ON THE GROWTH IMPLICATIONS OF FOREIGN AID FOR PUBLIC INVESTMENT CO-FINANCING*

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Abstract: In this paper we present an endogenous growth model with foreign transfers for public capital formation in order to analyze the implications for growth maximization when the public sector in recipient countries co-finances investment projects. Our main innovation is to show that, first, there is a unique growth-maximizing absorption rate of funds that decreases with the co-financing ratio and, second, that high amounts of assistance may be an impediment to growth due to the excess domestic taxation required to co-finance investment projects. We then derive a policy rule for designing the growth-maximizing co-financing share under a given level of assistance. Finally, we also highlight some implications for EU regional policies, which aim at fostering growth in poorer EU countries by co-financing public capital formation.

Keywords: foreign aid, public capital, EU regional policies.

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1. Introduction

Stimulating growth in poorer countries has been the primary goal of aid policy since World War II. However, despite earlier optimistic expectations on the growth impact of foreign aid, the success of aid programs among recipients has been largely disappointing: few countries have managed to experience large growth rates and increase their productivity, whereas in most cases aid has failed to boost growth rates in recipient countries.¹

Foreign aid to poorer countries has been mainly oriented towards assisting large-scale public investment and is often implemented according to a co-financing scheme where the recipient country co-finances the investment project by use of domestic resources. This mechanism is considered to act as an incentive device in cases where asymmetric information about the selection and monitoring of projects induces the typical moral hazard situation.²

However, there has been little attempt to investigate the growth effects of transfers for public investment when the latter come as foreign aid from abroad and the domestic public sector co-finances a share of the investment. Chatterjee et al. (2003) develop a general equilibrium model to examine the effects of transfers for public capital formation (‘tied’ transfers) and find that the growth impact of a ‘tied’ transfer depends upon the size of the government in the recipient economy and the co-financing arrangement. Their simulation results show that the positive effects of ‘tied’ transfers are mitigated under equal co-financing and that such a transfer may even prove welfare deteriorating under domestic co-financing if the recipient economy is relatively well endowed with public capital. In a similar vein, Chatterjee and Turnovsky (2004a, 2005) relax the assumption of unitary substitution between public and private capital by adopting a CES production function and find that the growth and welfare impact of ‘tied’ aid is larger for countries that have low substitutability between factors of production. Also, Chatterjee and Tunovsky (2004b) endogenize labor supply and show that both ‘tied’ and ‘untied’ (pure) aid generate different dynamics. In the case of ‘untied’ aid, these occur primarily through the labor-leisure choice and its effect on the marginal rate of substitution between consumption-leisure and

² Historically, the Marshall Plan was the first attempt to boost growth and targeted in transferring funds from the U.S. to European countries. The Plan amounted on average to around 3% of the recipient countries’ GDP during the 1949-1952 period and, although a large portion went directly to consumption needs, private and public investment were prime targets of the Plan. More importantly, the Marshall Plan entailed provisions on national co-financing by recipient governments: For every dollar of Marshall Plan aid received, the recipient country was required to place a matching amount of domestic currency in a counterpart fund to be used only for purposes approved by the U.S. government (De Long and Eichengreen, 1993).
on the real wage rate, which ultimately reduce the long-run growth rate. On the other hand, ‘tied’ aid generates an opposite gradual dynamic adjustment with significant trade-offs in welfare between the short run and the long run, as the agent increases his work effort and initially substitutes away from consumption toward investment.

Following this strand of the literature, we aim at providing a policy framework for analyzing the growth impact of ‘tied’ transfers in the context of an endogenous growth model with positive spillovers from public capital. The basic characteristics of ‘tied’ transfers incorporated here are the following: (i) there is a given amount of financial aid for public capital formation, which can be absorbed by the domestic economy, (ii) the public sector in the domestic economy co-finances investment projects, (iii) the public sector follows a balanced budget policy. The model thus belongs to the mainstream class of endogenous growth models developed by Barro (1990) and Barro and Sala-i-Martin (1992), which emphasize the role of government productive activities in achieving ongoing growth, but is similar in spirit to Futagami et al. (1993) and Turnovsky (1997a, 1997b) by adopting the view, put forward by Arrow and Kurz (1970), that the public capital stock rather than the flow of government expenditures is crucial for economic activity.

The present model extends the above theoretical literature by introducing foreign financial assistance for public investment into the endogenous growth framework, in order to investigate analytically the issue of the growth-maximizing design of foreign aid to poorer countries. The model acts in a complementary manner to the work by Chatterjee et al. (2003) and Chatterjee and Turnovsky (2004a, 2004b, 2005) by placing weight on the derivation of policy rules for growth maximization under external co-financing of public investment. In particular, the study by Chatterjee et al. (2003), which is closest in spirit to our paper, analyzes numerically the impact of permanent and transitory ‘tied’ transfers to highlight the ambiguous effects of aid on growth and welfare when the public sector co-finances infrastructure formation. Their model also examines the effects of increased public investment co-financing on the public debt and distinguishes between growth and welfare. Hence, the model by Chatterjee et al. (2003) provides an integrated framework for the analysis of ‘tied’ transfers; however, given its complexity the authors rely on simulations to analyze the steady-state and transitional effects of these transfers on growth, consumption and the public debt. The model presented here is simpler in nature, but is able to deliver analytical results in terms of comparative statics and simple policy guidelines for growth maximization under ‘tied’ aid transfers and domestic public investment co-financing.
Our basic result is that there is a unique growth-maximizing absorption rate of foreign funds, which decreases with the domestic co-financing ratio. Absorbing additional assistance under a co-financing scheme implies that the country has to raise its tax rate to finance the required national contribution. Thus, when aid exceeds a threshold the distortions generated by excess taxation may lead to a decline in the growth rate of the economy.

