Growth, Congestion of Public Goods, and Second-Best Optimal Policy

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Summary

This paper presents a general equilibrium endogenous growth model in which public spending is divided between public productive services and public consumption. A distinguishing feature of the model is the assumption that both components of public spending can be over used and, thus, congested by the private agents. We study the second-best dynamics of the model and prove that it is determinate. Moreover, we show that the optimal second-best policy could be not unique. Finally, the relationship between congestion and the optimal second-best policy, on the one hand, and congestion and the long run growth rate, on the other, is established.

Keywords: Endogenous growth, Congestion, Public spending, Second-Best

JEL Classification: H3, H5, O4

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1. Introduction

The literature on endogenous growth has highlighted various channels, through which an economy obtains a positive long run growth rate without asking for exogenous factors, as it happens in neoclassical growth models. The seminal work in this field is Barro (1990), where public services are introduced as an input into the private firms production function, so as production exhibits constant return to scale with respect to private inputs and services of public capital. The impact of public spending on the private sector, however, is wider than that, thus many authors have brought in the distinction between productive and unproductive public spending. The former is seen as a productive input, the latter usually enters the representative household's utility function, increasing welfare.

In these general equilibrium models, an important question to investigate is how to implement an optimal policy using distortionary taxation, and to understand how public spending should be divided between these two different activities. In particular, our aim in this paper is to study the dynamics of government spending composition in a second-best framework in which the public sector cannot directly choose the path for consumption and private capital, but realize its policy taking into consideration an indirect utility function that depends on the policy instruments. Moreover, a distinguishing characteristic of our approach consists in making an allowance for an important feature of public goods (productive and unproductive), the evidence that they get congested when the private sector overuse them. Among others, Barro and Sala-i-Martin (1995, 1992) have suggested that basically all public services, even national defense always cited as the purest of public goods, in some degree suffers from congestion. It should, therefore, be clear that incorporating it in a model with public spending cannot be avoided.

Many papers have studied public spending composition both in a socially planned and in a decentralized economy - see, among others, Devarajan, Swaroop and Zou (1996), Turnovsky (1996), Turnovsky and Fisher (1995), Cashin (1995) - very few works have, however, analyzed the composition of public spending in a second-best framework and, to the best of our knowledge, no one has analyzed the dynamic behavior of these economies when congestion is explicitly taken into account.

Among those authors that, from a second-best perspective similar to ours, have contributed to a better understanding of these themes, Glomm and Ravikumar (1997, 1994) have explored the role of productive government spending in a second-best environment when congestion is considered as a feature of the public goods but without taking into account the possibility that public spending also enhances household's utility. In addition, Glomm and Ravikumar (1994) find that the second-best tax rate does not depend on the degree of congestion. On the contrary, we prove that congestion has an important role to play in designing the optimal second-best policy.

This work builds on Piras (2001) who deals with the long-run equilibrium of an economy in various frameworks of analysis: the decentralized equilibrium, the social planner (first-best) optimum and the second-best outcome. However, he neither studies the dynamics of the model, nor does he characterize the equilibrium solutions for the second-best optimal policy instruments as we do.

Amongst the main results, we find that the model can have two equilibria. A determinate equilibrium solution always exists and, as a typical feature, it is characterized by a low level of the income tax rate together with a high share of public spending devolved to productive investment. However, under some parametric configuration, a second determinate solution with a high income tax and a low share of public productive spending also exists.

The organization of the paper is the following. In section 2 we present the basic structure of the decentralized economy with households, firms and the government. Section 3 examines the behavior of the private agents and derives their optimality conditions. In section 4 the second-best optimal policy is obtained and the dynamics of the economy is analyzed. In addition, some policy implications are also discussed. The role of congestion in designing the second-best optimal policy, together with the empirical implications of the model, is presented in section 5. Finally, section 6 concludes with a summary of the main results, whereas the proofs of the various propositions are relegated in an appendix.

2. The Structure of the Decentralized Economy

We consider a continuous time infinite-horizon decentralized economy with a private and a public sector; the former is composed by homogeneous households and firms, the latter by the government. We assume that agents have perfect foresight and refrain from studying time-inconsistency problems.

2.1. Households

Let us assume that the representative household has the following instantaneous utility function:

$$u(c, c_p) = \log c + \beta \log c_p \qquad \beta \geq 0 \tag{1}$$

where c is private consumption, c_p are (public) government consumption services, and β measures the relative importance of public to private consumption. Following Turnovsky (1996) government consumption services are assumed to be given by:

$$c_p = G_c^{\delta}\left(\frac{G_c}{Y}\right)^{1-\delta} = G_c Y^{\delta-1}, \qquad 0 \leq \delta \leq 1 \tag{2}$$

Here G_c is government consumption expenditure, Y is aggregate output, and δ measures the degree of congestion associated with the public good feature of G_c. When $\delta = 0$ there is proportional congestion since in order for each consumer to benefit from G_c as Y increases, G_c has to increase at the same rate of Y. On the contrary, when $\delta = 1$ there is no congestion, the public good is non-rival, non-excludable and the private agents benefit from it independently from the size of the economy. In the more general case in which $0 < \delta < 1$, there is partial congestion and G_c can increase proportionally less than Y and, still, the level of public consumption good available to each consumer stays constant.

Households obtain a net income from holding a capital stock, given by $(1-\tau)rk$, where τ is the income tax rate, r is the return to capital and k is per capita capital. We assume that k is the only productive factor available to households or, putting it differently, that raw labour does not matter for growth. This assumption is standard in the endogenous growth literature and is congruent with the hypothesis that capital has to be interpreted as a composite factor encompassing both physical and human capital (qualified labor).

Let us indicate the time derivative of a variable with a dot over it, then it follows that the household's budget constraint is:

$$c + \dot{k} = (1-\tau)rk \tag{3}$$

where $\dot{k}$ is net investment (savings).

2.2. Firms

There are different possibilities of introducing public production services into the kind of model we are dealing with. In this work, we assume that they are publicly provided goods that get congested when an excessive use of them is made,[1] and suppose that the representative firm production function takes the following form:

$$y = Ak\left(\frac{G_I}{K}\right)^{\alpha} \tag{4}$$

where y is firm's output, G_I are public production services, K is the aggregate stock of private capital, i.e. $K = Nk$, where N is the constant number of identical firms, for convenience normalized to one (of course this implies $K = k$), $0 < \alpha < 1$ is the elasticity of output with respect to G_I, and $A > 0$ is a scale parameter. It immediately follows from (4) that, for a given amount of G_I, increasing the aggregate level of capital lowers the public services available to the individual firm. In order to expand the productive public services for each firm, the government should keep the ratio of public services to aggregate private capital constant.

2.3. Public Sector

The government runs a balanced budget in every period, taxing income and splitting up its revenues G between public consumption and public production services, G_c and G_I respectively:

$$G = \tau y = G_I + G_c = g_I G + (1 - g_I)G, \tag{5}$$

where g_I is the share of public spending devoted to public production services. It is clear that, when making their decisions, the private sector takes the two policy instruments, τ and g_I, as given. On the contrary, the government maximizes the welfare of the representative

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[1] Barro and Sala-i-Martin (1995, 1992).

household by choosing the policy variables under its control, *given* the private sector behavior.[2]

3. The Behavior of Households and Firms

In the decentralized equilibrium, the representative household maximizes the discounted flow of instantaneous utility:

$$\max_{\{c,k\}} \int_0^{\infty} e^{-\rho t}\left[\log c + \beta \log c_p\right] dt\,, \tag{6}$$

subjected to the household budget constraint (3), where $\rho > 0$ is the discount rate, and $k_0 > 0$ is given. As it is well known, the first order conditions for such a problem lead to the growth rate of private consumption:

$$\gamma = \frac{\dot{c}}{c} = (1-\tau)r - \rho\,, \tag{7}$$

and the transversality condition:

$$\lim_{t\to\infty} e^{-\rho t}\lambda k = 0\,, \tag{8}$$

where λ is the shadow price of capital.

