

Public Capital, Taxation, and Private Sector Productivity

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The purpose of this paper is to examine empirically the relationship between public capital and distortionary taxation in a production function framework. The analyses and results should help assess whether the public investment effect or the distortionary effects of financing public investment dominate changes in productivity growth. Using U.S. postwar data, the paper finds, after controlling for distortionary taxes and after examining alternative production function specifications, that public capital contributes positively to private sector productivity.

The recent literature on endogenous growth theory has provided a new dimension to fiscal policy and growth research (see (12;18)). Much of the dissatisfaction with the traditional growth theory framework (see (4;11;20)) lies with the theory's failure to account for the cross-country divergence in growth rates, its reliance on exogenous technological change to explain long run growth, and its assignment of little or no role for government policy to affect the long run rate of economic growth. In exogenous growth models fiscal policy can affect the level of steady state per capita income but not the long run growth rate of the economy. Moreover in most of the traditional optimal growth theory literature, government expenditures are neither productive nor utility-enhancing - they largely conscript aggregate resources away from the private sector.

The renewed interest in government policies in the new growth literature is the motivation for this paper. Most empirical studies, however, have tended to focus either on fiscal expenditures or on distortionary taxation, but rarely jointly. For instance, some study public investment in a production function-growth accounting framework (see (1;2;9;14)), while others study the effects of distortionary taxation (see (10;13;19)). There are a number of advantages to integrating public investment and distortionary taxation in a production function-growth accounting framework. In a theoretical study (3), it is argued that there exists a "Laffer" type of relationship between public investment and the national growth rate: raising public investment from "low" levels has a positive effect on growth but at some point when the ratio of public investment to national income has reached a "critical" point, the distortionary effects of financing public

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investment (through distortionary taxation) dominate and work to reduce growth and thereby offset the benefits of increased public investment. The "critical" ratio of public investment to national income (in (3)) is determined by balancing the marginal social product of public investment against the opportunity cost of the marginal public investment.

Hence it would be of interest to determine which effect dominates as far as productivity growth is concerned: the public investment effect or the distortionary effects arising from financing public investment. This comparison has not been addressed in the existing empirical literature to date. Studies investigating the productivity impacts of public investment suppress financing issues, while studies investigating the distortionary effects of public finance on capital and labour supply treat public expenditures as exogenous. This permits either approach to keep the focus of the investigations on the first-round effects of either financing or spending. A first step at an integrated analysis should shed some light on the productivity effects of a fiscal expansion financed by distortionary taxation. The results would be useful for determining the long term productivity effects of either a balanced-budget expansion in public investment financed by current distortionary taxes or of a debt-financed expansion in public investment financed by future distortionary taxes (assuming there is initially underinvestment in public capital).

This paper adopts the production function-growth accounting model, augmented to allow for distortionary taxation, and focuses on U.S. time-series data for 1948-88. The paper is related to recent work by (5), who analyze the effects of public expenditures and taxes on long run per capita GDP growth. Their evidence is obtained from a cross-section of countries. A criticism can be raised as to whether dynamic issues can be studied using cross-sectional data. It is not straightforward to give dynamic interpretations to cross-sectional results. If, for example, at some point in time or during some period of time, countries with relatively higher growth rates have relatively lower shares of public investment in GDP, this need not suggest that public investment slows down growth but that faster growing economies devote a smaller share of GDP to public investment. Similarly, slower growing economies could be devoting a larger share of GDP to public investment to generate future growth. Thus cross-sectional results do create some ambiguities. A time dimension is needed in general in order to study dynamic "multiplier" effects.

Section I begins by specifying a simple two-sector model to illustrate how distortionary taxes affect private sector productivity. Section II discusses the data and the empirical results, and section III contains concluding remarks.

