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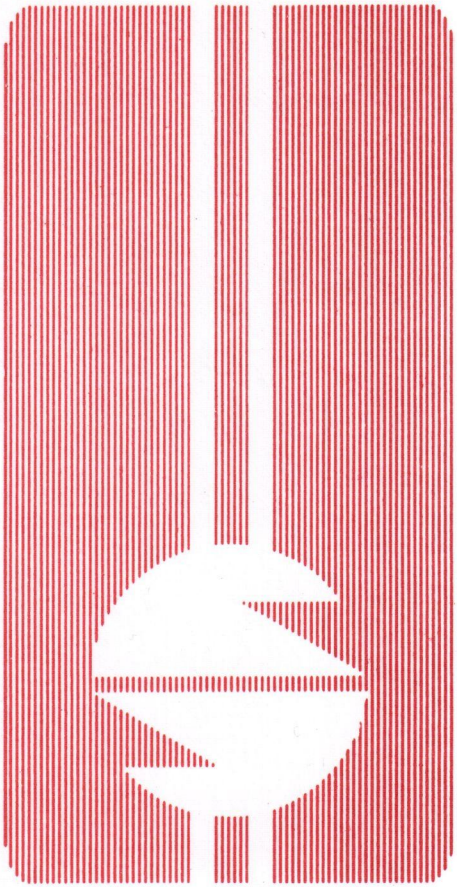

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INFRASTRUCTURE, PUBLIC CAPITAL AND GROWTH IN THE BRAZILIAN ECONOMY*

Stefano Florissi**

ABSTRACT

This study tries to measure the contribution of public capital and infrastructure capital to the growth of the Brazilian economy using an expanded aggregate production function. We check for the stationarity of the data and run two models: one with public capital and another with public capital and infrastructure capital. In our specifications the public capital variable is found to be weakly significant. The infrastructure capital variable, on the other hand, is found to be significant. When we test for Granger-causality we find that infrastructure is the only variable that causes future growth and that it is not caused by past growth. Given these results, we conclude that there are evidences of the importance of infrastructure capital, especially the energy subsector, in helping to promote economic growth.

1 . INTRODUCTION

It is possible that a considerable part of economic growth that in the past has been attributed to technical progress was in reality due to public capital formation, mainly in the form of infrastructure capital. Until recently it was uncommon to find studies that considered a production function with public capital as a variable. Beginning with Aschauer (1989), a number of studies have estimated regressions where the dependent variable is output and the independent variables are private capital, labor and public capital. In such regressions the levels of public capital are generally significant, and the consensus is that Aschauer made a significant contribution by drawing attention to the importance of public capital and by adding it to the conventional production function.

The main objective of this study is to try to observe what kind of impact public capital, and more specifically infrastructure capital (usually a subset of public capital), has had on the economic growth of Brazil in the recent past. Our study

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is divided in four sections.

In section two we briefly discuss public capital, adding it to the conventional aggregate production function and reviewing what can be learned from the experience of other studies. In section three we present our empirical results. We divide this section in two subsections, one for each of our models. The first model includes the variable that we call "public capital" and the second model includes this first variable and the variable that we call "infrastructure capital". This division comes from the fact that, in Brazil, the main providers of infrastructure services are public enterprises that are considered part of the private sector for national accounts computations. In section four we give some final considerations.

2. THEORETICAL BACKGROUND

2.1 Public capital and the expanded aggregate production function

Non-military public capital is usually measured as "core infrastructure" and "buildings". "Core infrastructure" includes not only highways, airports, ports, and mass transit facilities that link a nation together, but also electric and gas plants, water supply facilities and sewers that allow industry to operate, and sometimes also the telecommunications facilities that link people together inside and outside the nation. "Buildings" includes schools, hospitals, police and fire stations, court-houses, garages and passenger terminals, all of which contribute to an orderly environment that facilitates private production.

Public capital investment can expand the productive capacity of an area both by increasing resources and by enhancing the productivity of existing resources. For example, a well-constructed highway allows a truck driver to avoid circuitous back roads and to transport goods to markets in less time. The reduction in required time means that the producer has to pay the driver less hours of work and that the truck experiences less wear and tear. Hence, public investment in a highway enables private companies to produce their products at lower total cost. Similar stories can be told about telecommunications, mass transit, water and sewer systems, and other components of public capital.