As far as firms are concerned, they maximize profits and equalize the *private* marginal productivity of capital to its return, therefore, assuming also a zero depreciation rate, we have:

$$r = A\left(\frac{G_I}{K}\right)^{\alpha}. \tag{9}$$

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[2] An important question to investigate in the present framework would be the role of public debt: this comes next in our research agenda.

It is worth noticing that the *social* marginal productivity of capital is lower than (9), being equal to $r^{social} = (1-\alpha)r$, and this fact is due to the congestion of public production services which in not perceived by the private sector.

In the second-best, both households and firms regard the two policy instruments τ and g_I as given when taking their actions, whereas the government considers the private sector behavior as given and maximizes household's utility by optimally choosing τ and g_I. Let us express the return to capital as a function of the income tax rate and of the share of public spending on production services. Since public production services equal to $G_I = g_I \tau Y$, we have:

$$Y = \frac{G_I}{g_I \tau}. \tag{10}$$

By combining (4) and (10), we obtain:

$$G_I = B(g_I \tau)^{1/(1-\alpha)} k, \tag{11}$$

where $B = A^{1/(1-\alpha)}$, that, plugged into (9), yields:

$$r(g_I, \tau) = B(g_I \tau)^{\alpha/(1-\alpha)}, \tag{12}$$

which is the private return to capital as a function of the income tax rate and the share of public spending on investment.

As far as public consumption services are concerned, it is convenient to express them as a function of the two policy instruments and of the level of private capital. This is readily done by using (2), (4) and (11):

$$c_p(g_I, \tau, k) = B^{\delta} (1-g_I) g_I^{\delta\alpha/(1-\alpha)} \tau^{[1-\alpha(1-\delta)]/(1-\alpha)} k^{\delta}. \tag{13}$$

Equations (3), (7), (8), (12) and (13) thus summarize the decentralized competitive equilibrium.

4. Second-Best Optimal Policy

4.1. The Problem for the Government

In the real world the government cannot dictate the path of consumption or investment to the private sector; rather the public sector can manage an array of fiscal policy variables in order to achieve its goals. It follows that a second-best framework is more similar to the actual functioning of factual economies than both the socially planned and the decentralized ones. In such a framework, the government maximizes the representative household utility by choosing τ and g_I, but taking the evolution of consumption and private capital as constraints.[3] More formally, the optimization problem for the government is the following:

$$\max_{\{\tau, g_I\}} \int_0^\infty e^{-\rho t}\left[\log c + \beta \log c_p\right]dt \tag{6a}$$

$$\text{s. t.} \quad \dot{k} = (1-\tau)rk - c \tag{3a}$$

$$\dot{c} = \left[(1-\tau)r - \rho\right]c \tag{7a}$$

$$r(g_I, \tau) = B(g_I \tau)^{\alpha/(1-\alpha)}, \tag{12}$$

$$c_p(g_I, \tau, k) = B^\delta (1-g_I) g_I^{\delta\alpha/(1-\alpha)} \tau^{[1-\alpha(1-\delta)]/(1-\alpha)} k^\delta , \tag{13}$$

As it can be seen, the government plays as a Stackelberg leader and maximizes the welfare of the representative household taking the decentralized equilibrium as a constraint. Let μ_1 and μ_2 be the multipliers associated with (3a) and (7a) respectively, setting up the hamiltonian function and deriving the optimality conditions yields the following first order conditions:

$$\beta\left[1 - \alpha(1-\delta)\right] + \left[\mu_1 k + \mu_2 c\right] r(\alpha - \tau) = 0 , \tag{14}$$

$$\beta\left[\alpha\delta - g_I\left(1 - \alpha(1-\delta)\right)\right] + \alpha\left[\mu_1 k + \mu_2 c\right](1-g_I)(1-\tau)r = 0 , \tag{15}$$

$$-\dot{\mu}_1 = \frac{\beta\delta}{k} + \mu_1\left[(1-\tau)r - \rho\right], \tag{16}$$

$$-\dot{\mu}_2 = \frac{1}{c} - \mu_1 + \mu_2\left[(1-\tau)r - \rho\right] - \rho\mu_2, \tag{17}$$

and the requirement that utility must be bounded or, equivalently, that along the balanced growth path (BGP henceforth) the growth rate of the economy must be lower than the discount rate.

4.2. A Brief Discussion of the Second-Best Optimality Conditions

Equations (14) and (15) can be combined to get a negative relationship between the optimal second-best income tax rate $\bar{\tau}$, and the optimal second-best share of government spending devoted to public production services $\bar{g}_I$:[4]

$$\bar{g}_I = \frac{\left[1-\bar{\tau}(1-\delta)\right]\alpha}{\left[1-\alpha(1-\delta)\right]\bar{\tau}}. \tag{18}$$

It is interesting to point out that equation (18), that holds also with a more general isoelastic utility function and does not depend on preferences parameters, must be true in each time period and this fact can be interpreted in the following sense: when the public sector increases public spending on production services, it makes private capital more productive, hence output increases and, for a given amount of public revenues, the income tax rate can be decreased. From a different perspective, in order to maximize welfare which depends also on public consumption, the government can levy a high income tax rate and devolve a low level of its revenues to public production services, that is an elevated amount of public spending is devoted to public consumption.

A second point worth stressing is that if $\beta = 0$, then from (14) it follows $\bar{\tau} = \alpha$ and this from (18) implies $\bar{g}_I = 1$. Intuitively, when public consumption has no role in the utility of the representative household, then the second-best optimal policy implies, on the one side,

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[3] Arrow and Kurz (1970) study the second-best approach in the framework of the neoclassical growth model.

[4] Henceforth, a dash over a variable indicates its second-best optimal value.

that all public spending should be on public production services and, on the other side, that the income tax be equalized to the elasticity of output with respect to *G_I*. This is the well-known Barro (1990) result that, however, in the more general case we are analyzing, that is when $\beta > 0$, does not hold anymore. As a matter of fact, given the inverse relationship between $\bar{\tau}$ and $\bar{g}_I$, whenever $\bar{g}_I < 1$ it follows that $\bar{\tau} > \alpha$ or, saying it in other words, the second-best income tax rate is higher than the income tax that maximizes the BGP growth rate.[5]

4.3. The dynamics of the second-best

In order to study the model dynamics, we need to introduce a new variable, given by the consumption to capital ratio, which stays constant along the BGP. To accomplish that, we define $x \equiv c/k$, differentiate it with respect to time and use (3) and (7) to find that:

$$\dot{x} = x^2 - \rho x . \tag{19}$$

It is interesting to highlight that neither τ nor g_I appear in (19), and (see below) since in the dynamic equations for these two variables x does not enter either, it follows that the dynamics for τ and g_I is independent from x and vice versa.

