

Nº 297

ISSN 0104-8910

***INFRASTRUCTURE PRIVATIZATION IN A
NEOCLASSICAL ECONOMY: MACROECONOMIC
IMPACT AND WELFARE COMPUTATION***

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Janeiro de 1997

Infrastructure Privatization in a Neoclassical Economy: Macroeconomic Impact and Welfare Computation*

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Abstract

In this paper a competitive general equilibrium model is used 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 internalizing the externality, but it introduces distortions in the economy through the finance of its investments. It is shown that even making the best case for public action - maximization of individuals' welfare, no operation inefficiency and free supply to society of infrastructure services - privatization is welfare improving for a large set of economies. Hence, arguments against privatization based solely on under-investment are incorrect, as this maybe the optimal action when the financing of public investment are considered. When operation inefficiency is introduced in the public sector, gains from privatization are much higher and positive for most reasonable combinations of parameters.

* We gratefully acknowledge the comments of Afonso A. M. Franco Neto, Rodolfo Manuelli and participants of the 1996 SBE Meeting. We also thank CNPq for the financial support.

1 - Introduction

Infrastructure and privatization of public utilities have been, in the past years, subject of a large literature and moved to the center of the policy debate in countries around the world, both developed and developing. On the one hand, the productive impact of infrastructure has been investigated lately by an increasing number of studies, starting with Aschauer's pioneer paper(1989). These studies use different econometric techniques and data samples to estimate the output and productivity elasticity to public capital. Overall, although the magnitudes found vary considerably, the estimates (e.g. Aschauer (1989), Ferreira(1993), Duffy-Deno and Eberts(1991), 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 owned 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 summed 19.8 billions 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 public ("infrastructure"), and a positive externality due to the latter is assumed. A benevolent government can improve upon decentralized allocation 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.

This model economy was solved using simulation techniques on the lines of Kidland and Prescott(1982), although the model is non stochastic. Model's parameters and functional forms 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 more than one value for the external effect parameter and compare the results.

After solving the model, it was used to measure the welfare effect of privatization under alternative sets of parameters and to compare long run allocations. One of the main results is that, even making the best case for public action - maximization of individuals' welfare, no operation inefficiency and free supply to society of infrastructure services - privatization maybe welfare improving. Hence, arguments against privatization based solely on under-investment are mistaken, as this maybe the optimal action when the financing of public investment are considered. When operation inefficiency is introduced, gains from privatization are much higher and positive for most reasonable combinations of parameters.

On a pure theoretical ground, Devarajan, Xie and Zou(1995) investigate alternative systems of infrastructure services provision using distortionary taxes and part of our model borrow heavily **from** theirs. However, they work in an endogenous growth environment while we work with the traditional neoclassical growth model. This framework was chosen 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 worlds: 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)).

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. Finally, in section 6 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:

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

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 finance its investments by tax collection and supply G for free to firms. Hence, 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:

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

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

$$(2) \quad r_t = \theta \left(\frac{K}{H} \right)^{\theta-1} \left(\frac{G}{H} \right)^\phi \bar{G}^\gamma$$

$$(3) \quad w_t = (1 - \phi - \theta) \left(\frac{K}{H} \right)^\theta \left(\frac{G}{H} \right)^\phi \bar{G}^\gamma$$

A representative agent is endowed with one unit of time which he divides between labor and leisure (l). His utility at each period is defined over sequences of consumption and leisure, and it is assumed that preferences are logarithm in both its arguments¹:

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

¹Note 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.