To highlight the policy aspects of our results we discuss some implications for the design of co-financing policies for infrastructure building like those followed by the European Union (EU) involving financial assistance to poorer countries under regional policies. A natural implication is that since this type of financial assistance ultimately aims at a strong growth differential in favour of these countries, the co-financing ratios should be lower for less developed ones. Also, the amount of financial transfers to poorer countries should be determined in conjunction with the co-financing share, since for any co-financing share there is a unique amount of financial assistance that a country should absorb to maximize its growth rate. These suggestions seem to be in contrast with the implementation and evaluation of EU assistance programmes, whose success or failure is often assessed solely on the basis of the absorption rate of available funds.

The rest of the paper is structured as follows. Section 2 sets up a small open economy endogenous growth model and derives the balanced-growth path of the economy. Section 3 analyzes the dynamic behavior of the model and section 4 derives the growth-maximizing tax rate and co-financing share in the decentralized equilibrium. Section 5 discusses the implications for foreign assistance in the context of EU policies. Finally, section 6 concludes the paper.

2. A growth model with transfers for public capital formation

The present section describes an endogenous growth model with foreign transfers for public capital formation. The aim of this setup is to provide a simple macroeconomic framework, which will result in policy rules for achieving the highest growth rate in the recipient countries. To this extent, we take as given that there is some finite financial amount available by a donor (country, group of countries, international organisations) for co-financing public investment projects in the recipient country. So, in the current approach growth maximization is the sole objective of the capital transfers. In turn, we take the latter as given and we then attempt to focus on their design

3 Viewed on behalf of donor countries, this type of aid policies may have several perspectives. For instance, within the EU the decision to engage in this type of activities is also based on the need for social cohesion, which corresponds closely to the notion of strategic aid, as described by Drazen (2000).
2.1. Model description

Consider an economy populated by identical agents who consume and produce a single commodity, $Y$. There is no population growth. The labor force is equal to the population, with labor supplied inelastically. In this economy, the instantaneous utility function of an infinitely lived representative household is given by the constant intertemporal elasticity of substitution function:

$$U(c) = \frac{c^{1-\gamma} - 1}{1 - \gamma}$$

where $c$ denotes per capita consumption and $\gamma > 0$.

On the modelling of the production of the economy, most of the early strand of the literature on the growth impact of public expenditures has assumed that the productive side of the economy is affected by the current flow of government expenditures (see, for example, Barro, 1990, and Barro and Sala-i-Martin, 1992). Subsequent work, however, has suggested that it is the accumulated stock of public capital that is relevant for economic growth (Futagami et al., 1993, Turnovsky, 1997a, 1997b). Following the latter approach, a representative firm $j$ in the economy is assumed to produce its output, $Y_j$, using a Cobb-Douglas technology:

$$Y_j = K_j^\alpha \left( \frac{K_g}{L} L_j \right)^{1-\alpha}$$

where $0 < \alpha < 1$, $K_j$ and $L_j$ denote the stock of private capital and labor used by firm $j$ respectively, and the term $\left( \frac{K_g}{L} \right)$ captures the productivity of labor defined as the existing aggregate stock of public, $K_g$, capital per worker, since $L$ denotes the total labour force. The production function suggests that each individual firm benefits from an increase in economy-wide labor productivity.

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4 This scheme can be consistent with the donor(-s) attempt to minimize the income gap between the recipient country and some exogenous benchmark level under the restriction that there is a predetermined amount of available assistance. This amount may be the outcome of political negotiations, or derived as part of a more general framework where the donor has an objective function that minimizes the gap in per capita income between the donor (e.g. EU) and the recipient country. For a three-player bargaining game between the EU, the domestic government and the private sector on the decision to invest prior to entrance and the related hold-up problem, see Wallner (2003).
triggered by a rise in the public capital stock available in the economy.\textsuperscript{5}

New output may be transformed to either type of capital. For both types of capital, we assume that the accumulation process does not involve any adjustment costs. We assume that public capital depreciates at the constant rate $\delta_g$. Letting $G$ denote the rate of gross public investment\textsuperscript{6}, the net public capital stock accumulates at the rate:

$$K_g^* = G - \delta_g K_g$$

(3)

Now, under the provision of aid from abroad, $AID$, the government balanced budget constraint takes the general form:

$$G = \tau Y + AID$$

(4)

where $\tau$ is the domestic tax rate. In the current setup, aid is assumed to come as a percentage of gross public investment, $G$, at a rate (1-$\tau_f$). Therefore, the budget constraint under aid for public investment co-financing becomes:

$$G = \tau Y + (1 - \tau_f)G \Rightarrow G = \frac{\tau}{\tau_f} Y$$

(5)

where $\tau_f$ is the (domestic) co-financing ratio, and 0$<$ $\tau_f$ $\leq$ 1. In particular, for $\tau_f$ =1 the equation renders the standard Barro (1990) type of public expenditure financing.\textsuperscript{7} As equation (5) implies, the provision of public infrastructure is based on a co-financing scheme and hence does not leave room for a loose fiscal policy in order to finance increased public investment needs.\textsuperscript{8} It is to be

\textsuperscript{5} Notice that defining labor productivity in per capita terms eliminates the scale effect on the growth rate.

