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## The provision of public inputs in a federation under asymmetric information

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# W. E. P.

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## Würzburg Economic Papers

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The provision of public inputs in a federation under  
asymmetric information

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August 2004

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# The provision of public inputs in a federation under asymmetric information

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August 2004

## **Abstract**

In recent years informational problems have been introduced into local public finance. The main impetus of the analyses has been on the supply of local public goods, often under tax competition. The present paper extends recent contributions to study how inter-regionally mobile capital supplied by the first-period consumption-savings decision of the private sector is taxed in a closed federation to fund well informed local governments that differ in their costs of providing public inputs. The modified Samuelson-conditions for the optimal supply of local public inputs are derived and analyzed for different informational environments and instrumental abilities of the federal government. There exists a tendency to oversupply the public input in the low cost region which is also present in a numerical simulation where different informational environments are compared to the first-best and tax competition.

Keywords: Public Inputs; Asymmetric Information; Federation

JEL Classification: H21, H54, H70

## 1. Introduction

Oates [17] and Tiebout [20] have based the idea of the advantages of federally organized governments on two basic tenets: (1) decentralized government entities have better access to information which is locally relevant. (2) central government has to employ uniform levels of taxes or services irrespective of local conditions. However, in many theoretical contributions studying the basic problem of policymaking in a federal state, neither informational problems nor differences in regional circumstances have played a role.

The theoretical literature in local public finance has only recently begun to incorporate informational problems into the traditional analysis of mobile tax bases, tax competition and the efficient supply of local public goods and public factors.

Recent contributions incorporating asymmetric information are Boadway/Horiba/Jha [3], Bucovetsky/Marchand/Pestieau [6], Lockwood [15], Cremer/Marchand/Pestieau [10], Bordignon/Manasse/Tabellini [4], Raff/Wilson [18] and Dhillon/Perroni/Scharf. [11]. The focus of the majority of these papers has been on the role of informational asymmetries in the provision of local public goods and their effects on redistributive policies in a federation.

Cornes/Silva [7,8,9] in a series of contributions have analyzed asymmetric information in a federation, where local governments have informational advantages vis a vis the federal government. In their analyses, however, there are no mobile private activities between the regional economies. Transfers can only be effected by the federal government.

Lockwood [15] discusses the possibilities of interregional insurance with and without possible spillovers of local public goods, given informational asymmetries over preferences for local public goods, costs of providing these public goods and local endowments.

Dhillon/Perroni/Scharf [11] discuss problems regarding the supply of public goods. They study the possibility of Bayesian implementation of a tax coordination scheme when there is no legal tax harmonization, but where countries can benefit from voluntarily coordinated tax policy. This would correspond to the unified federal tax on capital income in the present paper.

Only Raff/Wilson [18] have studied the question of public inputs (e.g. infrastructure) under asymmetric information in the context of factor mobility. In their analysis labor is a mobile factor and a central government, with a redistributive objective, has to consider informational advantages of local governments in implementing an optimal allocation of transfers across regions to maximize a utilitarian welfare function of immobile landowners and mobile workers. Their local government has a lump sum tax at its disposal to finance the local input.

The classic reference is Zodrow/Mieszkowski [27] who derived an inefficiency result of local underprovision of public inputs based on an assumption about the production function. Their result has been generally derived by Matsumoto [16]. Keen/Marchand [12] have studied the impact of tax competition on the composition of local expenditures on local public goods and local public inputs, again in a context of symmetric information and countries. Their main result is that for any given tax revenue the expenditure mix is biased towards local public inputs in a vain attempt to attract additional capital.

The present paper deviates from this perspective in several instances. First, it studies the problem of the central/federal government as a revelation game, where the local governments first reveal their type to the center which implements an allocation of capital taxes and local public inputs based on the messages received. It takes into account that private capital is perfectly mobile across regions. Furthermore, the federal government can only levy a capital tax, which distorts the savings decision of the private agents. This approach from the tax competition literature rules out taxes on lump-sum incomes either on a local or federal level. This contrasts with much of the literature where local governments often can levy a local lump-sum tax and need federal funds only to supplement their expenditures or because they act only in the interest of local residents who receive the rent income. It is similar to the situation in the Federal Republic of Germany where Länder governments have practically no local source of revenue.

In contrast to Raff/Wilson [18] the federal government only serves in an efficiency enhancing capacity by levying a federal tax and thus possibly obviating the need to levy local source based capital taxes that are at the heart of the classical underprovision result of Zodrow/Mieszkowski [27].

The main role of the federal government would be that of an agent that is able to collect the revenue in a more efficient way and then transfer the money to the local authorities to spend. The center acts as an agent of the regions (tax collector) and is used to increase the efficiency of tax collection. Local governments nevertheless have an incentive to cheat on the collector. They may misrepresent their status. For example, in a recent decision East Lansing, MI, declared an area of the city as blighted in order to get additional state subsidies for its expenditures policy in that area. Another example is the recent discovery that state governments have been cheating the federal government by misrepresenting their Medicare expenditures in order to get a larger matching payment from the federal government. This was done by making a statement about planned state expenditures and then not actually paying them after receiving federal money. It could also be done by overpaying local providers of public inputs. This is the approach followed by Besfamille [2]. The local government can hire local providers at higher prices or grant them costly favors which makes it seem as if the provision of public inputs in the low cost regions was as expensive as in the high cost region.

The paper is organized as follows:

First, the formal model of a (closed) federation with two types of small regions is presented. Regions differ in their productive possibilities to transform private goods into public inputs. There exist low- and high-cost regions. Regional governments know their own cost type but the federal government does not. After the general equilibrium effects of the tax instruments are explored, the problem of the federal government under complete information is solved as a case of reference. In this environment, the federal government will set optimal investment for public inputs according to the rule: marginal productivity = marginal costs of public funds. The latter are greater than one because the capital income tax reduces the rate of interest and hence aggregate savings in the federation. A condition is derived which guarantees that uniform taxation of capital will be optimal under symmetric information.

The role of asymmetric information is then considered based on a direct revelation game, where the federal government implements a transfer-public investment scheme based on regional messages about types. Local governments misrepresenting their type can transfer excess payments from the federal government to their representative resident for consumption. Therefore, any welfare loss by a forced expenditure of local government surpluses in a non-utility maximizing way is ruled out. They are not able, however, to finance

any deficit which would result from misrepresentation by means other than the federal transfer.

It is demonstrated that under these assumptions a pooling equilibrium in public inputs is not possible. Further, it is shown that the incentive compatibility constraint of the low-cost region will be binding.

With uniform capital taxation, the investment rules for public inputs are derived. The input decisions for low-cost regions, contrary to standard results of no distortion at the top, will be distorted to take into account the impact of local public inputs on the informational rent received. The reason for this is that in a general equilibrium model, the direct effect of public inputs on productivity and hence utility in low cost regions will be dampened by increased rental payments to the (capital exporting) high cost regions for the capital employed. Input decisions in high cost regions will be distorted to take into account the necessary increases in the informational rent paid out to low cost regions.

If the federal government also has an additional local tax on capital at its disposal, it turns out that the public input decision of the low cost regions will no longer be distorted, i.e. no distortion at the top will hold with respect to public inputs. However, the capital input in the low cost region will now be subsidized. This counteracts the tendency to reduce the stock of capital in low cost regions, because of the informational rent concerns. The input decision for the high cost regions then has to absorb all distortions, those for the direct impact of the informational rent and also those of the capital subsidy.

A general welfare analysis in section 5 argues that the objective of the federal government will achieve a higher value, if it is able to levy a differentiated capital tax. This implies that the general conclusion of uniform capital taxes under symmetric information may no longer hold under asymmetric information between the federal government and local governments over important aspects of local economies.

Finally, a numerical simulation in a very much simplified model with only two regions and taxation of capital and capital income demonstrates the possibility that with uniform capital income taxation, public inputs may be oversupplied relative to the first best in the low cost region. Furthermore, it illustrates potential conflicts of interests between low cost and high



cost regions in forming a federation, as low cost regions may “win” under tax competition in the sense that the tax competition equilibrium may give them higher utility than either the first best or a federation with or without informational problems and employing distortionary taxes.

