

# Public Versus Private Provision of Infrastructure in a Neoclassical Growth Model

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## Abstract

This article studies the welfare and long run allocation impacts of privatization. There are two types of capital in this model economy, one private and the other initially public (“infrastructure”). A positive externality due to infrastructure capital is assumed, so that the government could improve upon decentralized allocations internalizing the externality, but public investment is financed through distortionary taxation. It is shown that privatization is welfare-improving for a large set of economies and that after privatization under-investment is optimal. When operation inefficiency in the public sector, subsidy to infrastructure accumulation and/or public consumption expenditures are introduced, gains from privatization are higher and positive for most reasonable combinations of parameters.

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# 1 Introduction

Infrastructure and privatization of public utilities have been, in the past years, the subject of extensive literature and moved to the center of the policy debate in both developed and developing countries around the world. On the one hand, the productive impact of infrastructure has been investigated lately by an increasing number of studies, starting with Aschauer's pioneering paper(1989). These studies use different econometric techniques and data samples to estimate the output and productivity elasticity to public capital. Although the magnitudes found vary considerably, the overall estimates (e.g. Aschauer (1989), Ai and Cassou(1995), Duffy-Deno and Eberts(1991), and Easterly and Rebelo(1993)) tend to confirm the hypothesis that infrastructure capital positively affects productivity and output, despite some important exceptions (e.g. Holtz-Eakin(1992) and Hulten and Swchartz(1992)). On the other hand, the perception of poor performance of public-operated infrastructure utilities, among other reasons, led to a flurry of privatization and concessions in a large and increasing number of countries. For instance, from 1988 to 1992, revenue from infrastructure privatization in developing countries totalled 19.8 billion of dollars (World Bank[1994]) and since then its pace has accelerated remarkably.

In this paper we use a competitive general equilibrium model, basically a variation of the neoclassical growth model, to investigate the welfare and long run allocation impacts of privatization. There are two types of capital in this model economy, one private and the other initially public ("infrastructure"), and a positive externality due to the latter is assumed. A benevolent government can improve upon decentralized allocation by internalizing the externality. However, it is assumed that lump sum taxation is not an option and that the government uses distortionary taxes to finance investment. This last feature introduces a trade-off in the public provision of infrastructure, as distortionary taxes may offset the productive effect - internal and external - of public capital. The net effect of privatization and other quantitative properties of this theoretical economy depend to a large extent on the relative strength of the two effects<sup>1</sup>.

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<sup>1</sup>The model could be interpreted also as a model of public versus private provision of education. In this case, the second type of capital would be called human capital instead of infrastructure and the exercises would compare welfare and allocation impacts when the education investment decision changes from totally public to totally private or private with public subsidy. The calibration of the parameters, of course, would change.

This model economy was solved by using simulation techniques on the lines of Kydland and Prescott(1982), although the model is non stochastic. The parameters and functional forms of the model were calibrated following the tradition of real business cycle models of matching features of the actual U.S. economy. We could not, however, settle for unique values of the internal and external effect of infrastructure capital, given the large and conflicting number of estimates in the literature. We chose, therefore, to use several values for the external-effect parameter and compare the results.

Two sets of experiments were performed, one measuring the welfare effects of privatization under alternative sets of parameters and the other comparing long run allocations. One of the main results of the paper is that when we make the best case for public action - maximization of individuals' welfare, no operation inefficiency, deterministic and known policy and free supply to society of infrastructure services - privatization will be welfare improving if the external effect is not strong enough, but for some reasonable combinations of parameters it may imply in welfare loss. However, when operation inefficiency is introduced, gains from privatization are higher and positive for most reasonable combinations of parameters. Moreover, if a subsidy to infrastructure accumulation is also allowed so that agents can internalize its externality, the benefits of private operation of infrastructure will increase for a given economy, as well as the number of economies which can profit from it.

On a purely theoretical ground, Devarajan, Xie and Zou(1998) investigate alternative systems of infrastructure-services provision using distortionary taxes and part of our model borrows from theirs. They work with a simple endogenous growth model with complete depreciation of capital types, while we work with the traditional neoclassical growth model. Moreover, we add more structure to the model - e.g., partial capital depreciation and labor/leisure choice. Hence, if on the one hand we are not able to derive close form solution, on the other hand we avoid assumptions that may be considered too strong by many.

Of course, one may object to the fact that we are not working in an endogenous growth environment as public investment may have long term effects. This framework was chosen, among other reasons, because in order to obtain sustainable growth it is necessary to assume empirically implausible values for the infrastructure coefficient in the production function. In other words: if we consider the usual capital share of 0.36, the coefficient of infrastructure in a Cobb-Douglas production function would have to

be 0.64 for the model to display sustainable growth. But the values estimated in the literature range from zero to 0.4, and even this last value (Aschauer's (1989) estimate) was discredited on methodological grounds (Gramlich(1994))<sup>2</sup>. Tentative solutions could be the addition of human capital to the model and/or the reinterpretation of capital in a broad sense that would include not only physical capital but also R&D and human capitals. In this last sense, Kocherlakota and Yi(1997), using U.S. and U.K. time series data, tested and accepted the endogenous growth model<sup>3</sup>. This result, however, does not help us on the calibration of the infrastructure coefficient.

Finally, some may consider our analysis is more about the general provision of public good rather than about infrastructure provision, due to the form externalities were introduced in the production function. This is a possible reading of the paper and we basically phrased it in terms of infrastructure provision following the literature mentioned above and so being able to use the parameter estimations of these papers in the calibration of our models.

This paper is organized as follows. Section two presents the model with public provision of infrastructure, Section three presents the model without government ( i.e., after privatization), Section 4 briefly discusses calibration and Section 5 discusses methodology and presents the main results of the simulations. The experiments with subsidy to investment in infrastructure are presented in section 6 as well as the introduction of public consumption and some considerations about transition dynamics and congestion. Finally, in section 7 some concluding remarks are made.

## 2 Model I: Public Infrastructure

In this economy a single final good is produced by firms from labor,  $H$ , and two types of capital,  $K$  and  $G$ . There is a positive externality generated by the average of capital  $G$ ,  $\bar{G}$ , so that the technology of a representative firm is given by:

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<sup>2</sup>Note, however, that Pereira and de Frutos(1999) estimated, in a vector auto-regressive framework, coefficient values very close to those in Aschauer(1989). As the former estimates take into account long term feedback effects and the non-stationarity of variables, they are not subject to the same criticism as those in the latter.

<sup>3</sup>On the other hand, Benhabib and Jovanovic(1991) and Jones(1995), among many, rejected the endogenous growth model in favor of the exogenous growth model.

$$Y_t = K_t^\theta G_t^\phi H_t^{1-\theta-\phi} \bar{G}_t^\gamma \quad (1)$$

In this first model, labor and  $K$ , private capital, are owned by individuals who rent them to firms. The second type of capital, infrastructure ( $G$ ), is owned by the government, who finances its investments by tax collection and supplies  $G$  for free to firms.

The technology above may be thought of as a generalization of a class of models that incorporates infrastructure or public capital to the production function. In the one hand, Aschauer(1989), Barro(1990) and Cassou and Lassing(1996), among others, assume no externality due to  $G$  (i.e.,  $\gamma = 0$ ) and constant returns to scale over  $K$ ,  $G$  and  $H$ . On the other hand, Turnovsky and Fisher (1995) and Glomm and Ravikumar (1994 and 1997) assume constant returns to scale to private factors only -  $K$  and  $H$  - and consequently  $\phi = 0$ . In this case the public good quality of  $G$  is emphasized. Finally, Devarajan, Xie and Zou (1998) work with a production function in which both  $\gamma$  and  $\phi$  are different from zero, but  $\theta + \gamma + \phi = 1$ .

