Output and Employment Effects of Public Capital

by

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I. Introduction

Over the past decade, a considerable amount of research has been conducted on the relationship between "public capital" or "infrastructure capital" and economic performance. Since the initial work of Aschauer (1989), researchers have used a variety of data sets of investigate an even wider variety of hypotheses regarding the linkages between public capital and the economy. In particular, many authors have made use of state level data to look at the importance of infrastructure to productivity (*e.g.*, Munnell (1990)), to costs of production in manufacturing sectors (*e.g.*, Morrison and Schwartz (1996); Nadiri and Mamuneas (1994)), and to overall economic growth (*e.g.*, Holtz-Eakin and Schwartz (1995)).

This paper, along with Aschauer (1997b), also makes use of state level data to consider the *static* and *dynamic* effects of the provision of public capital on economic growth. The basic notion is that a nonlinear relationship can be expected to arise between the level of the public capital stock--relative to the private capital stock--and output and employment growth at the state level. This nonlinearity might be due to a variety of reasons. One such reason, given by Barro (1990) and, by extension, Aschauer (1997a), is that the benefits of public capital rise at a diminishing rate but the costs of providing public capital (*e.g.*, through distorting taxation) rise at a constant rate. Another (related) reason, explored in Arrow and Kurz (1970), is that at any particular point in time the aggregate capital stock is misallocated unless the marginal product of public capital equals the marginal product of private capital. Both of these arguments imply that there should exist an output (and, by extension, an employmnet) growth maximizing level of the public capital stock relative to the private capital stock. For relatively low levels of public capital, increased public investment raises the economic growth rate; but for relatively high levels of public capital, increased in public investment decreases growth.

In the following section, these ideas are formalized to yield a simple two equation model in output and employment growth as a function of the public capital ratio as well as initial levels of output and employment. Subsequently, data for the 48 contiguous states over the period 1970 to 1990 are used to determine:

- the presence of a nonlinear relationship between public capital and economic growth and the exact magnitude of the growth maximizing public capital ratio
- the degree to which the actual public capital ratio falls short of the growth maximizing ratio and the implied marginal growth effect of public capital
- the separate impact of public debt and taxes on economic growth
- the degree to which the growth effect of public capital has changed over the decades of the 1970s and 1980s

- the extent to which the growth impacts of the public capital stock differ over the Snowbelt and Sunbelt
- the relative importance of different types of public capital--highways, water and sewer systems, as well as educational buildings and hospitals.

In brief summary, the results of the empirical analysis:

- substantiate the notion that the relationship between public capital and economic growth is nonlinear and provide estimates of a growth maximizing public capital stock lying somehwere between 50 and 70 pecent of the private capital stock
- provide reasonable estimates of a positive impact of public capital on economic growth for the average state over the sample period
- indicate significant negative impacts of public debt and taxes on growth
- suggest higher growth effects from public capital in the 1980s than in the 1970s
- show (somewhat) larger growth effects from public capital in the Snowbelt than in the Sunbelt
- uncover positive growth effects from both core (highways, water and sewers) and other (primarily schools and hospitals) public capital--with particualrly high impacts of urban infrastructure such as water and sewer capital.

II. Conceptual Framework

The analysis is based on a constant returns to scale production function, written in natural logarithms as

$$Y = A + a \cdot K + (1 - a) \cdot E \qquad (1)$$

where Y = natural logarithm of output of goods and services, K = natural logarithm of physical capital stock, E = natural logarithm of employment, and A = natural logarithm of total factor productivity. Total factor productivity is a function of the allocation of the total--public and private--capital stock as in

$$A = A(\frac{KG}{K}) \quad A'' < 0. \qquad (2)$$

At low levels of public capital relative to private capital, the marginal product of public capital exceeds that of private capital and output rises with an increase in public capital; consequently, $A' > 0$. However, at sufficiently high levels of public capital relative to private capital, the marginal product of public capital is exceeded by that of private capital and output falls with an increase in public capital; thus, $A' < 0$. In the empirical analysis to follow, A has the quadratic form

$$A = l \cdot (\frac{KG}{K}) \cdot (1 - (\frac{1}{2 \cdot m}) \cdot (\frac{KG}{K})) \qquad (3)$$

where

$$\frac{KG}{K} <(>)\ m \Rightarrow A' >(<)\ 0$$

and so an estimate of the parameter *m* represents an estimate of the level of the public capital stock (relative to the private capital stock) which maximizes output.

