Congestion, Excludability and Endogenous Growth

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VI. Summary

I. Introduction

In the late 80ies, several investigations of David Alan Aschauer on the impact of productive government expenditures on the performance of an economy stimulated a broad line of research (see e.g. Aschauer 1989; 1988}. Within endogenous growth theory, an introduction of a productive governmental input first took place by Barro (1990) and later was adopted by various other authors (see e.g. Barro and Sala-I-Martin 1992), Futagami, Morita, and Shibata (1993), or Turnovsky (1992; 1993; 1995). While the assumption of the public input as pure public good is extreme, several investigations refrain from these restrictions and analyze public production inputs as club goods or public goods that are subject to congestion. If the public input is characterized by excludability, the optimal financing consists of fees only (see e.g. Ott 2000). This result may be interpreted as the application of the benefit-received principle in a dynamic context. Congestion effects and the resulting optimal financing implications also have been introduced within economic models by Buchanan (1965), Sharp (1966), Musgrave (1968), Samuelson (1969), Evans (1970), Oakland (1969; 1972) or Cornes and Sandler (1996). This question was applied to road congestion or local public goods e.g. by Walters (1961), Mohring and Harwitz ((1962), Johnson (1964), Vickrey (1969), Edwards (1990) or Konishi, Weber, and Le Breton (1997). An introduction of congestion effects into models of endogenous growth first took place by Barro and Sala-I-Martin (1992), Turnovsky (1995) as well as Turnovsky and Fisher (1998) who took up the idea that nearly all sorts of government expenditure are characterized by congestion. This led to the develop-

* I thank the anonymous referee for constructive comments.

ment of theoretical models of endogenous growth that make allowance for congestion. Within these models the degree of congestion plays a central role to deduce the impact of public investment on the rate of accumulation of private capital. An individual's decision to accumulate capital contributes to the stock of aggregate capital. This weakens the relation between governmental and private input and ends up in a decrease of productivity for the remaining individuals as long as the public input is not expanded to the same extent as private capital. As the individual considers his behavior as negligible for the resulting aggregate stock of capital a negative external effect of private capital accumulation arises. The public input is financed by a distortionary income tax and a neutral tax on consumption. As a consequence of congestion, a negative external effect of capital accumulation arises because the individuals perceive the marginal product of capital as too high. A distortionary tax on income reduces the incentive to accumulate capital and thereby internalizes the negative external effect. The consumption tax is then used to balance the governmental budget and thereby allows for production efficiency as well as for the optimal expenditure ratio.

The model developed in this paper combines the two aspects already mentioned: It analyzes within an endogenous growth model the implications of different financing modes if the productive public input is congested and excludability is possible. The possibility of exclusion enables the planner to charge user fees. Examples of such public goods are highways financed by tolls or airports. Besides, the government may levy taxes on consumption and income. Hence, the total public budget consists of taxes and fee revenues. A typical congestion function from the public goods literature is adapted that covers the cases of no congestion at all and proportional congestion as well as all intermediate cases of partial congestion (see e.g. Edwards 1990, Glomm and Ravikumar 1994 or Tunrovsky and Fisher 1998). With the use of the instruments of dynamic optimization the centrally and the decentrally chosen growth rates as well as the optimal expenditure ratio may be determined. The planned growth rate serves as benchmark to assess the decentral decisions and with this to derive the fiscal parameters that allow for production efficiency. To induce a welfare maximum, the optimal expenditure ratio together with the optimal growth rate have to be fixed simultaneously. It can be shown that in the case of no congestion the planner should allow for the possibility to exclude non-payers and charge user fees from the firms to finance the public input. It follows a financing that consists of fees only that aside from production efficiency also allows for the optimal expenditure ratio. The optimal financing implications are different if congestion arises: The individuals do not take into account that an expansion of their private capital contributes to the aggregate stock of capital. This causes a negative external effect as the capital accumulation reduces the individually available amount of the public input for all other individuals if the public input does not grow to the same extent. Hence, an individual's decision to enhance his capital stock has to provide sufficient resources from his output to leave the relation between public input and private capital unchanged. A distortionary tax on income reduces this incentive. If the budget is balanced in each period, a higher income tax rate goes along with a lower level of fees. To allow for production efficiency, exactly one combination of fee and tax rates has to be fixed. But the consequence of this relation is a suboptimally high level of the expenditure ratio that has to be reduced by a negative consumption tax until the expenditure ratio reaches the optimal level. Hence, the optimal financing mix crucially depends on the existing degree of rivalry of the public input. The income tax serves to internalize the negative external effect, the corresponding rate of fees then allows for production efficiency, and the tax on consumption is used in order to guarantee the optimal expenditure ratio.