The problem of a representative firm is to pick at each period the levels of private capital and labor that maximize its profit, taking  $G$ ,  $\bar{G}$  and prices as given:

$$\underset{K_t, H_t}{Max} \quad K_t^\theta G_t^\phi H_t^{1-\theta-\phi} \bar{G}_t^\gamma - w_t H_t - r_t K_t$$

From the solution of this simple problem we obtain the expressions for the rental rate of private capital,  $r$ , and wages,  $w$ :

$$r_t = \theta \left( \frac{K_t}{H_t} \right)^{\theta-1} \left( \frac{G_t}{H_t} \right)^\phi \bar{G}_t^\gamma \quad (2a)$$

$$w_t = (1 - \phi - \theta) \left( \frac{K_t}{H_t} \right)^\theta \left( \frac{G_t}{H_t} \right)^\phi \bar{G}_t^\gamma \quad (2b)$$

A representative agent is endowed with one unit of time that he divides between labor and leisure (1). His utility at each period is defined over sequences of consumption and leisure, and it is assumed that preferences are

logarithm in both its arguments<sup>4</sup>:

$$U[c_0, c_1, \dots, h_0, h_1, \dots] = \sum_{t=0}^{\infty} \beta^t [\ln(c_t) + A \ln(1 - h_t)]$$

Families have one additional source of income, dividends  $\pi$ . Note that there is one factor of production ( $G$ ) that is not paid by the firm, as government supplies it for free. Hence, firms obtains an economic profit equal to  $\phi K_t^\theta G_t^\phi H_t^{1-\theta-\phi} \bar{G}_t^\gamma$  (the public capital share of output) which are distributed to the families - the owners of the firms - as dividends. All families receive equal amounts of total profits and take the dividends as given when solving their problem. Income from all sources are taxed by the government at the same tax rates  $\tau$  and total disposable income is used by agents for consumption and investment ( $i$ ). Note that households take as given the tax rates, which are assumed to be constant over time. Hence, households' budget constraint is given by:

$$c_t + i_t \leq (1 - \tau)w_t h_t + (1 - \tau)r_t k_t + (1 - \tau)\pi \quad (3)$$

It is assumed that households know the law of motion of private and public capital:

$$k_{t+1} = (1 - \delta)k_t + i_t \quad (4)$$

$$G_{t+1} = (1 - \delta_g)G_t + J_t, \quad (5)$$

where  $\delta$  and  $\delta_g$  are the depreciation rates of private and public capital, respectively, and  $J$  is investment in public capital. Consumers take government actions - tax rates and investment - as given and it is imposed government budget balance in every period (ruling out public debt):

$$\tau w_t H_t + \tau r_t K_t + \tau \pi = J_t, \quad \forall t \quad (6)$$

We can write the household's problem in a recursive form. The optimality equations can then be written as:

$$v(k, K, G, \bar{G}) = \underset{c, h, i}{Max} \left\{ [\ln(c) + A \ln(1 - h)] + \beta v(k', K', G', \bar{G}') \right\}$$

*s.t* :

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<sup>4</sup>Note that we use capital letters for aggregate variables, taken as given by the representative agent, and lower-case for variables over which he has control.

$$\begin{aligned}
c + i &= (1 - \tau)r(K, G, \overline{G})k + (1 - \tau)w(K, G, \overline{G})h + (1 - \tau)\pi(K, G, \overline{G}) \\
k' &= (1 - \delta)k + i \\
G' &= (1 - \delta_g)G + J \\
\tau rK + \tau wH + \tau \pi &= J \\
k_0 \text{ and } G_0 &> 0 \text{ and given} \\
c \geq 0, 0 \leq h &\leq 1
\end{aligned}$$

It can be shown that, after some simple manipulations, solutions for this problem satisfy the following conditions:

$$\frac{1}{c} = \frac{\beta \left( (1 - \tau)\theta \left(\frac{K^0}{H^0}\right)^{\theta-1} \left(\frac{G^0}{H^0}\right)^\phi \overline{G}^\gamma + (1 - \delta) \right)}{c'} \quad (7a)$$

$$\frac{A}{1 - h} = \frac{(1 - \tau)(1 - \phi - \theta) \left(\frac{K}{H}\right)^\theta \left(\frac{G}{H}\right)^\phi \overline{G}^\gamma}{c} \quad (7b)$$

Both equations are standard. The first is an Euler equation that says that the cost of giving up one unit of consumption today in equilibrium has to be equal to the discounted net return of the investment in  $k$  of this unit (we use  $x'$  for next period variable). Equation 7b equates the return of one extra unit of leisure with the net return, in terms of consumption, of one extra unit of labor.

A *recursive competitive equilibrium* for this economy is a value function  $V(s)$ ,  $s$  given by  $(k, K, G, \overline{G})$ , a set of decision rules for the household,  $c(s)$ ,  $h(s)$  and  $i(s)$ , a corresponding set of aggregate per capita decision rules,  $C(S)$ ,  $H(S)$  and  $I(S)$ ,  $S$  given by  $(K, G, \overline{G})$ , and factor prices functions,  $w(S)$  and  $r(S)$ , such that these functions satisfy: a) the household's problem; b) the firm's problem and equations 2 and 3; c) consistency of individual and aggregate decisions, i.e.,  $C(S) = c(s)$ ,  $H(S) = h(s)$ ,  $I(S) = i(s)$  and also  $\pi = \phi Y(S)$ ; d) the aggregate resource constraint,  $C(S) + I(S) + J(S) = Y(S)$ ,  $\forall S$ ; e) and the government budget constraint clears.

Following Chari, Christiano and Kehoe(1994) the existence of a commitment technology or some institution that forces the government to bind itself to a particular announced policy at time zero is supposed. Once the government picks its policy at the beginning of time, agents will choose their allocations so that prices and consumers' allocations will be described as functions of public policies.

Government therefore picks  $\tau$  in order to maximize the individual's welfare, taking as given optimal decision rules and the equilibrium expressions

for wages and rental rate of capital. It solves the following problem<sup>5</sup>:

$$\begin{aligned}
& \underset{\tau}{Max} \sum_{t=0}^{\infty} \beta^t [\ln(c_t(\tau)) + A \ln(1 - h_t(\tau))], \\
& \text{s.t} \\
& c_t(\tau) + i_t(\tau) = (1 - \tau)r_t(\tau)k_t(\tau) + (1 - \tau)w_t(\tau)h_t(\tau) + (1 - \tau)\pi(\tau) \\
& r_t = \theta K_t^{\theta-1} H_t^{-\theta-\phi} G_t^{\phi+\gamma} \\
& w_t = (1 - \phi - \theta)K_t^{\theta} H_t^{-\theta-\phi} G_t^{\phi+\gamma} \\
& \pi_t = \phi K^{\theta} H_t^{1-\theta-\phi} G_t^{\phi+\gamma} \\
& \tau r_t k_t + \tau w_t h_t + \tau \pi_t = J_t \\
& G_{t+1} = (1 - \delta_g)G_t + J_t
\end{aligned}$$

The optimal policy, the price rules  $w(\tau)$  and  $r(\tau)$  and allocations rules for consumption and investment that solve the above problem is a *Ramsey Equilibrium*. For the sake of simplicity, only in the first line of the restrictions did we write variables explicitly as a function of tax rates.