A short summary concludes.

## 2. The structure of the model

### 2.1. The private sector

We consider a federation composed of  $\mathbf{N}$  regions. There exist two types of regions,  $H$  and  $L$ , with  $n_H$  and  $n_L$ ,  $n_H + n_L = N$ , denoting the respective number of regions. They differ in their costs of providing local public inputs, e.g. infrastructure. We assume that use of the infrastructure,  $P$ , is completely nonrival. We proceed by first describing the private sector of each region and then the situation of the local governments.

Each region  $i$  is inhabited by an immobile representative agent. He derives utility from private consumption in the first and second period. His utility function is

$$(1) \quad U(C_1^i, C_2^i) = u(C_1^i) + C_2^i. \text{ }^1$$

He maximizes his utility subject to his budget constraint

$$(2) \quad C_2^i = (1+r)S^i + \pi^i + \alpha^i.$$

The assumption of a quasi-linear utility function is common both in agency problems as well as in the analysis of public goods as the presence of income effects severely complicates the analysis.<sup>2</sup> The agent can invest his savings  $S^i = W^i - C_1^i$ , where  $W^i$  denotes his endowment of a representative consumption good in the first period, in all regions and receives the net rate of interest  $r$  from doing so.<sup>3</sup> We assume that the representative agent is the sole owner of the representative firm in his region or state and thus all profit/rental income  $\pi^i$  accrues to him. Finally,  $\alpha^i \geq 0$  denotes a possible transfer payment from government  $i$  to agent  $i$ .

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<sup>1</sup> We denote agents or regions with superscripts and all other variables with subscripts.

<sup>2</sup> See, e.g. Laffont/Tirole [13], who use quasi-linear utility throughout.

<sup>3</sup> As we consider only a federal capital income tax it does not matter whether this tax is levied as a source-based or a residence-based tax.

In the present model with a complete capital market, the Fisher separation holds. Therefore, maximization of (1) subject to (2) gives the following savings function of the private agent,  $S^i = S^i(1+r)$ . We assume throughout that

$$(3) \quad \frac{\partial S}{\partial r} = S_r > 0.$$

Taking the profit as given, the indirect utility function of the agent is

$$(4) \quad \begin{aligned} V^i &= V(S(1+r(t^F, t^i, t^j, P^i, P^j)), \pi(1+r(t^F, t^i, t^j, P^i, P^j), t^F, t^i, P^i), \alpha^i) \\ &= V(t^F, t^i, t^j, P^i, P^j, \alpha^i) \end{aligned}$$

where  $t^i, P^i$  are the local tax on capital income and the locally provided public inputs and  $t^F$  denotes the federal capital tax.  $t^j, P^j$  are the respective instruments of the other type of region.<sup>4</sup>

To simplify the analysis and abstract from distributionary concerns between regions, we assume that both types of agents are endowed with an identical amount  $W^i = \bar{W}$ ,  $i = H, L$  of the first-period consumption good. Therefore, both savings functions are identical.

In his role as entrepreneur of the representative firm in region  $i$ , the agent maximizes profits, taking the level of local public inputs,  $P^i$ , the rate of interest  $r$  and the tax rates on capital income,  $t^i, t^F$ , as given:

$$(5) \quad \pi^i = F(K^i, P^i) - (1+r)K^i - t^i K^i - t^F K^i$$

Here  $F(K^i, P^i)$  denotes a neoclassical production function with decreasing returns to scale that exhibits the Inada conditions. The formulation in (5) assumes that the private firm is charged no price by the local government for the use of the public inputs  $P^i$ . A user charge based on the level of public inputs available would change the informational structure of the

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<sup>4</sup> We suppress the effect of the number of regions  $n^H$  and  $n^L$  from the formula, because we will keep these constant throughout.

model and allow the implementation of matching grants, because such payments would give additional information to the federal government.

We assume that neither the federal government nor the local governments are able to tax local profits directly.<sup>5</sup> The maximization of (5) then gives the local capital demand function

$K^i = K((1+r) + t^i + t^F; P^i)$ . Its partial derivatives are  $\frac{\partial K^i}{\partial r} = \frac{\partial K^i}{\partial t^i} = \frac{\partial K^i}{\partial t^F} = \frac{1}{F_{KK}^i} < 0$ . The

reaction with respect to the public inputs is  $\frac{\partial K^i}{\partial P^i} = -\frac{F_{KP}^i}{F_{KK}^i} > 0$ .

The equilibrium rate of interest in the federation is then determined by equalizing capital demands and savings:

$$(6) \quad n^L K^L(1+r+t^L+t^F; P^L) + n^H K^H(1+r+t^H+t^F; P^H) = (n^H + n^L)S(1+r)$$

Given the partial effects of the regional instruments and knowing both savings functions, we can derive the total effects of the instruments on the equilibrium rate of interest by totally differentiating (6) with respect to the instruments

$$(6') \quad (n^L K_r^L + n^H K_r^H - (n^L + n^H)S_r)dr + (n^L K_{t^F}^L + n^H K_{t^F}^H)dt^F + n^L K_{t^L}^L dt^L + n^H K_{t^H}^H dt^H + n^L K_{P^L}^L dP^L + n^H K_{P^H}^H dP^H = 0$$

where  $K_j^i$  denotes the partial derivative of the demand for capital in region  $i$  with respect to parameter  $j$ . This leads to

$$\frac{dr}{dt^F} = -\frac{(n^L K_r^L + n^H K_r^H)}{\Delta}, \text{ with } -1 < \frac{dr}{dt^F} < 0.^6$$

From the assumptions above it follows that  $\Delta = n^L K_r^L + n^H K_r^H - (n^L + n^H)S_r < 0$

Furthermore, we have

$$\frac{dr}{dt^L} = -\frac{n^L K_{t^L}^L}{\Delta} < 0$$

$$\frac{dr}{dt^H} = -\frac{n^H K_{t^H}^H}{\Delta} < 0$$

<sup>5</sup> This is in contrast to Raff/Wilson [18]

<sup>6</sup> Note that the impact is not equal to  $-1$ , because we have assumed an increasing savings function which absorbs part of the effect of the federal tax  $t^F$ .

$$\frac{dr}{dP^L} = -\frac{n^L K_{P^L}^L}{\Delta} > 0,$$

$$\frac{dr}{dP^H} = -\frac{n^H K_{P^H}^H}{\Delta} > 0.$$

## 2.2. The local government

In a model of strategic tax competition (for a recent example see Bayindir-Upmann [1]) a regional government would use these dependencies in determining its optimal policies, given its assumptions on the reaction of the other regions.<sup>7</sup> We will, however, assume that individual regions do not take into account their influence on the federal tax rate but view themselves as small regions without any influence on the federal tax and interest rate.<sup>8</sup>

In our simplified setting without a local source of revenue, the main function of a regional government is to determine its budget by sending a message  $\hat{\theta}$  to the federal government about its type/needs. In order to generate some leeway for local actions, we assume that the federal government does not actually know the true type of individual regions.

The optimization problem of a local government is to determine the message. Given the transfer schedule announced by the federal government this determines the transfer it will receive, the transfer payment to its citizen and the level of local public inputs to be provided. To generate a meaningful problem of asymmetric information we need two unobservable local characteristics. We assume that the federal government is not able to observe private final consumption besides the cost parameter in any region.

Another approach would be to let the regional government provide a local public good. Then the mix of expenditures for the regional government would be the object of study.<sup>9</sup> In the

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<sup>7</sup> This approach is also taken in the numerical exploration at the end of the present paper.

<sup>8</sup> It is doubtful, if this reasoning would still hold in a federation with large differences in regional size. If one views the European Union as a federation, it seems plausible that Germany or France as regions might both have and try to use their influence on the European interest rate. Especially as there does not exist a European federal tax authority.

<sup>9</sup> See Keen/Marchand [12] for a study of this problem with symmetric information and tax competition.

present context, however, we wish to focus on the supply of public inputs, possible informational rents and the distortionary role of tax instruments in use in the federation.