It is important to understand that the inclusion of public capital in the conventional aggregate production function is a very different discussion than the one present in classical Keynesian models (Ferreira, 1994). In these models the government affects the output level through the multiplier mechanism, in other words, through the demand side of the economy. In our present discussion the effect of public spending is felt through the *supply* side of the economy. Here, public spending, in the form of investment in public capital, affects the return of private inputs thus affecting private investment and labor.

Before we continue our discussion it is also important to clear a point that may be confusing. It is not the intention of this study to make direct comparisons between public and private management performances. We do not intend to discuss the validity or not of privatization, for example. Our main concern here is to estimate the contribution that what is usually called "public capital" has had in the growth of the Brazilian economy, basically because most of the stock of infrastructure capital, in Brazil, has been part of the stock of public capital in the past 25 years. And more important than public capital *per se* to our purpose here is core infrastructure, that may or may not be a form of public capital. Indeed, in most of Brazilian history some components of core infrastructure had been part of private and not public capital, although they historically represent only a small part of the total (Florissi, 1996).[1]

The basic idea of our model is simple: first, take a conventional aggregate production function,

$$Q = AF(K,L), \qquad (1.1)$$

where K is the stock of private capital, L is the labor force, and A is an index representing total factor productivity. Then, make A a function of the services provided by the government capital stock (G), rewriting (1.1) as:

$$Q = A^{*}F(K,L,G), \qquad (1.2)$$

where A^{*} is total factor productivity purged of the influence of the government capital stock. Using the Cobb-Douglas form and writing (1.2) in logs gives:[2]

$$lnQ = lnA^{*} + alnK + blnL + clnG, \qquad (1.3)$$

where a, b and c are the production elasticities.

It is also possible to use (1.3) to determine the rate of return on private and public capital, which equals their marginal products under the assumption of perfect competition. From the definition of elasticity,

$a = F_k K/Q$ and

$c = F_g G/Q$, so it follows that

$F_k = aQ/K$ and

$F_g = cQ/G$,

where F_k and F_g are the marginal products of K and G respectively.

2.2 A brief review of the literature

Beginning with Aschauer (1989), a number of studies have estimated

[1] Even public capital, under strict public finance theory, does not necessarily needs to be "public".

[2] Translog type functions could not be estimated satisfactorily due to high multicollinearity among the interaction terms.

regressions where the dependent variable is output within some area, and the independent variables are private capital, labor and public capital. In such regressions, the levels of public capital are generally significant, and the consensus is that Aschauer made a significant contribution by drawing attention to the importance of public capital and by adding it to the conventional aggregate production function. But there are some criticisms also.

Aschauer's original aggregate time series estimates (1989),[3] Munnell's reestimates (1990) and an earlier work by Holz-Eakin (1988) suggest that the impact of aggregate public capital on output is very large. These figures imply an elasticity for public capital of about 34-39% and (annual) rates of return on the range from 0.6 to above 1, which means a rate of return for public capital 3 to 5 times higher than the rate of return for private capital. Some authors consider that the implied impact of public capital investment on output emerging from these aggregate time series studies is too large to be credible. The criticisms may be divided in two groups: logic and econometric.

On the logic side, the first question involves the definition of the variables. The critics argue (Gramlich, 1994) that most of the studies use a definition of public capital that contains components such as education buildings, office buildings, hospitals, conservation facilities, police, court houses and fire stations (that usually add up to one-third of the total stock of public capital in these studies) that should not have much short term impact on aggregate output. Yet, both Aschauer (1989) and Argimón et. al. (1993) use also other definitions of the variable, restricted to core infrastructure, and still find very high rates of return.

Another logic problem, is argued, involves the high rate of return itself (Gramlich, 1994). For private capital, individuals are comparing the rate of return with the opportunity cost of their own funds, while for public capital they are comparing the rate of return with the opportunity cost of somebody else's funds. So, the criticism goes on, if public capital return is much higher than private capital return there should be a clamor to raise taxes or float bonds to invest in public capital and this, at least for the US, has not been observed, the critics conclude. But the fact is that this "clamor", if it exists or not, is hard to capture and the critics may not have a point here.