In this framework, the marginal products of private capital and of employment are given by

$$\frac{\partial \hat{Y}}{\partial \hat{K}} = \hat{A} \cdot a \cdot \hat{K}^{a-1} \hat{E}^{1-a} \tag{4}$$

and

$$\frac{\partial \hat{Y}}{\partial \hat{E}} = \hat{A} \cdot (1-a) \cdot \hat{K}^{a} \hat{E}^{-a} \tag{5}$$

where a caret represents the level of the corresponding variable (originally expressed in natural logarithms). Thus, an increase in the public capital stock also increases the marginal products of both factors of production as long as the public capital stock ratio lies below the output maximizing level of *m*.

Now, given that there are increasing costs of adjusting the private capital stock and employment, an increase in the public capital stock will cause a persistent differential between the marginal products of private capital and employment and their respective costs--the user cost of capital and the wage--and will generate persistent increases in the growth rates of private capital and employment. Analytically, letting *DK* and *DE* represent the growth rates of capital and employment, respectively, we have

$$DK = DK(A,K,E) \quad \frac{\partial DK}{\partial A} > 0 \ (for \ \frac{KG}{K} < m) \tag{6}$$

$$DE = DE(A,K,E) \quad \frac{\partial DE}{\partial A} > 0 \ (for \ \frac{KG}{K} < m). \tag{7}$$

The form of the production function implies that the growth rate of output, *DY*, may be written as the sum of three components--the growth rate of total factor productivity, the growth rate of the private capital stock relative to employment (weighted by the output elasticity of private capital), and the growth rate of employment. Thus,

$$DY = DA + a\cdot(DK - DE) + DE \tag{8}$$

or

$$DY = DA + a\cdot(DK(A,K,E) - DE(A,K,E)) + DE(A,K,E) \tag{9}$$

along with

$$DE = DE(A, K, E). \tag{10}$$

Finally, by inverting the production function to write the private capital stock as a function of output, total factor productivity, and employment, the private capital stock may be eliminated to obtain a two equation system in the growth rates of output and employment given by

$$DY = DY(A, Y, E) \tag{11}$$

$$DE = DL(A, Y, E). \tag{12}$$

Figure 1 illustrates the economic relationships of interest in the present study. As indicated in the top panel of the figure, when the public capital ratio lies below the output maximizing level of m an increase in the public capital ratio will result in an increase in both output and employment growth, $DX = DY, DE$. Also, the marginal growth effect of public capital, g, declines with an increase in the public capital ratio as a result of the nonlinear relationship between public capital and total factor productivity. This is shown in the bottom panel of the figure, where the marginal growth effect is positive for values of the public capital ratio below m but turns negative for values of the public capital ratio above m.

In general, the influence of the initial levels of output and employment on the growth rates of the respective variables will be ambiguous, depending upon factors such as the relative speeds of adjustment of capital and employment to their steady state values and the strength of income effects