Income from capital and labor are taxed by the government at tax rates τ_k and τ_h , respectively, 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:

$$(4) \quad c_t + i_t \leq (1-\tau_k) r_t k_t + (1-\tau_h) w_t h_t$$

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

$$(5) \quad k_{t+1} = (1-\delta)k_t + i_t$$

$$(6) \quad G_{t+1} = (1-\delta_g)G_t + J_t$$

where δ and δ_g are 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 that the government budget constraint is always in equilibrium (so that we rule out public debt):

$$(7) \quad \tau_k r_t K_t + \tau_h w_t H_t = J, \quad \forall t$$

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

$$v(k, K, G, \bar{G}) = \max_{c, h, i} \{ [\ln(c) + A \ln(1-h)] + \beta v(k', K', G', \bar{G}') \}, \quad 0 < \beta < 1.$$

$$s.t. \quad c + i \leq (1-\tau_k) r(K, G, \bar{G})k + (1-\tau_h) w(K, G, \bar{G})h \quad \forall t$$

$$k' = (1-\delta)k + i$$

$$K' = (1-\delta)K + I$$

$$G' = (1-\delta_g)G + J$$

$$\tau_k r_t K_t + \tau_h w_t H_t = J$$

$$k_0 \text{ and } G_0 > 0 \text{ given}$$

$$c \geq 0, 0 \leq h \leq 1$$

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

$$(8) \quad \frac{1}{c} = \frac{\beta \left((1 - \tau_k) \theta \left(\frac{K}{H} \right)^{\theta-1} \left(\frac{G}{H} \right)^{\theta} \bar{G}' + (1 - \delta) \right)}{c'}$$

$$(9) \quad \frac{A}{1-h} = \frac{(1 - \tau_h)(1 - \phi - \theta) \left(\frac{K}{H} \right)^{\theta} \left(\frac{G}{H} \right)^{\theta} \bar{G}'}{c}$$

Both equations are standard. The first one 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. Equation 8 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, \bar{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, \bar{G}) , and factor prices functions, $w(S)$ and $r(S)$, such that these functions satisfy: a) the household's problem; b) firm's problem and equations 2 and 3; c) consistency of individual and aggregate decisions, i.e., $C(S) = c(s)$, $H(S) = h(s)$ and $I(S) = i(s)$; d) the aggregate resource constraint, $C(S) + I(S) + J(S) = Y(S)$, $\forall S$; e) and the government budget constraint clears.

Government takes the individuals' actions as given in order to maximize their welfare. In this model, therefore, it is assumed a benevolent government. As we ruled out lump sum taxation, government actions create a trade-off between welfare and allocations. On the one hand, it distorts, through taxation, optimal decisions and reduces labor and capital returns. On the other hand, it supplies infrastructure taking into account the externality effect due to \bar{G} , which has a positive effect on returns and consequently on the equilibrium levels of capital, labor and output. Given that public infrastructure is supplied for free to firms, this is the best case scenario of public action in terms of welfare (ruling out lump sum tax or private supply of G jointly with a tax-subsidy scheme, which are

political unrealistic solutions). 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 in J , so that the isolated effect is under-investment in infrastructure. Of course, the absence of taxation may offset this negative effect.

Government therefore picks τ_k and τ_h in order to maximize 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:

$$\begin{aligned} \text{Max}_{\tau_k, \tau_h} \quad & E_0 \sum_{t=0}^{\infty} \beta^t [\ln(c_t(\tau)) + A \ln(1 - h_t(\tau))], \quad \tau = \{\tau_k, \tau_h\}, \\ \text{s.t.:} \quad & c_t(\tau) + i_t(\tau) = (1 - \tau_k)r_t(\tau)k_t(\tau) + (1 - \tau_h)w_t(\tau)h_t(\tau) \\ & r_t = \theta K_t^{\theta-1} H_t^{-\theta-\phi} G_t^{\phi+\gamma} \\ & w_t = (1 - \phi - \theta) K_t^{\theta} H_t^{-\theta-\phi} G_t^{\phi+\gamma} \\ & \tau_k r_t k_t + \tau_h w_t h_t = J_t \\ & G_{t+1} = (1 - \delta_g)G_t + J_t \end{aligned}$$

In the expression of w and r it is taken into account the positive external effect due to \bar{G} . For the sake of simplicity, only in the first line of the restrictions we wrote variables explicitly as function of tax rates.