In the expression of  $w$ ,  $r$ , and  $\pi$  the positive external effect due to  $\bar{G}$  is taken into account. As lump sum taxation was ruled out, government actions create a trade-off. On the one hand, through taxation it distorts optimal decisions and reduces labor and capital returns. On the other hand, it supplies infrastructure, which has a positive effect on returns and consequently on the equilibrium levels of capital, labor and output. Note that, in the economy without government, the external effect due to  $\bar{G}$  is not taken into account when individuals decide how much to spend on  $J$ , so that the isolated effect is under-investment in infrastructure. Of course, the absence of taxation may offset this negative effect.

### 3 Model II: Privatization

Suppose now private operation and ownership of infrastructure (type  $G$  capital), and assume too no government and hence no tax. Technology and the

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<sup>5</sup>Glomm and Ravikumar (1994) prove existence and uniqueness in a model very close to ours (the major difference is that  $\gamma = 0$  there). They use a condition to obtain uniqueness which is stronger than we need, given that there is no congestion in the present model. We only need that  $\gamma + \theta + \phi < 1$  for the constraint set to be convex, and this is assumed everywhere in the paper.

laws of motion of both capitals in this economy remain the same as before, but the problem of firms and households will change.

As in the previous problem, firms face the same static problem each period, but now they pick  $K$ ,  $H$  and  $G$  in order to maximize their profits:

$$\text{Max}_{K_t, H_t, G_t} \quad K_t^\theta G_t^\phi H_t^{1-\theta-\phi} \overline{G}_t^\gamma - w_t H_t - r_t K_t - \rho_t G_t$$

The expressions for the rental rate of capital  $K$  and wages, obtained from the solution of this problem, reproduces equations (2a) and (2b) while the expression for  $\rho$ , the rental rate of type  $G$  capital, is:

$$\rho_t = \phi \left( \frac{K_t}{H_t} \right)^\theta \left( \frac{G_t}{H_t} \right)^{\phi-1} \overline{G}_t^\gamma \quad (8)$$

Consumer's utility function remains the same, but not his/her budget constraint. In addition to consumption and investment in capital  $k$ , the consumer expends part of his/her income on investment on capital  $g$ , labeled  $j$ . Moreover, he/she now receives rents from  $g$  used by firms, so that his/her budget constraint is given now by:

$$c_t + i_t + j_t \leq r_t k_t + w_t h_t + \rho_t g_t \quad (9)$$

The solution of the present problem - and also of the previous one - is not equivalent to the allocations chosen by a social planner that acts to maximize the welfare of a representative agent, because of distortions. In both cases the solution follows recursive methods for distortionary economies, as explained in Hansen and Prescott(1995), and the equilibrium concept is the recursive competitive equilibrium due to Prescott and Mehra(1980). The expression for the household's problem in a recursive form closely follows the expression for the previous problem with the appropriate modifications and one additional state variable,  $g$ . It can be shown that, after some simple manipulations, solutions for this problem satisfy the following conditions:

$$\frac{1}{c} = \frac{\beta \left( \theta \left( \frac{K^0}{H^0} \right)^{\theta-1} \left( \frac{G^0}{H^0} \right)^\phi \overline{G}^\gamma + (1 - \delta) \right)}{c'} \quad (10)$$

$$\frac{1}{c} = \frac{\beta \left( \phi \left( \frac{K^0}{H^0} \right)^\theta \left( \frac{G^0}{H^0} \right)^{\phi-1} \overline{G}^\gamma + (1 - \delta_g) \right)}{c'} \quad (11)$$

$$\frac{A}{1-h} = \frac{(1-\phi-\theta) \left(\frac{K}{H}\right)^\theta \left(\frac{G}{H}\right)^\phi \bar{G}^\gamma}{c} \quad (12)$$

The second expression above was not present in the solution of the previous problem and is an Euler equation for capital  $g$ . The two remaining expressions, except for the absence of taxes, are equivalent to equations 7a and 7b. From equations 10 and 11 it can be seen that consumers equate the marginal productivity of the two capitals in every period. The definition of a recursive competitive equilibrium closely follows the definition in section 3, with minor changes due to the presence of one additional state variable,  $g$ .

## 4 Calibration

Quantitative properties of this theoretical economy depend to a large extent on the values of the model's parameters. Depreciation rate for  $K$  is taken from Kydland and Prescott's (1982), among many others, and is set equal to 0.025 per quarter. Output share of private capital,  $\theta$ , was set equal to 0.34, following Cooley and Prescott(1995).

Preference parameters follow Cooley and Hansen(1989), among others:  $\beta$  is set to 0.99 per quarter, which implies steady state interest rate equal to 6.5%, and  $A$  is set to 2, which implies that households spend 1/3 of their time working. Tax rates are free parameters and chosen endogenously in order to maximize the individual's welfare and are not calibrated to match observed values.

There are no independent estimates of  $\gamma$  (the coefficient of the externality effect due to  $\bar{G}$ ) that we know in the literature. As a matter of fact, most papers estimate  $\gamma$  and  $\phi$  jointly. To obtain  $\gamma$ , we first set  $\phi = 0.05$ , a value that matches post-war share of public investment ( $J/Y$ ) in the U.S. and it is the benchmark value used by Baxter and King(1993). We then subtracted this calibrated value from the joint estimates of  $\phi + \gamma$  in order to obtain the value of  $\gamma$ .

Using this method, we obtained  $\gamma$  values that range from zero to 0.30. For instance, Ratner (1983), using U.S. annual data from 1949 and 1973, estimates output elasticity with respect to public capital around 0.06, which imply  $\gamma$  to be equal to 0.01. Duffy-Deno and Eberts(1991) estimate similar and slighter higher values using data for 5 metropolitan areas of the U.S. The same is true in Canning and Fay(1993) - who used a variety of cross-country data bases - and Baffes and Shah(1998) - who worked with OECD

and developing country data.

Aschauer(1989) estimated much larger values that imply  $\gamma$  around 0.30. He used, however, the OLS method, which may have biased his results because of endogeneity of variables. The method used, as pointed out by Gramlich(1994), also has a problem of common trends between the infrastructure series and the output series employed. Moreover, the rate of return on public capital implied by these estimates lies above that of private capital, a very implausible result. Munnell(1990) finds values of the same order of magnitude for some U.S. regions and uses similar methods. For the U.S. states, however, her estimates imply  $\gamma$  between 0.01 and 0.07, depending on the public capital series used. Ai and Cassou (1995) use the GMM method to estimate Euler equations of a dynamic model and the implied  $\gamma$  in this case is 0.15. On the other hand, Holtz-Eakin(1992) and Hulten and Schwab(1992) found no evidence of public capital affecting productivity<sup>6</sup>.

Given the variety of magnitudes estimated, several values for the parameter  $\gamma$  were used, although most estimates indicate that values between zero and 0.02 are the most reasonable ones. In our experiments we used  $\gamma$  values from zero (no external effect ) to 0.05<sup>7</sup>. The depreciation rate of infrastructure capital (  $\delta_g$ ) is set to 0.025 per quarter, following again Baxter and King(1993).

## 5 Results

### 5.1 Long Term Allocations

The behavior of these economies is very sensitive to changes to  $\gamma$  and to the tax structure used to finance public investment. In general, the higher  $\gamma$ , the stronger the case for public provision of infrastructure. On the other hand, the more distorting is public financing, the greater will be the gains from privatization.

For any given  $\gamma$ , steady state utility increases initially with  $\tau$ , reaches a maximum at some  $\tau^*$ , and then monotonically decreases as  $\tau$  continues to increase . This is so because, for values below  $\tau^*$ , the positive effect

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<sup>6</sup>This list is by no means complete, the empirical literature on the subject is quite large. See Gramlich(1994) and Glomm and Ravikumar(1997) for surveys.