A final, and stronger, logic criticism is that the best that a production study can hope to say is that public capital has been productive in the past, and this does not mean at all that it is going necessarily to be again in the future. On the econometric side, the main criticism that is made is that of non-stationarity. Here the basic question is that while output can indeed be influenced by public capital, the trends may be explained for very different reasons, like energy prices,

[3] See Table 1 for details on results of the studies referred to

environmental regulations, changing technology, etc. This means that the data may not be stationary, but instead may tend to drift over time. Given the drift, the regression equation with the variables in levels may be picking up the common trend while in fact the variables are uncorrelated.

One way to deal with non-stationarity is to estimate the equations in first differences. Aaron (1990), Hulten and Schwab (1991) and Tatom (1991) found much lower estimates of the elasticity of public capital, often not even positive and always statistically insignificant. On the other hand, Flores de Fruto and Pereira (1993) and Argimón et al (1993), after a more "careful" econometrics, still find very high elasticities on public capital (see Table 1).

Table 1. Table of citations

STUDY	COUNTRY	AGGREGAT.	SPECIFIC.	PUBLIC CAPITAL ELASTICITY
H.-E. (88)	USA	National	OLS-CD-LL	.39
Asch. (89)	USA	National	OLS-CD-LL	.39
Mun. (90)	USA	National	OLS-CD-LL	.34
Aaron (90)	USA	National	OLS-CD-FD	NS
H&S. (91)	USA	National	OLS-CD-FD	NS
Tatom(91)	USA	National	OLS-CD-FD	NS
F-Fr.&P.(93)	USA	National	VAR-CD-FD	.54
Argimon. (93)	Spain	National	OLS-CD-ECF	.60

Notes: 1. In the column of "Specifications": OLS: Ordinary Least Squares; CD: Cobb-Douglas; LL: Log Levels; FD: First Differences; VAR: Vector Auto-Regression; ECF: Error Correction Form.
2. In the column of "PUBLIC C ELASTICITY", NS stands for "Non Significant".

Another problem discussed in the literature is that of causality. This problem can be explained with the following question (Gramlich, 1994): does infrastructure (or public) capital influence the growth of output or does the growth of output influence the demand for infrastructure (or public) capital? Munnell (1992) agrees that this is a legitimate criticism. She points out that capital investment (both public and private) "goes hand in hand with economic activity", but considers that this influence can exist without tainting the coefficient on public capital (as well as private capital) in estimated production functions.

Tatom (1993) does a series of lead-lag tests that indicate that causation may be more from output to public capital than the other way around. Flores de Fruto and Pereira (1993) make public capital an endogenous variable in a production function system of equations of output and input and find that public investment is indeed endogenous. But the later still finds a high elasticity for public capital. This latest study destroyed the notion that more careful econometrics leads inevitably to lower implied rates of return on public capital (Gramlich, 1994).

3. EMPIRICAL RESULTS

3.1 Empirical results of the first model[4]

In our present study (for both the first and the second models) "public capital" includes buildings and constructions (including highways), machinery and equipment for administration, health, education and roads/urbanization for the three administration levels (Federal, State and Municipal). "Infrastructure capital", that is going to be subtracted from private capital in the next subsection, includes energy, communications, water and sewage, and the railroad services. "Q" is defined as real GDP in 1980 prices and "L" is defined as the employed population.

We have checked for the stationarity of our time series.[5] The results indicate that all series are integrated of order 1. Hence we proceeded to test for co-integration. The tests carried out provided evidence that the null hypothesis of no co-integration could not be rejected. We thus proceed in our empirical study with the variables in first differences.

Table 2. Aggregate production function, 1968-92

	Regression 1	Regression 2	Regression 3
Dep.Variable Ind.Variables	Q	Q	Q
L	.26	.27	.27
	(2.40)	(2.51)	(2.59)
T=K+G	.53		
	(5.42)		
K		.51	.36
		(5.53)	(1.84)
G			.23
			(.897)
CU	.87	.89	.86
	(4.86)	(4.96)	(4.72)
CTE	.005	.003	.001
	(.008)	(.008)	(.002)
R^2	.88	.88	.89
DW	1.47	1.40	1.70
HSC	2.31	2.64	4.94
Norm.	.974	1.021	.746
F	50.15	51.52	38.46
CRS	3.32	3.96	.826

Notes. HSC is Bruesch-Pagan-Godfrey heterocedastic test, distributed as a χ^2 with "p" (# of parameters) degrees of freedom. Norm. is Jarque-Bera LM normality test, distributed as a χ^2 with 2 d.f. CRS is a Wald test with one degree of freedom. All variables in logs and first differences.