The structure of the paper is as follows: After describing the assumptions of the model in part II, the first-best optimum, consisting of planned growth rate and optimal expenditure ratio, is derived in section III as reference to assess the decentral choices. Part IV analyzes the equilibrium of a decentralized economy. In part V it is then investigated which financing methods allow for the macroeconomic optimum as a result of the decentral choices. The optimal financing mixes are derived for all degrees of congestion and a discussion of the economic implications of the fiscal instruments follows. The paper concludes with a short summary.

II. The Model

The analysis' starting point is a model of endogenous growth with constant returns to scale in the accumulated inputs. Each of the identical individuals is facing an infinite planning horizon and maximizes overall utility, *U*, as given by

(1) $$U = \int_0^{\infty} u(c) e^{-bt} dt .$$

The function $u(c)$ relates the flow of utility to the quantity of individuals consumption, *c*, in each period. The discount factor, e^{-bt}, involves the constant rate of time preference, $b > 0$. The utility of the representative household in each period is given by

(2) $$u(c) = \frac{c^{1-s}}{1-s}, \quad s > 0, \quad s \neq 1.$$

Hence, the elasticity of marginal utility equals the constant $-s$. The supply of labor is inelastic, so that a labor-leisure-choice needs not to be considered. The constant population consists of *n* individuals. As the feature of congestion is analyzed within this model it is necessary to distinguish between aggregate and individual quantities.

Each firm in the model produces the homogeneous good, *y*. The production function is

(3) $$y = kf\left(\frac{G^a}{k}\right), \quad f'(\cdot) > 0 \quad f''(\cdot) < 0, \quad 0 < \frac{G^a}{k} < f(\cdot) .$$

y denotes production per capita, *k* represents the amount of capital available to the representative firm. It is depreciated at the rate d. The variable G^a represents the individually available amount of the publicly provided input *G*. A detailed discussion of the relation between G^a and G follows below in equation (4). The public input G is provided by the government and equals total quantity of the public good. Within this model the public input is not necessarily non-rival in the production process, but, as will be explained in the context of the congestion function, rivalry may occur.[1] Aside from congestion, the public input is also characterized by excludability. The marginal product of each input is positive but diminishing and the production function satisfies the Inada conditions. The last condition in equation {3) will guarantee that the resulting growth rate is positive. Below, Cobb-Douglas production is assumed.

To determine the optimal consumption and accumulation decisions, the nature of the public good and the restrictions, if any, of availability to the individuals have to be explained in a more detailed way. The individual's availability of the public input may be expressed by the congestion function

$$G^a = G \cdot k^{1-e} K^{e-1}, \quad e \in [0,1], \tag{4}$$

where $K \equiv nk$ denotes the aggregate stock of capital and e the degree of congestion. The absence of any congestion is represented by $e = 1$, in which case the public good is fully available to the representative agent. The other polar case, $e = 0$, corresponds to proportional congestion.[2] An increase in G relative to aggregate capital, K, expands individually available amount of the public input and with this output per capita, y, in equation (4) for a given amount of individual capital, k. On the other hand, an increase in K for given G lowers the public services available to the individual firms and thereby reduces y.[3] Besides, if $0 < e < 1$, equation (4) just represents intermediate cases in which the public input is subject to partial congestion.

The government provides the input G that apart from the characteristic of congestion also possesses the feature of excludability. Governmental production does not exist, as the public sector buys a part of aggregate private production, $Y \equiv ny$, and makes it available as a public input.[4] Public input G and total output Y may be transformed in a ratio of 1:1. The provision of the public input G is financed by duties levied to the firms. Since both inputs, private capital as well as the public input, are essential for production the firms cannot renounce on the use of the public input and have to accept any financing chosen by the planner. It is supposed that the government, represented by a social planner, levies proportional taxes on income and consumption with the tax rates t and w. In contrast to the tax on income, the tax on consumption has no distortionary effect on the allocation as labor-leisure-choice is not analyzed. Because of the possibility

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[1] The discussion of (partially) congested public goods is not new as can be seen e.g. by the investigations of *Buchanan* (1965); *Musgrave* (1968); *Samuelson* (1969b); *Evans* (1970) or *Oakland* (1972).

