Humanities and Social Sciences
2020; 8(4): 117-123
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

Tong Yang

Graduate School of Social Sciences, Hiroshima University, Higashi-Hiroshima, Japan

Email address:
sunxuechanga@gmail.com

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. 117-123. 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). 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. There are large-jurisdiction models in the literature, including [10, 13] and many others.

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. 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. 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]).

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]). 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 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.

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 and, in each jurisdiction i (i=1, 2), the immobile resident is normalised to unity, with preferences defined by a strictly quasi-concave utility function $U_p^i(x_p^i, G_p^i)$, 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 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 $\alpha^i+\alpha^j=1$.

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

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

Therefore, the budget constraint of the resident in the second period requires that:

$$x_2^i = f_i(k_2^i) - f_{k2}^i(k_2^i)\, k_2^i$$

$$+\alpha^i\{[f_{k2}^i(k_2^i) - t_2^i]k_2^i + [f_{k2}^j(k_2^j) - t_2^j]k_2^j\} - h_2^i. \tag{9}$$

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:

$$s_p^i + s_p^j = h_p^i + h_p^j = m_p^i g_p^i + m_p^j g_p^j. \tag{12}$$

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. 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:

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

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:

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

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

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

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:

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

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:

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

This finding corresponds with the conclusions from the existing literature (for example, see [4]).

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.

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 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:

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

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

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

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

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

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

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

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

$$k_1^i = k_2^i$$

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

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:

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

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

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

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

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

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:

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

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

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:

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

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:

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

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

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:

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

4. Discussion

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

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

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. 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).

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:

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

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 $\frac{\partial m_1^i}{\partial(\overline{k_1^i} - k_1^i)} > 0$, 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.

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,

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

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.

Acknowledgements

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

References

[1] Akai, N., Ihori, T., (2002) Central government subsidies to local public goods, *Economics of Governance*, 3 (3), 227-239.

[2] Akai, N., Sato, M., (2019) The role of matching grants as a commitment device in the federation model with a repeated soft budget setting. *Economics of Governance*, 20, 23-39.

[3] Barro, R. J., (1979) On the determination of the public debt. *Journal of Political Economy*, 87 (5), 940-971.

[4] Bjorvatn, K., Schjelderup, G., (2002) Tax competition and international public goods. *International Tax and Public Finance,* 9 (2), 111-120.

[5] Boadway, R., Pestieau, P., Wildasin, D., (1989) Non-cooperative behavior and efficient provision of public goods. *Public Finance/Finances Publiques,* 44 (1), 1-7.

[6] Bucovetsky. S., (1991) Asymmetric tax competition. *Journal of Urban Economics*, 30, 167-181.

[7] Burbidge, J. B., Myers, G. M., (1994) Population mobility and capital tax competition. *Regional Science and Urban Economics*, 24, 441-459.

[8] Coates, D., (1993) Property tax competition in a repeated game. *Regional Science and Urban Economics*, 23, 111-119.

[9] DePater, J., and Myers, G. M., (1994) Strategic capital tax competition: a pecuniary externality and a corrective device. *Journal of Urban Economics*, 36, 66-78.

[10] Hauer, A., and Wooton, I., (1999) Country size and tax competition for foreign direct investment. *Journal of Public Economics*, 71 (1), 121-139.

[11] Hindriks, J., S., Peralta, and S., Weber, (2008) Competing in taxes and investment under fiscal equalization. *Journal of Public Economics*, 92 (12), 2392-2402.

[12] Jensen, R., and E. F., Toma, (1991) Debt in a model of tax competition. *Regional Science and Urban Economics*, 21 (3), 371-392.

[13] Kanbur, R., and Keen, M., (1993) Jeux Sans frontieres: tax competition and tax coordination when countries differ in size. *American Economic Review*, 83 (4), 877-892.

[14] Kawachi, K., and Ogawa, H., (2006) Further analysis on public-good provision in a repeated-game setting. *Finan zArchiv*, 62, 339-352.

[15] King, I., McAfee, R., and Welling, L., (1993) Industrial blackmail: dynamic tax competition and public investment. *Canadian Journal of Economics*, 26 (3), 590-608.

[16] Lee, K., (1997) Tax competition with imperfectly mobile capital. *Journal of Urban Economics*, 42, 222-242.

[17] Noiset, L., (2003) Is it tax competition or tax exporting? *Journal of Urban Economics*, 54, 639-647.

[18] Ogawa, H., (2000) Imperfect capital mobility and local government behavior in a two-period economy. *Bulletin of Economic research*, 52, 151-166.

[19] Ogawa, H., (2006) Tax competition, spillovers, and subsidies. *Annals of Regional Science*, 40, 849-858.

[20] Ogawa, H., (2007) Strategic taxation on mobile capital with spillover externality. *Finanz Archiv*, 63, 33-45.

[21] Roberts, R. D., (1992) Government subsidies to private spending on public goods, *Public Choice,* 74 (2), 133-152.

[22] Wildasin, D. E., (1991) Some rudimentary 'duopolity' theory, *Regional Science and Urban Economics*, 21, 393-421.

[23] Wildasin, D. E., (2003) Fiscal competition in space and time. *Journal of Public Economics*, 87 (11), 2571-2588.

[24] Zodrow, G. R., and Mieszkowski, P., (1986) Pigou, Tiebout, property taxation, and the underprovision of local public goods. *Journal of Urban Economics*, 19, 356-370.