We now state formally how regions differ: we assume that the difference between L- and H-type regions lies in a cost parameter  $\theta \in \{\theta^L, \theta^H\}$  that determines the transformation between private goods and public inputs. The local government of region  $i$  wishes to maximize the indirect utility function of its representative agent

$$(7) V^i = V(t^F, t^i(\hat{\theta}^i), P^i(\hat{\theta}^i), \alpha^i(\hat{\theta}^i)),$$

subject to its budget constraint

$$T^i(\hat{\theta}^i) + t^i(\hat{\theta}^i)K^i(1+r+t^i(\hat{\theta}^i)+t^F, P^i(\hat{\theta}^i)) - \theta^i P^i(\hat{\theta}^i) - \alpha^i(\hat{\theta}^i) \geq 0$$

and the instrumental constraint  $\alpha^i(\hat{\theta}^i) \geq 0$ .

$\hat{\theta}^i \in \{\theta^L, \theta^H\}$  denotes the message about its type (e.g. rate of transformation) which it sends to the federal government.  $\theta^i$  denotes its true type (e.g. rate of transformation). With two types ( $H$  and  $L$ ) and the assumption  $\theta^H > \theta^L$ , this implies that type  $L$  has to sacrifice fewer units of the private good to provide the same amount of public inputs than does type  $H$ .<sup>10</sup> The actual amount of public inputs provided,  $P_i(\hat{\theta}^i)$ , depends on the message to the federal government, because we assume that the federal government can observe both the stock of private capital and the marginal product of capital in order to levy a tax on capital income.

Finally,  $\alpha^i(\hat{\theta}^i)$  denotes the transfer of possible excess receipts from the local government to the local private sector. This formulation implies that the local government does not prefer bureaucratic waste, as such, but would use local budgetary surpluses in a welfare maximizing way, i.e. to maximize the welfare of its representative agent. If such transfers actually do happen, a welfare loss will nevertheless result, because of the excess burden of the capital tax.

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<sup>10</sup> Hence the single-crossing property holds.

We also note that the local government has no local source of revenue. This implies that in the welfare maximization problem of the federal government it is necessary to impose the restriction that  $\alpha^i \geq 0$  for both types of regions. Otherwise, a negative  $\alpha^i$  would imply a local lump sum tax on local profits. In the present setting, no federal tax on capital to finance the local public inputs would be needed, if such a local lump sum tax was available.

In the present setting with only two types of governments, local governments have a binary choice about the message they send to the federal government. Either a local government tells the truth or it misrepresents its type. We can therefore incorporate the local choices into the problem of the federal government by adding standard truth telling or incentive compatibility constraints.

As a point of reference we will start with the second-best situation (without informational constraints) before we proceed to third-best (with informational problems).

### 3. The problem of the federal government with complete information

In this section we present the problem of the federal government if it encounters no informational problems. We assume that the federal government maximizes an additive social welfare function that is the sum of the utilities of both regions subject to the relevant constraints. Hence the Lagrangian of the federal government is to maximize

$$\begin{aligned}
 (10) \quad Z^{CI} = & n^L V^L[\cdot] + n^H V^H[\cdot] \\
 & + \lambda^L (T^L + t^L K^L (1+r[\cdot]) + t^L + t^F, P^L) - \theta^L P^L \\
 & + \lambda^H (T^H + t^H K^H (1+r[\cdot]) + t^H + t^F, P^H) - \theta^H P^H \\
 & \mu(t^F (n^L + n^H) S(r) - n^H T^H - n^L T^L)
 \end{aligned}$$

subject to the capital market equilibrium, which is implicit in the presence of the equilibrium rate of interest in (10).<sup>11 12</sup>

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<sup>11</sup> The capital market equilibrium itself contains the optimal investment decision by the representative firms and the savings decisions by both private agents.

<sup>12</sup> We have also incorporated the fact that no local transfer incomes will be paid in this situation, because financing them incurs a welfare loss. I.e., we have set  $\alpha^L = \alpha^H = 0$ .

The first order conditions of (10) with respect to the capital taxes are:

$$(11) t^L: \quad -n^L K^L + \lambda^L \left( K^L + t^L \frac{dK^L}{dt^L} \right) + \lambda^H \left( t^H \frac{dK^H}{dt^L} \right) + \lambda^F \left( t^F (n^H + n^L) \frac{dS}{dt^L} \right) = 0$$

$$(12) t^H: \quad -n^H K^H + \lambda^L \left( t^L \frac{dK^L}{dt^H} \right) + \lambda^H \left( K^H + t^H \frac{dK^H}{dt^H} \right) + \lambda^F \left( t^F (n^H + n^L) \frac{dS}{dt^H} \right) = 0$$

$$(13) t^F: \quad -n^H K^H - n^L K^L + \lambda^L \left( t^L \frac{dK^L}{dt^F} \right) + \lambda^H \left( t^H \frac{dK^H}{dt^F} \right) + \lambda^F \left( (n^L + n^H) S + t^F (n^H + n^L) \frac{dS}{dt^F} \right) = 0$$

Because of the properties of the capital demand functions

$$\frac{dK^i}{dt^i} = \frac{\partial K^i}{\partial t^i} + \frac{\partial K^i}{\partial r} \frac{dr}{dt^i} = \left( 1 + \frac{dr}{dt^i} \right) K_r^i, \quad \frac{dK^i}{dt^j} = K_r^i \frac{dr}{dt^j}, \quad \frac{dK^i}{dt^F} = \frac{\partial K^i}{\partial t^F} + \frac{\partial K^i}{\partial r} \frac{dr}{dt^F} = \left( 1 + \frac{dr}{dt^F} \right) K_r^i,$$

$i = L, H$ ,

and the reaction of savings to taxes,  $\frac{dS}{dt^i} = S_r \frac{dr}{dt^i}$ ,  $i = L, H$ ;  $\frac{dS}{dt^F} = S_r \frac{dr}{dt^F}$ , as well as the capital market equilibrium, only two of these three equations are independent. Therefore, we drop  $t^F$  from the problem to inquire what regional taxes the federal government will set in equilibrium.  $T^L$  and  $T^H$  will then be used by the federal government to allocate the tax revenues as needed between the two groups of regions. Hence we can rewrite the problem of the central government as

$$(10') \quad \begin{aligned} Z^{Cl} = & n^L V^L[.] + n^H V^H[.] \\ & + \lambda^L (t^L K^L (1+r[.] + t^L, P^L) - T - \theta^L P^L) \\ & + \lambda^H \left( \frac{n^L}{n^H} T + t^H K^H (1+r[.] + t^H, P^H) - \theta^H P^H \right) \end{aligned}$$

based on the presumption that the federal government will transfer money  $T$  from the low cost regions to the high cost regions to balance the budgets. (11) and (12) simplify to

$$(11') t^L: \quad -n^L K^L + \lambda^L \left( K^L + t^L \frac{dK^L}{dt^L} \right) + \lambda^H \left( t^H \frac{dK^H}{dt^L} \right) = 0$$

$$(12') t^H: \quad -n^H K^H + \lambda^L \left( t^L \frac{dK^L}{dt^H} \right) + \lambda^H \left( K^H + t^H \frac{dK^H}{dt^H} \right) = 0$$

Furthermore, we get

$$(14) T: \quad -\lambda^L + \frac{n^L}{n^H} \lambda^H = 0$$

$$(15) P^L: \quad n^L F_p^L + \lambda^L \left( t^L \frac{dK^L}{dP^L} - \theta^L \right) + \lambda^H \left( t^H \frac{dK^H}{dP^L} \right) = 0$$

$$(16) P^H: \quad n^H F_p^H + \lambda^L \left( t^L \frac{dK^L}{dP^H} \right) + \lambda^H \left( t^H \frac{dK^H}{dP^H} - \theta^H \right) = 0$$

The total reactions are given by

$$\begin{aligned} \frac{dK^L}{dP^L} &= \frac{\partial K^L}{\partial P^L} + \frac{\partial K^L}{\partial r} \frac{dr}{dP^L} = K_p^L + K_r^L \frac{dr}{dP^L}, \quad \frac{dK^H}{dP^L} = \frac{\partial K^H}{\partial r} \frac{dr}{dP^L} = K_r^H \frac{dr}{dP^L}, \\ \frac{dK^L}{dP^H} &= \frac{\partial K^L}{\partial r} \frac{dr}{dP^H} = K_r^L \frac{dr}{dP^H}, \quad \frac{dK^H}{dP^H} = \frac{\partial K^H}{\partial P^H} + \frac{\partial K^H}{\partial r} \frac{dr}{dP^H} = K_p^H + K_r^H \frac{dr}{dP^H} \end{aligned}$$

From (14) we get

$$(17) \quad \frac{\lambda^L}{n^L} = \frac{\lambda^H}{n^H}.$$

The transfer of revenue by the federal government leads to the equalization of the marginal cost of public funds (MCPF) for both types of regions.