As far as the dynamic equations for τ and g_I are concerned, we differentiate (14) and combine the result with (3a), (7a), (16) and (17) to get:

$$\frac{\dot{r}}{r} - \frac{\dot{\tau}}{\alpha - \tau} = \theta(\tau - \alpha)r - \rho , \tag{20}$$

where $\theta = (1+\beta\delta)/\beta[1-\alpha(1-\delta)] > 0$ simplifies the notation. Now, differentiating (12) and plugging the result into (20), after some algebra yields:

$$\frac{\dot{\tau}}{\tau} = \left[\frac{(\alpha-\tau)(1-\alpha)}{(1-\alpha)\tau - \alpha(\alpha-\tau)}\right]\left[\rho + \left(\frac{\alpha}{1-\alpha}\right)\frac{\dot{g}_I}{g_I} + \theta(\alpha-\tau)(g_I\tau)^{\alpha/(1-\alpha)}B\right]. \tag{21}$$

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[5] For a more general discussion on these points, see Piras (2001).

We need to find another equation linking the evolution of τ and g_I; this can be done by differentiating (18) with respect to time:

$$\frac{\dot{g}_I}{g_I} = -\left[\frac{1}{1-\tau(1-\delta)}\right]\frac{\dot{\tau}}{\tau}. \tag{22}$$

Equations (21) and (22) form a system in two unknowns, the growth rates of the two policy instruments, and although time consuming, it is possible to find an explicit form solution for it given by:

$$\dot{g}_I = \frac{g_I}{\tau}\Omega(\tau)\Sigma(\tau, g_I), \tag{23}$$

$$\dot{\tau} = [\tau(1-\delta)-1]\Omega(\tau)\Sigma(\tau, g_I), \tag{24}$$

where:

$$\Omega(\tau) = \left[\frac{(\tau-\alpha)(1-\alpha)}{[1-\tau(1-\delta)]-\alpha[1-\alpha(1-\delta)]}\right], \tag{25}$$

$$\Sigma(\tau, g_I) = \left[\rho + \theta(\alpha-\tau)(g_I\tau)^{\alpha/(1-\alpha)}B\right]. \tag{26}$$

Thus, equations (19), (23) and (24) summarize the model dynamics. However, the discussion regarding the relationship between $\bar{\tau}$ and $\bar{g}_I$ given in the previous subsection has made it clear that these two policy instruments must always move in opposite direction in order for equation (18) to hold and for the optimality conditions (14) and (15) to be satisfied. Putting it differently, the two policy instruments $\bar{\tau}$ and $\bar{g}_I$ are not independent each other and, as a consequence, one of the two dynamic equations (23) or (24) can actually be dropped because it is redundant. This is the reason why we plug (18) into (26), so that the function $\Sigma(\tau, g_I)$ actually becomes a function of τ alone, and study the dynamics of equations (19) and (24) instead of (19), (23) and (24).

Local stability analysis techniques near the equilibrium are easily applied to this two equations system, in order to find the following Jacobian matrix evaluated at the BGP:

$$J = \begin{bmatrix} \rho & 0 \\ 0 & \Psi(\bar{\tau}) \end{bmatrix}, \tag{27}$$

where it is shown in the Appendix that:

$$\Psi(\bar{\tau}) = \left[\bar{\tau}(1-\delta) - 1\right]\Omega(\bar{\tau})\frac{\partial \Sigma(\bar{\tau})}{\partial \bar{\tau}} > 0 . \tag{28}$$

The following proposition states the main result about the dynamics of the model:

Proposition 1: the two eigenvalues associated with the determinant of the Jacobian matrix (27) are $\kappa_1 = \rho > 0$ and $\kappa_2 = \Psi(\bar{\tau}) > 0$.

Proof: see the Appendix.

Proposition 1 states that the dynamics of the system is, from the mathematical point of view, unstable. In this model such a result implies that all the endogenous variables, x, τ and g_I, jump immediately to the BGP without transitional dynamics and that, beginning from time zero, it actually behaves as an *Ak* model *à la* Rebelo (1991). In other words, given the initial level of capital stock k_0, there is a unique initial value for c_0, τ_0 and g_{I0}, which corresponds to their long-run value, such that the economy reaches the BGP equilibrium that turns out to be determinate.

It is worth noticing that if we linearized equations (19), (23) and (24), we would found two positive and a zero eigenvalue, (i. e. a singular Jacobian matrix) meaning that one equation of the three dimensional linearized dynamic system is a linear combination of another one. This fact is not surprising at all, since from the economic point of view, given the inverse relationship between $\bar{\tau}$ and $\bar{g}_I$, then only one of these two policy instruments can be independently chosen by the government, the other being residually obtained through (18).

However, this is not the end of the story, in the next subsection we will see that, under some parametric configurations, it could be the case that the policy maker can choose between two types of fiscal policies rules: the first type is one in which a high level of the income tax is coupled with a low level of public spending on productive services; the second one, on the contrary, is characterized by a low level of the income tax rate together with an high level of public spending devoted to public production services.

4.4. Optimal Second-Best Values of the Policy Variables.

Given that $\dot{\bar{\tau}} = 0$ and $\dot{\bar{g}}_I = 0$ must be true in every time period, if we go back to (23) and (24), it is clear that the only possibility for such a result to hold, is that equation (26) be zero,[6] that is:

$$\Sigma(\bar{\tau}, \bar{g}_I) = \left\lfloor \rho + \theta\left(\alpha - \bar{\tau}\right)\left(\bar{g}_I\bar{\tau}\right)^{\alpha/(1-\alpha)} B \right\rfloor = 0 \,. \tag{29}$$

Thus, we have a non-linear two equations system, (18) and (29), that in spite of being impossible to solve analytically with respect to $\bar{\tau}$ and $\bar{g}_I$, it yields an implicit definition of the two policy instruments with respect to preferences, technology and congestion parameters. This result points out that the second-best optimal policy cannot be spelled out without taking congestion into account, and contrasts sharply with Glomm and Ravikumar (1994) who find that congestion externalities springing from public goods does not affect the design of the optimal second-best policy.[7]

Characterizing a solution is not an easy job, however. To accomplish such a task, first we differentiate (29) to find that:

$$\frac{d\bar{g}_I}{d\bar{\tau}} = -\frac{\bar{g}_I\left(\bar{\tau} - \alpha^2\right)}{\bar{\tau}\left(\bar{\tau} - \alpha\right)\alpha} < 0 \,. \tag{30}$$

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[6] The other possibility for $\dot{\bar{\tau}} = 0$ and $\dot{\bar{g}}_I = 0$ to be true, is that $\tau = \alpha$ in (25). However, this is not possible since we already know that in the second-best $\bar{\tau} > \alpha$.

[7] See below for the way in which congestion affects the optimal policy.

Therefore, the relationship between the optimal second-best income tax rate and the share of public spending on productive services implicitly defined by (29), as one would expect, is negative too. Second, we differentiate (18) obtaining:

$$\frac{d\bar{g}_I}{d\bar{\tau}} = -\frac{\alpha}{\left[1-\alpha\left(1-\delta\right)\right]\bar{\tau}^2} < 0 . \tag{31}$$

By comparing (30) and (31), we find:

Proposition 2: let $\tau_{cr} = \left(1-\delta\right)^{-1} - \left(1-\delta\right)^{-1}\alpha + \alpha^2$:

(i) if $\bar{\tau} < \tau_{cr}$, then (31) is greater than (30);

(ii) if $\bar{\tau} > \tau_{cr}$, then (30) is greater than (31).

Proof: see the Appendix.