<sup>7</sup>For values of  $\gamma$  above 0.05 results do not change qualitatively, although magnitudes are considerably different.

of infrastructure on productivity outweigh the negative impact of taxation on returns, so that private capital, output, consumption and utility levels increase with tax rates. For tax rates large enough ( $\tau > \tau^*$ ), the negative effect of taxation dominates.

The optimal tax rate increases with  $\gamma$ . For  $\gamma$  equal to zero (no externality), 0.025 and 0.05,  $\tau^*$  is 0.05, 0.08 and 0.10, respectively, and it increases to 0.13 and 0.15 for economies with  $\gamma$  equal to 0.075 and 0.10, respectively. In the case of large externality effect,  $\gamma = 0.3$ , for instance, the optimal tax rate is 0.35, which implies that optimal public sector share ( $\tau * (r_t k_t + w_t h_t) / Y_t$ ) is 0.33, considerably larger than the actual public sector share. On the other hand, for  $\gamma$  between zero and 10 per cent, the optimal public sector share is smaller than the observed share. Of course, once public consumption is introduced in the model those values could change.

Steady state equilibrium levels of  $K$ ,  $G$  and  $Y$  also increase with  $\gamma$ , even considering, in the case of public provision of infrastructure, that higher  $\gamma$  imply higher (optimal) tax rates. Table one below presents the steady state levels of capital types  $K$  and  $G$  and output as  $\gamma$  increases from zero to 0.05.

Table 1: Long Run Allocations

$\gamma$	Public G			Private G		
	$Y$	$K$	$G$	$Y$	$K$	$G$
0.0	1.05	9.63	2.09	1.08	10.49	1.54
0.01	1.07	9.76	2.59	1.09	10.57	1.55
0.02	1.10	9.93	3.08	1.10	10.65	1.57
0.03	1.14	10.15	3.64	1.11	10.73	1.58
0.04	1.18	10.39	4.24	1.12	10.82	1.59
0.05	1.22	10.67	4.89	1.13	10.91	1.61

Note that the effect of changes in  $\gamma$  is much stronger in the model with public provision of infrastructure. While  $G$ ,  $K$  and  $Y$  increase at most 4,6% when  $\gamma$  goes from zero to 0.05, in the economy with private  $G$ ,  $K$  increases 11%,  $Y$  16% and  $G$  more than doubled its value in the model with public infrastructure. The reason for this result, of course, is the fact that in the last model the positive externality due to  $G$  is taken into account but not in the economy with private infrastructure. In the last case, the provision of type  $G$  capital is a function of its (private) marginal product, which depends

directly on  $\phi$ , but not on  $\gamma$ , as can be seen in expression 11. This fact also explains why there is always a relative under-investment in  $G$  in the model in which it is privately provided, even for small values of  $\gamma$ : when its value is 0.025,  $G$  and  $J$  are twice as large when they are publicly provided than when they are privately provided. This, of course, is the optimal behavior for this economy: there is nothing intrinsically "bad" in the fact that the first economy invests more in  $G$  than the second.

Figures one and two below display the difference in the levels of income and consumption, respectively, between the economy with private provision of  $G$  and the economy in which it is publicly provided as the level of  $G$  increases to its steady state value (in other words: the vertical axis in figure one, for instance, measures the income level in the economy without government minus the income level in the economy with government.). In this case,  $\gamma$  was set equal to 0.01, while  $\tau$  was kept in its optimal level and  $K$  and  $H$  to their steady state levels. It is interesting to note that, on the one hand, income difference increases as  $G$  increases - the economy without government gets relatively richer closer to the steady state. Differences in the consumption levels, on the other hand, after initially increasing, fall with  $G$ . It is, however, always positive: not only income is higher in the economy without government but investment in capital type  $G$  is much smaller outside of and in the state state. For this reason, as shown in the next section, in this economy welfare is higher when infrastructure is private rather than publicly provided. Hence, as measured by welfare, there is over-investment in infrastructure in the economy with government for this combination of parameters.

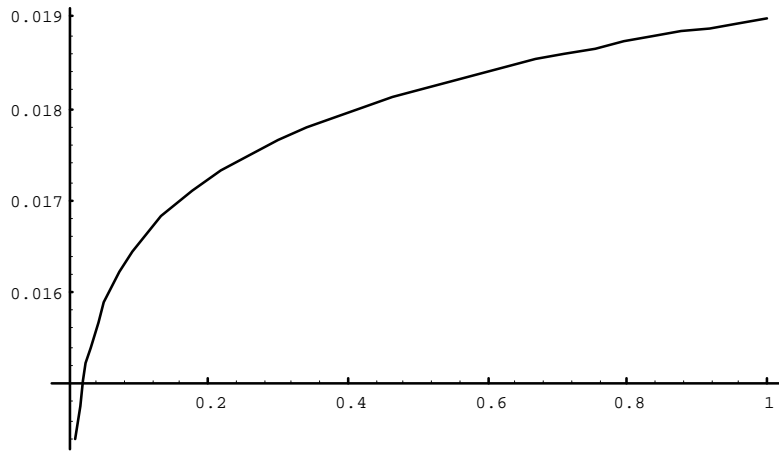


Figure1: Difference in income levels as function of inputs ( $\gamma = 0.01$ )

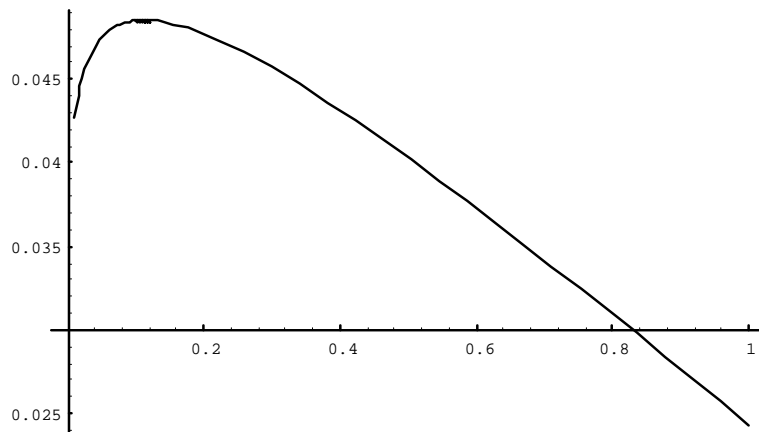


Figure 2: Difference in consumption levels as function of inputs ( $\gamma = 0.03$ )

There are two additional facts worth mentioning. The first is the huge dimension of public capital - when compared to private capital and also to the  $G$  stock of economies with smaller  $\gamma$  - when  $\gamma$  is 0.30, a value in line with estimates by Aschauer(1989). In this case  $G$  is more than twice  $K$  and 36 times larger than the stock of public capital of the economy with  $\gamma$  equal to 0.05.. The second fact is related to the  $K-G$  ratio. In 1990, non-military public net capital stock was something between 41% of private net stock, using a broad measure, or 24%, when we only consider equipment and “core” infrastructure (highways, sewer system, utilities, water supply

system, airport and transit system) at State and local government levels (Munnel(1994)). From table 1 we could make the point, therefore, that these values imply  $\gamma$  below 0.04 as  $G/K$  is 0.41 when  $\gamma$  is 0.04 and 0.22 when  $\gamma$  is zero<sup>8</sup>. Both facts reinforce our decision to use only  $\gamma$  values between zero and 0.05 in the simulation exercises.