Using (17) to solve (11') for  $n^L K^L$  and then dividing it by  $n^L K^L$  and doing the same in (12') wrt  $n^H K^H$  we get the following equality:

$$(18) \quad \begin{aligned} 1 + t^L \frac{K_r^L}{K^L} + \frac{1}{n^L K^L} \frac{dr}{dt^L} (t^L n^L K_r^L + t^H n^H K_r^H) &= \\ 1 + t^H \frac{K_r^H}{K^H} + \frac{1}{n^H K^H} \frac{dr}{dt^H} (t^L n^L K_r^L + t^H n^H K_r^H) & \end{aligned}$$

$$\text{Writing } \frac{\partial K^L}{\partial r} \frac{r}{K^L} = \varepsilon_r^{K^L}, \quad \frac{\partial K^H}{\partial r} \frac{r}{K^H} = \varepsilon_r^{K^H}, \quad \frac{\partial S}{\partial r} \frac{r}{S} = \varepsilon_r^S$$



(18) can be simplified to

$$(18^*) \quad t^L \frac{\varepsilon_r^{K_L}}{r} - t^H \frac{\varepsilon_r^{K_H}}{r} = \frac{t^L n^L K^L \frac{\varepsilon_r^{K_L}}{r} + t^H n^H K^H \frac{\varepsilon_r^{K_H}}{r}}{n^L K^L \frac{\varepsilon_r^{K_L}}{r} + n^H K^H \frac{\varepsilon_r^{K_H}}{r} - (n^H + n^L) S \frac{\varepsilon_r^S}{r}} \left( \frac{\varepsilon_r^{K_L}}{r} - \frac{\varepsilon_r^{K_H}}{r} \right)$$

Assuming  $\varepsilon_r^{K^L} = \varepsilon_r^{K^H} = \varepsilon_r^K$ , we get

$$(19) \quad \frac{\varepsilon_r^K}{r} (t^L - t^H) = \left( \frac{\varepsilon_r^K}{r} \right)^2 \frac{(t^L n^L K^L + t^H n^H K^H)}{(n^H + n^L) S \left( \frac{\varepsilon_r^K}{r} - \frac{\varepsilon_r^S}{r} \right)} (1-1) = 0$$

Hence we have

*Result 1:* If the elasticity of the demand for capital is identical and constant in both regions, the optimal tax rates chosen by the federal government under symmetric information will be equal,

$$(20) \quad t^{H*} = t^{L*} = t.$$

( A sufficient condition for the optimal tax rates to be equal in both regions is that the elasticities of the demand for capital with respect to the interest rate are identical and constant across regions)<sup>13</sup>

From now on, we will assume that the production function exhibits this property.

Given (20) and (17), the marginal cost of public funds will be

$$(21) \quad \frac{\lambda^L}{n^L} = \frac{\lambda^H}{n^H} = \frac{S}{S + t \frac{\partial S}{\partial r} \frac{dr}{dt}} = \frac{1}{1 + \varepsilon_r^S \varepsilon_t^r} > 1,$$

---

<sup>13</sup> If we set  $t^L = t^H = t$  in (18\*), this implies that  $S_r = 0$  for the equation to hold, independent of the values of  $\varepsilon_r^{K_i}, i = H, L$ .

where  $\varepsilon_t^r = \frac{dr}{dt} \frac{t}{r} < 0$  denotes the elasticity of the rate of interest wrt the capital tax. Let

$\varepsilon_{P^L}^r = \frac{dr}{dP^L} \frac{P^L}{r} > 0$  and  $\varepsilon_{P^H}^r = \frac{dr}{dP^H} \frac{P^H}{r} > 0$  denote the elasticities of the rate of interest wrt to the respective public inputs.

Then the public inputs will be provided according to the following two formulas:

$$(22) \quad F_p^L = \theta^L \text{MCPF} \left( 1 - \frac{t(n^L + n^H)S}{n^L P^L \theta^L} \theta^L \varepsilon_r^S \varepsilon_{P^L}^r \right)$$

$$(23) \quad F_p^H = \theta^H \text{MCPF} \left( 1 - \frac{t(n^L + n^H)S}{n^H P^H \theta^H} \theta^H \varepsilon_r^S \varepsilon_{P^H}^r \right)$$

These equations reveal that there are two countervailing tendencies at work in deciding the level of public inputs provided in both types of regions.

First, there is a tendency to provide less than the optimal amount of public inputs, because the MCPF are greater than one for both regions. Equating the real benefits of additional infrastructure ( $F_p^i$ ) to the real (physical) marginal cost ( $\theta^i$ ) would therefore not be optimal. On the other hand, there exists a mitigating effect of providing infrastructure on the tax base, which tends to increase the optimal amount in the two types of regions. How strong this mitigating effect is depends on the inverse share of the spending on infrastructure in one type of region (the higher the total share the less effective the mitigating effect). Furthermore, the stronger the reaction of the savings to an increase in the rate of interest and the stronger the increase in the rate of interest for a given increase in the level of public inputs, the stronger will be the mitigating effect.

We now proceed to study the problem of the government under incomplete information, i.e., when the actual type of any region is private information which only the local government of that region knows.

#### 4. The problem of the federal government with incomplete information

##### 4.1. Uniform taxes on capital

Based on the result of the previous section, we first analyze the decision of the federal government when it employs a uniform tax on capital throughout the federation.

When the federal government does not know the type of an individual region, it has to take into account that a region may misrepresent itself in its message to the federal government. Analytically, it has to take into account incentive compatibility constraints known from agency theory to guarantee truth-telling by individual regions at the optimum.

For a  $L$ -region this constraint is

$$(24a) \quad V^L \geq V^H + T^H - \theta^L P^H$$

and for a  $H$ -region, it is

$$(24b) \quad V^H \geq V^L + T^L - \theta^H P^L.$$

The economic intuition behind eqs. (24) is that any region must prefer a truthful message about its type to misrepresenting. Taking a typical  $L$ -region as an example, it will get utility  $V^L$  if it sends a truthful message. If it lies, it will get the utility of a  $H$ -region, because it will have an identical stock of public inputs and capital, identical profits and identical utility from savings. However, in addition to that it will have an excess of funds to transfer to its citizen for consumption. The reason for this is that it will receive a transfer from the federal government  $T^H$ , but will need only  $\theta^L P^H$  to produce the amount of public inputs expected and observed from a  $H$ -region.

We consider incentives in an existing federation and ignore therefore any participation constraints that may well be binding in the present situation.<sup>14</sup> Given the possible advantages of tax competition for specific types of regions, it may well be difficult for a federation to form.<sup>15</sup>

To further abstract from possible problems with the local enforcement of federal taxes, we assume that all tax revenue accrues at the federal level. The federal government then transfers money to the regions in accordance with the type messages it has received.

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<sup>14</sup> See eg the recent paper by Cornes/Silva [7].

<sup>15</sup> See Wilson [25,26], Bucovetsky/Wilson [5].