Proposition 2 defines a critical value for the income tax rate below which (29) is steeper than (18), and vice versa, but it says nothing on whether they actually intersect. As a matter of fact, without investigating further, we cannot be sure that a feasible couple of $\bar{\tau}$ and $\bar{g}_I$ exist such that (29) and (18) are mutually satisfied, nor that they intersect only once. The following three propositions establish existence, uniqueness or multiplicity and feasibility.

Proposition 3: when $0 \le \delta < 1$ and $\alpha\delta/\left[1-\alpha(1-\delta)\right] > \left[\rho/\left(\theta(1-\alpha)\right)\right]^{(1-\alpha)/\alpha}$, then two couples of $\bar{\tau}$ and $\bar{g}_I$ exist such that equations (29) and (18) are verified. Let us call $\left(\bar{\tau}^L, \bar{g}_I^H\right)$ and $\left(\bar{\tau}^H, \bar{g}_I^L\right)$ these two pairs, where *H* and *L* mean high and low, respectively; then $\left(\bar{\tau}^L, \bar{g}_I^H\right)$ is such that $\alpha < \bar{\tau}^L < 1$ and $\alpha\delta/\left[1-\alpha(1-\delta)\right] < \bar{g}_I^H < 1$, whereas $\left(\bar{\tau}^H, \bar{g}_I^L\right)$ implies $\bar{\tau}^H > 1$ and $0 < \bar{g}_I^L < \alpha\delta/\left[1-\alpha(1-\delta)\right]$.

Proof: see the Appendix.

A visual description of Proposition 3 is given in Figure 1 which clearly shows that it could be the case that, although the optimal second-best values for the policy variables are not unique, one solution is not feasible since it would imply an income tax rate higher than one, thus we are left with only one candidate for the equilibrium (see below for a more general discussion).

Figure 1 here.

Proposition 4: when $0 \leq \delta < 1$ and $\alpha\delta/[1-\alpha(1-\delta)] < [\rho/(\theta(1-\alpha))]^{(1-\alpha)/\alpha}$, then there exist two couples of $\bar{\tau}$ and $\bar{g}_I$, $(\bar{\tau}^L, \bar{g}_I^H)$ and $(\bar{\tau}^H, \bar{g}_I^L)$, such that equations (29) and (18) are jointly verified; in both cases $\alpha < \bar{\tau}^j < 1$ and $\alpha\delta/[1-\alpha(1-\delta)] < \bar{g}_I^i < 1$, where *j*, *i* = *H*, *L*.

Proof: see the Appendix.

Figure 2 here.

Figure 2 portraits a visual description of Proposition 4, corroborating, in fact, that both $(\bar{\tau}^L, \bar{g}_I^H)$ and $(\bar{\tau}^H, \bar{g}_I^L)$ lie into the unitary interval. In addition, when congestion is proportional ($\delta = 0$), the inequality $\alpha\delta/[1-\alpha(1-\delta)] < [\rho/(\theta(1-\alpha))]^{(1-\alpha)/\alpha}$ reduces to $(\beta\rho)^{(1-\alpha)/\alpha} > 0$, which always holds, and we have the following:

Corollary 1: when $\delta = 0$ there exist two couples of $\bar{\tau}$ and $\bar{g}_I$ such that $\alpha < \bar{\tau}^j < 1$ and $0 < \bar{g}_I^i < 1$, where *j*, *i* = *H*, *L*.

Figure 3 here.

Corollary 1 is graphically depicted in Figure 3, in which it is shown that an economy that undergoes proportional congestion faces either a high income tax coupled with a low share of public spending on productive investment, or a low income tax combined with a high share of public spending devoted to public production services.

Finally, when the public consumption good does not suffer from congestion, Proposition 5 clearly establishes the existence of a unique feasible solution.[8]

Proposition 5: when $\delta = 1$, if $\alpha^{\alpha/(1-\alpha)}(1-\alpha) > \rho\beta/(1+\beta)$, then two couples of $\bar{\tau}$ and $\bar{g}_I$ exist such that equations (29) and (18) are verified. Let us call $(\bar{\tau}^L, \bar{g}_I^H)$ and $(\bar{\tau}^H, \bar{g}_I^L)$ these two pairs; then $(\bar{\tau}^L, \bar{g}_I^H)$ is such that $\alpha < \bar{\tau}^L < 1$ and $\alpha < \bar{g}_I^H < 1$, whereas $(\bar{\tau}^H, \bar{g}_I^L)$ implies $\bar{\tau}^H > 1$ and $0 < \bar{g}_I^L < \alpha$.

Proof: see the Appendix.

Figure 4 here.

Figure 4 is quite similar to Figures 1. The difference is that when $\delta = 1$, both equations (18) and (29) imply that as $\bar{g}_I \to 0$, $\bar{\tau} \to \infty$.

4.5. Discussion and Policy Implications

The previous subsection has shown two possible outcomes for the second-best optimal policy, the first is one in which there exist two solutions, one of which feasible and the other

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[8] It should be pointed out that the restriction $\alpha^{\alpha/(1-\alpha)}(1-\alpha) > \rho\beta/(1+\beta)$ is almost superfluous, since for realistic values of parameters, it always holds, and it is necessary to assume values of α close to one to reverse it.

unfeasible, let us call it outcome A, while the second envisages two feasible solutions (outcome B).

The feasible solution of outcome A is characterized by a relatively low value for the income tax rate and a relatively high value for the share of government spending on public investment $\left(\bar{\tau}^{L}, \bar{g}_{I}^{H}\right)$. In other words, welfare maximization implies that the size of the government should be small but, at the same time, a large amount of public spending should be devoted to productive public services.

Outcome B, which is more likely to occur in economies where congestion externalities are elevated, hints at the possibility of two solutions for the optimal second-best policy: the first one is similar to the feasible solution of outcome A, while the second is one in which a high level of the income tax is coupled with a low level of public spending on productive services $\left(\bar{\tau}^{H}, \bar{g}_{I}^{L}\right)$. It is very difficult to measure welfare, and thus utility levels, that the representative household obtains in these two solutions: it could be the case that they yield the same welfare, but it could also be not. If the utility levels are different, then the government has no alternative but to choose the solution with the higher welfare. On the contrary, if the utility levels are the same, then the government can select between a policy with a high income tax and a low share of public production services, on the one hand, and a low income tax and a high share of public production services, on the other. However, given outcome A, it seems more likely that welfare levels could differ between these two solutions, and that, in such an event, solution $\left(\bar{\tau}^{L}, \bar{g}_{I}^{H}\right)$ would be preferred.

These findings suggest that countries in which the public sector is large and, at the same time, the share of public spending on productive services is small, reach a lower level of welfare with respect to countries in which, on the contrary, the government keeps its share of output low and, prevailingly, devolves its spending to the private sector in the form of productive services, rather than consumption services. Karras (1996) reports that, in developing countries, the average size of the government is increasing, contrary to what is happening in developed countries, in which it is decreasing. Had we evidence of the public production services shares trends, we could infer more definite statements about welfare tendencies in those countries. We think that this is an open question that deserves to be further investigated at the empirical as well as the theoretical level.

5. Congestion, Second-Best Optimal Policy and Empirical Implications

In order to investigate more deeply on the optimal second-best policy, particularly on the way in which it depends on congestion, totally differentiating equations (18) and (29) with respect to δ we find:

Proposition 6: assume $\beta \geq \alpha/(1-\alpha)$, when the second-best optimal policy is $\left(\bar{\tau}^L, \bar{g}_I^H\right)$, then an increase in the degree of congestion increases $\bar{\tau}^L$ and decreases $\bar{g}_I^H$. On the contrary, when the second-best optimal policy is $\left(\bar{\tau}^H, \bar{g}_I^L\right)$, then an increase in the degree of congestion decreases $\bar{\tau}^L$ and increases $\bar{g}_I^H$.