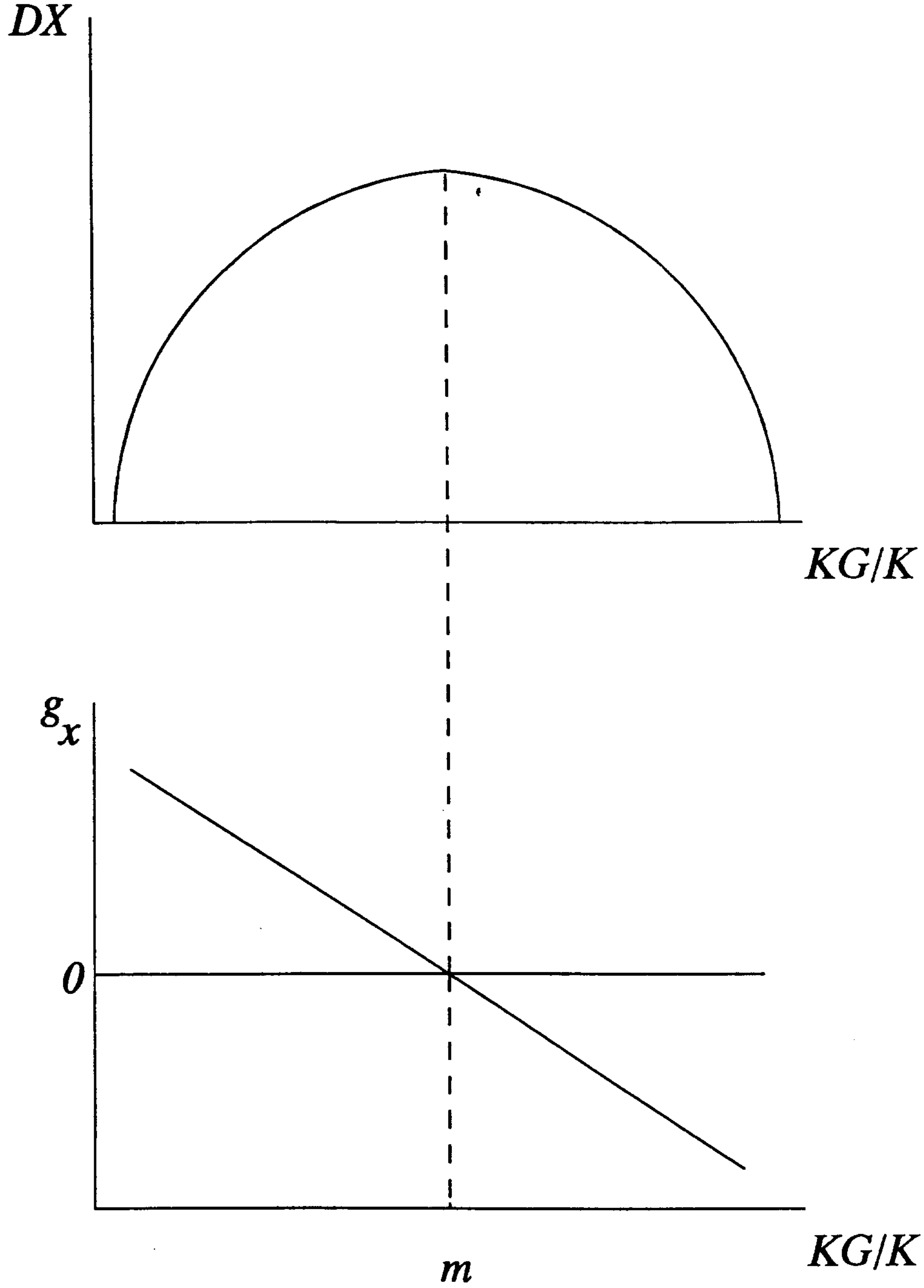

Figure 1

in the determination of labor supply. These latter features are only of incidental interest in the present study and, therefore, are not explicitly investigated either conceptually or empirically.[1]

III. Empirical Analysis

The basic data employed in this paper cover the 48 contiguous United States over the period from 1970 to 1990. These data are tailored in such a way as to (1) allow the analysis to capture the long run, as opposed to the short run, effect of public capital (as well as flow government spending, debt, and taxes) on output and employment growth and (2) allow a role for other (perhaps unspecified) determinants of economic growth. In particular, the long run effect of public capital on the economy can be captured by utilizing data which are averaged over a sufficiently long time period, while a role for other (state specific as well as temporal) factors can be achieved through the use of fixed effects regression methods. To accomplish these ends, a small panel data set is constructed by averaging the basic data over 10 year periods, resulting in 96 total observations--sufficient to allow for separate state specific and temporal effects while maintaining a focus on the long run effects of government policy on the economy.

Table 1 presents descriptive statistics for the basic data used in this paper. Output growth [*DY*] is measured as average annual growth in real gross state product; current dollar gross state product, available from various issues of the *Survey of Current Business* (U.S. Department of Commerce, Bureau of Economic Analysis) has been placed in constant (1982) dollar terms using the deflator for gross national product.[2] Output growth averaged 2.9 percent per year and ranged between a high

Descriptive Statistics 48 contiguous States 1970s & 1980s (96 observations)				
	mean	minimum	maximum	standard deviation
DY	.029	-.033	.064	.017
DL	.025	-.005	.068	.014
KG/K	.446	.194	.793	.136
CG/K	.113	.036	.247	.043
B/K	.139	.035	.416	.077
T/K	.080	.023	.194	.034
U	.058	.031	.120	.016