Therefore, the following budget constraints will apply for L- and H-regions and the federal government respectively:

$$(25a) \quad T^L = \theta^L P^L + \alpha^L$$

$$(25b) \quad T^H = \theta^H P^H + \alpha^H$$

$$(25c) \quad t(n^L + n^H)S = n^L T^L + n^H T^H$$

The Lagrangian of the federal government then is to maximize

$$(26) \quad \begin{aligned} zz = & n^L V^L + n^H V^H \\ & + \lambda^L (T^L - \theta^L P^L - \alpha^L) \\ & + \lambda^H (T^H - \theta^H P^H - \alpha^H) \\ & + \lambda^F (t^F (n^L + n^H)S - n^L T^L - n^H T^H) \\ & + \mu^L (V^L - (V^H + T^H - \theta^L P^H)) \\ & + \mu^H (V^H - (V^L + T^L - \theta^H P^L)) \end{aligned}$$

where  $\alpha^i \geq 0, i = H, L$  denote possible information rents that the two types of government may obtain. In our model, they do not waste these possible rents but give them as transfers for consumption to their representative agents.<sup>16</sup> The first order conditions of this problem are

$$(27) \quad t^F : \quad \begin{aligned} & -n^L K^L - n^H K^H + \lambda^F \left( (n^H + n^L)S + t^F (n^H + n^L)S_r \frac{dr}{dt} \right) \\ & + \mu^L \left( -K^L \left( 1 + \frac{dr}{dt} \right) + K^H \left( 1 + \frac{dr}{dt} \right) \right) \\ & + \mu^H \left( -K^H \left( 1 + \frac{dr}{dt} \right) + K^L \left( 1 + \frac{dr}{dt} \right) \right) = 0 \end{aligned}$$

$$(28) \quad \alpha^L : \quad n^L - \lambda^L + \mu^L = 0$$

$$(29) \quad \alpha^H : \quad n^H - \lambda^H + \mu^H = 0$$

$$(30) \quad T^L : \quad \lambda^L - n^L \lambda^F - \mu^H = 0$$

$$(31) \quad T^H : \quad \lambda^H - n^H \lambda^F - \mu^L = 0$$

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<sup>16</sup> This is different from the approach taken by Boadway et al. [3] where the informational rents are consumed by the local government and do not show up in the rest of the general equilibrium structure.

$$\begin{aligned}
(32) \quad P^L: \quad & n^L F_p^L - \lambda^L \theta^L + \lambda^F (t^F (n^L + n^H) S_r \frac{dr}{dP^L}) \\
& + \mu^L (F_p^L - K^L \frac{dr}{dP^L} + K^H \frac{dr}{dP^L}) \\
& + \mu^H (-K^H \frac{dr}{dP^L} - F_p^L + K^L \frac{dr}{dP^L} + \theta^H) = 0
\end{aligned}$$

$$\begin{aligned}
(33) \quad P^H: \quad & n^H F_p^H - \lambda^H \theta^H + \lambda^F (t^F (n^H + n^L) S_r \frac{dr}{dP^H}) \\
& + \mu^L (-K^L \frac{dr}{dP^H} - F_p^H + K^H \frac{dr}{dP^H} + \theta^L) \\
& + \mu^H (F_p^H - K^H \frac{dr}{dP^H} + K^L \frac{dr}{dP^H}) = 0
\end{aligned}$$

In addition to this, the three budget constraints (25abc), the incentive compatibility constraints (24a, 24b) and the capital market equilibrium have to hold.

The only solution to eqs. (28)-(31) has  $\lambda^F = 1, \lambda^L = n^L + \mu^H, \lambda^H = n^H + \mu^H, \mu^L = \mu^H$ .

However, using these values in (27), it simplifies to

$$(27') \quad t^F (n^L + n^H) S_r \frac{dr}{dt} = 0$$

This equation implies that for (28) to (31) to hold,  $\lambda^F = 1$ , i.e., there must be no excess burden in raising money for the federal government. From (27'), this will be the case if either

- $t = 0$ , which would violate the budget constraint in the present model,
- $\frac{\partial S}{\partial r} = 0$ , which would violate the assumption about the utility function made above,

or

- $\frac{dr}{dt} = 0$ , which would also violate the assumptions already made.

Therefore not all of the above first order conditions can hold simultaneously. In line with the literature on information economics, we will assume that the truth-telling constraint on the high cost type will not be binding at the optimum. Hence we will assume  $\mu^H = \alpha^H = 0$  from now on.

The economic reason for this is straightforward. Whenever the optimal infrastructure in L-regions is higher than that in H-regions, H-regions will not be able to misrepresent

themselves, if their additional production cost of mimicking L-regions,  $(\theta^H - \theta^L)P^L$  is greater than the additional money L-regions get beyond their production costs,  $\alpha^L$ . It will be seen in the following analysis that the marginal cost of providing public inputs in the L-regions will be lower than in H-regions, hence at the optimum  $P^L > P^H$ , which implies  $K^L > K^H$ .

Therefore L-regions also pay a rental payment of  $(K^L - K^H)r$  to H-regions, which any lying H-region would have to incur, too. (A H-region would go from paying  $rK^H$  for its capital employed to paying  $rK^L$ , which is also a cost of misrepresentation.)

Without  $\alpha^H$  and  $\mu^H$ , the following system of equations determines the optimal solution of the federal government:

$$(27'') \quad t: \quad -n^L K^L - n^H K^H + \lambda^F \left( (n^H + n^L)S + t(n^H + n^L)S_r \frac{dr}{dt} \right) \\ + \mu^L \left( -K^L \left( 1 + \frac{dr}{dt} \right) + K^H \left( 1 + \frac{dr}{dt} \right) \right) = 0$$

$$(28) \quad \alpha^L: \quad n^L - \lambda^L + \mu^L = 0$$

$$(30') \quad T^L: \quad \lambda^L - n^L \lambda^F = 0$$

$$(31') \quad T^H: \quad \lambda^H - n^H \lambda^F - \mu^L = 0$$

$$(32') \quad P^L: \quad n^L F_p^L - \lambda^L \theta^L + \lambda^F (t(n^L + n^H)S_r \frac{dr}{dt}) \\ + \mu^L (F_p^L - K^L \frac{dr}{dP^L} + K^H \frac{dr}{dP^L}) = 0$$

$$(33') \quad P^H: \quad n^H F_p^H - \lambda^H \theta^H + \lambda^F (t(n^H + n^L)S_r \frac{dr}{dP^H}) \\ + \mu^L \left( -K^L \frac{dr}{dP^H} - F_p^H + K^H \frac{dr}{dP^H} + \theta^L \right) = 0$$

Again, the budget constraints (25abc), the incentive compatibility constraint (24a) of the low cost type and the capital market equilibrium have to hold.

From (30') we get

$$\lambda^L = n^L \lambda^F.$$

This implies that the marginal cost of public funds which will be imputed to the low cost regions is the true MCPF that the federal government incurs. One unit of tax money delivered to a single low cost region incurs a MCPF for the federal government of  $\lambda^F$  times the number of regions that will get this additional money,  $n^L$ .

From (31'), together with (28) and (26') we get

$$\lambda^H = n^H \lambda^F + n^L (\lambda^F - 1).$$

The imputed MCPF for a high cost region are composed of two elements. First, as for low cost regions, are the social cost of providing the tax revenue to  $n^H$  regions. Second, the increase in a payment to the high cost regions makes it more attractive for low cost regions to misrepresent themselves. The federal government has to compensate for this, by increasing the informational rent it gives to the low cost regions. The social cost of financing these additional rents are measured by the term  $n^L (\lambda^F - 1)$ . There are  $n^L$  low cost regions, which will get the additional rent payment. The welfare loss of such a payment to an individual low cost region is given by  $\lambda^F - 1$ , because one dollar of tax revenue costs the federal government  $\lambda^F$  dollars to raise, but in our model it will generate only one additional dollar of utility in private consumption in the low cost regions.

That the MCPF is indeed greater than one in the present situation can be seen by using  $\lambda^L$  and  $\lambda^H$  from above in (27'') and solving for  $\lambda^F$ :

$$(34) \quad \lambda^F = \frac{(n^H + n^L)S + n^L(K^H - K^L)\left(1 + \frac{dr}{dt}\right)}{(n^H + n^L)S + n^L(K^H - K^L)\left(1 + \frac{dr}{dt}\right) + t(n^L + n^H)S_r \frac{dr}{dt}} > 1$$

Thus  $\lambda^F$  will be greater than unity in the present situation, because  $-1 < \frac{dr}{dt} < 0$ . From this it follows that the expression is positive and the denominator will be less than the numerator leading to an excess burden in raising revenue via the capital tax.