[4] For information about the data and the construction of the series, see Florissi (1996).

[5] These and other test results are available with the author upon request.

Before we present our results some observations are needed: 1) It must be said at the outset that the problem of multicolinearity between the capital stock variables is severe here. The correlation coefficient between public and private capital is .89. Thus it will not be surprising if the capital stock coefficients are not significant when both variables are present. 2) We introduce a demand side variable on our model, namely the capacity utilization level. This is so because not necessarily all capital stock (or labor force) was actually being used to generate output, due to demand fluctuations (Aschauer, 1989; Munnell, 1990).

The results can be summarized as follows: in Table 2 we have our model without the constant returns to scale hypothesis. Looking at regression 3 we see that the public capital coefficient is .23, while the private capital coefficient is .36. But they are estimated with such imprecision that cannot be distinguished from zero. The results do not change if we use White's heteroscedastic consistent covariance matrix. But note that we cannot reject the hypothesis of constant returns to scale in all inputs. We thus proceed to reparametrize the model using this hypothesis.

The selected model is the one in Table 3, regression 3. The labor coefficient is of the order of .32. The public capital coefficient, significant (although weakly) at the 5% level, is of the order of .38. Thus the private capital coefficient should be around .3. This is in line with previous results. For example, Aschauer and Munnell found coefficients in the range of .34 to .39. But those were not tested and corrected for non-statonarity. We have corrected thus avoiding the peril of spurious regressions.

Table 3. Aggregate production function estimation, 1968-92
(under constant returns to scale)

	Regression 1	Regression 2	Regression 3
Dep.Variable Ind.Variables	Q-K	Q-K	Q-K
L-K	.40 (4.52)	.33 (3.05)	.32 (3.54)
G		-.16 (-1.09)	
G-K			.38 (1.98)
CU	.71 (4.30)	.82 (4.29)	.78 (4.90)
CTE	-.08 (-1.33)	-.01 (-.13)	-.04 (-.632)
R^2	.78	.81	.83
DW	1.18	1.09	1.81
F	41.11	28.06	32.55
HSC	3.41	3.47	3.97
Norm.	1.20	1.48	.789

When we test for causality in our production function we find the following (see Florissi for detailed output): the t-statistics indicate that public capital, or for that matter not any of the inputs, Granger-cause output growth. Only past GDP performance seems to explain present output. Also, output Granger-cause all inputs and the past behavior of the inputs seem to explain their own behavior.

3.2 Empirical results of the second model

In this subsection we estimate the production function using our constructed variables for infrastructure enterprises. The variables constructed are estimates of the stock of capital of energy, communications, water and sewage, and railways companies for the period 1973-1992. Those variables had to be constructed from original sources, since published national accounts data consider public enterprises, which are the providers of most of the infrastructure services in Brazil, as part of the private sector.[6]

So in this subsection we consider: 1) "private capital" as the previous stock of private capital net of the stock of capital of infrastructure enterprises; 2) public capital as measured before; 3) a new variable, total public capital, as the capital stock of infrastructure enterprises plus the stock of public capital; and 4) two infrastructure variables, one that includes all subsectors and another one that includes only the energy subsector.

As in the previous subsection, we begin by studying the non-stationarity of our variables and whether the estimating regressions are co-integrated. All variables are found to be I(1). Then, we do not reject the hypothesis of no co-integration for the various models. Given these results, again we run our models in the first differences. A word of caution against some of the estimates is that we continue to have, for this 1973-1992 subsample, strong correlation between private and public capital stock. One thus expect low t-ratios in models including both variables.

Looking at net private capital (Table 4, regression 1) we see that its contribution is lower now, around .3, from around .5 in the previous 1968-1992 subsample. This may indicate that a significantly important part of private capital was subtracted, namely infrastructure capital.