Table 1

of 6.4 percent and a low of -3.3 percent. Employment growth [DE] is measured as average annual growth in non-agricultural employment as taken from various issues of *Employment, Hours, and Earnings, State Areas* (U.S. Department of Labor, Bureau of Labor Statistics).[3] The growth rate of employment ranged between 6.8 percent and -0.5 percent and, over the entire sample, averaged 2.5 percent. Public and private capital stocks, both expressed in 1982 constant dollar terms, were obtained from Munnell (1990). The public capital stock, taken as a ratio to the private capital stock, averaged 44.6 percent and took on a minimum value of 19.4 percent and a maximum value of 79.3 percent. Government consumption [CG] is measured as total government spending *minus* public capital outlays and, in the empirical analysis, is expressed as a ratio to private capital. This variable averaged 11.3 percent and ranged between a low of 3.6 percent and a high of 24.7 percent. Public sector debt [B] is expressed relative to the private capital stock and averaged 13.9 percent. Taxes [T] are measured as total own source revenues *minus* interest payments, are expressed as a ratio to private capital, and ranged between 2.3 percent and 19.4 percent. Finally, the unemployment rate [U]--used to control for "cyclical" effects on the growth rates of output and employment, ranged between 3.1 and 12.0 percent and took on an average value of 5.8 percent over the sample as a whole.

A. Public Capital, Output and Employment Growth: Basic Results

The empirical analysis begins with estimates of the regression equation

$$DX = l_X \cdot \left(\frac{KG}{K}\right) \cdot \left(1 - \left(\frac{1}{2 \cdot m_X}\right) \cdot \left(\frac{KG}{K}\right)\right) + \underline{a}_X \cdot \underline{z} + e_X \tag{13}$$

where, in turn, X represents output, Y, and employment, E, respectively. Here, the vector z, common to both growth rate expressions, includes the initial (1970, 1980) levels of (the natural logarithms of) output and employment as well as the unemployment rate. Further, each equation includes intercept terms (fixed effects) to capture state and decade specific influences on the growth rates of output and employment.

Table A.1 presents ordinary least squares [OLS], weighted least squares [WLS], and seemingly unrelated regression [SUR] results of estimating the basic expressions for output and employment growth. The OLS estimates indicate that the level of the public capital stock which maximizes the growth rates of output and employment, respectively, equals 60.3 and 56.8 percent of the private capital stock. These growth maximizing values for the public capital stock are estimated fairly tightly, with a 95 percent confidence interval for m of (.515, .691) in the output growth expression and (.498, .638) in the employment growth expression. Output and employment growth are positively (and significantly) affected by increases in the initial level of output and negatively (and significantly) influenced by increases in the initial level of employment. Similarly, the unemployment rate has a positive (though relatively insignificant) effect on output growth and a positive (and significant) impact on employment growth. In part, this last result may be rationalized on the basis of differential effects of recessionary shocks to states' economies, with output and employment growth higher in high unemployment states as the national economy emerges from a business slump.

The WLS estimates employ (the square roots of) output per employed person, output, and

Output and Employment Growth Effects of Public Capital

$$DX = l_X \cdot \left(\frac{KG}{K}\right) \cdot \left(1 - \frac{1}{2 \cdot m_X} \cdot \left(\frac{KG}{K}\right)\right) + a_X \cdot z + e_X$$

$$X = Y, E$$

	OLS		WLS [√y]		WLS [√Y]		WLS [√E]		SUR	
	DY	DE	DY	DE	DY	DE	DY	DE	DY	DE
l_X	.779 (.202)	.358 (.095)	.830 (.189)	.394 (.100)	.731 (.157)	.319 (.073)	.710 (.163)	.311 (.072)	.779 (.121)	.358 (.059)
m_X	.603 (.044)	.568 (.035)	.597 (.040)	.571 (.033)	.634 (.023)	.613 (.021)	.639 (.024)	.612 (.022)	.603 (.022)	.568 (.022)
Y	.069 (.033)	.090 (.019)	.075 (.031)	.098 (.018)	.084 (.026)	.096 (.014)	.074 (.031)	.089 (.016)	.069 (.027)	.090 (.013)
E	-.130 (.040)	-.132 (.021)	-.134 (.038)	-.140 (.020)	-.154 (.033)	-.137 (.016)	-.144 (.040)	-.129 (.019)	-.130 (.028)	-.132 (.014)
U	.258 (.226)	.237 (.086)	.305 (.227)	.253 (.090)	.070 (.203)	.195 (.074)	.044 (.205)	.194 (.071)	.195 (.074)	.237 (.071)
R^2	.598	.863	.637	.888	.835	.931	.826	.923	.598	.863
SER x10(-3)	10.672	5.249	10.634	5.406	8.488	4.289	8.510	4.251	10.672	5.249
SSR x10(-3)	4.783	1.157	4.749	1.228	3.026	.773	3.042	.759	4.783	1.157

Notes: standard errors are in parentheses; all equations include individual state and decade fixed effects.