Given this result, the optimal levels of public inputs in the low-cost regions will be determined according to

$$(35) \quad F_p^L = \theta^L - \left( \frac{\lambda^F - 1}{\lambda^F} \right) (K^H - K^L) \frac{dr}{dP^L} - \frac{t}{n^L} (n^H + n^L) S_r \frac{dr}{dP^L}$$

This can be simplified using  $T^H = \theta^H P^H$  in the truth-telling-constraint and solving for  $\alpha^L$ :

$$(36) \quad \alpha^L = \pi^H - \pi^L + P^H (\theta^H - \theta^L)$$

Abusing notation to depict the marginal impact the other variables have on the endogenous informational rent, we get

$$(37) \quad \frac{\partial \alpha^L}{\partial P^L} = -F_p^L - (K^H - K^L) \frac{dr}{dP^L}.$$

Using this in (35), we get

$$(35') \quad F_p^L = \lambda^F \theta^L + (\lambda^F - 1) \frac{\partial \alpha^L}{\partial P^L} - \lambda^F \frac{t}{n^L} (n^H + n^L) S_r \frac{dr}{dP^L}$$

The level of public inputs in low cost regions will be determined by three factors.

The first factor is the marginal physical cost of public inputs,  $\theta^L$ , times the MCPF.

The higher the marginal cost or the MCPF, the lower the optimal level of public inputs  $P^L$ .

The second term captures the effect on the informational rent of an increase in the level of public inputs in the L-regions. Given that their stock of capital is higher than in the H-regions, the resulting increase in the rental payment compared to H-regions caused by the increase in the rate of interest provides an incentive for the L-regions to misrepresent themselves. This has to be compensated by a marginal increase in the informational rent, which causes an additional welfare loss of  $\lambda^F - 1$ .



Finally, the third term,  $-\lambda^F \frac{t(n^H + n^L)S_r \frac{dr}{dP^L}}{n^L} < 0$ , captures the positive effect of an increase in the level of public inputs on the federal tax base, which is positive and therefore provides a countervailing positive influence to increase public inputs in the  $L$ -regions.

Using  $\lambda^F$  from (34) explicitly, (35) reduces to

$$(35'') \quad F_p^L = \theta^L - (n^H + n^L)K^H \frac{t}{n^L} \frac{(n^H + n^L)S_r \frac{dr}{dP^L}}{(n^H + n^L)S + n^L(K^H - K^L) \left(1 + \frac{dr}{dt}\right)} < \theta^L$$

This implies that the federal government will provide public inputs in the low cost region beyond the level it would, if it took into account only the physical marginal cost. The tax base effect dominates the rent effect in (35'). Whether the actual level is greater than the level the federal government would choose in the first-best scenario or in a world with distortionary taxes but without informational problems remains to be seen.

Public inputs in the high cost region will be determined according to

(38)

$$F_p^H = \frac{1}{n^H - n^L(\lambda^F - 1)} \left( \lambda^F n^H \theta^H - t \lambda^F (n^H + n^L) S_r \frac{dr}{dP^H} + (\lambda^F - 1) n^L \left( \theta^H - \theta^L + \frac{dr}{dP^H} (K^L - K^H) \right) \right)$$

This equation is similar to (35) but for the denominator and the last term in brackets. More light can be shed on this equation, if we use (36) again and denote the partial effect on  $\alpha^L$  of an increase in  $P^H$  as

$$(39) \quad \frac{\partial \alpha^L}{\partial P^H} = F_p^H + (\theta^H - \theta^L) + (K^L - K^H) \frac{dr}{dP^H}$$

Using (39) in (38) gives us

$$(38') \quad F_p^H = \lambda^F \theta^H + (\lambda^F - 1) \frac{n^L}{n^H} \frac{\partial \alpha^L}{\partial P^H} - \lambda^F \frac{t}{n^H} (n^H + n^L) S_r \frac{dr}{dP^H}$$

This equation shows that the level of public inputs in the high cost region will be influenced by three components as well.

First, the actual cost of providing public inputs will be taken into account, given that the federal government has to use a tax with an excess burden to finance the expenditures of the H-type regions.

Second, the federal government takes into account that an increase in the level of public inputs in the H-regions will necessitate an increase in the payments to the L-type regions to let them abstain from misrepresenting themselves. This welfare cost,  $(\lambda^F - 1) \frac{n^L}{n^H} \frac{\partial \alpha^L}{\partial P^H}$ , adjusted for the numbers of both types of regions in the federation, will tend to decrease the level of public inputs in the H-regions, because it makes this provision more costly to the federal government and hence society.

Finally, the tax base effect,  $-\frac{t\lambda^F(n^H + n^L)S_r}{n^H} \frac{dr}{dP^H}$ , will mitigate the decision with a tendency

to increase public inputs beyond the level that would be warranted by taking into consideration only the actual costs of providing them.

We summarize these results as

**Proposition 1: Under asymmetric information about the costs of public inputs and using only a uniform tax on capital, the federal government will set public input levels according to (35``) and (38` ). Both public input distortions will be distorted in two ways:**

- (1) to take into account the impact of public inputs on informational rents received by the low cost type**
- (2) to take into account the impact of public inputs on the federal tax base.**

The basic situation of uniform capital taxes can also be studied by viewing the following Figure 1, where for presentational simplicity the type parameter differentiates the regions in their fixed and not their variable cost of providing public inputs. The partial production function  $F()$  takes into account that a higher level of  $P$  will attract a higher stock of private capital which results in an additional increase in production.

Figure 1 here

As shown, in a first-best situation, the federal government would implement an identical amount of infrastructure  $P^*$  in both regions. They would get a budget equivalent to the distance 0-2. The government of the L-region is then able to transfer 1-2 back to its citizen for consumption. With lump-sum taxes this would be the maximal rent that would be possible for the L-type region. Gross final “income” before (federal) taxes in period 2 would then be 0-4 in the L-region (remember that 1-2 is equal in size to 3-4 to denote the transfer  $\alpha_L$ ) and 0-3 in the H-region. As the tax on capital incurs an excess burden, the provision of this maximal informational rent will in general not be optimal for the federal government.

If the federal government would set the level of public inputs in the H-region to  $P_1^H$ , the L-region would receive no informational rent. If it misrepresented its type, it would get a budget of 5-7 needing only 5-6 for production purposes and transferring back to the citizen 6-7. Being truthful it would get a budget of 0-1 and not be able to make a transfer back to its citizen. Both alternatives would result in a pre-tax level of goods  $5-9 = 0-3$ . Such a low level of public inputs in the H-region would result in a rather high productivity of public inputs in this region (in 8). This result, low public inputs in the H-region, no informational rent for the L-region cannot, however, be ruled out in the present context. If the marginal costs of public funds are high enough, this can be an optimal solution.

If the marginal productivity of public inputs in the H-region is sufficiently high, however, the provision of some informational rent to the L-region will be warranted. The reason for this rent can be seen if  $P_2^H$  is the level of inputs in the H-region. A mimicking L-region would get a pre-tax level of 10-11, which also has to be supplied if it behaves truthfully. Hence 3-12 would be the informational rent the L-region receives in that case.<sup>17</sup>

#### 4.2. Differentiated capital taxes

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<sup>17</sup> The argument is only approximately correct, because the negative consequences for final consumption  $C_2^L$  of the larger capital stock  $K^L$ , i.e. a transfer to the H-region via  $r(K^L - S)$  given that  $K^L > S$  and a larger tax payment than the H-region of  $t(K^L - K^H)$  are not included in the graph.

In this subsection we explore the optimal policies of the government when it has an additional instrument at its disposal, namely, if it is able to levy different taxes on the capital employed in the two types of regions. Given that the possible misrepresentation of the L-regions is the problem, we will analyze the policies of the federal government when it may levy a separate tax or subsidy on capital employed by low cost regions.