## 5.2 Welfare Effects of Privatization

The welfare measure used compares steady states and is based on the change in consumption required to keep the consumer as well-off under the new policy (privatization) as under the original one, when infrastructure was publicly provided. The measure of welfare loss (or gain) associated with the new policy is obtained by solving for  $x$  in the following equation:

$$\bar{U} = \ln(C^* (1 + x)) + A \ln(1 - H^*)$$

In the above expression  $\bar{U}$  is steady-state utility level under the original policy,  $C^*$  and  $H^*$  are consumption and hours worked associated with the new policy. Welfare changes will be expressed as a percent of steady-state output ( $\Delta C/Y$ ), where  $\Delta C (= C^*x)$  is the total change in consumption required to restore an individual to his/her previous utility level.

Before investigating the results of the welfare exercises, a look at figures 3 and 4 may be illustrative.

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<sup>8</sup>Care must be taken, however, when comparing first moments; for instance, the capital-output ratios displayed in table 1 are well above the actual ratios for the U.S. economy.

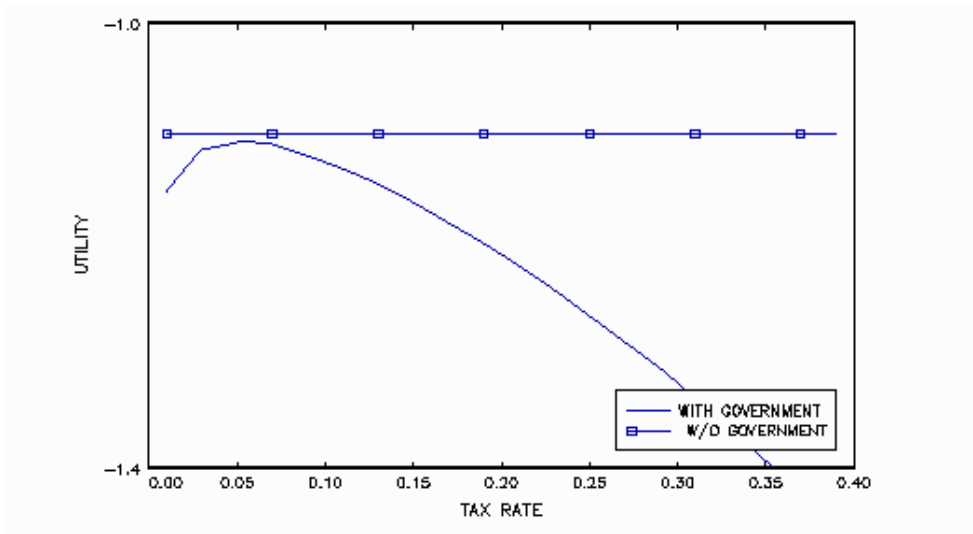


Figure 3: Steady state utility levels ( $\gamma = 0.0$ )

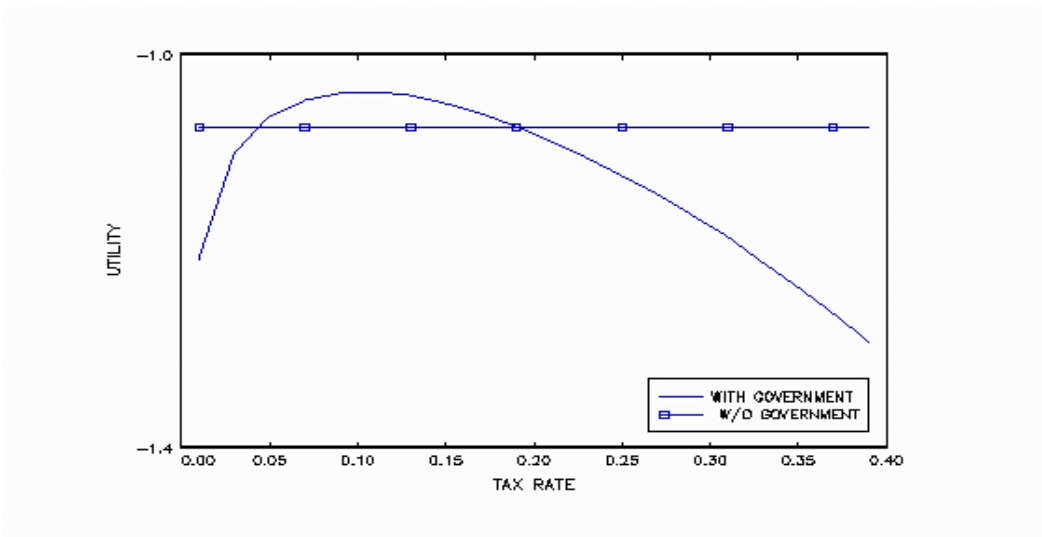


Figure 4: Steady state utility levels ( $\gamma = 0.03$ )

The horizontal line represents consumer's utility level in the economy with private infrastructure. Utility is, of course, invariant to tax rates in this model. The other line represents utility levels in the economy with

government. As already commented, it initially increases with  $\tau$ , reaches a maximum at  $\tau^*$  and then decreases when the distortionary effect of taxation outweighs the productive impact of infrastructure. In figure 3  $\gamma$  is zero and the economy with public infrastructure is dominated, in terms of utility, by the economy with private provision of infrastructure, for any tax rate. On the other hand, for  $\gamma$  equal to 0.03, there is a tax interval where utility levels are greater in the economy with government than in the economy without it. Hence, in the first case there is potential for welfare gains from privatization while in the second case society may lose from it (if the government behaves optimally).

Table 2 below displays the result of the welfare calculations. In all cases tax rates are picked so that they maximize the representative agent's utility as explained in section 2.

Table 2: Welfare Effects of Privatization

$\gamma$	$\tau$	$\Delta C/Y$
0.0	0.05	-0.71 %
0.01	0.06	-0.23 %
0.02	0.07	0.48 %
0.03	0.08	1.39 %
0.04	0.09	2.29 %
0.05	0.10	3.79 %

Positive numbers mean a welfare cost - after privatization, it is necessary to give back x% of consumption to agents in order to keep them as well-off as they were before privatization - while negative numbers mean a welfare gain, as consumption should decrease for utilities to be equalized. Hence, according to the model simulations presented above, privatization is welfare improving if the true value of  $\gamma$  is less than 0.01 (as a matter of fact, for  $\gamma$  less than 0.014). This gain is decreasing with  $\gamma$ , which makes sense: for small  $\gamma$  the fact that the benevolent government takes the positive externality due to  $\bar{G}$  into account when picking  $\tau$  is of minor importance when compared to the distortion introduced to finance public investment.

For the case in which  $\gamma$  is 0.01, there is a small welfare gain of 0.23% of GNP. Here the internal and external effects of infrastructure add up to 0.06, a value in line with estimates in a large number of studies. As a proportion of consumption, instead of GNP, it was calculated to be 0.32%. Taking

the consumption per capita in 1994 for the U.S. as being approximately 18,500 dollars, this result implies that in the long run, after privatization, each individual would increase his/her consumption by only 59 dollars a year. So, even though privatization is welfare improving the gain is very small. Maximum gain occurs for economies in which the true  $\gamma$  is zero. In this case welfare gain as a proportion of GNP is 0.71% and as a proportion of consumption is almost 1%. Not very large but more relevant: annual consumption would increase by almost 180 dollars in the long run.

This result, however, is very sensitive to the choice of parameters, especially  $\gamma$ . If the true  $\gamma$  is 0.02, not far from some estimates in the literature - and well below Aschauer's and Munnell's estimates - society loses with private provision of infrastructure services. In this case there is a welfare loss of half percent of GNP. Of course, as  $\gamma$  increases, the loss due to the private operation of infrastructure increases, reaching almost 4% when  $\gamma$  is 0.05 ( and the total effect of infrastructure adds up to 0.1). In summary: when we make the best case for public operation of infrastructure (e.g., no operation inefficiencies, benevolent government, etc.) we may have welfare losses associated with privatization, for some reasonable combination of parameters.