\textsuperscript{6} Public investment may refer to large-scale projects in transportation, communications and energy sectors that improve the infrastructure of the economy, but also to projects in education and health that affect directly the productivity of the labor force. In the rest of the paper the terms ‘infrastructure’ and ‘public capital’ will be used interchangeably.

\textsuperscript{7} We exclude the possibility of full foreign financing ($\tau_f$=0), in which case the above equation is undefined. Of course, from the recipient country’s point of view it would be trivially optimal to receive the total investment amount in the form of foreign assistance. In the present setup, however, the donor finances only a portion of total expenditure. Under full foreign financing of public investment and in the absence of restrictive contracts and monitoring schemes (which are always difficult to implement in practice), recipient countries would be motivated to engage in investment projects that would not be undertaken in the absence of assistance, or are undesirable for the donor. By ensuring that part of the total investment cost is carried out by the domestic economy, partial domestic financing thus renders investment projects incentive compatible.

\textsuperscript{8} Although this may appear a restrictive assumption, the financing scheme adopted here, which is typical for this
noted that, conceptually, this form of financial aid may cover both conditional budget support (support to recipient government’s budget while imposing conditionality on how to allocate the resources) and project aid (assistance directly linked to specific projects) programmes, which are the two main forms of aid policies.\(^9\)

Turning to private capital accumulation, we assume that private capital depreciates at the constant rate \(\delta_k\). Letting \(I\) denote the rate of gross private investment, the net private capital accumulates then at the rate:

\[
\dot{K} = I - \delta K
\]  

(6)

2.2. Decentralized equilibrium

Each consumer can accumulate government bonds, \(b\), paying a real interest rate \(r\). Thus, the intertemporal budget constraint takes the form:

\[
\dot{b} = rb + (1 - \tau)y - c - i
\]  

(7)

where \(y\), and \(i\) denote output, and private investment in per capita terms, respectively. The infinitely lived representative household in our economy maximizes overall utility by solving the following infinite horizon utility maximization problem:\(^{10}\)

\[
\max \int_0^\infty e^{-\gamma t} \left( \frac{c^{\gamma} - 1}{1 - \gamma} + q(i - \delta_k k) + \lambda [rb + (1 - \tau)y - c - i] \right) dt
\]

s.t. (2), (6), (7).

The Hamiltonian for this problem is:

\[
H = e^{-\gamma t} \frac{c^{\gamma} - 1}{1 - \gamma} + q(i - \delta_k k) + \lambda [rb + (1 - \tau)y - c - i]
\]  

(8)

where \(q\) is the shadow value of the private capital stock and \(\lambda\) is the shadow price of wealth. After some manipulation and aggregation, it can be shown that the optimality conditions with respect to

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\(^9\) For an extensive presentation and comparison, see Cordella and Dell’Ariccia (2003).

\(^{10}\) Under the present setting, we assume that foreign transfers from abroad do not enter into the utility function.
\( c, i, b, \text{ and } k \) amount to:

\[
\dot{c} = \frac{1}{\gamma} (r - \rho) \tag{9}
\]

\[
r + \delta_k = (1 - \tau) \alpha \left( \frac{K_g}{K} \right)^{1-a} \tag{10}
\]

In addition, the following transversality conditions must hold:

\[
\lim_{t \to \infty} (q e^{-\alpha t}) = 0 \tag{11}
\]

\[
\lim_{t \to \infty} (\lambda e^{-\alpha t}) = 0 \tag{12}
\]

Substituting equation (10) into equation (9) we obtain:

\[
\dot{c} = \frac{1}{\gamma} \left[ (1 - \tau) \alpha \left( \frac{K_g}{K} \right)^{1-a} - \rho - \delta_k \right] \tag{13}
\]

From equation (6), the growth rate of private capital is given by:

\[
\frac{\dot{K}}{K} = (1 - \tau) Y - C - \delta_k \quad \Rightarrow \quad \frac{\dot{K}}{K} = (1 - \tau) \left( \frac{K_g}{K} \right)^{1-a} - \frac{C}{K} - \delta_k \tag{14}
\]

while from equations (3) and (5) the corresponding growth rate of public capital is:

\[
\frac{\dot{K}_g}{K_g} = \frac{\tau}{\tau_f} \left( \frac{K}{K_g} \right)^{1-a} - \delta_g \tag{15}
\]

since the aggregate production function can be written as:

\[
Y = K^\alpha K_g^{1-\alpha} \tag{16}
\]

Now, let us define \( z \) as the ratio of public to private capital stock, and \( x \) as the ratio of consumption to private capital stock:
Consequently, by equations (13), (14) and (15), and under the simplifying assumption that $\delta_k = \delta_g = 0$, we can write $\frac{\dot{z}}{z}$ and $\frac{\dot{x}}{x}$ as:

$$\frac{\dot{z}}{z} = \frac{\tau}{\tau_f}z^{-\alpha} - (1 - \tau)z^{1-\alpha} + x$$  \hspace{1cm} (19)$$

$$\frac{\dot{x}}{x} = \frac{1}{\gamma}[(1 - \tau)\alpha z^{1-\alpha} - \rho] - (1 - \tau)z^{1-\alpha} + x$$  \hspace{1cm} (20)$$