Table A.1

employment, respectively, and generate similar coefficient estimates. Specifically, the growth maximizing value for the public capital stock ranges between .597 and .639 for output growth and between .517 and .613 for employment growth. As with the OLS results, the point estimates for the growth maximizing values of the public capital stock are larger in the output growth expression than in the employment growth expression; for instance, the WLS estimate of the coefficient *m* using (the square root of) output as a regression weight is .634 for output growth, somewhat larger than .613 for employment growth. The initial levels of output and employment continue to have the same positive and negative impacts on both output and employment growth. Finally, the unemployment rate remains as a positive (though fairly insignificant) determinant of output growth and a positive (and quite significant) determinant of employment growth.

The SUR method entails a joint estimation of the expressions for output and employment growth. This method results in the same point estimates as the OLS method but, by exploiting the correlation between output growth and employment growth, allows for a reduction in standard errors associated with the individual coefficient estimates on the order of 50 percent. As a result, the confidence intervals for the relevant coefficients become considerably tighter; a 95 percent confidence interval for *m* is now (.563, .647) in the output growth expression and (.524, .612) in the employment growth expression. Despite the similar coefficient estimates of *m* for output and employment growth, however, the hypothesis that the coefficients are equal can be statistically rejected with a high degree of confidence (value of chi-square statistic = 6.841; probability value = 0.009).

Using the OLS/SUR point estimates of m, Chart A.1 indicates the degree to which the public capital stock ratio falls below (or above) the output growth maximizing value (m = .603) for the 96 observations in the sample. The average public capital ratio equals .446, some 26 percent below the growth maximizing level, and the largest number--14 of 96 (or 14.6 percent)--of the observations are clustered closely around this value. Further, the vast majority--84 of 96 (or 87.5 percent)--of the observations can be seen to lie below the output growth maximizing value of the public capital ratio, with the gap between the growth maximizing level and actual levels reaching as high as 68 percent. Still, 12 observations lie above the output growth maximizing value, suggesting that these particular states (during specific decades) might have achieved higher economic growth through reductions in the public capital stock.

Table A.2 presents calculations of the degree to which the output and employment growth maximizing values of the public capital stock exceed the average value of the public capital stock (of .446) for the various estimates reported in Table A.1. This gap--labeled g_m--ranges between .151 and .188 for output growth and .122 and .167 for employment growth. Further, a test of the hypothesis of an equality between estimated growth maximizing and actual average values of the public capital stock--labeled h_m--easily results in a rejection of the hypothesis, with the relevant chi-square statistic ranging between the very high values of 23.001 and 138.052 for output growth and 19.717 and 118.061 for employment growth.

Table A.2 also contains calculations of the marginal growth effect of an increase in public capital on