I. Empirical Specification

The basic specification centers around the Solow production function:

$$(1) \quad y = A f(k_p, h)$$

with $A = A(\psi)$, where ψ is a vector of technical change variables which shift the production function over time. The stock of private capital is given by k_p and private labour hours by h . The function f is assumed to be Cobb-Douglas. In the exogenous growth literature the ψ vector was exogenously specified. In the endogenous growth literature ψ is determined endogenously from within a structural growth model. One of the things on which the long term growth rate can depend is public goods, such as "knowledge" spillover capital that enables a universe of economic agents to exploit for production. One conjecture is that the aggregate stock of private capital should be included in ψ on the grounds that the stock of knowledge embodied in the stock of aggregate private capital is available to all producers as a public good. In an economy with learning-by-doing, one could argue that "experience" is incorporated in the increases in the stock of private capital accumulated. Thus increased private capital formation can give rise to external effects which individual producers do not take into account, leading the social and private marginal rates of return to capital formation to diverge. Thus capital formation can affect both movements along a production function as well as shifts in it over time.

A further possibility is that the ψ vector includes social overhead capital (i.e. public infrastructure) which is available to private producers also in the form of a public good. An increase in the availability and provision of infrastructure should enhance private production opportunities, and alleviate any congestions arising from a greater number of private and public producers using existing infrastructure facilities. Inadequately maintained infrastructure should on the other hand work to limit the productive potential of social overhead capital and possibly interfere with private production, and thus impact negatively on economic growth.

Thus A can be specified as:

$$(2) \quad A = A(k_p, k_g), \quad A_1 > 0, A_2 > 0$$

where k_g is the net stock of public capital.

The functional form for (1) will be:

$$(1)' \quad y = A_0 e^{\gamma} k_p^{\alpha_1} h^{\alpha_2} k_g^{\alpha_3}$$

where $\alpha_1 + \alpha_2 + \alpha_3 = 1$ implies constant returns. This assumption of constant returns will be tested. If constant returns applies only

to private inputs (k_p, h), this would imply that there is a scale effect associated with public capital and increasing returns over all inputs. A_0 is a constant parameter and e^{γ} an exogenous exponential growth term.

Next it is necessary to control for government financing. The impact of public investment on productivity growth should depend not only on the size and nature of the public investment but on how it is financed (taxation or debt) and on the timing of the fiscal plans - that is, on when expenditure and financing changes are implemented and whether they are temporary or permanent. The microeconomic details of the government's objective function, policy rules, and constraints will not be dealt with in this paper. The focus here is on the production function-growth accounting framework and on the impact of public investment and taxation at that level - the microfoundations are studied in (15).

To motivate the introduction of taxes, this section follows the presentation in (6;19). Assume there are two sectors. In sector 1, factor supplies are taxed, while in sector 2, factor supplies are not taxed. (The results would be the same if sector 2 was also taxed, but at a rate less than that of sector 1.) Examples of such two sector distinctions include the rural versus urban sector, manufacturing versus agricultural sector, or corporate versus household sector. The differential treatment of taxes gives rise to distortions since factor resources shift from the taxed to untaxed sector. In equilibrium, the net-of-tax marginal productivities of factor supplies are equalized across sectors. Since sector 1 is taxed and sector 2 is not, at the existing distribution of factor resources, sector 1 has higher marginal productivities of factor inputs than does sector 2. If the tax rate on sector 1 were raised, factor resources would flow from sector 1 to 2 - that is, flow in a direction against equalizing marginal productivities or in a direction magnifying differential marginal productivities. This should impact negatively on aggregate output growth.

Let the superscript i denote sector i (where $i = 1, 2$). Each sector's production function is given by a form like equation (1): $y^i = A f(k_p^i, h^i)$. Aggregate output is then given by:

$$y = y^1 + y^2 = A [f(k_p^1, h^1) + f(k_p^2, h^2)]$$

where $f(k_p^i, h^i) = k_p^{\alpha_1} h^{\alpha_2}$, $i = 1, 2$.