2.3. Balanced growth

Equations (19) and (20) form a system of two differential equations that describes the dynamic behavior of the economy. The stationary solution of this system ($\dot{z} = \dot{x} = 0$) must have at least one real solution, in order for output, and the capital stocks $K$ and $K_g$ to follow a balanced growth path $\bar{g}_y$ where $\frac{\dot{Y}}{Y} = \frac{\dot{K}}{K} = \frac{\dot{K}_g}{K_g}$. From equations (14) and (15), and from the definition of the balanced growth path, we have that the equilibrium growth rate of the economy is:

$$\bar{g}_y = \frac{\tau}{\tau_f}z^{-\alpha} = (1 - \tau)z^{1-\alpha} - \bar{x}$$  \hspace{1cm} (21)$$

Finally, the transversality condition (11) can be expressed in terms of the state variable, $z$, as:

$$\lim_{t \to \infty} (qe^{-(r_{st} + \gamma)t}z) = 0$$  \hspace{1cm} (22)$$

which implies that in the steady state the rates of growth of output, private and public capital must not exceed the real interest rate (see also Turnovsky, 1997b). Equivalently, the
transversality condition requires $\bar{\tau} > \frac{\tau}{a(1-\tau)\tau_f}$.

The steady-state values of $z$ and $x$ are determined by the intersection of the $z = 0$ locus with the $x = 0$ locus. From equations (19) and (20), setting $z = x = 0$, we obtain:

\[
\bar{\tau} = (1-\tau)\bar{z}^{1-a} - \frac{\tau}{\tau_f} \bar{y} \tag{23}
\]

\[
\bar{\tau} = (1-\tau)\bar{z}^{1-a} - \frac{1}{\gamma} [(1-\tau)\bar{z}^{1-a} - \rho] \tag{24}
\]

For a well-defined steady state, both $z$ and $x$ must be positive. From the above pair of equations we can establish that a necessary and sufficient condition for a well-defined steady state is $\gamma > a$. Substituting equation (24) into (23), we get the equilibrium value of $z$ in terms of the parameters of the model:

\[
\frac{\tau}{\tau_f} z^{-a} = \frac{1}{\gamma} [(1-\tau)\bar{z}^{1-a} - \rho] \tag{25}
\]

By differentiating the above equation with respect to $\tau$ and $\tau_f$, we get the long-run effects of changes in the tax rate and the co-financing ratio, respectively, on the steady state value of public to private capital stock:

\[
\frac{\partial \bar{z}}{\partial \tau} = \frac{\tau_f}{J} > 0 \tag{26a}
\]

\[
\frac{\partial \bar{z}}{\partial \tau_f} = -\frac{\tau}{\tau_f} J < 0 \tag{26b}
\]

since $J = \frac{\alpha \tau}{\bar{z} \tau_f} + \frac{(1-\tau)(1-a)}{\gamma} > 0$. The long-run effects of changes in the tax rate and the co-financing ratio on the growth rate of the economy can be derived by differentiating equation (21)
with respect to \( \tau \) and \( \tau_f \), respectively. We can show that:

\[
\frac{\partial \bar{g}_y}{\partial \tau} = \begin{cases} 
> 0 & \text{if } \tau < 1 - \alpha \\
= 0 & \text{if } \tau = 1 - \alpha \\
< 0 & \text{if } \tau > 1 - \alpha
\end{cases} \tag{26c}
\]

\[
\frac{\partial \bar{g}_y}{\partial \tau_f} < 0 \tag{26d}
\]

3. Transitional dynamics and policy changes

3.1. Linearization around the steady state and equilibrium dynamics

The dynamics of the economy are described by equations (19) and (20). Since the dynamic system that describes the economy is nonlinear, we proceed by considering the linearized system around the steady state. The linearized dynamics are represented by:

\[
\begin{bmatrix}
\dot{z} \\
\dot{q}
\end{bmatrix} = A \begin{bmatrix}
z - \bar{z} \\
q - \bar{q}
\end{bmatrix} \tag{27}
\]

where

\[
A = \begin{bmatrix}
-\alpha - (1 - \tau)(1 - \alpha)z^{-\alpha} & z \\
\frac{\alpha}{\gamma - 1} (1 - \alpha)(1 - \tau)z^{-\alpha}x & \bar{x}
\end{bmatrix}
\]

It is straightforward to show that the determinant of the Jacobian matrix, \( A \), is negative, which implies that the two roots of the matrix are of opposite sign. Therefore, the equilibrium is a saddle point with an upward sloping stable and a downward sloping unstable branch. Since the initial value of \( x \) is not predetermined, we can choose a unique value that is consistent with the stable manifold, given the inherited public to private capital ratio, \( z \), to obtain the steady-state values \((\bar{x}, \bar{z})\).

Finally, from equations (14) and (15), the linearized transitional paths of the growth rates of public and private capital are given respectively by the following equations:

\[
\frac{\dot{K}_g}{K_g} = -\alpha \frac{\tau}{\tau_f} z^{-\alpha} (z - \bar{z}) \tag{28}
\]
\[
\frac{\dot{K}}{K} - \ddot{g} = \left[ -\alpha \frac{\tau}{\tau_f} z^{1-a} - \frac{\mu}{z} \right] (z - \bar{z})
\]  

(29)

where \(\mu < 0\) is the stable eigenvalue associated with (27). Following Turnovsky (2000, pp. 493-494), these paths are illustrated in Figure 1; the positively sloped locus \(XX\) corresponds to the growth rate of private capital whereas the negatively sloped locus \(YY\) corresponds to the growth rate of public capital.