3 - Model II: Privatization

We aim to use this model economy to investigate the welfare and allocation effects of privatization. For privatization in the present general equilibrium environment we mean changing from public to private the operation and ownership of infrastructure (type G capital), so that we are moving to an economy without tax distortions and government. Technology and the laws of motion of both capitals remain the same, but the problem of firms and households 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:

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

The expressions for the rental rate of capital K and wages, obtained from the solution of this problem, reproduces equations 2 and 3, while the expression for the rental rate of type G capital G is:

$$(10) \quad \rho_t = \phi \left(\frac{K_t}{H_t} \right)^\theta \left(\frac{G_t}{H_t} \right)^\phi \bar{G}_t^\gamma$$

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 in capital g , labeled j . Moreover, he/she receives now rents from g used by firms, so that his/her budget constraint is given by:

$$(11) \quad c_t + i_t + j_t = r_t k_t + w_t h_t + \rho_t g_t \quad \forall t$$

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). Writing the household's problem in a recursive form, the optimality equations can then be written as:

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

$$s.t. \quad c + i + j \leq r(K, G, \bar{G})k + w(K, G, \bar{G})h + \rho(K, G, \bar{G})g \quad \forall t$$

$$k' = (1-\delta)k + i$$

$$K' = (1-\delta)K + I$$

$$G' = (1-\delta_g)G + J$$

$$g' = (1-\delta_g)g + j$$

$$k_0 \text{ and } g_0 > 0 \text{ given}$$

$$c \geq 0, 0 \leq h \leq 1$$

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

$$(12) \quad \frac{1}{c} = \frac{\beta \left(\theta \left(\frac{K}{H} \right)^{\theta-1} \left(\frac{G}{H} \right)^{\phi} \bar{G}' + (1-\delta) \right)}{c'}$$

$$(13) \quad \frac{1}{c} = \frac{\beta \left(\phi \left(\frac{K}{H} \right)^{\theta} \left(\frac{G}{H} \right)^{\phi-1} \bar{G}' + (1-\delta_g) \right)}{c'}$$

$$(14) \quad \frac{A}{1-h} = \frac{(1-\phi-\theta) \left(\frac{K}{H} \right)^{\theta} \left(\frac{G}{H} \right)^{\phi} \bar{G}'}{c}$$

The second expression above was not present in the solution of the previous problem and it is an Euler equation for capital g . The two remaining expressions, except for the absence of taxes, are equivalent to equations 8 and 9. From equations 12 and 13 it can be seen that consumers pick K and G so that their marginal productivity in every period are equal. The definition of a *recursive competitive equilibrium* follows closely the definition in section 3, with minors changes due to the presence of one additional state variable, g .

4 - Calibration

Quantitative properties of this theoretical economy depend to a large extend on the values of the models' parameters. Depreciation rate for K and the sum of capital shares ($\theta + \phi$) are taken from Kidland and Prescott's (1982) closed-economy study, and are set equal to 0.025 per quarter and 0.36 respectively. We divided capital shares setting θ , the private capital share, equal to 0.31 and ϕ , type g capital share, equal to 0.05. The last value 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). The depreciation rate of infrastructure capital, δ_g , is set to 0.025 per quarter, matching δ and following again Baxter and King(1993).

Preference parameters follow Cooley and Hansen(1989): β 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 his/her time working. Tax rates are free parameters and chosen endogenously in order to maximize individual's welfare, so that they are not calibrated to match observed values.

There are multiple estimations of gamma, the coefficient of the externality effect due to \bar{G} , in the literature². Ferreira(1993) using maximum likelihood methods estimates values ranging from 0.02 to 0.05 depending on the series and specific methodology used. Duffy-Deno and Eberts(1991) estimate similar values using data for 5 metropolitan areas of the U.S., as well as Canning and Fay(1993), using a variety of cross-country data bases, Baffes and Shah(1993), who worked with OECD and developing country data, among others. Aschauer(1989) estimated much larger values, 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 used. 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 and uses similar methods³. On the other hand, Holtz-Eakin(1992) and Hulten and Swchartz(1992) found no evidence of public capital affecting productivity.

