^j}{\partial t_1^i}\right]. \quad (19)$$

Rearranging (19) with cancellation, we have:

$$\frac{\partial u_1^i}{\partial t_1^i} = U_{G1}^i\left[\frac{1}{1-m_1^i}\left(k_1^i + t_1^i\frac{\partial k_1^i}{\partial t_1^i}\right) + \frac{1}{1-m_1^j}\left(\beta_{ji}t_1^j\frac{\partial k_1^j}{\partial t_1^i}\right)\right] + U_{x1}^i\left[\left(\overline{k_1^i} - k_1^i\right)\frac{\partial r_1}{\partial t_1^i} - k_1^i\right]$$

$$+\delta^i U_{G2}^i\left[\frac{1}{1-m_2^i}\left(f_{k2}^i-\frac{1-\alpha^i}{\alpha^i}k_2^i f_{kk2}^i\right)\frac{\partial k_2^i}{\partial t_1^i}+\frac{1}{1-m_2^j}\beta_{ji}t_2^j\frac{\partial k_2^j}{\partial t_1^i}\right]. \tag{20}$$

Using (2) and the assumption that $k_1^i=k_2^i$, the first-order condition can be written as:

$$\frac{\partial u_1^i}{\partial t_1^i}=U_{G1}^i\left[\frac{1}{1-m_1^i}\left(k_1^i+t_1^i\frac{\partial k_1^i}{\partial t_1^i}\right)-\frac{1}{1-m_1^j}\left(\beta_{ji}t_1^j\frac{\partial k_1^i}{\partial t_1^i}\right)\right]+U_{x1}^i\left[\left(\overline{k_1^i}-k_1^i\right)\frac{\partial r_1}{\partial t_1^i}-k_1^i\right]$$

$$+\delta^i U_{G2}^i\left\{\frac{1}{1-m_2^i}\left[f_{k2}^i-\frac{1-\alpha^i}{\alpha^i}k_2^i f_{kk2}^i\right]-\frac{1}{1-m_2^j}\beta_{ji}t_2^j\right\}\frac{\partial k_1^i}{\partial t_1^i}=0. \tag{21}$$

It can be derived that the second-order condition is satisfied under some realistic functional assumptions and the properties of the equilibria are fully determined (see [20]).

The optimal corrective device that the central government should choose is given by:

$$m_1^i=1-\frac{U_{G1}^i\left(k_1^i+t_1^i\frac{\partial k_1^i}{\partial t_1^i}\right)}{U_{x1}^i\left[k_1^i-\left(\overline{k_1^i}-k_1^i\right)\frac{\partial r_1}{\partial t_1^i}\right]+U_{G1}^i\left(\frac{1}{1-m_1^j}\beta_{ji}t_1^j\frac{\partial k_1^i}{\partial t_1^i}\right)-\delta^i U_{G2}^i\left[\frac{1}{1-m_2^i}\left(f_{k2}^i-\frac{1-\alpha^i}{\alpha^i}k_2^i f_{kk2}^i\right)-\frac{1}{1-m_2^j}\beta_{ji}t_2^j\right]\frac{\partial k_1^i}{\partial t_1^i}}. \tag{22}$$

The Pareto-optimal condition is derived by:

$$\max_{x_1^i,g_1^i} U_1^i(x_1^i,G_1^i)+U_1^j(x_1^j,G_1^j)+\varphi\left[U_2^i(x_2^i,G_2^i)+U_2^j(x_2^j,G_2^j)\right]$$

$$\text{s.t. } x_1^i+x_1^j+g_1^i+g_1^j=f_i(k_1^i)+f_j(k_1^j)$$

$$x_2^i+x_2^j+g_2^i+g_2^j=f_i(k_2^i)+f_j(k_2^j),$$

where we assume that the discount factor for the central government is $\varphi\geq 0$. The Lagrange function is given by:

$$L(x_1^i,g_1^i,x_2^j,g_2^j)=U_1^i+U_1^j+\varphi(U_2^i+U_2^j)+\pi\left[x_1^i+x_1^j+g_1^i+g_1^j-f_i(k_1^i)-f_j(k_1^j)\right]$$

$$+\omega\varphi\left[x_2^i+x_2^j+g_2^i+g_2^j-f_i(k_2^i)-f_j(k_2^j)\right].$$

Differentiating $L(x_1^i,g_1^i,x_2^j,G_2^j)$ with respect to $x_1^i,g_1^i,x_2^j,g_2^j,\pi$ and ω gives us:

$$\frac{\partial L}{\partial g_1^i}=U_{G1}^i+\beta_{ij}U_{G1}^j+\pi=0,$$

$$\frac{\partial L}{\partial x_1^i}=U_{x1}^i+\pi=0,$$

$$\frac{\partial L}{\partial g_2^i}=\varphi\left(U_{G2}^i+\beta_{ij}U_{G2}^j+\omega\right)=0,$$

$$\frac{\partial L}{\partial x_2^i}=\varphi\left(U_{x2}^i+\omega\right)=0,$$

$$\frac{\partial L}{\partial \pi}=x_1^i+x_1^j+g_1^i+g_1^j-f_i(k_1^i)-f_j(k_1^j)=0,$$

$$\frac{\partial L}{\partial \omega}=\varphi\left[x_2^i+x_2^j+g_2^i+g_2^j-f_i(k_2^i)-f_j(k_2^j)\right]=0,$$

which can be rewritten as:

$$U_{G1}^i+\beta_{ij}U_{G1}^j=U_{x1}^i, \tag{23}$$

$$U_{G2}^i+\beta_{ij}U_{G2}^j=U_{x2}^i. \tag{24}$$

A comparison of (22), (23) and (24) shows that the optimal matching grant rate (the Pigovian tax rate) that the central government should choose is given by:

$$m_1^i = 1 - \frac{U_{G1}^i\left(k_1^i + t_1^i \frac{\partial k_1^i}{\partial t_1^i}\right)}{\left(U_{G1}^i + \beta_{ij} U_{G1}^j\right)\left[k_1^i - \left(\overline{k_1^i} - k_1^i\right)\frac{\partial r_1}{\partial t_1^i}\right] + U_{G1}^i\left(\frac{1}{1-m_1^j}\beta_{ji} t_1^j \frac{\partial k_1^i}{\partial t_1^i}\right) - \delta^i U_{G2}^i\left[\frac{1}{1-m_2^i}\left(f_{k2}^i - \frac{1-\alpha^i}{\alpha^i} k_2^i f_{kk2}^i\right) - \frac{1}{1-m_2^j}\beta_{ji} t_2^j\right]\frac{\partial k_1^i}{\partial t_1^i}}. \tag{25}$$

Notably, this result is an extension of [18] with reference to a particular case. It may appear that it is a kind of extensive form game in which the central government does not have to commit in the second period to the matching grant that it chose in the first period. However, the matching grant can be used as a commitment device in some situations (see, for example, [2]). Therefore, to simplify the analysis in the model, we assume that the central government can commit in the second period to the matching grant that it chose in the first period.

4. Discussion

To sign $\frac{\partial m_1^i}{\partial \delta^i}$, we differentiate the optimal corrective device with δ^i, yielding:

$$\frac{\partial m_1^i}{\partial \delta^i} = -\frac{U_{G1}^i U_{G2}^i\left(k_1^i + t_1^i \frac{\partial k_1^i}{\partial t_1^i}\right)\left[\frac{1}{1-m_2^i}\left(f_{k2}^i - \frac{1-\alpha^i}{\alpha^i} k_2^i f_{kk2}^i\right) - \frac{1}{1-m_2^j}\beta_{ji} t_2^j\right]\frac{\partial k_1^i}{\partial t_1^i}}{\left\{\left(U_{G1}^i + \beta_{ij} U_{G1}^j\right)\left[k_1^i - \left(\overline{k_1^i} - k_1^i\right)\frac{\partial r_1}{\partial t_1^i}\right] + U_{G1}^i\left(\frac{1}{1-m_1^j}\beta_{ji} t_1^j \frac{\partial k_1^i}{\partial t_1^i}\right) - \delta^i U_{G2}^i\left[\frac{1}{1-m_2^i}\left(f_{k2}^i - \frac{1-\alpha^i}{\alpha^i} k_2^i f_{kk2}^i\right) - \frac{1}{1-m_2^j}\beta_{ji} t_2^j\right]\frac{\partial k_1^i}{\partial t_1^i}\right\}^2}. \tag{26}$$

We assume that we are on the left-hand side of a Laffer curve, $k_1^i + t_1^i \frac{\partial k_1^i}{\partial t_1^i} > 0$. As $\frac{\partial k_1^i}{\partial t_1^i} < 0$, the sign of $\frac{\partial m_1^i}{\partial \delta^i}$ depends only on the bracketed term in the numerator. On the one hand, the hyperopic jurisdictional government has an incentive to decrease the tax rate in the first period to attract the private capital because the jurisdictional government considers the income in the second period (the income effect). The first term in the bracketed term of the numerator is positive. However, if the spillover effect in the second period is taken into account by the hyperopic jurisdictional government, the jurisdictional government has an incentive to increase the tax rate in the first period to drive out the private capital and obtain the spillover benefits from the other jurisdiction (the spill-in effect). The second term in the bracketed term of the numerator is negative. The relationship between the corrective device in the first period and the degree of hyperopia of the jurisdictional government significantly depends on the relative size of the two effects that are working in the opposite direction in the second period, as stated succinctly in the following proposition.