3.2. A change in the co-financing ratio

We can now investigate the dynamic behavior of the economy when the co-financing ratio, \(\tau_f\), decreases (the share of public investment financed from abroad rises) and the domestic tax rate, \(\tau\), remains constant leading to a rise of total public investment \(G\). The economy is initially at the steady state equilibrium (point \(E_1\) in Figure 1). When a permanent cut in the co-financing ratio is introduced, the immediate effect of the lower co-financing ratio is to raise the share of output devoted to aggregate public investment. As a result, the rate of growth of public capital increases, and the ratio of public to private capital stock, \(z\), begins to incline. As \(z\) inclines, the average productivity of private capital rises causing its growth rate to increase (see equation (14)), while the average productivity of public capital falls causing its growth rate to decrease (see equation (15)). The transitional dynamics of the growth rate of public capital are illustrated in Figure 1 by the initial jump from point \(E_1\) to \(A\), followed by the continuous decline along the new stable path \(Y'Y'\), towards the new steady state equilibrium at point \(E_2\). The growth rate of private capital rises gradually along the path \(E_1E_2\).

At the new steady state both the growth rate of the economy and the ratio of public to private capital stock will be higher. Hence, as expected, increased financial assistance for public capital formation has a positive effect on the growth rate of the economy. An interesting policy conclusion is that although the tax rate remains unaltered, the steady state relative government size given by the ratio of public to private capital stock increases after a decrease in the co-financing share. The rise in total public investment provides the economy with extra infrastructure at no cost, which triggers the rise in public capital accumulation.

Figure 1 also illustrates the transitional dynamics of a temporary decrease in the co-financing ratio. When the co-financing ratio is reduced, the growth rate of public capital jumps to point \(A\).
on the new stable path $Y'Y'$. The growth rate of public capital begins to decline along this path until it reaches point $B$, which corresponds to the time that the decrease in the co-financing ratio is terminated. At this point, the growth rate of public capital jumps back to the initial stable path $YY$ at point $D$, and begins to move back to the initial equilibrium at point $E_1$. The growth rate of private capital moves towards $S$ on the stable path $XX$ and then moves back to the initial equilibrium at point $E_1$.

### 3.3. A change in the tax rate

Government policy affects the growth of the economy through two channels. Taxation affects negatively the marginal product of private capital, while public investment increases the productivity of labor. At low values of $\tau$ the positive effect of public investment dominates and, hence, the growth rate of the economy rises with the tax rate. However, as the tax rate $\tau$ rises the negative impact of taxation eventually dominates and the growth rate declines, as the benefits accrued by externalities may be outweighed by the costs of taxation associated with public investment financing. This is another manifestation of the well-known inverse U-shaped effect of taxation on growth popularized by Barro (1990).

The dynamic behaviour of the economy, when the tax rate increases, is illustrated in Figure 2. The economy is initially at the steady state equilibrium (point $E_1$). A permanent increase in the tax rate has two immediate effects. First, the higher tax rate reduces the return to private capital. As a result, the rate of accumulation of private capital decreases. At the same time, the increase in the tax rate raises the share of output devoted to public investment, and the rate of accumulation of public capital increases. Both the increase in the growth rate of public capital and the decrease in the growth rate of private capital cause the ratio of public to private capital stock, $z$, to begin to incline. As $z$ inclines, the average productivity of private capital rises causing its growth rate to increase (see equation (14)), while the average productivity of public capital falls causing its growth rate to decrease (see equation (15)).

The transitional dynamics in the growth rate of private capital are illustrated in Figure 2 by the initial jump from point $E_1$ to point $B$, followed by the continuous decline along the new stable path $X'X'$ towards the new steady state equilibrium at point $E_2$. The dynamic adjustment in the growth rate of public capital is illustrated by the initial jump from point $E_1$ to point $A$, followed by the continuous incline along the new stable path $Y'Y'$ towards the new steady state.
equilibrium at point $E_2$. At the new steady state the ratio of public to private capital stock will be higher, while the growth rate of the economy can be higher or lower, depending on whether the tax rate is less or greater than $(1-\alpha)$; see equation (26c).

4. Growth-maximizing policy in the decentralized equilibrium

We can now address the question of growth-maximizing policy under foreign aid for public investment co-financing by calculating the growth-maximizing tax rate $\tau^*$. From equation (21) we get that the growth maximizing tax rate satisfies the following condition:

$$\frac{\partial G}{\partial \tau} = 0 \Rightarrow \frac{\partial \tau}{\partial \tau} = \frac{\bar{z}}{\alpha \tau}$$

(30)

From equations (25) and (30) we then get that the growth-maximizing tax rate, $\tau^*$, is independent of foreign assistance and equals:

$$\tau^* = 1 - \alpha$$

(31)

This result is similar to that obtained by, among others, Barro (1990), Glomm and Ravikumar (1994) and Devarajan et al. (1998). The growth-maximizing tax rate in the decentralized equilibrium is equal to the elasticity of public capital in the aggregate production function. However, what is interesting in the present case is that the co-financing ratio, $\tau_f$, does not affect the growth-maximizing tax rate $\tau^*$. Consequently, *the growth-maximizing level of locally financed public investment as a share of output is independent of foreign assistance for capital formation.*

A natural interpretation of this condition emerges when one considers that efficiency in public finance requires that, at the optimum, the marginal cost of public investment should equal its marginal benefit. A unit increase in $G$ ($\Delta G = 1$) raises the cost of the recipient country by $\tau_f$. At the same time, the marginal benefit for the recipient country from this unit equals the marginal product of total (domestic and foreign) public investment, which operates through the accumulation of public capital and its impact via the production function. However, in the present setup the rise of output needed to finance the rise in $G$ is now smaller by $\tau_f$ through equation (5). Both the marginal cost and the marginal benefit are scaled down by the same factor $\tau_f$, which renders the efficiency condition independent of $\tau_f$. 