If it is assumed that the tax structure is still more distorting than the structure above, the benefits from privatization increase. Suppose ( just as an illustration) that public investment is entirely financed by taxes on capital gains (dividends plus rental gains). Although an extreme assumption, this idea may capture the fact that in many countries, Brazil for one, savings, finance intermediation and even gross revenues are heavily taxed. We let all other parameters remain the same and repeated the experiment of table 2, which consists of estimating the welfare gains from privatization when government chooses tax rates optimally. The results are displayed in table 3 below:

Table 3: Welfare Effects of Privatization (capital tax only)

$\gamma$	$\tau$	$\Delta C/Y$
0.00	0.10	-1.92%
0.01	0.12	-1.74%
0.02	0.14	-1.36%
0.03	0.16	-0.79%
0.04	0.18	-0.06%
0.05	0.19	0.84%

The welfare gains from privatization in this economy are much higher, as one could expect. For  $\gamma$  equal to 0.02 the gains are now 1.36% of GNP, or 1.85% of total consumption, which amounts to an increase of \$342 dollars in the annual per capita consumption in the long run. At the same time, welfare losses with privatization will only occur now for  $\gamma$ s above 0.041. It is also shown in the table that when  $\gamma$  is 0.03, instead of a loss of 1.4% as in the previous case, there is now a gain of 0.8% of GNP. The reason for these results are simple, the gains from internalizing the positive externality are now offset by higher distortions, so that you need higher externality for privatization not to be welfare improving. Of course, assuming a tax structure with less distortions (e.g., only tax on labor income) would imply the opposite results and weaken the case for privatization.

### 5.3 Welfare effects of privatization with investment losses

Perhaps the most popular argument favoring privatization is based on the supposed inefficiency of public companies when compared to private counterparts. In one way or another, the idea is that the former are not profit maximizing. They may operate according to some political objective (inflation control or patronage), they may operate aiming to maximize the income of their employees or they may operate with higher levels of red tape or employment. In all these cases operational costs are well above minimization level, so that society as a whole could gain if those firms were transferred to the private sector.

Pinheiro(1997) examines data of the 46 federal companies privatized in Brazil from 1981 to 1994. He shows that, after privatization, on average, revenues went up by 27%, sales per worker increased by 83% and profit by 500%. At the same time the number of employees fell by 31%. In certain companies, such as the federal railroad or the Rio de Janeiro energy supplier, productivity went up by almost 100% in less than two years. Hulten (1996), on the other hand, finds that "*...those countries that use infrastructure inefficiently pay a growth penalty in the form of a much smaller benefit from new infrastructure investments.*" He estimated that one-quarter of the differential growth rate between Africa and East Asia could be attributed to the difference in effective use of infrastructure resources.

A tentative and simple way of modeling these inefficiencies is to suppose

that investment costs are higher in the public sector. There is informal evidence that this is in fact the case, and the reason is not necessarily corruption but the very nature of the government's business and relationship with the private sector. In a number of countries in Latin America, for instance, private firms charge an over-price to government companies as an insurance against payment delay or default risk, two common practices. In addition to that, most purchases from public companies have to be done through public bids and in general this is a long and bureaucratic process. Those firms cannot simply ask prices by phone or fax and pick the best one, in general there is a huge number of legal procedures that take time and cost money and, in fact, end up inducing collusion of suppliers. For instance, the official development bank of the Brazilian central government (BNDES) calculated that the construction of a hydroelectric plant that they would finance for a public firm had its cost cut by half after it was transferred to private hands. In an extreme case, the cost of investment projects of a privatized steel mill in Brazil dropped to one third of its original figures.

A simple way to model this fact is to suppose that instead of (6) we now have:

$$J_t = (1 - \lambda)(\tau r_t K_t + \tau w_t H_t + \tau \pi_t), \forall t, 0 \leq \lambda < 1 \quad (13)$$

so that a fraction  $\lambda$  of tax revenues is lost and only  $(1 - \lambda)$  is effectively invested. This is equivalent to suppose that public investment is  $1/(1 - \lambda)$  more expensive than private investment. All the other features of the model, and the parameter values, are maintained. We have reproduced the privatization experiments of table 2, but now we wonder whether the introduction of investment losses in the public sector implies considerably larger gains from privatization. In table 4 below we assumed  $\lambda$  equal to 0.2, supposing moderate losses, and the results from table 2 ( $\lambda$  equal to zero) are reproduced for the sake of comparison:

Table 4: Welfare Effects of Privatization  
w/ Investment Losses in the Public Sector

$\gamma$	$\Delta C/Y$	
	$\lambda=0$	$\lambda=0.20$
0.00	-0.71 %	-2.00 %
0.01	-0.23%	-1.79 %
0.02	0.48 %	-1.37 %
0.03	1.39 %	-0.76 %
0.04	2.29 %	0.02 %
0.05	3.79 %	0.98 %

The results above show that even a moderate investment loss may imply sizable differences when considering privatization. If investment in the public sector is 25% more costly than in the private sector (as  $\lambda = 0.20$  implies  $1/(1 - \lambda) = 1.25$ ) privatization is welfare improving for economies with  $\gamma$  up to 0.039, a value in the upper bound of most estimates in the literature. In the case of  $\gamma$  equal to 0.03 a welfare loss of 1.39% of GNP is turned into a gain of 0.76%, i.e., a difference of more than 2% of GNP. The distortion introduced by the tax system and the high inefficiency of investment operations offset the gains of internalizing the external effect of infrastructure capital, even for high values of the externality parameter. Moreover, the gains are now much larger in the interval in which privatization was already welfare improving: for  $\gamma$  equal to 0.01, the welfare gains from privatization increased more than 8 times.

Another interesting exercise would be to calculate the investment loss necessary, for each  $\gamma$ , to turn privatization into a socially desirable program. In the case of  $\gamma$  equal to 0.02 ( so that the external and internal coefficients of infrastructure capital add up to 0.07) any  $\lambda$  larger than 0.056 would make privatization welfare improving. In other words: if the investment loss in this case is above of 5.6%, privatization would imply in welfare gains. In this case, a very small inefficiency is enough to justify private operation of infrastructure. For economies with  $\gamma$  equal to 0.03, 0,04 and 0.05, investment losses (i.e.,  $\lambda$ ) above 13.4%, 20.2% and 26.2%, respectively would turn privatization from a welfare losing program into a welfare improving program. Those values are not far from the evidence of operation inefficiency of public companies in Latin America, for instance.

## 6 Privatization with Subsidy to Infrastructure Accumulation and Further Issues

The simulations showed that privatization maybe welfare improving for a large number of economies, specially in the presence of operation inefficiency. Without those, however, economies with reasonable combination of parameters will still suffer with privatization. Could private operation of infrastructure be welfare improving for all economies with appropriate tax-subsidy schemes, as found by Devarajan, Xie and Zhou (1998) in an endogenous growth environment? Also, can we “solve” the under-investment result that is optimal but maybe non-intuitive, as one does not see infrastructure stocks decreasing after privatization? A model is constructed below to answer these questions. A subsidy to the accumulation of type  $G$  capital, financed by proportional taxes on the return of all factors, is introduced in the model of section 3. Hence, the subsidy scheme is done so that after privatization agents will internalize, at least partially, the external effect due to infrastructure. As we will see, the answer to the questions above are as follows: 1) an optimal tax-subsidy scheme increases the benefits and the set of economies in which privatization is welfare improving but it does not dominate public provision of infrastructure when  $\gamma$  is large enough; 2) there is less under-investment, but under public provision equilibrium  $G$  is still larger than under private provision.