Proof: see the Appendix.

Obviously, when the feasible optimal policy is unique as in outcome A, then an increase of congestion invariably boosts the income tax and lessens the share of public spending on investment. However, when outcome B is relevant and congestion turns out to be stronger, the government pursues different strategies, depending on which of the two optimal policies has been followed ever since.[9] In such an eventuality, as a reaction to a worsening in congestion externalities, we should empirically observe differences across economies in the

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[9] We are implicitly assuming that the variation of δ does not change any of the inequalities on which sufficient conditions have been given.

conduct of fiscal policy. Unfortunately, this kind of evidence, to the best of our knowledge, does not exist.

As a final remark, notice that differentiating equation (7) with respect to δ, we get:

$$\frac{\partial\gamma}{\partial\delta}=\frac{r}{(1-\alpha)}\left\{\left[\frac{\alpha-\bar{\tau}}{\bar{\tau}}\right]\frac{\partial\bar{\tau}}{\partial\delta}+\left[\frac{\alpha(1-\bar{\tau})}{\bar{g}_I}\right]\frac{\partial\bar{g}_I}{\partial\delta}\right\}. \tag{32}$$

Corollary 2: under the $\left(\bar{\tau}^L,\bar{g}_I^H\right)$ equilibrium, an increase in the degree of congestion lowers the growth rate; whereas if the equilibrium solution is $\left(\bar{\tau}^H,\bar{g}_I^L\right)$, then an increase in the degree of congestion speeds it up.

From the empirical point of view, Corollary 2 implies that in economies in which the solution is of the $\left(\bar{\tau}^L,\bar{g}_I^H\right)$ type, we should observe lower growth rates as a consequence of an increase of congestion, whereas countries with a $\left(\bar{\tau}^H,\bar{g}_I^L\right)$ type solution should display higher growth rates as a reaction to higher congestion externalities. Unluckily, measuring the degree of congestion of public goods at aggregate national level is not an easy task and, as far as we know, it has not yet been performed. However, in a sample of California counties during the years from 1977 to 1988, Boarnet (1997) finds that congestion reduction of streets and highways is productive. As a matter of fact, this author suggests that, in order to increase productivity, the reduction of congestion of existing infrastructure services is probably more efficient than expanding them by building new ones. In addition, working with a general equilibrium model for Ohio, Seung and Kraybill (2001) hint at the likelihood that accounting for congestion in the use of infrastructure has a negative, though slight, impact on regional output. Thus, the little empirical evidence we have so far broadly accords with $\left(\bar{\tau}^L,\bar{g}_I^H\right)$ type solution, but further empirical research has to be done in order to test for the theoretical findings we have reached.

As a final general reflection, these results can help to shed new light also on the empirically observed cross-sectional differences in growth experiences amongst nations. Indeed, one of the main causes called for to explain the astonishing dissimilarities in the growth process among countries, has been found in the conduct of fiscal policy by the governments. If, from the theoretical perspective of the endogenous growth theory, such an influence is hard to dispute, from the empirical viewpoint, no general consensus exists yet. Among others, Kormendi and Meguire (1985) found no evidence that the growth rate is affected by government consumption, Barro (1990) and Ram (1986), on the contrary, reported a significant role of public spending on growth, but Levine and Renelt (1992) showed that the growth rate of government consumption has only a fragile relationship with the growth rate of output.[10] Perhaps, these mixed, and in some sense disappointing, results are imputable, as suggested by Tanzi and Zee (1997, p.200), at "…the different time horizon contemplated by the public finance economists and the growth theorists." Anyhow, further research has to be done to asses the role of public spending, and of its composition, on the growth process of both developed and developing economies.

5. Conclusions

In this paper we have investigated the second-best solution of a general equilibrium endogenous growth model with public consumption services and productive public spending. An important and distinguishing characteristic of the model we have proposed is the presence of congestion externalities associated to the public goods. Since this fact is considered as peculiar of almost all public goods, it is surprising that, up to now, very few works have investigated it in a context of growth.

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[10] The list of empirical works dealing with the role of public spending on growth is very long, for a survey, see Tanzi and Zee (1997) and references therein.

We think that a second-best framework is closer to the actual functioning or real world economies than both the centralized and the decentralized framework. In such a structure, firstly both firms and households take their optimal decisions regarding savings and consumption, secondly the government takes the decentralized equilibrium as a constrain and maximizes households welfare.

The dynamics of the model is determinate: given the initial level of private capital, there exists a unique value for the initial level of consumption and the policy instruments, such that the economy reaches the BGP equilibrium. This result implies that transitional dynamics is absent in the model and that the economy is always on its long run equilibrium that, however, might be not unique. Depending on parameters configuration, we have shown that it is possible to obtain multiple solutions as well as a unique solution. When the final outcome yields two equilibria, we have found that one of them is characterized by a relatively low income tax rate coupled with a relatively high share of public spending on public production services, the other, on the contrary, by a relatively high income tax coupled with a relatively low share of public production services. An increase in congestion causes an increment of the income tax and a reduction of both the share of public spending on production services and the growth rate, in the former case; a reduction of the income tax and a boost of the share of public spending on public production services and the growth rate, in the latter. If the solution is unique, then the equilibrium is characterized by a relatively low income tax rate and a relatively high share of public spending on public production services, qualitatively similar to the first kind of equilibrium.

Finally, as far as the empirical implications are concerned, the inverse relationship between the degree of congestion of public goods and the growth rate of output, seems confirmed in the very few works that have dealt with such an issue, thus indirectly pointing out to a greater relevance of the $\left(\bar{\tau}^{L}, \bar{g}_{I}^{H}\right)$ solution: further research, however, has to be done.

Appendix

A.1 Proof of Proposition 1

The matrix (27) is diagonal, hence the eigenvalues are those given in the proposition. In order to prove that $\kappa_2 = \Psi(\bar{\tau}) = [\bar{\tau}(1-\delta)-1]\Omega(\bar{\tau})\dfrac{\partial\Sigma(\bar{\tau})}{\partial\bar{\tau}} > 0$, tedious computations show that the sign of $\Omega(\bar{\tau})$ and $\partial\Sigma(\bar{\tau})/\partial\bar{\tau}$ depends on $\bar{\tau}$ being greater or smaller than a critical value of the income tax: $\tau_{cr} = (1-\delta)^{-1} - (1-\delta)^{-1}\alpha + \alpha^2$. More precisely, if $\bar{\tau} < \tau_{cr}$, then $\Omega(\bar{\tau}) > 0$ and $\partial\Sigma(\bar{\tau})/\partial\bar{\tau} < 0$; on the contrary, if $\bar{\tau} > \tau_{cr}$, then $\Omega(\bar{\tau}) < 0$ and $\partial\Sigma(\bar{\tau})/\partial\bar{\tau} > 0$. Both cases lead to $\kappa_2 > 0$.

A.2 Proof of Proposition 2

It is simply matter of algebra; it suffices to substitute equation (18) for $\bar{g}_I$ into equation (30), to see that the Proposition holds.

A.3 Proof of Proposition 3

For simplicity, let us set $B = 1$. We need to prove that the inequalities $0 \leq \delta < 0.5$ and $\alpha\delta/[1-\alpha(1-\delta)] > [\rho/(\theta(1-\alpha))]^{(1-\alpha)/\alpha}$ are sufficient for the existence of $(\bar{\tau}^L, \bar{g}_I^H)$ and $(\bar{\tau}^H, \bar{g}_I^L)$, where the former is feasible, while the latter is infeasible. For a better understanding, looking at Figure 1 is useful.