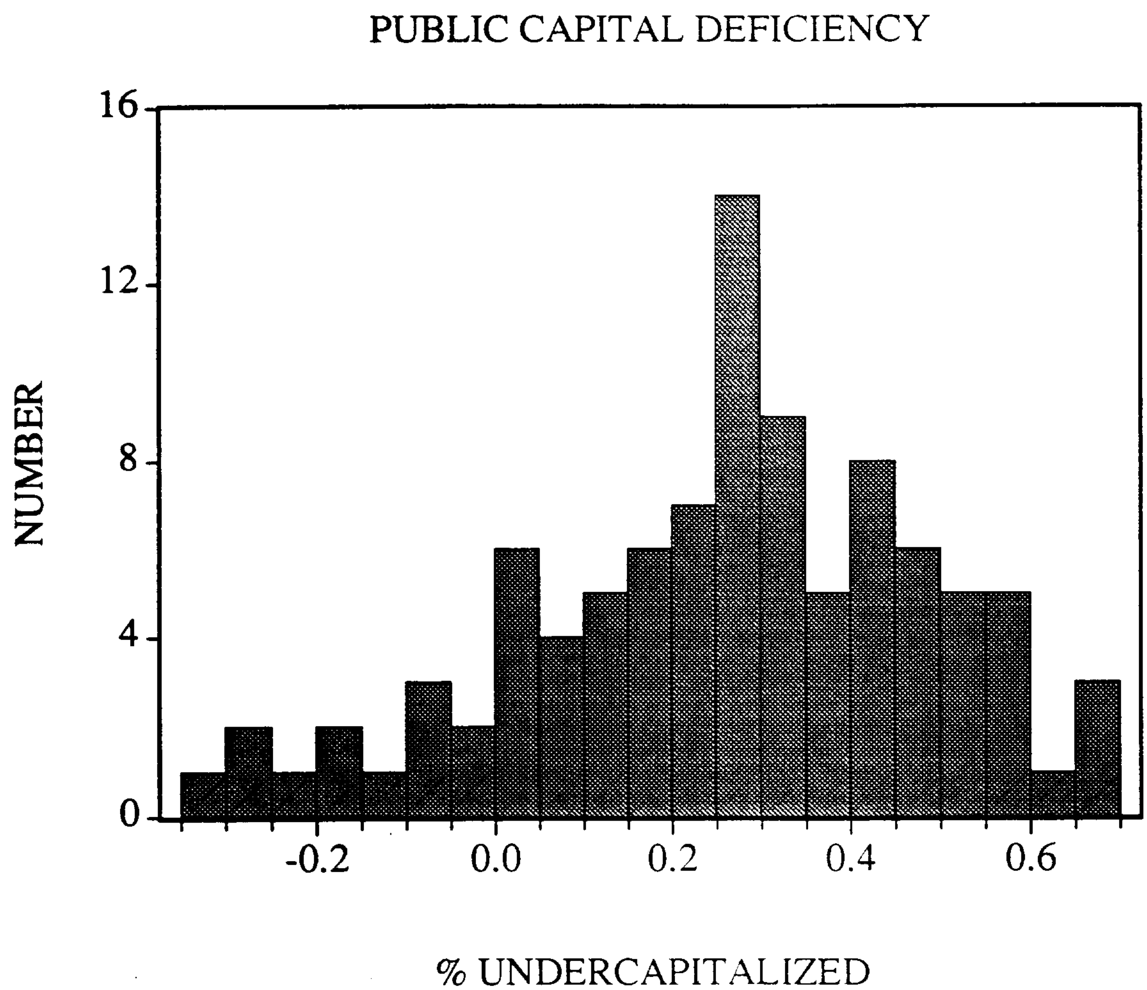
PUBLIC CAPITAL DEFICIENCY
NUMBER
16
12
8
4
0
-0.2
0.0
0.2
0.4
0.6
% UNDERCAPITALIZED

Chart A.1

Output and Employment Growth Effects of Public Capital

$$g_m = m - (\frac{\overline{KG}}{K})$$

$$g_l = l \cdot [1 - (\frac{1}{m}) \cdot (\frac{\overline{KG}}{K})]$$

$$h_m: \quad m - (\frac{\overline{KG}}{K}) = 0$$

$$h_l: \quad l \cdot [1 - (\frac{1}{m}) \cdot (\frac{\overline{KG}}{K})] = 0$$

	OLS		WLS [√y]		WLS [√Y]		WLS [√E]		SUR	
	DY	DE	DY	DE	DY	DE	DY	DE	DY	DE
g_m	.157	.122	.151	.125	.188	.167	.179	.166	.157	.122
g_l	.202	.077	.210	.086	.217	.087	.214	.084	.202	.077
	Value of χ^2 statistic: (p-values in parentheses)									
h_m	23.001 (<.001)	19.717 (<.001)	25.279 (<.001)	22.888 (<.001)	138.052 (<.001)	118.061 (<.001)	130.108 (<.001)	108.986 (<.001)	91.440 (<.001)	49.432 (<.001)
h_l	10.599 (.001)	5.940 (.015)	11.806 (.001)	6.672 (.010)	18.183 (<.001)	12.799 (<.001)	16.957 (<.001)	11.978 (.001)	26.930 (<.001)	16.054 (<.001)

Table A.2

output and employment, given as

$$g_l = l \cdot [1 - (\frac{1}{m}) \cdot (\frac{\overline{KG}}{K})] \tag{14}$$

where an overline denotes a sample average value. The calculated marginal growth effect lies between .202 and .217 for output and between .077 and .087 for employment. A test of the hypothesis that this growth effect is zero for the average state during the sample period--labeled h_l --also allows an easy rejection of the hypothesis, with chi-square values between 10.599 and 26.930 for output growth and between 5.940 and 16.957 for employment growth.