Using this additional instrument, the Lagrangian of the federal government becomes

$$\begin{aligned}
(40) \quad zz = & \quad n^L V^L + n^H V^H \\
& + \lambda^L (T^L + t^L K^L - \theta^L P^L - \alpha^L) + \lambda^H (T^H - \theta^H P^H) \\
& + \lambda^F (t(n^L + n^H)S - n^L T^L - n^H T^H) \\
& + \mu^L (V^L - (V^H + T^H - \theta^L P^H))
\end{aligned}$$

The first-order conditions of this problem are in general quite similar to the ones of problem (26), taking into account that we have already left out  $\alpha^H$  and the truth-telling constraint for the H-type. The first-order conditions are

$$(41) \quad \alpha^L : \quad n^L - \lambda^L + \mu^L = 0$$

$$(42) \quad T^L : \quad \lambda^L - n^L \lambda^F = 0$$

$$(43) \quad T^H : \quad \lambda^H - n^H \lambda^F - \mu^L = 0$$

$$\begin{aligned}
(44) \quad t^F : & \quad -n^L K^L - n^H K^H + \lambda^L t^L \frac{dK^L}{dt} + \lambda^F \left( (n^H + n^L)S + (n^H + n^L)S_r \frac{dr}{dt} \right) \\
& + \mu^L \left( -K^L \left( 1 + \frac{dr}{dt} \right) + K^H \left( 1 + \frac{dr}{dt} \right) \right) = 0
\end{aligned}$$

$$\begin{aligned}
(45) \quad t^L : & \quad -n^L K^L + \lambda^L \left( K^L + t \frac{dK^L}{dt^L} \right) + \lambda^F \left( t(n^L + n^H)S_r \frac{dr}{dt^L} \right) \\
& + \mu^L \left( -K^L \left( 1 + \frac{dr}{dt^L} \right) + K^H \frac{dr}{dt^L} \right) = 0
\end{aligned}$$

$$\begin{aligned}
(46) \quad F_P^L : & \quad n^L F_P^L + \lambda^L \left( t^L \frac{dK^L}{dP^L} - \theta^L \right) + \lambda^F \left( t(n^H + n^L)S_r \frac{dr}{dP^L} \right) \\
& + \mu^L \left( F_P^L - K^L \frac{dr}{dP^L} + K^H \frac{dr}{dP^L} \right) = 0
\end{aligned}$$

$$\begin{aligned}
(47) \quad F_p^H & n^H F_p^H + \lambda^L t^L \frac{dK^L}{dP^H} - \lambda^H \theta^H \\
& + \lambda^F t^F (n^L + n^H) S_r \frac{dr}{dP^H} \\
& + \mu^L \left( -F_p^H - K^L \frac{dr}{dP^H} + K^H \frac{dr}{dP^H} + \theta^L \right) = 0
\end{aligned}$$

From (41)-(43) we get the familiar

$$\lambda^L = n^L \lambda^F$$

and

$$\lambda^H = n^H \lambda^F + n^L (\lambda^F - 1)$$

Using these to solve for  $t^L$  and  $t^F$  in (44) and (45), we get

$$(48) \quad t^F = \left( \frac{\lambda^F - 1}{\lambda^F} \right) \frac{r}{\varepsilon_r^S} > 0$$

and

$$(49) \quad t^L = \left( \frac{\lambda^F - 1}{\lambda^F} \right) \left( \frac{n^H + n^L}{n^H} \right) \frac{r}{\varepsilon_r^{K^H}} < 0$$

with  $\varepsilon_r^{K^H} = \frac{\partial K^H}{\partial r} \frac{r}{K^H} < 0$  denoting the elasticity of the stock of capital in H-regions with respect to the rate of interest. Again,  $\lambda^F > 1$  will hold in this environment.<sup>18</sup> However, (49) implies that the federal government will pay a subsidy for the use of capital in the L-regions.

The intuition for the surprising property that the federal government is subsidizing capital employed in the L-regions is that this subsidy increases  $\pi^L$  and reduces  $\pi^H$ . This reduces their willingness to misrepresent and hence reduces their informational rent.

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<sup>18</sup> There exists a  $t^L$ , which makes  $\lambda^F = 1$ . However, this  $t^L$  will multiplicatively depend on  $t^F$ . But it will imply  $t^F = 0 = t^L$ , hence all budget constraints would be violated. Therefore,  $\lambda^F > 1$  will hold again.

Using the expressions for  $t^L$  and  $t^F$ , we get the following results concerning the optimal provision of public inputs in the two types of regions:

$$(46') \quad F_p^L = \theta^L$$

$$(47') \quad \begin{aligned} F_p^H = & \lambda^F \theta^H + (\lambda^F - 1) \frac{n^L}{n^H} \frac{\partial \alpha^L}{\partial P^H} \\ & - \lambda^F \frac{t^F}{n^H} (n^H + n^L) S_r \frac{dr}{dP^H} \\ & - \lambda^F t^L \frac{n^L}{n^H} K_r^L \frac{dr}{dP^H} \end{aligned}$$

The federal government no longer distorts the public input decision in the low cost region. This is equivalent to the usual result of no distortion at the top of the type parameter distribution.

However, it distorts the capital input decision. Subsidizing capital employed in the low cost region will make misrepresentation less attractive for the L regions.

The input decision of the H-regions will be distorted in several intuitively reasonable ways. First, the actual cost of providing public inputs financed at social cost will be taken into account. Second, the impact on the informational rent of the L-regions will increase the cost of financing infrastructure in the H-regions. Third, the tax base effect will lower the effective marginal cost of providing additional public inputs  $P^H$ . Finally, increasing  $P^H$  reduces the stock of capital the L-regions have at their disposal. Hence at the margin the subsidy will have to be increased for capital to stay where there are more public inputs available. This increases the calculated costs for providing infrastructure to the H-regions.

We summarize this discussion as

**Proposition 2: Given asymmetric information and the ability to levy differentiated taxes on capital employed in both types of regions, the federal government will subsidize capital in the L-region. Furthermore, public inputs will be set according to (46') and (47'), which imply that**

- (1) **there will be no distortion in the input decision of the L-regions**
- (2) **the input decision of the H-regions will incorporate all distortions**

## 5. Welfare analysis

An explicit welfare analysis in the present model is complicated by the general structure employed. Some general conclusions may be derived based on the observation of binding constraints.

Welfare will be higher without informational constraints, as any information rents necessitated by them cause a welfare loss of  $n^L(\lambda^F - 1)$  at the margin, as long as distortionary taxes have to be employed. Without informational problems, either taxes could be reduced or more public inputs could be produced, increasing welfare.

More interesting is the comparison between the two regimes in section four. Although a uniform tax on capital is optimal in section three, using only a uniform tax on capital under asymmetric information vis-a-vis a differentiated tax structure is likely to be welfare inferior. The reason for this is that problem (26) is a variation of (40) with the additional implicit constraint that  $t^L = t^H = t$ . Adding another binding constraint cannot increase the value of the optimum of (26) compared to the value of the optimum of (40).

## 6. A numerical exploration

To further study the implications of the model, we conduct a numerical simulation in a model that is similar to those that has already been used in the literature on tax competition.<sup>19</sup> There are only **two** regions, one of each type. In addition to a **log-linear utility function**,  $u = \text{Log}[c_1] + c_2$ , we assume that the production function is Cobb-Douglas and of the form

$$F = A(K^i)^\alpha (P^i)^\beta, i = H, L.$$

In the simulation we set  $\alpha = .5$ ,  $\beta = .25$  and  $A = 10$ . We employ the following cost function for the public inputs:  $C^i(P^i) = P^i + \theta^i, i = H, L$ . In the table below we have employed  $\theta^L = 0$  and  $\theta^H = 10$ . Furthermore, the tax is levied not on the stock of capital but on capital income:  $(1+t)rK^i, i = H, L$ .