Firstly, we see that when $\tau = 1$, (18) and (29) yield, respectively, $g_I = \alpha\delta/[1-\alpha(1-\delta)]$ and (not marked in Figure 1) $g_I = [\rho/(\theta(1-\alpha))]^{(1-\alpha)/\alpha}$: this proves that for $\tau = 1$, equation (18) lies above (29). Secondly, when $\tau = 1/(1-\delta) > 1$, (18) is zero, whereas (29) (not marked in Figure 1) equals $g_I = [\beta\rho(1-\delta)/(1+\beta\delta)]^{(1-\alpha)/\alpha}(1-\delta) > 0$: this proves that for $\tau = 1/(1-\delta)$, (29) is above (18). Thus, we have shown that there exists a pair such as $\left(\bar{\tau}^H, \bar{g}_I^L\right)$, with $\bar{\tau}^H > 1$ which is infeasible.

Now, we have to prove that a feasible $\left(\bar{\tau}^L, \bar{g}_I^H\right)$ exists. In order to accomplish that, let us compute, from (29), the value of τ when $g_I = 1$ (which is the value given by equation (18) when $\tau = \alpha$):

$$\rho + \theta(\alpha - \tau)\tau^{\alpha/(1-\alpha)} = 0 \tag{33}$$

from which:

$$\frac{\rho}{\theta(\tau - \alpha)} = \tau^{\alpha/(1-\alpha)} \tag{34}$$

Figure 5 here.

The left-hand side is a strictly decreasing function of τ, with asymptotes $+\infty$ as $\tau \to \alpha$, and 0 as $\tau \to +\infty$. As depicted in Figure 5, the right-hand side is an increasing function of τ, strictly concave if $\alpha < 0.5$, strictly convex if $\alpha > 0.5$; in both cases there is a unique τ such that (34) is verified. In addition, for $\tau = 1$ the left-hand side equals $\rho\beta[1-\alpha(1-\delta)]/[(1+\beta\delta)(1-\alpha)]$, which turns out to be less than one if $\rho < [(1+\beta\delta)(1-\alpha)]/\alpha\beta\delta$. Notice that for every finite value of ρ when $\delta = 0$, and for $\rho < (1-\alpha)/\alpha\beta$ when $\delta = 1$ (basically, for all plausible values of the discount rate) this inequality holds.

Therefore, the value of τ when $g_I = 1$ given by (29) lies between α and 1, and from this reasoning and looking back at Figure 1, it follows that when $g_I = 1$ the curve defined by equation (29) lies on the right with respect to that defined by (18), and since (29) is steeper than (18) for $\tau < \tau_{cr}$ and vice versa, it must be the case that they also intersect for a value of $\bar{g}_I^H < 1$ and $\alpha < \bar{\tau}^L < 1$.

A.4 Proof of Proposition 4

The first part of the proof follows the same reasoning of Proposition 3. For $\tau = 1$ and under the restriction $\alpha\delta/[1-\alpha(1-\delta)] < [\rho/(\theta(1-\alpha))]^{(1-\alpha)/\alpha}$, equation (29) lies above (18); whereas, when $g_I = 1$ the function defined by (29) lies on the right (above) with respect to that defined by (18).

Now, let us compute, for $\tau = \tau_{cr}$, the value taken by g_I in equation (18):

$$g_I(\tau = \tau_{cr}) = \frac{\alpha^2(1-\delta)}{1-\alpha[1-\alpha(1-\delta)]} \tag{35}$$

and in equation (29):

$$g_I(\tau = \tau_{cr}) = \left[\frac{(1-\delta)\rho}{\theta(1-\alpha)[1-\alpha(1-\delta)]}\right]^{(1-\alpha)/\alpha}\left[\frac{(1-\delta)}{1-\alpha[1-\alpha(1-\delta)]}\right] \tag{36}$$

A simple simulation exercise suffices to prove that, for all plausible parameter values, the inequality $\alpha^{2\alpha/(1-\alpha)}(1-\alpha) > (1-\delta)\rho\beta/(1+\beta\delta)$ always holds, ant this is sufficient to prove that (35) is greater than (36). Hence, when $\tau = \tau_{cr}$, (18) lies above (29).

It follows that equations (18) and (29) cross twice and that both intersections conduct to a feasible couple of $\bar{\tau}$ and $\bar{g}_I$.

A.5 Proof of Proposition 5

It is omitted since it is a simple replication of the proofs given for Propositions 3 and 4.

A.6 Proof of Proposition 6

Totally differentiation of equations (18) and (29) gives $\partial\bar{\tau}/\partial\delta = \Delta_\delta/\Delta$, where:

$$\Delta = \frac{\alpha(1-\delta)}{\bar{g}_I}\left(\tau_{cr} - \bar{\tau}\right) > 0 \qquad \Rightarrow \qquad \bar{\tau} < \tau_{cr} \tag{37}$$

$$\Delta_\delta = \frac{r(\alpha - \bar{\tau})\alpha}{\left[1-\alpha(1-\delta)\right]^2 \beta(1-\alpha)\bar{g}_I}\left[(\varsigma - \psi) - (\varsigma(1-\delta) - \psi)\bar{\tau}\right] < 0 \qquad \Rightarrow \tag{38}$$

$$\Rightarrow \quad \bar{\tau} < \frac{\varsigma - \psi}{\varsigma(1-\delta) - \psi} = \hat{\tau},$$

whereas $\varsigma = (1-\alpha)\left[\beta(1-\alpha) - \alpha\right]$ and $\psi = \alpha(1+\beta\delta)$ simplify the notation.

Firstly, we notice that if $\delta = 0$, then $\hat{\tau} = 1$ and, for any feasible $\bar{\tau}$, $\Delta_\delta < 0$ holds. When $0 < \delta \leq 1$, if we impose $\hat{\tau} \geq 1$, which in turn implies $\beta \geq \alpha/(1-\alpha)$, the inequality $\bar{\tau} < \hat{\tau}$ is automatically verified. Hence, we can claim that $\Delta_\delta < 0$ and since $\bar{\tau}$ and $\bar{g}_I$ always move in opposite directions, the Proposition is proved.