Suppose, again, that tax rates are the same for all the factors of production and equal to  $\tau$ , so that consumer’s budget constraint is given by

$$c_t + i_t + j_t = (r_t k_t + w_t h_t + \rho_t g_t) (1 - \tau), \forall t \quad (14)$$

Assume that the consumer’s objective function, the production function and the firm’s problem remain the same as before. Hence, equilibrium expressions for the factor rewards are the same as in model II, the privatized economy. Government uses tax revenues to subsidize type  $g$  capital formation, so that its law of motion is now given by:

$$g_{t+1} = (1 - \delta)g_t + (1 + \psi)j_t$$

where  $\psi$  is the subsidy rate. It is imposed that the public budget balances every period:

$$\psi J_t = (r_t K_t + w_t H_t + \rho_t G_t)\tau,$$

so that the value of one of the instruments of fiscal policy,  $\psi$  or  $\tau$ , is automatically determined after the other one is picked by the government. Consumer's problem in a recursive form is given by:

$$\begin{aligned}
v(k, K, g, G, \bar{G}) &= \max_{c, h, i} \left\{ \ln(c) + A \ln(1 - h) \right\} + \beta v(k', K', g', G', \bar{G}'), \\
&\text{s.t.} \quad : \\
c + i + j &\leq (r(K, G, \bar{G})k + w(K, G, \bar{G})h + \rho(K, G, \bar{G})g) (1 - \tau), \forall t \\
k' &= (1 - \delta)k + i \\
K' &= (1 - \delta)K + I \\
G' &= (1 - \delta)G + (1 + \psi)J \\
g' &= (1 - \delta)g + (1 + \psi)j \\
\psi J_t &= (r_t K_t + w_t H_t + \rho_t J_t) \tau \\
k_0 \text{ and } g_0 &> 0 \text{ and given}
\end{aligned}$$

It can be shown that, after some simple manipulations, solutions for this problem satisfy the following conditions:

$$\frac{1}{c} = \frac{\beta \left( \theta (1 - \tau) \left( \frac{K^0}{H^0} \right)^{\theta-1} \left( \frac{G^0}{H^0} \right)^\phi \bar{G}'^\gamma + (1 - \delta) \right)}{c'} \quad (15a)$$

$$\frac{1}{c} = \frac{\beta \left( \phi(1 + \psi) (1 - \tau) \left( \frac{K^0}{H^0} \right)^\theta \left( \frac{G^0}{H^0} \right)^{\phi-1} \bar{G}'^\gamma + (1 - \delta) \right)}{c'} \quad (15b)$$

$$\frac{A}{1 - h} = \frac{(1 - \phi - \theta) (1 - \tau) \left( \frac{K^0}{H^0} \right)^\theta \left( \frac{G^0}{H^0} \right)^\phi \bar{G}'^\gamma}{c} \quad (15c)$$

Equations 15a and 15c are standard Euler equations for capital type  $K$  and labor, and their interpretations follow those in section 2. Equation 15b is the Euler equation for capital type  $G$  in the presence of subsidy. Everything else constant, it says that the higher  $\psi$ , the more the consumer will be willing to save and invest in the present period. However, everything else is not constant: higher subsidies will have to be financed through higher taxes, which decreases the net return to capital and, consequently, savings in the present period.

As in section II, government picks  $\psi$  (or  $\tau$ ) in order to maximize the individual's welfare, taking as given optimal decision rules and the equilibrium expressions for wages and rental rate of capital. Its actions create a trade-off.

On the one hand, through taxation it distorts optimal decisions and reduces the return of labor and of both capitals. On the other hand, the subsidy allows, at least partially, the internalization of type  $G$  capital externality, which increases welfare. Tax rates adjust in order to balance public budget. As in section 2, we are solving for a Ramsey equilibrium.

After solving this problem the experiments of section 5.2. were replicated in order to calculate the welfare costs or gains of privatization. Results are presented in table 5 below.

Table 5:Welfare Effects of Privatization w/ Subsidy

$\gamma$	optimal tax rate ( $\tau^*$ )	optimal subsidy ( $\psi$ )	$\Delta C/Y$
0.0	0.005	0.125	-0.815%
0.01	0.009	0.211	-0.513 %
0.02	0.013	0.287	-0.071 %
0.03	0.016	0.340	0.499 %
0.04	0.020	0.407	1.188%
0.05	0.024	0.470	1.990%

Two main differences were found between the results of the first simulations and the present ones, as one can see by comparing table 5 and table 2. First, as we could expect, for a given  $\gamma$  welfare gains are bigger with than without subsidy, as agents now internalize the external effect due to  $G$ . This difference increases with  $\gamma$ : when  $\gamma$  is zero it is only 0.1%, but it rises to 0.28% when  $\gamma$  is 0.01. The intuition is simple: the higher the external effect due to infrastructure capital, the more society gains by subsidizing its investment.

The second difference is that the set of economies that can benefit from privatization is now larger. Without subsidy, privatization is welfare improving only for economies in which the actual  $\gamma$  is smaller than 0.014, but in the presence of subsidy the gains are positive for economies with  $\gamma$  up to 0.022. This means that if the true total (internal and external) output elasticity of infrastructure is below 0.72, than its operation by private hands would increase society welfare. For those parameters values, private operation of infrastructure joint with subsidy to investment in the sector dominates the two other operation schemes examined. However, when the external effect is large enough public provision of infrastructure dominates privatization with or without subsidy to infrastructure investment. When  $\gamma$  is 0.04, for instance,

the loss from private provision of infrastructure services is 1.18% in the first case and 2.49% in the last one. This is so because there is also taxation on labor and type  $K$  capital. In Devarajan, Xie and Zou(1998), for instance, there is no leisure decision as in the present model so that here increases in  $\tau$  to finance the subsidy also affect the return to labor and distort agents' decision. Note also that the optimum subsidy increases with  $\gamma$ , as one might expect. Of course, if investment losses were also assumed, as in the previous section, the set of economies that benefit from privatization would further increase .

Table 6 below compares allocations before and after privatization. It still the case that type  $G$  capital and  $J$  are considerably smaller under private than public provision, even in the presence of subsidy. Hence, under-investment in infrastructure remains the optimal action after privatization and the externality is only partially internalized.

Table 6: Long Run Allocations

$\gamma$	Public G			Private G w/ subsidy		
	$Y$	$K$	$G$	$Y$	$K$	$G$
0.00	1.05	9.63	2.09	1.09	10.51	1.74
0.01	1.07	9.76	2.59	1.11	10.62	1.89
0.02	1.10	9.93	3.08	1.22	10.74	2.02
0.03	1.14	10.15	3.64	1.14	10.87	2.15
0.04	1.18	10.39	4.24	1.16	11.02	2.28

Comparing the results above with private provision without subsidy (table I), however, there is an increase in the equilibrium quantities of  $G$  for any  $\gamma$  as the externality is now taken into account. Furthermore, this variable becomes much more sensitive to changes in the parameter  $\gamma$ . For instance, moving from economies with no externality to economies with a 0.04 externality, the long run stock of  $G$  increases 31%. Without subsidy,  $G$  is almost insensitive to  $\gamma$ , and the above change in  $\gamma$  would increase the optimal stock of  $G$  by only 3%. Notice, however, that under the tax-subsidy scheme, total capital stock ( $K + G$ ) of the economy under private provision of infrastructure is larger than under public provision in economies in which  $\gamma$  is below 0.02. In this case over-investment in  $K$  compensates the under-investment in  $G$ .

In all the models studied here we have made the assumption of no public consumption expenditures. However, they represent about 15 percent of U.S.