Given the variety of magnitudes estimated we chose to use several values for the parameter gamma, although our intuition and most estimates point to values between 0.025 and 0.5. In most of our experiments we used gamma equal to zero (no external effect), 0.025, 0.05, 0.075, 0.10 and 0.30. The last value corresponds to Aschauer's estimates.

² As a matter of fact, most papers estimate $\gamma+\phi$ jointly. We subtracted 0.05, the calibrated value of phi, from these estimates in order to obtain a value for gamma.

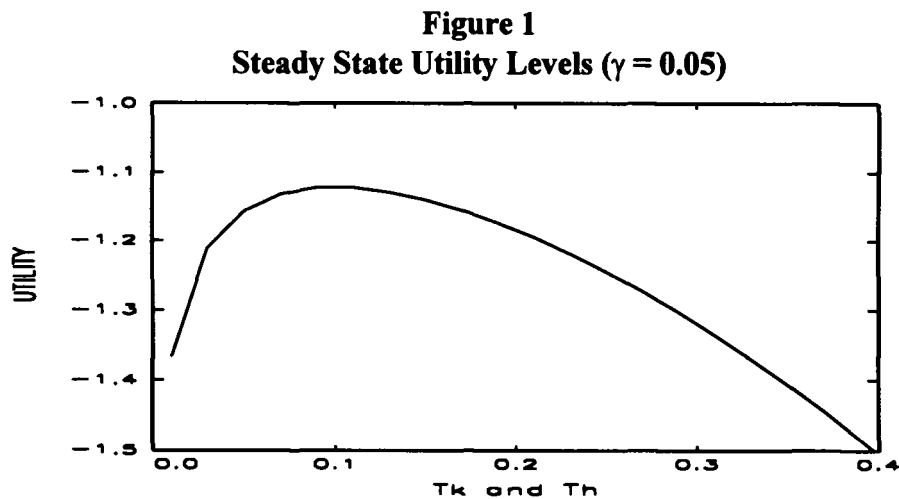
³Ferreira(1995) shows that elasticities of this order of magnitude imply that output and capital allocations in equilibrium increase with labor tax rates while τ_n is smaller than 0.61. In other words: if labor tax rate goes from 0.55 to 0.56, values well above the corresponding values for the U.S. economy, private capital and output in equilibrium will increase - and not decrease as one could expect - as the productive effect of infrastructure is so strong that it offsets the distortionary effect of taxation. This is a very non intuitive result, specially at this level of tax rates, which weakens Aschauer's and Munnell's estimates.

5 - Results

5.1 Long Term Allocations

The behavior of these economies is very sensible to changes in gamma and in 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 distortive is public financing, greater will be the gains from privatization.

Let's assume initially that τ_k and τ_h are the same, so that the government just picks one value labeled τ . For any given gamma, steady state utility increases initially with τ , reaches a maximum at some τ^* , and then monotonically decreases with τ . This is so because, for values below τ^* , the positive effect of infrastructure on productivity outweighs 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. This can be seen in figure 1 below, where gamma was set to be equal to 0.05.



The optimal tax rate increases with gamma. In the above case τ^* is 0.10. For gamma equal to 0.0 (no externality) τ^* is 0.05 and for gamma equal to 0.025 it is 0.07. When gamma is equal to 0.075 and 0.10, τ^* is 0.13 and 0.15, 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 ($\tau^*(r_l k_l + w_l h_l)/Y$) is 0.33, considerable 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.

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 gammas imply higher (optimal) tax rates. Table one below shows that capital types K and G and output increase with gamma in both models.