The marginal output and employment growth effects for the various states over the two decades in the sample are traced out in Figures A.1 and A.2, respectively, using the OLS/SUR point estimates from Table A.1. As is evident from the figure, the marginal growth effect ranges fairly broadly, between a high of .528 and a low of -.245 for output growth and between a high of .265 and a low of -.106 for employment growth. However, for the average state over the 1970s and 1980s, the growth effect is positive for both output and employment.

To better judge the reasonableness of the estimates, Table A.3 presents estimates of the impact of a 1 standard deviation increase in the public capital ratio (from its average value of .446 to .582) on output and employment growth. In order to avoid over-estimating the impact of public capital--the relationship between public capital and growth having been found to be non-linear--the growth rate

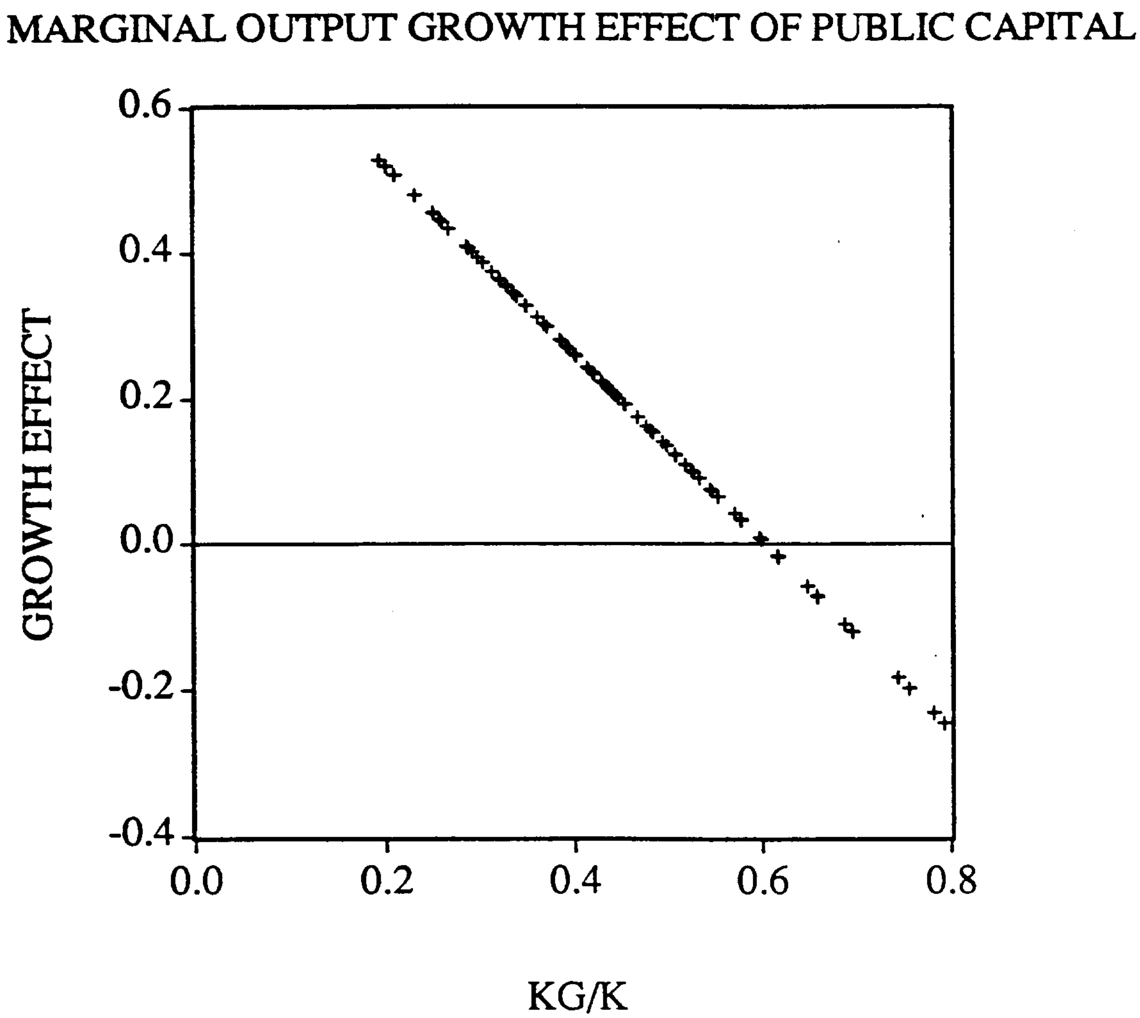
MARGINAL OUTPUT GROWTH EFFECT OF PUBLIC CAPITAL
GROWTH EFFECT
0.6
0.4
0.2
0.0
-0.2
-0.4
0.0
0.2
0.4
0.6
0.8
KG/K