Proposition 2: When the income effect is larger than the spill-in effect in the second period, the optimal matching grant rate (the Pigovian tax rate) in the first period from the central government to a more hyperopic jurisdictional government should be increased (decreased). Conversely, when the spill-in effect is larger than the income effect in the second period, the optimal matching grant rate (the Pigovian tax rate) in the first period from the central government to a more hyperopic jurisdictional government should be decreased (increased).

Notice that the external validity of this proposition depends on a political strategy of the politicians. The benefits that the politicians can obtain in one jurisdiction (the re-election rent) equals the marginal increase in the probability of re-election multiplied by the value of being re-elected. Of course, these factors are seen as the exogenous variables in this model. If the politicians would like to stand for election for the next term, the conclusion would be valid and could also be a benchmark for some extensions in the future. However, if the politicians would like to stand down, they would be myopic and their discount factor might be zero in the first period. The result would collapse into the finding in [20].

To see the properties of the capital allocation among the two jurisdictions in such an equilibrium, differentiation of the optimal corrective device with respect to $\overline{k_1^i} - k_1^i$ shows that:

$$\frac{\partial m_1^i}{\partial\left(\overline{k_1^i} - k_1^i\right)} = -\frac{U_{G1}^i\left(U_{G1}^i + \beta_{ij} U_{G1}^j\right)\left(k_1^i + t_1^i \frac{\partial k_1^i}{\partial t_1^i}\right)\frac{\partial r_1}{\partial t_1^i}}{\left\{\left(U_{G1}^i + \beta_{ij} U_{G1}^j\right)\left[k_1^i - \left(\overline{k_1^i} - k_1^i\right)\frac{\partial r_1}{\partial t_1^i}\right] + U_{G1}^i\left(\frac{1}{1-m_1^j}\beta_{ji} t_1^j \frac{\partial k_1^i}{\partial t_1^i}\right) - \delta^i U_{G2}^i\left[\frac{1}{1-m_2^i}\left(f_{k2}^i - \frac{1-\alpha^i}{\alpha^i} k_2^i f_{kk2}^i\right) - \frac{1}{1-m_2^j}\beta_{ji} t_2^j\right]\frac{\partial k_1^i}{\partial t_1^i}\right\}^2} > 0. \tag{27}$$

This equation corresponds with that of [6] and [16]. It is obvious that the equilibrium is a symmetric equilibrium when $\overline{k_1^i} - k_1^i = 0$, which means the capital does not move at all. The jurisdiction is a capital exporter if $\overline{k_1^i} - k_1^i > 0$, and it is a capital importer if $\overline{k_1^i} - k_1^i < 0$. As $\frac{\partial m_1^i}{\partial\left(\overline{k_1^i} - k_1^i\right)} > 0$, we have the following relationships for jurisdiction i:

$$\text{if } \overline{k_1^i} - k_1^i > 0 \text{ then } m_1^i > m_1^{i*},$$

$$\text{if } \overline{k_1^i} - k_1^i = 0 \text{ then } m_1^i = m_1^{i*},$$

$$\text{if } \overline{k_1^i} - k_1^i < 0 \text{ then } m_1^i < m_1^{i*},$$

where m_1^{i*} is the optimal matching grant rate from the central government in a symmetric equilibrium. This conclusion is a generalisation of that derived by [18] in a strategic tax competition model. We obtain the third result as follows.

Proposition 3: In the first period, the optimal matching grant rate (the Pigovian tax rate) from the central government to a capital-exporting jurisdictional government is larger (smaller) than that in the symmetric equilibrium. However, the optimal matching grant rate (the Pigovian tax rate) from the central government to a capital-importing jurisdictional government is smaller (larger) than that in the symmetric equilibrium.