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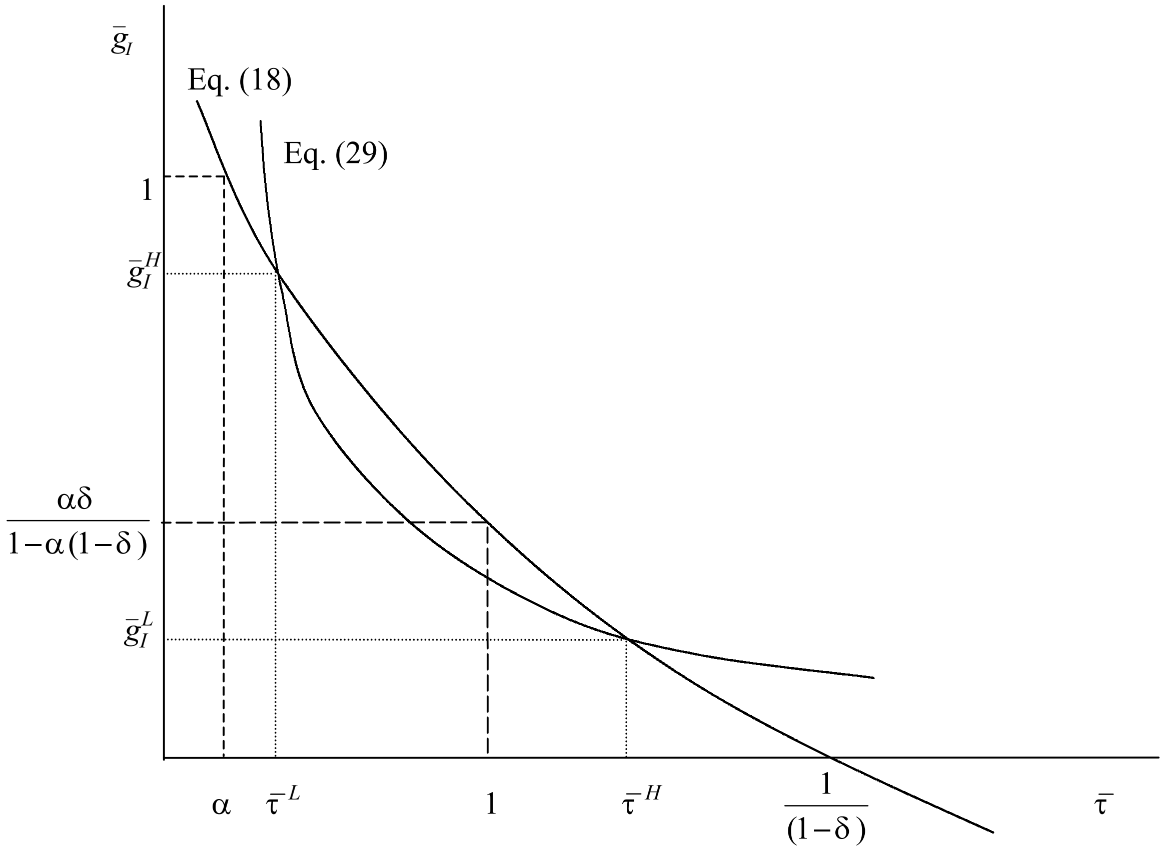

Fig. 1 – A unique feasible solution in the general case $0 \le \delta < 1$.

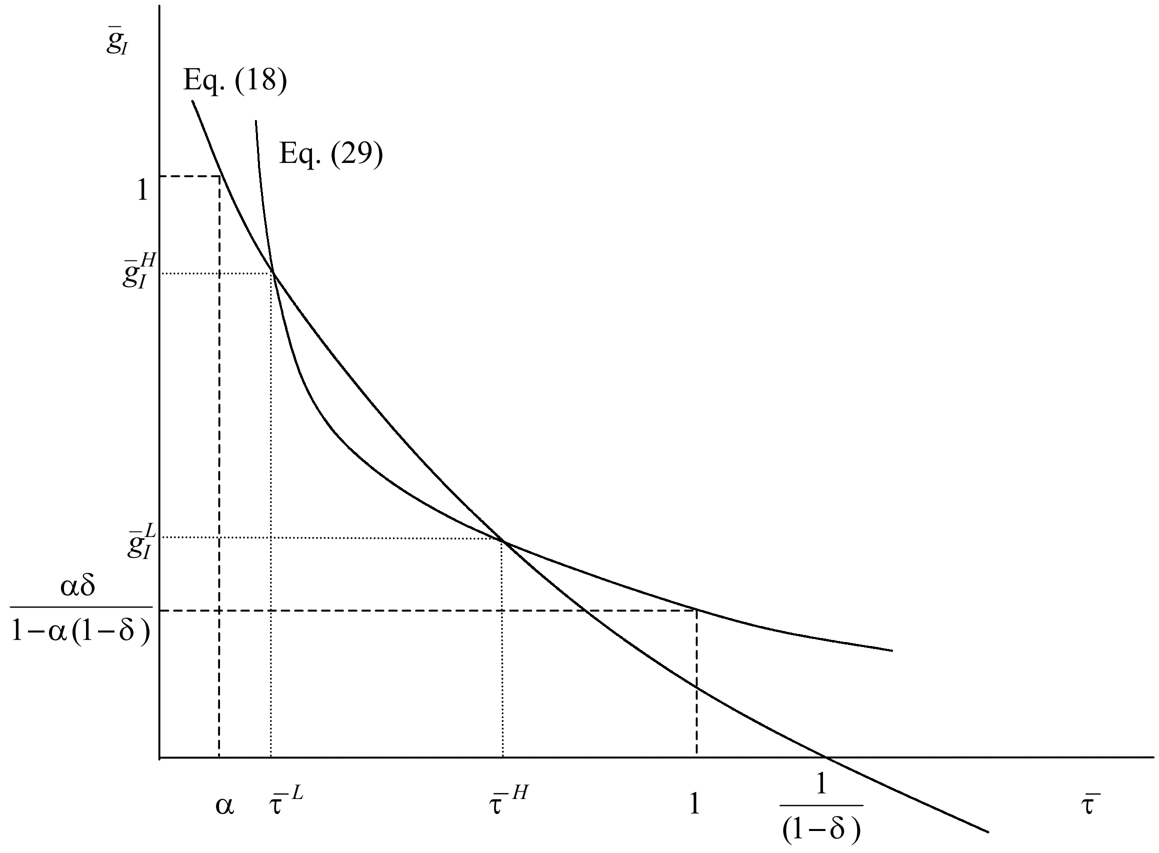

Fig. 2 – Two feasible solutions in the general case $0 \leq \delta < 1$.