[2] This term is borrowed from *Turnovsky* and *Fisher* (1998).

[3] One could alternatively assume, that G has to rise in relation to total output Y in order for G^a / k to remain constant. The results would be essentially the same.

[4] Alternatively, one could suppose that the government disposes of the same production technology as the private firms and produces G. This assumption would not affect the results.

of excluding non-payers from the use of G, the planner may also charge a non-distortionary user fee, q, from the producers. Thus, the government has various possibilities of financing the provision of the public input: it may choose only taxes, only fees, or a mixture of both. Tax revenues then compensate the lower fees and vice versa. The benevolent social planner will determine the fiscal instruments in such a way that the optimal growth rate together with the optimal expenditure ratio results as a consequence of the decentral choices. Then, the utility attained by the representative agent is maximized.

The budget is balanced in each period, debts or government wealth as well as negative fees or tax rates do not exist. Thus, the public budget constraint, which is composed of aggregate revenues and aggregate expenditures, G, has the form[5]

$$G = tY + qG + wC \quad (5)$$

where $t = 0$, $w = 0$ $(q = 0)$ indicates financing solely by fees (taxes), and $t \neq 0$, $w \neq 0,$ $q \neq 0$ represents a mixed financing. The budget constraint can be re-written to represent the financial contribution of each firm to total public input as

$$\frac{G}{n} = ty + q\frac{G}{n} + wc \ . \quad (6)$$

Hence, different combinations of the instruments may be determined to attain a given level of the public budget.

III. First-Best Optimum

In this section the welfare maximizing growth rate f^* as well as the optimal expenditure ratio $\left(\frac{G}{ny}\right)^*$ are derived as a benchmark to assess the decentral choices and to determine the optimal fiscal policy. f^* is independent of the fiscal parameters, t, w, q, and can be realized as consequence of the decentralized decisions if tax rates and fees are determined adequately. By fixing the instruments the level of the resulting expenditure ratio is determined simultaneously.

Abstracting from government consumption, the central planning problem is to maximize the utility of the representative agent as given by equation (1) and (2) subject to the accumulation constraint

$$\dot{k} = kf(\cdot) - c - \frac{G}{n} - dk \ . \quad (7)$$

The formal representation of the planner's optimization problem thus leads to the following Hamiltonian

[5] C represents aggregate consumption $C \equiv nc$.

(8) $$H(c,k,G,l)=\frac{c^{1-s}}{1-s}e^{-bt}+l\left[kf(\cdot)-c-\frac{G}{n}-dk\right].$$

The social planner decides on the individual use of *c* and *k* as well as on the optimal amount of the public input, *G*. As the planner knows that aggregate capital is composed of total individual capital, $K=nk$, the congestion function in (4) simplifies to

(9) $$G^a=\frac{G}{n^{1-e}},\quad G^a\in\left[\frac{G}{n},G\right].$$

Maximizing over *c* and *k* leads to the equilibrium growth rate f^p

(10) $$f^p=\frac{1}{s}\left[f(\cdot)-f'(\cdot)\frac{G^a}{k}-d-b\right]$$

This is a well known growth rate within endogenous growth theory as it covers within the brackets the marginal product of capital as well as the rates of depreciation and time preference. To deduce the optimal growth rate f^*, the optimal ratio $(G^a/k)^*$ – or analogously $f'(\cdot)^*$ – has to be determined. This may be derived if the planner optimizes over the amount of the public input, *G*. The optimal amount of the public input is attained if the marginal benefits to productivity just match the unit resource costs of the additional government expenditure. Formally, this result may be derived by optimizing the Hamiltonian in equation (8) over the parameter *G*. This allows for production efficiency that guarantees a coincidence of marginal product and marginal costs of the public input and leads to the additional necessary condition