The intuition behind this result is interpreted as follows. The capital exporter desires a high after-tax return to private capital to increase the capital income arising from exporting capital. Thus, in the first period, the capital exporter would choose a lower tax rate and a lower level of local public goods than in the symmetric equilibrium to manipulate the terms of trade [1]. For that reason, in the first period, the optimal matching grant rate (the Pigovian tax rate) from the central government to a capital-exporting jurisdictional government is larger (smaller) than that in the symmetric equilibrium. Conversely, the capital importer desires a low after-tax return to private capital to reduce the capital costs arising from importing capital. Thus, in the first period, it would choose a higher tax rate and a higher level of local public goods than in the symmetric equilibrium to manipulate the terms of trade. Accordingly, in the first period, the optimal matching grant rate (the Pigovian tax rate) from the central government to a capital-importing jurisdictional government is smaller (larger) than that in the symmetric equilibrium.

Now, we state the boundaries of the research and applications of the model. In some suburban areas, for example, less populated areas surrounding a metropolitan area but of lower socioeconomic status, beneficial spillovers of local public goods from the urban core are necessary and essential for the suburban residents. If the politicians in these kinds of jurisdictions place a significant weight on the distant future, the under-provision of local public goods might be eased to some extent. Accordingly, the central government should decrease the current period's optimal matching grant rate to some extent. However, in some urban areas, for example, a densely populated urban core in a metropolitan area with high socioeconomic status, benefit spillovers of local public goods from the surrounding territories are unnecessary and negligible for these urban residents. If the politicians in these kinds of jurisdictions place a significant weight on the distant future, the under-provision of local public goods might be aggravated to some extent. Accordingly, the central government should increase the current period's optimal matching grant rate to some extent.

This result is quite different from [18]. One jurisdictional government might tax private capital in the first period to receive more benefit spillovers from other jurisdictions in the second period even if a lump-sum tax is available for the benevolent and hyperopic jurisdictional government. Of course, the robustness and external validity of this research requires further analysis and the incorporation of other key assumptions such as, for example, political re-election motivations.

5. Conclusions

This paper has focused on the effect that the degree of hyperopia of jurisdictional government has on the optimal corrective device in a two-period model in which spillover effects are considered. We have obtained the following results.

(1) If the spillover effect is larger than the tax-exporting effect in the second period, the central government should choose a matching grant as a corrective device. Conversely, if the spillover effect is smaller than the tax-exporting effect in the second period, the central government should choose a Pigovian tax as a corrective device.

(2) When the income effect is larger than the spill-in effect in the second period, for example, if the production technology in the jurisdiction is significantly higher than in other jurisdictions and the spillover benefits received by the jurisdiction are not very large, the optimal matching grant rate (the Pigovian tax rate) in the first period, which is set by the central government and directed to the more hyperopic jurisdictional government, should be increased (decreased). Conversely, when the spill-in effect is larger than the income effect in the second period, for example, the production technology in the jurisdiction is significantly lower than in other jurisdictions and the spillover benefits received by the jurisdiction are relatively large, the corresponding optimal matching grant rate (the Pigovian tax rate) in the first period should be decreased (increased).

(3) In the first period, the optimal matching grant rate (the Pigovian tax rate) from the central government to a capital-exporting jurisdictional government is larger (smaller) than that in the symmetric equilibrium. However, the optimal matching grant rate (the Pigovian tax rate) set by the central government in relation to a capital-importing jurisdictional government is smaller (larger) than that in the symmetric equilibrium.

(4) For simplicity, it has been assumed that capital is perfectly immobile in the second period. If we introduce transactions costs into the model in the second period, our results may be adjusted quantitatively. However, our findings about the provision of local public goods will not be changed even if capital is imperfectly mobile in the second period.

There is no inter-temporal redistribution via public debt or public investment as would usually be relevant when determining public finances across time (for example, [3] and [12]). In a dynamic model, the timing of and commitment to policies (for example, see [23]) matter. However, for simplicity's sake, these issues are not addressed in the present research. In addition, alternative ways of redistributing resources between jurisdictions (for example, sharing the tax revenue, as in [11]) may lead to more efficient outcomes. This topic is left for future research.

It is worth noting that the degree of hyperopia of jurisdictional government is determined by the probability of re-election and the rent from being re-elected for the politicians. If the politicians in the jurisdiction can obtain high

[1] See [20] and [7].

rent from being re-elected or if the probability that the politicians will be re-elected in the next term is very high, the jurisdictional government may be possess greater foresight in this term, and vice versa. Although these factors are seen as the exogenous variables in this study, the finding could provide a benchmark for some extensions in the future. Therefore, in future work, it would be interesting to take into account these issues concerning the incumbents and the anti-incumbency factors.

Acknowledgements

We thank Amanda Fitzgibbons, PhD, from Edanz Group (https://en-author-services.edanzgroup.com/) for editing a draft of this manuscript.

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