Table 1
Long Run Allocations

	Public G			Private G		
γ	K	G	Y	K	G	Y
0.0	7.53	1.70	0.89	7.84	1.26	0.89
0.025	7.77	2.90	0.95	7.90	1.28	0.90
0.05	8.16	3.90	1.02	8.00	1.29	0.91
0.075	8.72	5.60	1.13	8.10	1.31	0.92
0.30	43.36	109.29	7.77	9.65	1.56	1.06

Note that the effect of changes in gamma is much higher in the model with public provision of infrastructure. While these three variables increase at most 3.9% when gamma goes from zero to 0.075 in the economy with private G , K increases 15%, Y 26% and G more than tripped 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 is taken into account but not in the economy with private G . In the last case, the provision of type G capital is function of its (private) marginal product, which depends directly on ϕ , but not on gamma, as it can be seen in expression 9. This fact also explains why there is always under-investment on G in the model where it is private provided, even for small values of gamma: when its value is 0.025, G and J are twice as large when they are public provided then when they are private provided. Note, however, that under-investment is the optimal action for this economy and for some values of the externality parameter it is welfare improving when compared to the model with public G .

There are two additional facts worth mention. The first is the huge dimension of public capital when gamma is 0.30 - when compared to private capital and also to G of economies with smaller gammas. In this case it is more than twice K . 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 gammas below 0.05 as G/K is 0.47 when gamma is 0.05 and 0.37 when gamma is 0.025. Care must be taken, however, when comparing first moments, as the capital output ratios displayed in table 1 are well above the actual ratios for the U.S. economy.

5.2 Welfare Effects of Privatization

The welfare measure used compares steady states and it 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 public 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 $\Delta C (= C^* \cdot x)$ is the total change in consumption required to restore an individual to his/her previous utility level.

A look at figures 2 and 3 before we investigate the results of the welfare exercises may be illustrative.

Figure 2
Steady State Utility Levels
with Public and Private Infrastructure ($\gamma=0.05$)

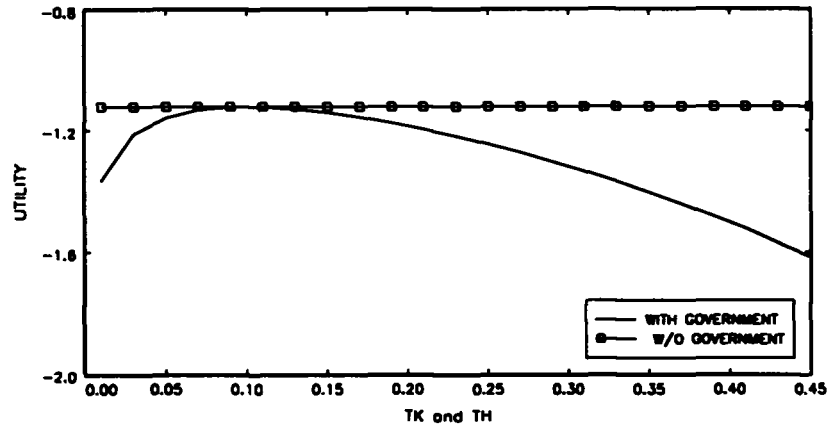
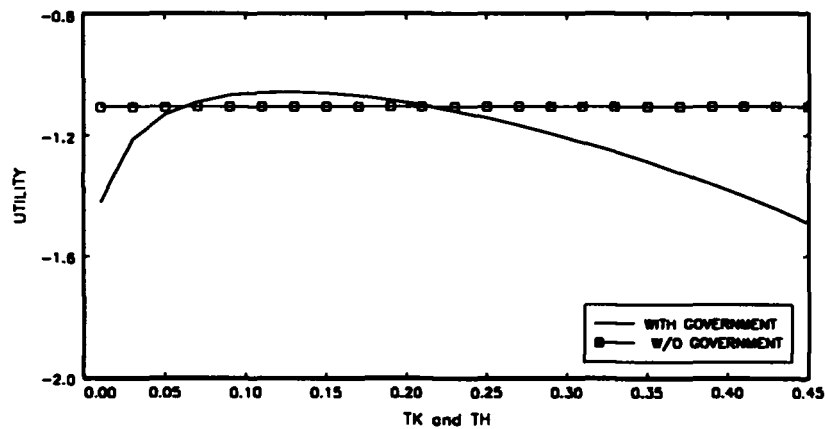


Figure 3
Steady State Utility Levels
with Public and Private Infrastructure ($\gamma=0.075$)



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. In figure 2 γ is 0.05 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 γ equal to 0.075, 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 with it (if the government behaves optimally).