(11) $$f'(\cdot)n^e=1.$$

Besides, it may be shown that this condition also determines the optimal expenditure ratio, $\left(\frac{G}{ny}\right)^*$. Therefore, from equation (3) and (9) the relation

(12) $$\frac{G^a}{k}=\frac{G}{ny}f(\cdot)n^e$$

can be derived. Aside from this, for the production function (3), the partial production elasticity of the public input turns out to be

(13) $$h\equiv\frac{f'(\cdot)\frac{G^a}{k}}{f(\cdot)}.$$

Substituting equation (11) and (13) into (12) and solving for $\left(\frac{G}{ny}\right)^*$ leads to the optimal expenditure ratio that equals partial production elasticity of the public input, h. If the production function is assumed to be Cobb-Douglas, the optimal expenditure ratio is constant. Note that the optimality condition (11) also determines the optimal relation of $(G^a / k)^*$.

Substituting for equation (11), (12) and (13) in the growth rate (10) leads to the optimal growth rate determined by the social planner

(14) $$f^* = \frac{1}{s}\left[f\left(\frac{G^a}{k}\right)(1-h) - d - b\right].$$

The first term inside the brackets represents the social marginal return on capital: To maintain the expenditure ratio constant, an increase of *ny* by one unit requires an increase of *G* by h units. To calculate the social return on capital, the term $f(\cdot)$, which is the effect of *k* on *y* has to be adjusted by the factor $(1-h)$. The growth rate f^* determines the optimal consumption path and displays the characteristic that a reallocation of consumption may not increase lifetime utility of the representative individual. As the level of $f(\cdot)$ decreases with an increase in the rivalry, the optimal growth rate also depends on the existing degree of congestion, e. It satisfies the Keynes-Ramsey rule, according to which consumption per capita grows at a positive rate if the net marginal product of capital exceeds the rate of time preference. As in the model of Barro (1990}, the economy jumps into the steady-state, i.e. no transitional dynamics exist in the model. Moreover, within steady-state private consumption as well as governmental expenditure and output grow at the same constant rate.

IV. Equilibrium in a Decentralized Economy

In a decentralized economy, the optimal growth rate f^* together with the optimal expenditure ratio $\left(\frac{G}{ny}\right)^*$ may be reached if the government levies fees and taxes in an appropriate way to finance the public production input.[6] To determine the adequate financing instruments, the decentral growth rate has to be derived and both growth rates – planned and decentral – have to be compared. The optimal financing mix is then derived to identify levels of taxes and fees that result in a coincidence of both rates.[7]

The representative individual's optimization leads to the market equilibrium growth rate. The individual is confronted with the following circumstances: it utilizes his income for consumption, the payment of fees and taxes as well as for

[6] For a discussion of the impacts of different fiscal instruments and the role of the public sector see e.g. *Musgrave* (1959), *Atkinson* and *Stiglitz* (1980), *Stiglitz* (1986), *Bös* (1991), *Seitz* (1994), *Kapur* (1995), *Myles* (1995) or *Cornes* and *Sandler* (1996).

[7] Another way to derive the optimal financing instruments consists in proving that individual utility as given by equation (1) is maximized at the maximum level of the growth rate and then to determine the financing instruments that allow for a maximum of the growth rate.

the net accumulation of private capital. The intertemporal restriction of the private individual is then represented by the accumulation function

$$\dot{k} = (1-t)kf(\cdot) - (1+w)c - q\frac{G}{n} - dk \,. \tag{15}$$

Using equation (1), (2) and (15), the individual's optimization problem may be solved with the help of the following Hamiltonian

$$H(c,k,G,l) = \frac{c^{1-s}}{1-s}e^{-bt} + l\left[(1-t)kf(\cdot) - (1-w)c - \frac{qG}{n} - dk\right] . \tag{16}$$