Let τ represent a vector of distortionary tax rates, say $\tau = (\tau_K, \tau_L)$, where τ_K is a tax rate on capital and τ_L a tax rate on labour. Let $w_K(\tau)$, $w_L(\tau)$ be the shares of capital and labour respectively in sector 1, the taxed sector:

$$\begin{aligned} k_p^1 &= w_K(\tau) k_p & \text{and} & \quad h^1 = w_L(\tau) h \\ k_p^2 &= (1 - w_K(\tau)) k_p & \text{and} & \quad h^2 = (1 - w_L(\tau)) h \end{aligned}$$

where $k_p^1 + k_p^2 = k_p$, and $h^1 + h^2 = h$.

Assume $\partial w_K(\tau)/\partial \tau_K < 0$ and $\partial w_L(\tau)/\partial \tau_L < 0$. Assume also that in the absence of taxes that $w_K(0) = w_L(0) = 0.5$; that is, equal supplies of resources in each sector.

Substituting these expressions into aggregate output gives:

$$(3) \quad y = A k_p^{\alpha_1} h^{\alpha_2} \Gamma$$

where

$$(4) \quad \Gamma = [w_K^{\alpha_1} w_L^{\alpha_2} + (1 - w_K)^{\alpha_1} (1 - w_L)^{\alpha_2}].$$

Here the tax arguments within the share functions are omitted so as to avoid cluttering up the notation. Note the conditions here for aggregation: both sectors face the same external productivity term A and have identical production function parameters α_1, α_2 .

The economic interpretation of Equation (4) is that Γ measures the distortions arising from a tax system which drives wedges between the marginal factor productivities of different sectors. To see this, start by log differentiating equation (4) around some initial steady state - ie. $y = y^*$, $\tau_K = \tau_K^*$, and $\tau_L = \tau_L^*$, where the steady-state tax rates are non-zero. This yields:

$$(5) \quad d \log \Gamma = [(\partial Y^1 / \partial \tau_K) + (\partial Y^2 / \partial \tau_K)] (\partial \tau_K / Y) + [(\partial Y^1 / \partial \tau_L) + (\partial Y^2 / \partial \tau_L)] (\partial \tau_L / Y)$$

where:

$$\partial Y^1 / \partial \tau_K = (\alpha_1 w_K' / w_K) Y^1 < 0$$

$$\partial Y^1 / \partial \tau_L = (\alpha_2 w_L' / w_L) Y^1 < 0$$

$$\partial Y^2 / \partial \tau_K = - (\alpha_1 w_K' / (1 - w_K)) Y^2 > 0$$

$$\partial Y^2 / \partial \tau_L = - (\alpha_2 w_L' / (1 - w_L)) Y^2 > 0$$

since the derivatives $w_K' = \partial w_K(\tau) / \partial \tau_K$ and $w_L' = \partial w_L(\tau) / \partial \tau_L$ are negative.

Thus equation (5) has a simple interpretation. As long as tax rates drive wedges between the marginal factor productivities of the two sectors, the two inner brackets in equation (5) will be negative in value since the marginal productivity of factor inputs will be higher in the taxed sector - that is, in sector 1. (The marginal productivity of factors in the taxed sector is higher to offset the higher taxes that have to be paid.)

Now, to conform to equation (1)', $A = A_0 e^{\gamma k_p^{\alpha_3}}$. (Later, A will be allowed to be a function of private capital to determine whether any interindustry spillovers can be captured from aggregate k_p).

Taking the logs of the production function (3) and using equation (5) gives:

$$(6) \quad \log y = \alpha_0 + \alpha_1 \log k_p + \alpha_2 \log h + \alpha_3 \log k_g + \gamma T \\ + \phi_K \tau_K' + \phi_L \tau_L'$$

where T is the exogenous time trend, and

$$\alpha_0 = \log A_0 \quad \Gamma = \text{constant}$$

$$\phi_K = [(\partial Y^1 / \partial \tau_K) + (\partial Y^2 / \partial \tau_K)] / Y^*, \quad \phi_L = [(\partial Y^1 / \partial \tau_L) + (\partial Y^2 / \partial \tau_L)] / Y^*$$

are each evaluated at the initial steady state equilibrium. Furthermore the tax rates are deviations from steady-state:

$$\tau_K' = (\tau_K - \tau_K^*) \quad \text{and} \quad \tau_L' = (\tau_L - \tau_L^*).$$