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

Table 2
Welfare Effects of Privatization

γ	$\tau_k = \tau_h$	$\Delta C/Y$
0.0	0.05	-4.77 %
0.025	0.08	-3.28 %
0.05	0.10	-0.72 %
0.075	0.13	2.82 %
0.10	0.15	7.49 %
0.30	0.35	158.83 %

Positive numbers mean a welfare cost - it is necessary to give back, after privatization, 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, if the true value of gamma is less than 0.05 (actually, less than 0.055) society would benefit with privatization. This gain is decreasing with gamma, which makes sense: for small gammas the fact that the benevolent government takes the positive externality due to \bar{G} into account when picking τ is of minor importance when compared to the distortion introduced to finance public investment.

Note that if the true gamma is 0.025 - a value estimated in a large number of studies - the welfare gain is 3.28% of GNP, which is indeed very significant. As a proportion of consumption, instead of GNP, it was calculated to be 4.89%. Taking the consumption per capita in 1994 for the U.S. as being approximately 18.500 dollars, this result implies that each individual would increase his/her consumption in the long run, after privatization, in 904.6 dollars a year. This numbers also mean that even making the best case for public action - maximization of individuals' welfare, no operation

inefficiency and free supply to society of infrastructure services - privatization maybe welfare improving and arguments against it based solely on under-investment are incorrect, as this maybe the optimal action when the financing of public investment are considered.

This result is however very sensible to parameters choice, specially gamma. If the true gamma is 0.075, not far from some estimates in the literature - and well below Aschauer's and Munnell's estimates - society loses with privatization of infrastructure capital. In this case there is a welfare cost of 2.82% of GNP. Note also that the estimate of welfare cost when gamma is 0.30 is unrealistic high, one and a half times the GNP. This is because the positive externality due to aggregate G (\bar{G}) is so high that the gains from public operation of infrastructure are huge - even taking into account that sizable distortions are introduced in the economy, as optimal taxes rates are 0.35 - so that there is no question that government is more efficient in providing it.

If it is assumed that the tax structure is still more distortive than the structure above, the benefits from privatization increases. Suppose just as an illustration that public investment is entirely financed by capital tax. 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 optimally tax rates. The results are displayed in table 3 below:

Table 3
Welfare Effects of Privatization (capital tax only)

γ	τ_k	$\Delta C/Y$
0,00	0,11	-6.19
0,025	0,17	-5.63
0,05	0,21	-4.19
0,075	0,27	-1.92
0,10	0,31	1.17
0,30	0,61	87.05

The welfare gains from privatization in this economy where the tax structure is more distortive are much higher, as one could expect. For γ equal to 0.025 the gains are now 5.63% of GNP, or 7.88% of total consumption, which amounts to an increase of \$1.458 dollars in the annual per capita consumption in the long run. At the same time, welfare losses with privatization will only occur now for γ s above 0.091. It is also shown in the table that when γ is 0.075, instead of a loss of 2.82% as in the previous case, there is now a gain of 1.92% 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 externalities (γ s) for privatization to be welfare improving. Of course, assuming a tax structure less distortive (e.g., only tax on labor income) would imply the opposite results and weaken the case of privatization.

5.3 Welfare effects of privatization with investment losses

Maybe the most popular argument favoring privatization is based on the supposed inefficiency of public companies when compared to private counterparts. In a way or another, the idea is that those firms 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 are transferred to the private sector.

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 government's business and their relationship with the private sector. In a number of countries in Latin America, for instance, private firms charge an over-price to government's companies as an insurance against payment delay or default risk, two common practices. In addition to that, most purchases from public companies has 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. For instance, the official development bank of the Brazilian central government (BNDES) calculated that the construction of a hidro-eletrical plant they would finance for a public firm had its cost dropped by half after it was transferred to private hands. The cost of investment projects of a privatized steel mill in Brazil, in certain extreme cases, dropped to one third of its original figures. The rule of thumb, in Brazil at least, is that investment costs are at least 20% lower after privatization.