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Next, it is important to determine an “efficient” co-financing scheme regarding foreign assistance for public capital formation, $AID'$.\textsuperscript{11} Equations (4), (5) and (31) then imply that:

$$\frac{AID'}{Y} = \tau \frac{1 - \tau_f'}{\tau_f'} \Rightarrow \frac{AID'}{Y} = (1-\alpha) \frac{1 - \tau_f'}{\tau_f'} \quad (32)$$

Relationship (32) determines an “efficient” co-financing ratio, $\tau_f'$, in the sense that this co-financing ratio allows a recipient country to absorb a given amount of foreign assistance, $AID'$, at the most efficient (growth-maximizing) way. The “efficient” co-financing ratio declines with the amount of available assistance. Alternatively, for a given co-financing ratio, equation (31) determines the efficient amount of foreign assistance that the recipient country can absorb, as a share of aggregate output. This result is important because it implies that it is not optimal for an economy to absorb an amount of public capital assistance that is greater than the specific fraction of its output defined by (32). This occurs because the absorption of an amount of assistance which is larger than the one implied by equation (32) requires a higher tax rate than $\tau^* = 1-\alpha$ to finance national investment; this in turn distorts the market for private capital and reduces ceteris paribus the growth rate of the economy.

We close this section by noting that aid policy targets mainly the growth rate of real per capita income and does not usually place any weight on welfare. Albeit restrictive, this assumption lies behind most aid programmes, since both donors and recipient governments typically aim at increasing the growth rate of the recipient economies through aid inflows. An additional reason for our focus on the growth rate is that the latter is easier to measure than some other objectives of the government. In our model it can be shown that the tax rate that maximizes the growth rate of the economy also maximizes welfare in the decentralized economy (see Appendix).\textsuperscript{12}

5. Some policy implications for EU assistance to poorer member countries

The policy rules developed in the previous section can yield interesting results in cases where an external donor co-finances public investment projects in a recipient country. The

\textsuperscript{11} Notice that the co-financing rate $\tau_f$ is not a policy variable, as it is predetermined by the donor; hence, we avoid referring to a ‘growth-maximizing co-financing rate’.

\textsuperscript{12} Notice that, as shown in Turnovsky (1997b), when public capital enters the production function as a stock, the first-best tax policy includes an additional time-varying component.
current section attempts to illustrate the analysis by discussing the general model implications in the context of EU regional policy. In particular, in the next subsection the implications of the model for EU financial assistance for infrastructure formation to poor member countries are discussed. Subsequently, a short quantitative illustration of these implications for future member countries in the context of EU assistance for capital formation is presented.\footnote{We would like to stress at this point that the results of the previous section hold for the balanced growth path whereas, undoubtedly, most of the recipient countries are on a transition period regarding their growth pattern. However, the policy implications could also be viewed as a general blueprint for policymakers in cases where growth has stagnated over a long period.}

5.1. General implications

The starting point of the discussion concerns the EU regional policy designed to assist poorer member countries. In particular, the EU has recognized the importance of infrastructure as a tool for activity-enhancing policies by envisaging the positive effects from a rise of public infrastructure. Since 1989, under interventions through the Structural Funds and the Cohesion Fund covered by regional Objective 1 (economic adjustment of less developed regions), the EU aims at assisting poorer countries by co-financing large-scale investment projects, with the corresponding co-financing shares determined on the basis of Regional Development Plans for each country.

One can then attempt to evaluate the EU financing policy under such a scheme in the context of the growth-maximizing conditions of the model developed earlier. An interesting result of the model is that, under financial assistance for public investment, the growth rate of the economy is a negative function of the domestic co-financing ratio for public capital assistance. A lower co-financing ratio implies that the economy can absorb a larger amount of assistance, which will increase the growth rate of the economy.

In terms of our model the goal of convergence with richer countries can take the form of reaching a target level of real per capita income as fast as possible by creating a strong growth impact in the recipient country. This growth impact can be easily calculated from equations (21) and (31) and equals:

\[
\bar{g}_y - g^*_y = \frac{\alpha}{\gamma} \left[ (z)_{1-a} - (z^*)_{1-a} \right] > 0
\]  \hspace{1cm} (33)
where $g^*_Y$ and $z^*$ denote the steady state values of the growth rate and the ratio of public to private capital stock, respectively, in the absence of financial aid ($\tau_f=1$). Equations (26b) and (33) then imply that the growth impact is getting larger as the co-financing ratio decreases. Therefore, the role of the donor is to determine the co-financing ratio that produces a growth impact that enables the recipient country to reach the income target at a given time period, given that the growth-maximizing tax rate equals the output elasticity of public capital.

In the context of EU regional policy the co-financing ratios should be planned in such a way that the growth rates of less developed countries exceed the average growth rate in the EU. In addition, since for given co-financing ratios the ability of a country to absorb foreign assistance depends on its output level, the model implies that the co-financing ratios should be positively related to a country’s level of GDP; as poorer countries must achieve a higher growth rate than richer ones for convergence to take place, they have to absorb a larger amount of financial assistance as GDP percentage. However, in practice the EU first decides upon the maximum amount of financial assistance that each eligible member country can receive, and then determines common maximum foreign co-financing shares through EU funds. For instance, the co-financing shares range from 75% to 85% of total eligible cost for Objective 1 regions. The determination of the foreign co-financing rate takes then place on a project appraisal basis and is calculated as the ‘financing gap’, i.e. expected revenues minus costs as percentage of costs.\(^{14}\)

The current model implies that from a macroeconomic perspective this is not the most efficient sequence of decisions, since the growth rate of the economy is a negative function of the domestic co-financing share. The EU and recipient countries should rather opt for a co-financing ratio on the basis of the desired growth path for the less developed economy and then EU authorities should determine the optimal amount of financial assistance that each country can absorb in order to achieve the planned growth rate. This point shows that the emphasis placed on the available amount of financial assistance for recipient countries and the achieved absorption rate is often misleading. Trying to maximize the absorption of available funds may impede growth if for the given co-financing ratio the suggested (‘growth-maximizing’) assistance is less than the available assistance, as the recipient country will have to increase the tax rate above the desired level.\(^{15}\) Instead, the country eligible for a higher amount of public capital assistance

\(^{14}\) See European Commission (2002).