The reason for this variation is purely computational. As we have to determine the capital market equilibrium of the private sector both in a tax competition model with heterogeneous types and in the model under asymmetric information, a given production function may either not allow the determination of an explicit equilibrium rate of interest or may prevent the typical problems of asymmetric information from arising.<sup>20</sup>

The endowment of the representative agents is set to  $W = 100$ . Solving the model with these numerical values gives the following results for the model with asymmetric information:

**Table 1 here**

The first column refers to the reference case of complete information whereas the second column presents the results from the model with asymmetric information and a binding incentive compatibility constraint for the low-cost region. The third column depicts a tax competition situation where each regional government levies a source based capital income

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<sup>19</sup> See Bayindir-Upmann [1].

<sup>20</sup> For the Cobb-Douglas production function and linear costs of  $\theta^i P^i$  the numerical structure resulted in an equilibrium where the H-region wanted to misrepresent itself but could not and the L-region could misrepresent but did not want to imitate the H-region. Hence a separating equilibrium without an informational rent for the L-region could be maintained.



tax to finance its public inputs. Finally, in the last column a situation with lump-sum taxation is presented where each government gets the revenue to finance the optimal amount of public inputs.

The numerical results reveal that a federal government will induce an oversupply of the public input in the low-cost region relative to the first-best level. The utility of both regions in the optimum under asymmetric information will be lower than in the first-best which is no surprise. The tax competition results, on the other hand, reveal that both regions would have divergent interests if they were to decide whether they should form a federation. The low-cost region profits from tax competition and would only reluctantly enter a federation with the high-cost regions but for other political reasons.

Comparing the situation with and without informational asymmetries one sees that the sum of utilities is larger without informational problems but that the distribution is markedly different from that with asymmetric information. This would provide an incentive to the low-cost region to resist the implementation of measures designed to alleviate the informational asymmetries between itself and the federal government.

## 7. Summary and Conclusion

The purpose of the present paper was to study the impact of asymmetric information and instrumental availability on the supply of local public inputs in a federation that has only a distortionary tax on capital at its disposal. Tax decisions are taken centrally and expenditure decisions are under the authority of well-informed local governments. This situation resembles the Federal Republic of Germany where the federal government is the main source of revenue for the Länder governments.

It was shown that with uniform taxes on capital, public input decisions will be distorted for both types of regions to take into account the impact of these inputs on the informational rent of the  $L$ -cost regions and on the federal tax base.

If the federal government is able to levy differentiated taxes on capital, it will subsidize capital employed in the low cost regions to reduce the informational rent. This is more efficient than distorting the public input decisions of the low cost regions in this instrumental

and informational environment. Public input decisions by high-cost regions will have to incorporate the effects pertaining to tax base, informational rent and capital subsidy payments. Based on a general discussion about binding constraints it is argued that differentiated taxes on capital are welfare superior to a uniform tax on capital under asymmetric information in the present structure. In the presence of a binding incentive compatibility constraint, welfare under asymmetric information will be less than in the second-best.

A numerical exploration revealed how the level under asymmetric information in both regions deviates from the second-best optimum and the first-best optimum. A surprising result was that in the optimum under asymmetric information the local public input may be oversupplied in the low-cost region relative to the first-best level.

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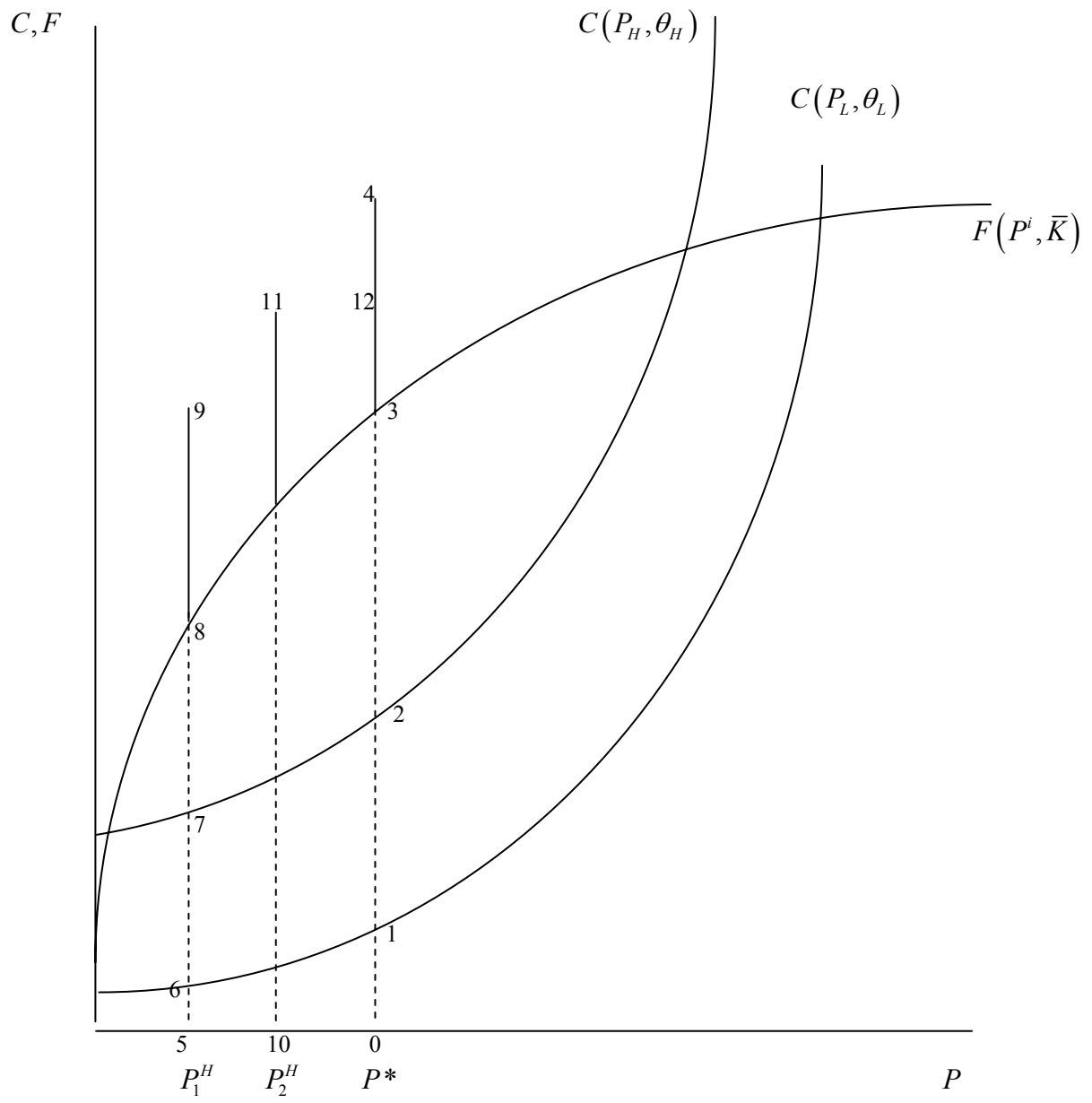
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Table 1

## Equilibrium Allocations

	Symmetric information, federal state	Asymmetric information, federal state	Tax competition	First-best, H- region pays $\theta_H$
$r$	0.687841	0.664229	0.780238	1.46535
$S$	98.5462	98.4945	98.7183	99.3176
$P^L$	71.5992	74.1149	59.0131	72.7675
$P^H$	71.5992	68.8847	39.1375	72.7675
$K^L$	98.5462	100.296	114.038	99.3176
$K^H$	98.5462	96.6927	83.399	99.3176
$U^L$	212.542	217.476	225.262	217.92
$U^H$	212.542	207.476	191.481	207.92
$U^L + U^H$	425.084	424.952	416.743	425.84
$t$	1.13005	1.2059	$t^L$ : 0.663244	
			$t^H$ : 0.755136	
$T^L$	71.5992	78.836	$t^L r K^L$ : 59.0131	
$T^H$	81.5992	78.885	$t^H r K^H$ : 49.1375	
$\alpha^L$		4.72109		
$\lambda^F$	1.01669	1.01846	$\lambda^L$ : 1.6805	
			$\lambda^H$ : 2.69732	

Figure 1



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