With constant returns over all inputs, (6) becomes:

$$(6)' \quad \log(y/k_p) = \alpha_0 + \alpha_2 \log(h/k_p) + \alpha_3 \log(k_g/k_p) \\ + \gamma T + \phi_K \tau_K' + \phi_L \tau_L'$$

(6)' is basically the production function used in Aschauer (1), augmented to include distortionary tax rates. This equation will be the focus of empirical investigation in the next section. The signs of ϕ_K , ϕ_L are expected to be negative, and the signs of α_2 , α_3 to be positive. In the empirical section, the log of the capacity utilization rate will be added to equation (6)' in order to control for business fluctuations.

II. Data and Empirical Results

The empirical analysis is carried out on U.S. macroeconomic annual data 1948-88. Data on public and private capital, hours worked, private sector output, and taxes are from the Bureau of Economic Analysis **National Income and Product Accounts of the United States 1929-82** and **Fixed Reproducible Tangible Wealth in the United States 1925-85**. Data for additional years are obtained from the **Survey of Current Business**, September and October 1989. The capacity utilization rate is from the Federal Reserve Board (as reported in the annual **Economic Report of the President**).

The taxes used are corporate income taxes and individual income taxes. Unfortunately the latter are not a very good proxy for labour income taxes as they consist of interest income taxes of the personal sector. Payroll taxes would be better but there are insufficient time-series data on them. On the other hand the

Table 1
Unit Root and Cointegration Test Results
(Augmented Dickey-Fuller (ADF) Test)

	<u>ADF p-value</u>
Private Output y	0.35
Private Capital k_p	0.99
Public Capital k_g	0.98
Public Capital k_g net of Military Capital	0.99
Error Term in Regression of y on k_p and k_g	0.00178
Error Term in Regression of y on k_p and k_g net of Military Capital	0.01139

individual income taxes would be a source of distortions to the extent that they create disincentives for saving. The tax rates are obtained by using gross private domestic product as the tax base. As discussed in (5;13;19), the average ratio of tax revenues to private GDP proxies for the overall level of tax distortions. An alternative approach is to estimate the "unobservable" marginal tax rates. In a cross-country study by (10), changes in tax revenues are regressed on changes in GDP for each country to obtain a marginal tax rate for that country. The main difficulty with this approach is that it is appropriate for cross-country studies (and not for time-series studies of individual countries) since only one marginal tax rate is estimated per country (over some sample period). Another difficulty is that the estimates of marginal tax rates are sensitive to the sample period (see (5)). A time-series analysis, on the other hand, should pick up the effects of tax distortions on productivity growth over time.

The results are presented in the next five sub-sections. Before the main results are presented, a number of tests relating to specification are first conducted, such as tests of non-stationarity, cointegration, returns to scale, "externalities" from private capital, and alternative functional forms.

A. Tests of Non-Stationarity

A number of unit root and cointegration tests were conducted

which detect the presence of non-stationarities in output and in both the private and public capital stocks. These variables are however cointegrated. The tests were based on the augmented Dickey-Fuller (ADF) tests. The results therefore indicate that it is statistically better to estimate the equations in levels.

To evaluate whether the data are better represented as trend-stationary (TS) or difference-stationary (DS), consider the following:

$$\Delta z(t) = \mu + \rho z(t-1) + \gamma t + e(t),$$

where z is the variable in question. The DS specification is preferred if the null hypothesis $H_0: \rho = 1$ and $\gamma = 0$ is not rejected. Otherwise if $\rho < 1$, the TS specification is preferred. The relevant (critical) t -distribution for testing the null hypothesis $\rho = 1$ is presented in Fuller (7). The results of the test for $z = (y, k_p, k_g)$ for 1948-88 are reported in Table 1. Based on the p -values, one cannot reject the null that y , k_p , and k_g are each non-stationary but are together cointegrated. Thus in the following empirical results, the regression errors are found to be stationary.