\(^{15}\) Interestingly, the World Bank notes that “...development assistance, like so many other economic inputs, is subject
should negotiate for a lower domestic co-financing ratio in order to achieve a higher growth rate.\textsuperscript{16}

5.2. A quantitative evaluation for the EU Structural Funds

In this subsection we illustrate the model implications in the context of EU regional policies. In particular, in order to deliver an indicative quantitative experiment related to the model results on co-financing we focus on the ten new member countries (Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia), which receive financial aid from the EU through the Structural Funds to enhance convergence with more developed EU member states. As displayed in the first column of Table 1, the income in these countries (with the exception of Cyprus and Slovenia) is substantially smaller than the average EU income. Although the growth rates of these countries are higher than the average EU growth rate (see column 2), attaining convergence through EU financial assistance is a high priority target for both recipient and donor EU countries.

To conduct the numerical exercise a first requirement is a quantitative measure of the growth-maximizing tax rate $\tau^*$ in these economies or, equivalently, an estimate of the elasticity of public capital of the production function according to (30). Spurred by the work of Aschauer (1989), several empirical studies have sought to assess the magnitude of this elasticity for developed economies. However, obtaining econometric estimates of this elasticity for the countries under consideration is practically impossible due to lack of reliable data on public capital. To overcome this problem, we approximated the parameter of interest by postulating three alternative values, namely 5\%, 10\% and 20\%.\textsuperscript{17}

Next, the amount of resources available for future financial assistance through Structural Funds has to be specified. We use data from the Third Report on Economic and Social Cohesion (European Commission, 2004), which provides a quantitative assessment of the amounts available through the Structural Funds for the countries under consideration (see column 3). We
to diminishing returns. Even countries with excellent policies are limited to their capacity to absorb such aid. Once official assistance reaches around 12 percent of GDP, its potential contribution to growth is usually exhausted\textsuperscript{16}’ (World Bank, 1999, p.73).

\textsuperscript{16} It should be noticed that in our model there is no fungibility of foreign aid, as the growth-maximizing share of domestic public expenditures is independent of foreign aid co-financing.

\textsuperscript{17} Button (1998) reports that the range of estimated output elasticities of public infrastructure investments varies between 0.03 and 0.39. For an extensive survey on the empirical estimates of the impact of public capital in the production function, see Pfaehler et al. (1996).
then calculate the allocation and the amount available as a share of output for each country, which are displayed in the fourth and fifth columns of Table 1. Interestingly, financial assistance as a ratio of GDP appears to be inversely related to relative income, which implies that poorer (richer) countries receive a relatively large (small) fraction of EU transfers.

Now, according to (32) the countries, which are expected to receive high (low) assistance as GDP percentage, should have relatively low (high) domestic co-financing shares in order to be able to attain full absorption of funds. The last column in the second part gives the suggested co-financing shares according to the policy rules developed earlier on. Poor countries have relatively low implied co-financing shares; for instance, for $\tau=5\%$ the co-financing shares are $59.1\%$ for Latvia and $75.0\%$ for Lithuania, whereas almost full domestic financing is suggested for richer countries (for instance, $96.1\%$ for Cyprus and $76.8\%$ for Slovenia). The overall picture of wide differences among suggested co-financing shares is also confirmed for public capital elasticities equal to $10\%$ and $20\%$, and -most importantly- the distance between co-financing shares for richer and poorer countries appears again substantial. Therefore, albeit indicative, these numerical results confirm that the differences in the co-financing ratios for the countries under consideration should be substantial to attain the maximum growth rates.

6. Concluding remarks

In this paper we presented an endogenous growth model that allows for foreign co-financing of infrastructure formation, in order to analyze the implications for economic growth. Our theoretical findings can be summarized as follows: (i) a rise in the share of foreign assistance for public capital formation raises the equilibrium growth rate of the economy, (ii) the growth-maximizing tax policy or, equivalently, the public investment share in output that is domestically financed do not depend on the amount of capital transfers from abroad, and (iii) given the available amount of financial assistance for investment there is a unique co-financing ratio that ensures growth maximization.

The implications of transfers for public capital formation were highlighted in the context of the EU financial assistance to poorer countries. The analysis developed here can also be applied to aid programmes for less developed and underdeveloped economies, which have gained larger importance during the last decades as foreign aid for co-financing public investment projects rises steadily to cover the needs of poor countries. According to the results presented in the paper,
financial assistance programmes should be designed according to the specific needs and characteristics of the recipient country that are often termed as the “absorptive capacity” of the recipient, i.e. the ability of a country to receive aid and use it effectively. This illustration may also partly explain why “...foreign aid has at times been a spectacular success [and] at times an unmitigated failure” (World Bank, 1998, p.1). Under large income disparities and different technological parameters between recipients the adoption of uniform policy rules is likely to lead to limited and inefficient use of aid resources. Therefore, donors should attempt to place emphasis on country-specific interventions based on economic conditions and key parameters in recipient countries. On their part, recipients should not necessarily attempt to augment the size of aid programmes at all costs, but rather opt for increased foreign co-financing.
References
Cordella T. and G. Dell’Ariccia, 2003, ‘Budget support versus project aid’, *IMF WP/03/88*.
Jersey.