The regression with public capital (#2) corroborates evidence from our previous regressions: the contribution of labor is about 1/3, as is for public capital. Private capital has a smaller output elasticity than public capital, as before, but here it is noticeably smaller (point estimate .17). Note that the individual t-ratios of private and public capital are small, as expected from multicolinearity.

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[6] Unfortunately, we were not able to find separate data on highways.

Table 4. The Impact of infrastructure, 1973-92

	Reg.1	Reg.2	Reg.3	Reg.4	Reg.5	Reg.6	Reg.7
Dep Variable	Q	Q	Q	Q	Q	Q	Q
Ind.Variables							
L	.32	.31	.28	.30	.30	.30	.30
	(3.0)	(2.9)	(3.2)	(3.3)	(3.4)	(3.1)	(3.2)
K	.307	.17	.33	.42	.35	.36	.37
	(3.9)	(1.2)	(4.9)	(2.6)	(5.2)	(2.2)	(4.9)
I				.08	.07	.07	.07
				(2.3)	(2.7)	(1.8)	(2.3)
G		.29		-.14		.02	
		(1.3)		(-.5)		(.07)	
GT=			.14				
G+I			(2.7)				
CU	.51	.61	.71	.65	.68	.70	.70
	(2.8)	(3.1)	(4.3)	(3.8)	(4.2)	(3.7)	(3.9)
R^2	.87	.88	.91	.915	.91	.80	.90
F	32.6	25.8	37.0	28.0	36.9	24.4	32.9
DW	2.06	2.43	2.59	2.36	2.52	2.24	2.45
HSC	.58	5.52	4.17	5.03	4.47	3.26	1.99
Norm.	2.56	.59	.50	.29	.35	.45	.47

Note: I is infrastructure (all subsectors) capital in regressions 1-5; and in regressions 6 and 7, the energy infrastructure subsector (E) only

Consider now regression 3 where we aggregate all infrastructure stock and public capital (GT). Here, the auxiliary R-squares (not shown) are much lower, [7] indicating that multicolinearity should not be a problem. The picture that is sketched from the estimates endows private capital with an output elasticity of .33 and labor with .28. Public capital and infrastructure jointly have an output elasticity of .14.

The next regression (#4) has as co-variates labor, net private capital, infrastructure and public capital. The coefficients of labor and private capital do not change noticeably. The main result is the significant elasticity of infrastructure capital stock (point estimate .08). The coefficient of public capital is negative and not significant. Given this result we re-estimate this equation without that variable (regression 5). The results are only confirmed, i.e., infrastructure has a significant impact on aggregate output (point estimate .07).

We now consider the contribution of the energy utility subsector only. This subsector is, by far, the largest infrastructure subsector, accounting for roughly 2/3's of the stock of infrastructure capital in our sample.The results are presented in regressions 6 and 7. They are very similar to regressions 4 and 5. Labor has an output elasticity of .3, private capital .36 and energy infrastructure .07. Public capital is not significant.

So far, our conclusions are thus as follows: in this subsection, using original

[7] R-square of OLS regressions of each independent variable on the other independent variables.

estimates for infrastructure capital (energy, communications, water and sewage, and railroad companies), and then obtaining an estimate of private capital net of those subsectors, we observed that the output elasticities in the aggregate production function for the Brazilian economy are of the order of .3, .35 and .07 for labor, private capital and infrastructure respectively. The public capital stock was found not to be significant in explaining economic growth.

It is worth stressing that, in regression 3, when we add together public capital and infrastructure capital in a single "total public capital" variable the model has a very good fit from what could be expected from earlier criticisms. All variables are significant and have substantial rates of return, with private capital more than twice as productive as public capital. More than a nice result *per se*, this may be a strong indication that the subset of public capital that is really productive is the core infrastructure subset given the fact that, when you later on separate them, only core infrastructure remains significant.