B. The Role of the Capacity Utilization Rate, Tests of Constant Returns, and Endogeneity

The first two columns in Table 2 show estimates of equation (6)' with and without the capacity utilization rate. The stock of public capital here excludes the stock of military public capital. Without adjusting for business fluctuations, the output elasticity of private capital is negative. Controlling for fluctuations raises this elasticity to 0.37 (or $1 - 0.44 - 0.19$) and reduces the output elasticities of the other inputs, as can be seen from column 2. Thus not controlling for business cycles would lead one to overestimate the output elasticities of the inputs included in the regression.

One test is to determine whether one can reject the null hypothesis of constant returns that is embedded in equation (6)'. The F -statistic for testing this hypothesis is 3.7 for which the critical 5% $F(1,35)$ is 4.12. Another test is a test of the null hypothesis that constant returns apply to the private inputs (k_p, h) only. The F -statistic for this test is 9.162, so that the assumption of increasing returns to all three inputs is rejected.

Next, consider the possibility of simultaneity - that is, as productivity increases, input demands increase as does the demand for public capital. Previous work by (1;9) examine the possibility that causality may go from output to public capital but find that the causality interpretation underlying the production function relation is more robust (that is, the direction is primarily public capital to output). As column 3 shows, an instrumental variables

Table 2
Main Results 1948-1988

Dependent Variable: $\log Y/k_p$						
Estimation Method:	1. OLS	2. OLS	3. INST	4. OLS	5. OLS	6. INST
c	2.43 (0.6)	-0.58 (0.55)	0.06 (0.4)	-0.23 (0.46)	0.31 (0.4)	-0.09 (0.54)
$\log (h/k_p)$	0.82 (0.15)	0.44 (0.098)	0.61 (0.07)	0.47 (0.08)	0.6 (0.07)	0.59 (0.08)
$\log (k_s/k_p)$	0.46 (0.09)	0.19 (0.07)	0.27 (0.09)	0.21 (0.06)	0.29 (0.054)	0.26 (0.06)
$\log cu$	--	0.34 (0.04)	0.34 (0.03)	0.28 (0.035)	0.28 (0.036)	0.36 (0.07)
T	-0.0015 (0.0003)	-0.0015 (0.00016)	-0.00015 (0.00016)	-0.0005 (0.0004)	-0.0016 (0.0003)	-0.0017 (0.0007)
$\log r_K'$	--	--	--	0.034 (0.013)	-0.006* (0.012)	-0.009 (0.028)
$\log r_L'$	--	--	--	-0.033 (0.017)	-0.005* (0.016)	-0.004 (0.02)
Adj. R ²	0.78	0.93	0.94	0.94	0.94	0.94
SER	0.019	0.011	0.01	0.01	0.009	0.011

Notes: Variables are as defined in the text. cu denotes the capacity utilization rate, SER standard error of regression, and INST instrumental variables estimation using the constant term (c), trend (T), and one-period lagged values of the variables in the equation as instruments. The p-values of the Augmented Dickey-Fuller Test statistics are sufficiently low as to indicate stationarity in all the regression errors. In regression 5, * indicates that the tax variables were lagged one period.

estimation (using the one-period lagged values of the variables in the equation, the constant and trend terms, as instruments) continues to find a significant contribution of public capital to private sector productivity. The output elasticity of public capital (0.27) exceeds that of private capital (inferred to be 0.12).