Appendix: Welfare maximization in the decentralized equilibrium

In the Appendix we show that tax policies in the decentralized equilibrium have similar effects on growth and welfare. First, consumption grows at a rate $\bar{g}_y$ and, hence, its time path is given by:

$$c_t = c_0 e^{\bar{g}_yt} \quad (A.1)$$

where $c_0$ is endogenously determined. From equation (21) we can write:

$$z = \left( \frac{\tau}{\bar{g}_y \tau_f} \right)^{\frac{1}{\alpha}} \quad (A.2)$$

$$\frac{c_0}{k_0} = (1 - \tau) \left( \frac{\tau}{\bar{g}_y \tau_f} \right)^{\frac{1-\alpha}{\alpha}} - \bar{g}_y \quad (A.3)$$

Substituting equation (A.3) into equation (A.1) we get that:

$$c_t = \left( (1 - \tau) \left( \frac{\tau}{\bar{g}_y \tau_f} \right)^{\frac{1-\alpha}{\alpha}} - \bar{g}_y \right) k_0 e^{\bar{g}_yt} \quad (A.4)$$

Substituting the above equation into the welfare function, we get:

$$W(\tau) = \int_{-\infty}^{\infty} e^{-\rho t} \left( \left( (1 - \tau) \left( \frac{\tau}{\bar{g}_y \tau_f} \right)^{\frac{1-\alpha}{\alpha}} - \bar{g}_y \right) k_0 e^{\bar{g}_yt} \right)^{1-\gamma} dt \quad (A.5)$$

Maximizing welfare with respect to $\tau$ is similar to maximizing $c_0$ with respect to $\tau$, since $W(\tau)$ is a monotonic function of $c_0$. Maximizing $c_0$ with respect to $\tau$ we get:

$$\frac{\partial}{\partial \tau} \frac{1 - \tau - \alpha}{\alpha} \bar{g}_y = \frac{1 - \tau - \alpha}{\tau - \alpha} \quad (A.6)$$

which is satisfied for the tax rate that maximizes the growth rate of the economy.
TABLE 1.
Suggested co-financing of new EU member countries through Structural Funds 2004-2006
based on ‘Third Report on Economic and Social Cohesion’

<table>
<thead>
<tr>
<th>Country</th>
<th>GDP/EU (PPS)</th>
<th>Average growth rate (1996-2000)</th>
<th>Structural Funds 2004-2006 (21.7 bn Euros)</th>
<th>% of Structural Funds allocation</th>
<th>Estimated annual inflow as GDP% (τ=0.05)</th>
<th>(τ=0.10)</th>
<th>(τ=0.20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyprus</td>
<td>82</td>
<td>3.8</td>
<td>101</td>
<td>0.5</td>
<td>0.21</td>
<td>96.1</td>
<td>98.0</td>
</tr>
<tr>
<td>Czech Rep.</td>
<td>60</td>
<td>0.8</td>
<td>2328</td>
<td>10.7</td>
<td>0.81</td>
<td>86.1</td>
<td>92.5</td>
</tr>
<tr>
<td>Estonia</td>
<td>37</td>
<td>4.9</td>
<td>618</td>
<td>2.8</td>
<td>2.14</td>
<td>70.0</td>
<td>82.4</td>
</tr>
<tr>
<td>Hungary</td>
<td>51</td>
<td>4.1</td>
<td>2847</td>
<td>13.1</td>
<td>1.11</td>
<td>81.9</td>
<td>90.0</td>
</tr>
<tr>
<td>Latvia</td>
<td>28</td>
<td>4.7</td>
<td>1366</td>
<td>6.3</td>
<td>3.46</td>
<td>59.1</td>
<td>74.3</td>
</tr>
<tr>
<td>Lithuania</td>
<td>29</td>
<td>3.2</td>
<td>1036</td>
<td>4.8</td>
<td>1.67</td>
<td>75.0</td>
<td>85.7</td>
</tr>
<tr>
<td>Malta</td>
<td>52</td>
<td>6.5</td>
<td>79</td>
<td>0.4</td>
<td>0.40</td>
<td>92.6</td>
<td>96.2</td>
</tr>
<tr>
<td>Poland</td>
<td>39</td>
<td>5.2</td>
<td>11369</td>
<td>52.4</td>
<td>1.24</td>
<td>80.2</td>
<td>89.0</td>
</tr>
<tr>
<td>Slovakia</td>
<td>48</td>
<td>4.1</td>
<td>405</td>
<td>1.9</td>
<td>0.38</td>
<td>92.9</td>
<td>96.3</td>
</tr>
<tr>
<td>Slovakia</td>
<td>71</td>
<td>4.3</td>
<td>1560</td>
<td>7.2</td>
<td>1.51</td>
<td>76.8</td>
<td>86.9</td>
</tr>
</tbody>
</table>

Notes:
4. In 1999 prices.
FIGURE 1. Stable adjustment paths for growth rates of public and private capital stocks and the effects of a fall in the co-financing ratio
FIGURE 2. The effects of a rise in the tax rate