In this optimization problem, the individual considers the congestion function (4) as given, thereby neglecting the fact that the aggregate stock of capital is composed of the sum of individual capital stocks. Hence, the individual ignores that his capital accumulation increases the stock of total capital and thereby reduces the amount of the public input available for the others thus causing congestion. The individual considers his own decision as negligible at the economy-wide level. To derive the equilibrium growth rate, the individual chooses *c*, *k* and – because of the possibility of exclusion – also *G*. The first-order conditions with respect to *c* and *k* lead to the decentral growth rate for a given level G^a / k that, using equation (4), turns out to be

$$f^d = \frac{1}{s}\left[(1-t)\left(f(\cdot) - ef'(\cdot)\frac{G^a}{k}\right) - d - b\right], \tag{17}$$

with $\left(f(\cdot) - ef'(\cdot)\frac{G^a}{k}\right)$ representing the private marginal product of capital. The growth rate depends on the same parameters as f^* and additionally on the level of the income tax rate as well as on the congestion parameter e. On the one hand, a positive level of the distortionary income tax t drives a wedge between private and social marginal product of capital for all levels of G^a / k. On the other hand, this wedge is also influenced by the degree of congestion: for all $e < 1$, the decentrally perceived before-tax marginal product of capital is too big compared to the effective marginal product. In this case, the individual only takes into account the productivity enhancing effect of an increase of private capital thus neglecting the productivity reducing effect that arises as consequence of increasing congestion. The wedge between individually perceived and effective marginal product increases with the degree of congestion (that is with a decrease of e).

As consequence of excludability the private firm also decides on the use of the input *G* and increases the demand of the public input until marginal product and marginal costs of the use of *G* are equalized. Making use of the relation $K = nk$, this yields the condition for production efficiency to determine the optimal level G^a / k as

(18) $$f'(\cdot)n^e = \frac{q}{1-t} ,$$

that compared to the planned condition for production efficiency in equation (11) also covers two of the three fiscal instruments. At the same time, equation (11) together with (18) formulate the unique relation of income tax rates and fees that allows for production efficiency, $q = 1-t$.

From equation (13) and (17) the following decentral growth rate arises

(19) $$f^D(t) = \frac{1}{s}\left[(1-t)(f(\cdot)(1-eh)) - d - b\right].$$

One may observe two counteracting effects within this growth rate: An increase in the degree of congestion $(e\downarrow)$ ceteris paribus ends up in a higher growth rate whereas a higher income tax rate reduces the decentral growth rate. The implications of these effects will be discussed in a more detailed manner in the next part.

V. Optimal Fiscal Policy

To close the gap between centrally and decentrally determined growth rates, the fee and tax rates have to be chosen appropriately. With this the utility-maximizing growth rate can be obtained as consequence of individual decisions. Besides, it is necessary to fix the expenditure ratio at the optimal level $\left(\frac{G}{ny}\right)^* = h$. In contrast to the congestion model of Barro and Sala-I-Martin (1995) or Turnovsky (1995), in which the income tax rate guarantees production efficiency and the tax on consumption is used to realize the optimal expenditure ratio, the rate of fees and the interdependencies between the fiscal instruments have to be taken into account. Because of the relation in equation (18), the optimal income tax rate depends upon the optimal rate of fees and vice versa, if production efficiency is to be reached. To fix one of the two rates automatically implies fixing the other one as well. At the same time, the corresponding level of public expenditure is influenced by such a decision (see equation (6)). The tax on consumption is then used to balance the budget in order to allow for the optimal expenditure ratio.

In the following part of the paper the optimal fiscal parameters are derived. Then, the two benchmark cases of proportional congestion $(e = 0)$ and no congestion $(e = 1)$ will be analyzed. We examine which combinations of the fiscal parameters lead to a coincidence of decentral and planned growth rates. Then follows a discussion of the intermediate cases of partial congestion, i.e. $0 < e < 1$.

Equating decentral and planned growth rates from equation (14) and (19) leads to the optimal income tax rate

(20) $$t_e^* = \frac{h(1-e)}{1-eh}, \quad t_e^* \in [0, h],$$

with $\partial t_e^* / \partial e < 0$. Hence, t_e^* increases with the degree of congestion and reaches a maximum at the level of the optimal expenditure ratio. Together with the conditions for production efficiency of the social planner (11) and the individuals (18), the corresponding rate of fees turns out to be

(21) $$q_e^* = \frac{1-h}{1-eh}, \quad q_e^* \in [1-h, 1],$$

with $\partial q_e^* / \partial e > 0$. The rate of fees increases as congestion decreases with a maximum level of one in the case of no rivalry $(e = 1)$. The implications of different levels of the fiscal parameters are as follows:

The case of no congestion $(e = 1)$: In the case of no rivalry, the optimal income tax rate is $t_1^* = 0$ and the corresponding optimal fee rate turns out to be $q_1^* = 1$. The optimal financing mix consists of pure financing by fees and the resulting expenditure ratio equals partial elasticity of production of the public input h, if the public budget is solely financed by these two instruments. At the same time, the optimal level of the consumption tax becomes zero. That is, the planner may realize production efficiency together with optimal expenditure ratio with a pure financing by fees. Both tax rates, t and w become zero. As consequence of the absence of rivalry, private capital accumulation in fact leads to an increase of the aggregate capital stock but this does not influence the productivity of the public input for the remaining individuals. There is no external effect that has to be internalized by a distortionary tax and no congestion costs arise. On the contrary, a transition from fees to a financing by income taxes would lower the decentral growth rate, thus inducing welfare losses as consequence of a suboptimally low growth rate. On the other hand a financing by a consumption tax would lead to a suboptimally high growth rate.

The case of proportional congestion $(e = 0)$: If the public input is proportionally congested the optimal financing implies an income tax rate that equals partial elasticity of the public input $t_0^* = h$ and a level of the fee rate $q_0^* = 1-h$. The income tax then internalizes the negative externality that arises from capital accumulation: An individual's decision to expand private capital gives rise to an increase in aggregate capital, thus reducing the individually available amount of the public input for the other firms. Hence, the productivity of private capital for all individuals decreases if the public input is not expanded by the same factor as the aggregate capital stock. To avoid the negative effect of private capital accumulation, a firm has to provide sufficient resources to expand the public input and thus to maintain the relation between aggregate capital and aggregate public input unchanged. A tax on income at the level of the expenditure ratio ends up in an increase of the public input in the required size. A reduction of the tax rate would result in a mixed financing and the economy would end up with excessive growth.

At the same time, in case of proportional congestion, the rate of fees is positive in order to allow for production efficiency, so that a mixed financing consisting of income taxes and fees results. But the planner has to take into account that aside from production efficiency, the income tax and the rate of fees also influence the amount of public expenditure and with this the expenditure ratio. If the public input is solely financed by the instruments already derived in equation (20) and (21) the arising expenditure ratio becomes unity if the level of the consumption tax is fixed at zero. Total output would be used to provide the public input with the consequence of a negative growth rate. In order to avoid that clearly suboptimal result, the consumption tax has to be used to lower the expenditure ratio until it reaches the optimal level h. It is obvious that, except in the case $e = 1$, the planner cannot realize production efficiency and optimal expenditure ratio simultaneously if income taxes and fees are his only instruments, that is, if the consumption tax is fixed at zero.

The level of the consumption tax may be determined explicitly for all levels of e by solving the public budget constraint (6) for w and using the optimal rates of fees q_e^* taxes t_e^* as well as the relation between consumption and capital. The latter ratio may be derived from the planners accumulation decision (7) and utilizing the planned growth rate (14) for the growth rate of capital. The consumption-capital-ratio turns out to be

(22) $$\frac{c}{k} = \frac{1}{s}\left[b - (1-s)\left(f(\cdot)(1 - \frac{G}{ny} - d\right)\right].$$

For the optimal level of the expenditure ratio, $\left(\frac{G}{ny}\right)^* = h$, the tax on consumption is

(23) $$w_e^* = \frac{sf(\cdot)(1-e)(h-1)}{[b-(1-s)[f(\cdot)(1-h)-d]][1-eh]} \leqq 0, \quad \forall e \in [0,1].$$

It takes on the value zero if there is no congestion $(e = 1)$ and is negative in case of congestion, as can be seen from the term $(h-1)$ in the numerator. In other words, w_e^* is negative if any congestion arises and reaches the minimum possible level for proportional congestion. Changes in the degree of congestion affect the optimal level of the consumption tax: $\partial w_e^* / \partial e > 0$. The implications are analogous to the cases of partial congestion and will be discussed there.