We modeled this fact in a very simple way. Suppose that instead of equation 7 we have

$$(15) \quad J = (1-\lambda) (\tau_k r_t K_t + \tau_h w_t H_t), \quad \forall t, \quad 0 \leq \lambda \leq 1$$

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 parameters values, are maintained. We reproduced the privatization experiments of table 2, but now we want to know if introducing investment losses in the public sector will imply in considerable larger gains from privatization. In table 4 below, two values of lambda, 0.2 and 0.5, are used, supposing moderate and high losses, and results from table 2 (lambda equal to zero) are reproduced for the sake of comparison:

Table 4
Welfare Effects of Privatization
with Investment Losses in the Public Sector

γ	$\Delta C/Y$		
	$\lambda=0$	$\lambda=0.20$	$\lambda=0.50$
0.00	-4.77 %	-5.89%	-8.17%
0.025	-3.28 %	-4.99%	-8.45%
0.05	-0.72 %	-3.12%	-7.91%
0.075	2.82 %	-0.37%	-6.59%
0.10	7.49 %	3.31%	-4.67%
0.30	158.83 %	116.50%	53.63%

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 ($\lambda = 0.20$) privatization is welfare improving for gammas up to 0.075, a value in the upper bound of most estimates of this parameter. In this case, a welfare loss of 2.82% of GNP is turned into a small gain of 0.37% after assuming investment losses. Moreover, the gains are now much larger in the interval where privatization is welfare improving: for gamma equal to 0.05, the welfare gains from privatization increased more than 4 times.

As one could expect, in the extreme case of a very inefficient public sector - i.e., investment cost twice as large as in the private sector ($\lambda = 0.5$) - the case for privatization is much stronger, even for high values of gamma. When gamma is 0.1, for instance, society benefit from privatization is 4.67% of GNP or 7.5% of consumption. The distortion introduced by the tax system and the high inefficiency of investment operations offsets the gains of internalizing the external effect of infrastructure capital, even for high values of the externality parameter.

6 - Conclusion and Summary

It may seem that the model and its simulations left unanswered the basic question it was supposed to answer: what are the allocation and welfare implications of privatization? However, this model economy, although in certain dimensions highly simplified, does deliver some lessons and intuitions that allow us to answer this question.

The first lesson, also present in Devarajan et al. (1995), 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. For instance, if we believe that the actual value of the sum of the external and internal effect of public capital is on the lines of the estimates of Ferreira (1993), Duffy-Deno and Eberts (1991), Canning and Fay (1993) and Baffes and Shah (1993) - who found values between 0.07 and 0.1 (which imply gamma from 0.02 to 0.05) - then our results imply that privatization is welfare improving. And this is true even making strong

hypothesis 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. However, if the actual value of the internal and external effect of infrastructure capital is above these estimates then privatization is welfare decreasing. Our simulations with capital income taxation only, on the other hand, showed that for a given externality effect, the more distortive the financing of public investment, the higher the benefits from privatization.

A second conclusion is that, when inefficiencies in the public sector are allowed, the case for privatization is considerable strengthened. And inefficiency is without question a serious problem in the operation of public infrastructure operation. 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 showed that investment costs could drop to half after privatization. Although inefficiency was modeled in a very simple way, the results from the simulations showed that the presence of even a small waste or overprice on investment can imply in sizable benefits from privatization. And would also increase the set of economies (i.e., economies with larger externalities) that could benefit from it.

There are several ways we could extend this model. An immediate one is to calculate welfare changes along transition paths and not only steady states, as temporary losses may well offset long run gains when future is discounted. We could also drop the hypothesis of a benevolent government and of free supply of infrastructure services and suppose that government charges a fix price for it. Firms would take this price as given and pick the profit maximizing level of g . Taxes would be levied in order to cover eventual losses if prices charged were too low to cover costs, as it is often the case with public services.

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