We now explore the causality between infrastructure and output (see Table 5). We analyze the causality in the framework of regressions 5 and 7 in our table 4. It is found that infrastructure Granger-causes output and not vice-versa. The other variables, as in our first model, do not cause output but are caused by it. We also run the same tests for the energy subsector. The conclusions are the same, i.e., output is caused by energy capital stock but not the contrary. This is an important result and provides final evidence that infrastructure makes a significant contribution to output. The elasticities, while positive and significant, are small, of the order of 7 to 8%, compared to an elasticity of the private capital stock of about 30%. This is intuitively appealing and in the lines of criticism of earlier estimates of production, and also are very similar to some reestimations of Aschauer's and Munnell's data done by Ferreira (1994).

Table 5. Causality tests for infrastructure (all variables)

Dep.Variable Ind.Variables	Q	L	K	I	CU
Q(t-1)	-.38	.02	.002	-1.04	.03
	(-.49)	(.025)	(.002)	(-.28)	(.06)
L(t-1)	.31	.29	.36	-.16	.10
	(.35)	(.71)	(.88)	(-.097)	(.46)
K(t-1)	.27	-.05	.52	1.61	-.20
	(.81)	(-.11)	(1.32)	(1.23)	(-.91)
I(t-1)	.21	.18	.17	.15	.065
	(2.96)	(2.09)	(2.16)	(.46)	(1.17)
CU(t-1)	.58	.91	-.18	.19	.07
	(1.04)	(1.10)	(-.27)	(.07)	(.15)
LMAR(1)	.69	.96	1.00	1.27	1.05

When we look to the rates of return for private and public capital we find the following: For regression 3, table 4; $F_k = aQ/K = 0.245$ and $F_{gt} = cQ/GT = 0.202$,

where F_{gt} is the marginal product of public capital plus infrastructure capital, GT. For regression 5, table 4; $F_k = aQ/K = 0.260$ and $F_i = cQ/I = 0.231$, where F_i is the marginal product of infrastructure capital, I.
For regression 7, table 4; $F_k = aQ/K = 0.201$ and $F_e = cQ/E = 0.370$, where F_e is the marginal product of energy infrastructure capital, E.

These results look much more reasonable than the rates of return found in the literature, that are most of the time above 0.55 for public capital.

4. CONCLUSION

Using an extended aggregate production function to include "public capital", we first found that this variable contributes to economic growth with a coefficient of the order of .3 to .4, although with a weak significance that is dependent on a CRS assumption. Testing for Granger-causality we found that the past behavior of output influences the present level of public capital (as well as labor and private capital) but not the other way round.

Including "infrastructure capital" in the model, we found that public capital is not significant now. Infrastructure capital, on the other hand, was found to be significant, although with an output contribution of only about 7 to 8% (compared to an output elasticity of private capital of about 30%). When we tested for the Granger-causality of the infrastructure capital variable, we found that infrastructure is the only variable that Granger-causes future growth and that it is not affected by past economic growth.

Given the results of our first model, and then comparing them to the results of our second model, what seems to be our strongest evidence is that the "core infrastructure" component of public capital is likely to be much more important in explaining economic growth than the other components of public capital. Given also the fact that 2/3's of our infrastructure sample is composed of the energy subsector, our results are more likely to be correctly interpreted if we maintain our considerations only for this particular subsector.

Finally, as an extension of this research, we suggest to incorporate data on human capital and also to use endogenous growth models in addition to the neoclassical specification. Another extension would be, if data is available, to use pooled time series cross-section data across states since, as Gramlich (1994) points out, some of the econometric interpretation problems could be lessened by using this kind of data.

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SINOPSE

INFRA-ESTRUTURA, CAPITAL PÚBLICO E CRESCIMENTO NA ECONOMIA BRASILEIRA

Este estudo procura mensurar a contribuição do capital público e da infraestrutura para o crescimento da economia brasileira usando uma função de produção agregada expandida. Verificamos a estacionariedade dos dados e estimamos dois modelos: um com capital público e outro com capital público e capital de infraestrutura. Em nossas especificações encontramos a variável capital público sendo apenas marginalmente significativa. Por outro lado, encontramos a variável capital de infra-estrutura sendo significativa. Quando testamos para causalidade tipo Granger, encontramos que capital de infraestrutura é a única variável que causa crescimento futuro e que não é causada por crescimento passado. Dados estes resultados, concluimos que há evidências da importância e significância do capital de infraestrutura, especialmente o setor energético, em ajudar a promover o crescimento econômico.