The case of partial congestion $(0 < e < 1)$: From equation (20), (21) and (23) it becomes obvious that the degree of rivalry influences the levels of all fiscal instruments in the following way

(24) $$\frac{\partial t_e^*}{\partial e} < 0, \quad \frac{\partial q_e^*}{\partial e} > 0, \quad \frac{\partial w_e^*}{\partial e} > 0,$$

where increasing rivalry goes along with a lower level of e . The optimal level of the income tax increases with growing congestion, whereas the contrary holds true for the rate of fees and the consumption tax rate. But one has to consider that the two instruments, q_e^* and t_e^* may not be used as substitutes in order to augment a suboptimally low level of the decentral growth rate. The consumption tax rate can be determined independently, whereas the rate of fees is related to the income tax rate via the conditions for production efficiency (equation (11) and (18)) that have to be fulfilled in the planned and the decentral economy. If congestion arises, the planner would induce a suboptimally high expenditure ratio $\frac{G}{ny} \in (h,1]$ if his budget consisted only of the income taxes and the fees. Besides, the wedge between optimal and effective expenditure ratio grows with the degree of congestion. Hence, the planner needs a third instrument that leaves the condition for production efficiency unchanged but allows for the optimal expenditure ratio. As already determined, the negative tax on consumption in equation (24) performs this taste.

The negative consumption tax may be interpreted as a governmental subsidy to consumption in order to augment the initial consumption level. If rivalry occurs the incentives for private capital accumulation are too big. Hence, a distortionary income tax that reduces this incentive is apt to internalize the negative externality arising from private capital accumulation. The corresponding level of the growth rate is reduced by the income tax. But at the same time, to allow for production efficiency, the higher tax rate goes along with a lower level of fees, thus increasing the incentive to individual capital accumulation as well as the corresponding growth rate. In the case of an optimal expenditure ratio, the total effect of an income tax on the growth rate is a suboptimally high growth rate, as the individuals perceive the marginal product of capital suboptimally high. Compared to the optimal levels, the incentive for capital accumulation increases and the consumption levels decrease. Hence, although the planner's intention to increase the income tax was to lower the level of capital accumulation he ends up with the opposite result. To subsidize private consumption gives rise to a higher level of consumption, thus reducing private capital accumulation and with this the resulting growth rate. The optimal level of the consumption subsidy increases with the degree of congestion.

VI. Summary

This paper investigates how a productive governmental input should be financed if the public input is characterized by excludability and congestion. Congestion is included by postulating a congestion function to represent the negative externality that arises from private capital accumulation in the case of congestion. All cases of rivalry, from the absence over partial until proportional congestion, are included within the formal representation. The possibility of exclusion enables the government to levy aside from taxes also user fees to finance the provision of the public input. After deriving the optimal and the decentral growth rates, it is analyzed which combination of fees and taxes leads to the coincidence of both growth rates, thus allowing for production efficiency. All fiscal instruments depend on the present degree of congestion. While the optimal income tax rate increases with congestion, the contrary holds true for the optimal rate of fees and consumption tax: They decrease with increasing congestion. But aside from production efficiency, the planner has to consider the resulting expenditure ratio. The optimal financing mixes for the two benchmark cases of no congestion and proportional congestion $(e = 0, e = 1)$, as well as for all intermediate cases of partial congestion $(0 < e < 1)$ are analyzed. It turns out that the optimal financing implications in the case of absence of rivalry give rise to a pure financing by fees. If congestion arises, a distortionary income tax is used to internalize the negative external effect induced by private capital accumulation. At the same time, because of an interdependency of income tax rate and rate of fees, the expenditure ratio becomes suboptimally high. Thus, a negative consumption tax is needed in order to guarantee an optimal level of the expenditure ratio. The explicit levels of all three instruments are derived and it is shown that production efficiency together with the optimal expenditure ratio results as consequence of the decentral decisions when these optimal policies are implemented.

Summary

This paper investigates within an endogenous growth model how a congested productive governmental input should be financed if exclusion is possible. The instruments are taxes and fees. To create the macroeconomic equilibrium the planner has to ensure production efficiency together with the optimal expenditure ratio. The optimal instruments depend on the degree of congestion. In case of no congestion only user fees are charged. If congestion exists, a distortionary income tax internalizes the negative external effect arising from capital accumulation. The fee is set to enable production efficiency and a negative consumption tax allows for the optimal expenditure ratio.

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