GDP, for instance, being important by any means. If they are included in the model, investment in infrastructure would not increase the tax from 0 to a positive number, but from a positive number to a larger positive number, implying that our estimations underestimate the excess burden. In fact, simulations of economies in which public consumption exists found that the optimal  $\tau^*$  was higher for each level of  $\gamma$  and sldo the welfare gains from privatization.

We changed Model I by the inclusion of public consumption ( actually, lump sum transfers to the families), so that tax revenues were divided in fixed proportions between public consumption ( say,  $\chi \in (0, 1)$ ) and public investment ( with a share of  $(1 - \chi)$  of tax revenues). After privatization public investments go to zero as before and public consumption is kept constant as a proportion of output. We replicate the exercises of Section 5.2 for different values of  $\chi$ . The introduction of public consumption reinforces the case of private provision of infrastructure as the gains from privatization increases considerably in every economy. Moreover, the interval of economies in which privatization improves welfare is larger now. For instance, when  $\gamma = 0.01$  welfare gains jump from 0.23% to 1.11% and they will be positive for economies with  $\gamma$ 's up to 0.029, when they were negative for values of  $\gamma$  greater than 0.014 in the standard model. As one could expect, the optimal  $\tau^*$  increases for any  $\gamma$ . For instance, in the case of  $\chi = 0.75$ , it goes from 0.05 to 0.096, when  $\gamma = 0$ , and from 0.07 to 0.124, when  $\gamma = 0.02$ . The introduction of investment losses and/or subsidy to private investment in  $G$  would of course compound this effect.

A final experiment was the introduction of congestion to public capital, following Glomm and Ravikumar (1994). In this case infrastructure's contribution to the private sector is decreasing in type  $K$  capital and labor. The production function is modified to  $Y_t = K_t^\theta \vartheta_t^\phi H_t^{1-\theta-\phi} \bar{\vartheta}_t^\gamma$ , where  $\vartheta_t = G_t/K_t^\rho H_t^\nu$ . The introduction of congestion reduces utility, as one could expect, and the welfare gains of privatization. When  $\gamma = 0.00$  (no external effect due to type  $G$  capital), and  $\rho = \nu = 0.3$ , for instance, the welfare gains of privatization goes from 0.71 to 0.42 and for economies in which  $\gamma = 0.01$ , privatization now decreases welfare as opposed to a small gain in the case of no congestion. Of course results could be different if we assumed that government could not impose optimal taxes. In this case the existence of congestion could make stronger the case of privatization, since congestion externalities could then be priced by the private sector.

One potential caveat to our results is that transition paths have not been

taken into consideration. Hence, a policy that maximizes steady-state utility in an economy that exhibits transition dynamics may lead to misleading results. In models such as Barro(1990), Glomm and Ravikumar(1994) and Devarajan, Xie and Zou(1998) this problem does not arise because they do not have transition dynamics, which is not case here. However, in our model, the transition to a new steady state after a policy change is almost instantaneous. Hence, steady-state analysis is not problematic. Figure 5 below may be illustrative:

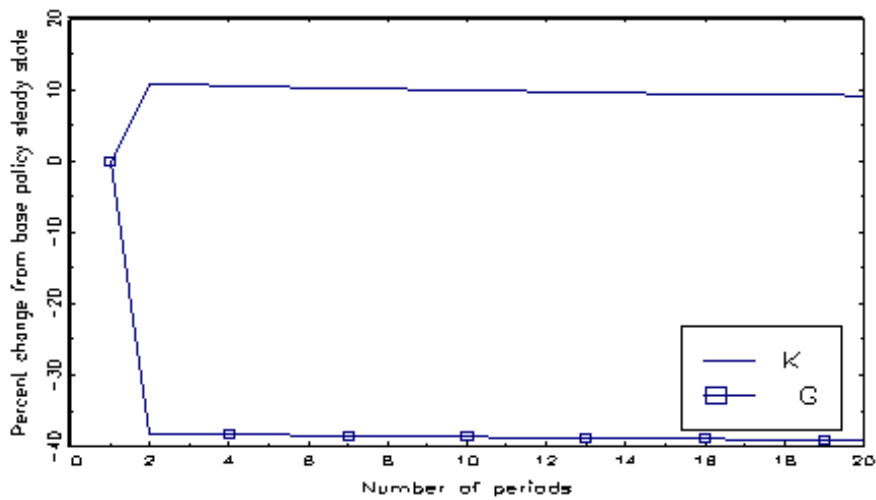


Figure 5: Transition paths of  $K$  and  $G$  after privatization ( $\gamma = 0.01$ )

Figure 5 displays the percent change of  $K$  and  $G$  after privatization (without subsidy) for the case in which  $\gamma = 0.01$ . From equations (10) and (11) one can verify that the ratio  $G/K$  is constant across periods in this model. Thus, once  $G$  is transferred to private hands, the economy jumps to this ratio in order to equalize the returns to both capitals that adjust to levels very close to the new steady-state levels<sup>9</sup>. As a consequence, the welfare effects of privatization were not dramatically different from previous calculations once transition paths were introduced. However, they were slightly smaller in most cases.

<sup>9</sup>In the first period, the sum of  $G$  and  $K$  remains constant but  $G$  decreases and  $K$  increases as the externality due to the former is not taken into account now.

## 7 Conclusion and Summary

This model economy, although in certain dimensions highly simplified, does deliver some lessons and intuitions that allow us to better understand the welfare and allocation implications of infrastructure privatization.

The first lesson, also present in Devarajan, Xie and Zhou (1998), is that privatization can be welfare-enhancing in one country and welfare-decreasing in another, depending on the relative importance of distortionary taxation and the positive externality due to infrastructure. Our simulations showed that if we make strong hypotheses that favor the case of public provision of infrastructure, such as a benevolent government maximizing individuals' welfare, no operation inefficiency and free supply of infrastructure services to society, private operation of infrastructure only dominates public operation if the actual value of the sum of the external and internal effects of public capital is relatively small (below 0.065). Estimates of Ratner(1983), Duffy-Deno and Eberts(1991), Canning and Fay(1993) and Baffes and Shah(1993) found values between 0.05 and 0.10 for the sum of these coefficients, while Aschauer(1989) and Munnell found it to be around 0.4. On the other hand, the simulations with only capital income taxation showed that for a given externality effect, the more distorting the financing of public investment, the higher the benefits from privatization.

A second conclusion is that the case for privatization is considerably strengthened when inefficiencies in the public sector are allowed. And inefficiency is without question a serious problem in the operation of public infrastructure. For instance, the World Bank(1994) estimates that timely maintenance expenditures of \$12 billion dollars would have saved road reconstruction costs of \$45 billion in Africa in the past decade, while informal evidence from Brazil has indicated that investment costs could drop to half after privatization. Simulations in section 5.3 showed that even a small over-price on investment considerably increases the benefits of privatization. And they would also increase the set of economies (i.e., economies with larger externalities) that could benefit from private provision of infrastructure. For instance, if investment costs decrease by one quarter after privatization, then for almost all reasonable sets of parameters private operation of infrastructure would dominate its operation by the public sector. The introduction of public consumption expenditures in the model reinforced considerably this result.

Although it may be politically unfeasible to implement an optimal tax-

subsidy scheme such as the one proposed in section 6, there are considerable gains for society from doing so. First, it increases the welfare benefits of privatization, as private agents internalize the external effect due to privatization. Second, it expands the set of economies in which privatization is welfare improving, even though it does not dominate public provision of infrastructure when  $\gamma$  is large enough. Finally, there is less under-investment with respect to the privatization without subsidy scheme, in spite of the fact that under public provision equilibrium  $G$  is always larger than under private provision.

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