C. External Effects to Private Capital

Romer's hypothesis of external effects to private capital rests on the existence of Arrow's learning-by-doing benefits in private capital accumulation (see (17)). Suppose:

$$y_i = \kappa^\eta k_i^\beta h_i^{1-\beta}$$

where κ is the aggregate average stock of private capital - that is, the k_i 's summed across $i = 1, \dots, N$, and divided by N , where N is the number of firms. The justification for this specification is that increased knowledge and experience are embodied in each new machine; this external effect is essentially ignored by private producers. (Note that the purpose of the division by N is to avoid scale effects. Not dividing by N yields the implication that larger economies grow faster, which is controversial). If in equilibrium all N firms are identical, so that $k_i = k$, $h_i = h$, the aggregate production function is:

$$(y/k) = \kappa^\eta (h/k)^{1-\beta}$$

and if $\eta + \beta > 1$, the aggregate economy will exhibit increasing returns to private capital. However, estimating equation (6)' with private capital stock entered as an additional regressor (but without the tax variables), yields:

$$\begin{aligned} \log (y/k_p) = & 0.9 + 0.35 \log (h/k_p) + 0.22 \log (k_g/k_p) - 0.25 \log k_p \\ & (0.98) \quad (0.1) \quad \quad (0.07) \quad \quad (0.12) \\ & + 0.007 T + 0.38 \log cu \\ & (0.004) \quad (0.04) \end{aligned}$$

where standard errors are in parentheses. Since the estimated η is negative and the total output elasticity is 0.16 (or less than one), there does not appear to be empirical support for the 'external effects to private capital' specification.

D. Translog Specification

Another alternative to (6)' is the translog production function, which augments (6)' with input-squared terms and input

cross-product terms. In this case, the coefficient estimates of the new terms and of the values of α_2 and α_3 in equation (6)' are not only negative but exceed unity in absolute value. For this reason, the rest of this paper maintains the Cobb-Douglas functional form.

E. Role of Distortionary Taxation

In columns 4-6 in Table 2, the tax variables are entered as additional regressors (thus giving the full equation (6)'). The tax variables r_K' , r_L' are in logs in order to give elasticity interpretations to the coefficients. This does not affect the coefficients of the other variables and yields the same elasticity results that would have been obtained upon multiplying the average share of distortionary taxes in aggregate private output per capital stock, (y/k_p) , to the coefficients of the tax variables in natural units. The variables, r_K' and r_L' , according to the theoretical model, are to be expressed as deviations from steady-state. The sample averages of the tax rates are used as proxies for their steady-state values.

First, the coefficient estimates of the input variables do not change appreciably. In column 4, which should be compared to column 2, the output elasticity of private capital is reduced to 0.32. The coefficient on the corporate income tax rate does not have the expected sign in column 4. This results because of simultaneity: as output increases, tax revenues tend to increase as well. Equation 5 therefore uses the one period lagged values of the tax rate variables, and finds that their coefficients are negative but insignificant. Instrumental variables estimation also yields negative and insignificant coefficients - see column 6. The lack of significance of the tax variables in the aggregate private production function indicates that the distortionary effects of financing public investment are not likely to offset the positive contribution of public investment to productivity growth.

III. Conclusions

Since intertemporal fiscal policy plans involve meeting intertemporal budgetary constraints, it is important to integrate public investment and taxation variables in productivity analyses in order to weigh the short term and long term benefits of the investment itself against the possible economic distortions associated with its financing. The results support the view that public capital contributes significantly to private sector productivity. Distortionary taxes on the other hand are found to have insignificant impacts on private sector productivity when examined alongside public capital. The results on public infrastructural capital agree with those of (1;14). On the other hand, they conflict with the results of cross-sectional analysis,

which largely find that public investment is not as significant as found in time-series studies (see (2;16)). As argued in the introduction, this can be attributed to the way one interprets time-series versus cross-sectional analyses and results.

As extensions, it would be important to consider the sensitivity of measures of productivity to alternative assumptions about market structure, particularly about whether the aggregate economy behaves perfectly competitively. The presence of markup behavior can lead one to overestimate changes in total factor productivity - see (8). Secondly, it would be useful to adopt an alternative approach, such as a cost function approach, to evaluating the effects of infrastructure capital and distortionary taxes on firm-level or industry-level productivity and input demands.

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