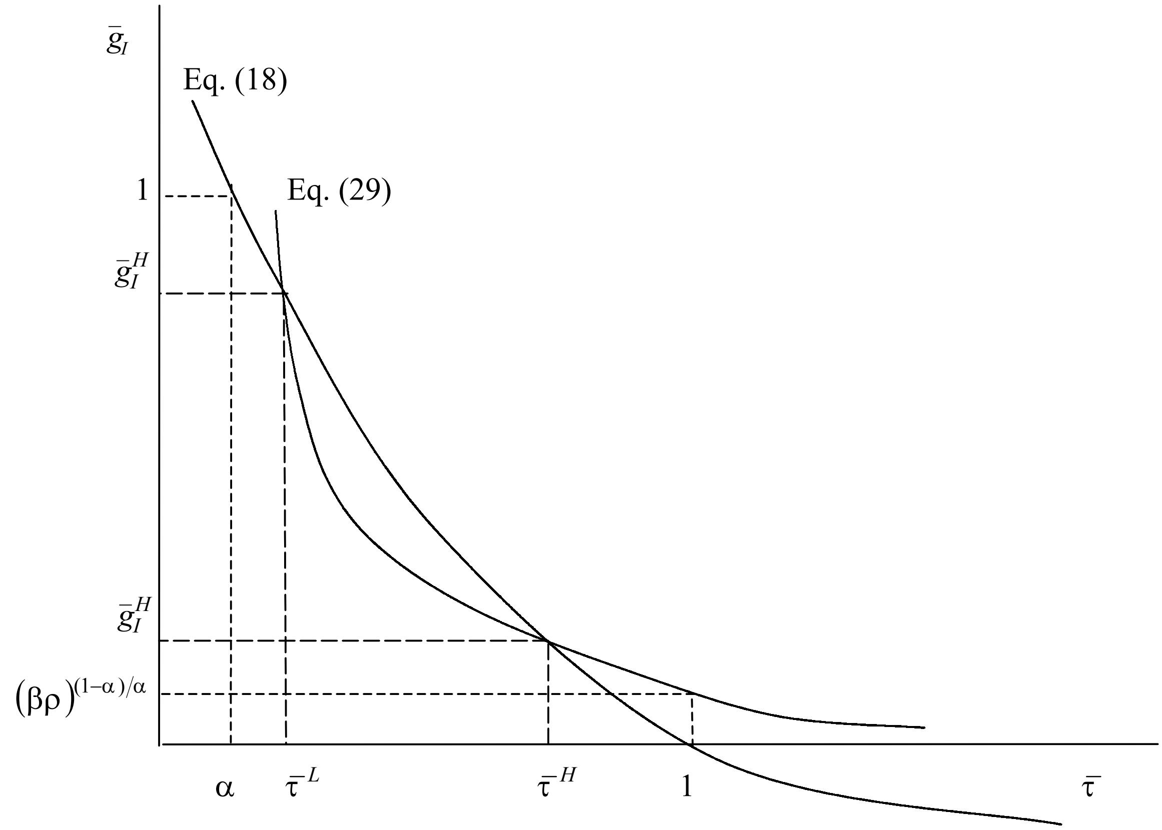

Fig. 3 – Two feasible solutions when congestion is proportional.

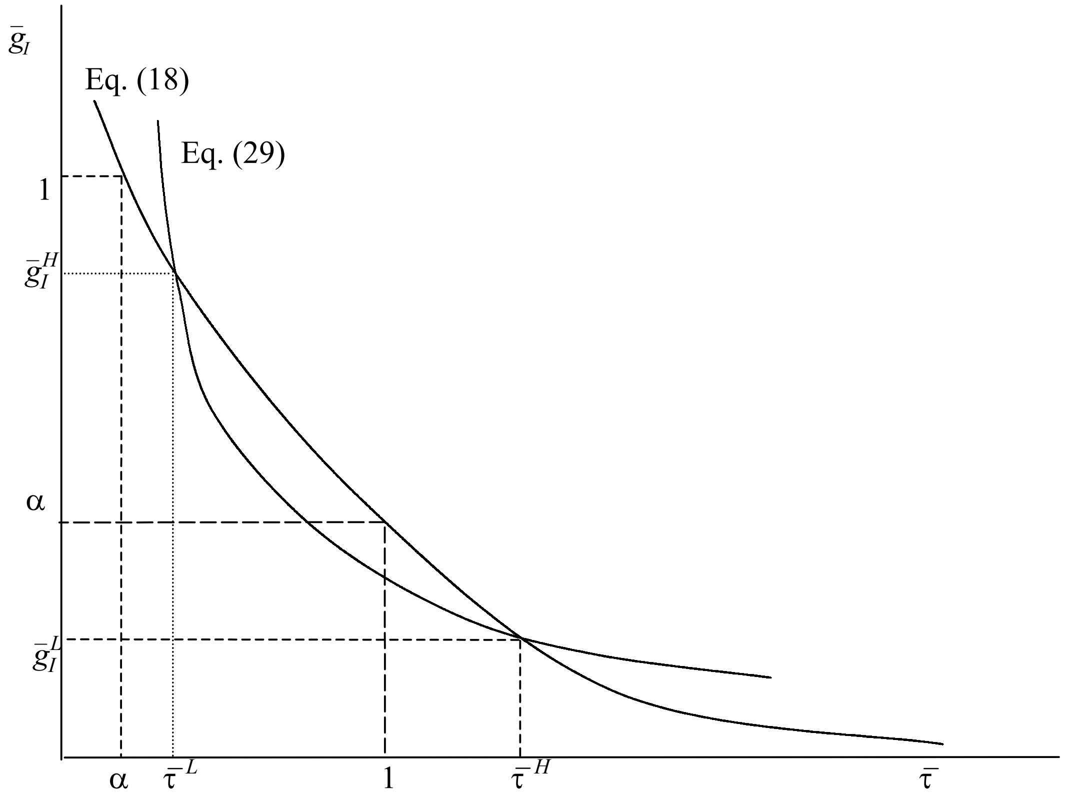

Fig. 4 – A unique feasible solution when congestion is absent.

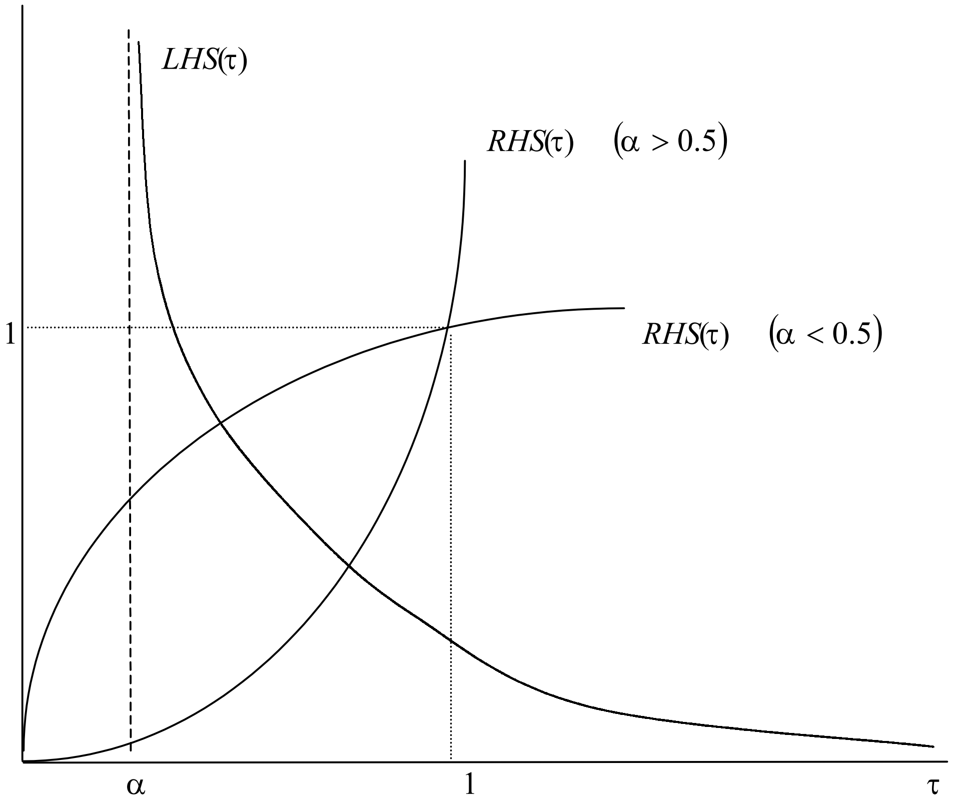

Fig. 5 – The properties of right-hand side (*RHS*) and left-hand side (*LHS*) of equation (34).

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(lx) This paper was presented at the EuroConference on "Auctions and Market Design: Theory, Evidence and Applications", organised by the Fondazione Eni Enrico Mattei, Milan, September 26-28, 2002

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(lxiv) This paper was presented at the International Conference on "Theoretical Topics in Ecological Economics", organised by the Abdus Salam International Centre for Theoretical Physics - ICTP, the Beijer International Institute of Ecological Economics, and Fondazione Eni Enrico Mattei – FEEM Trieste, February 10-21, 2003

(lxv) This paper was presented at the EuroConference on "Auctions and Market Design: Theory, Evidence and Applications" organised by Fondazione Eni Enrico Mattei and sponsored by the EU, Milan, September 25-27, 2003

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