Figure A.1

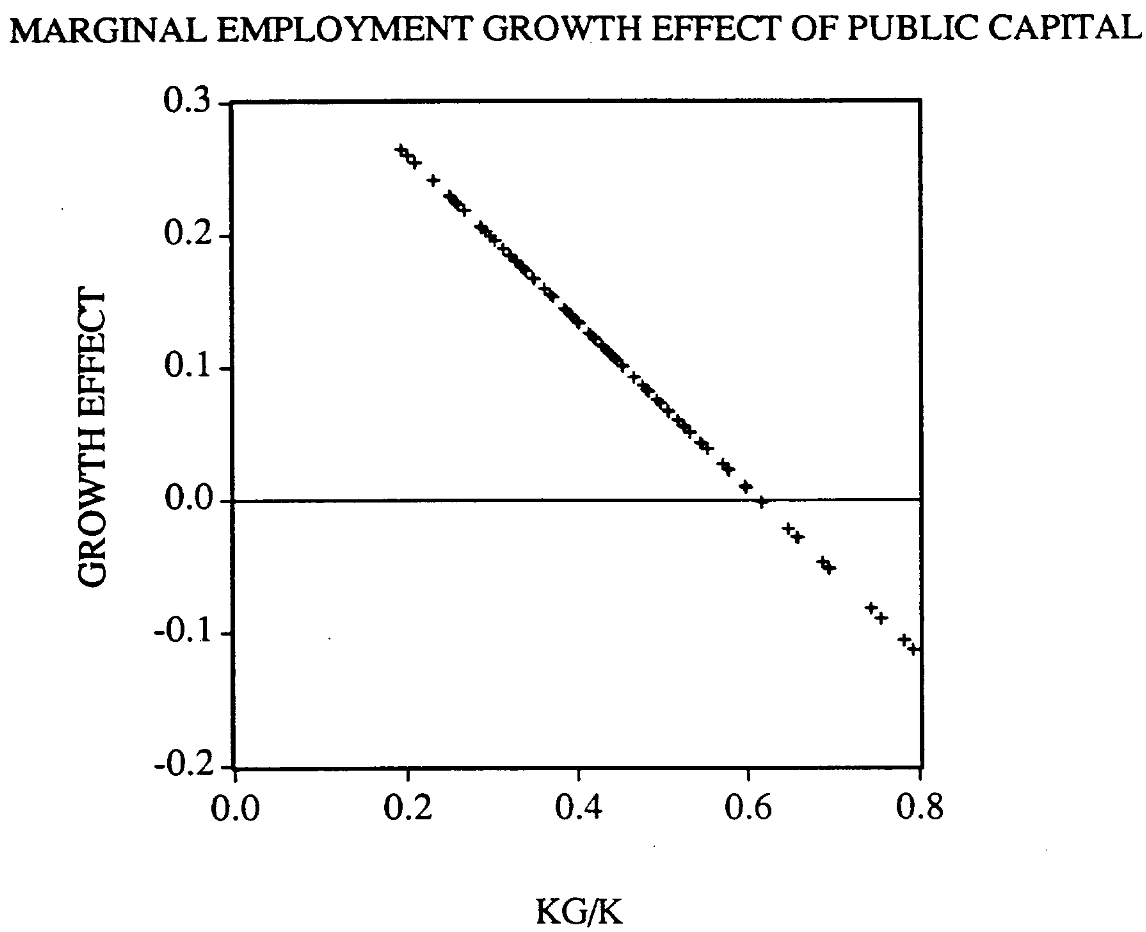
MARGINAL EMPLOYMENT GROWTH EFFECT OF PUBLIC CAPITAL
GROWTH EFFECT
0.3
0.2
0.1
0.0
-0.1
-0.2
0.0
0.2
0.4
0.6
0.8
KG/K

Figure A.2

Output and Employment Growth Effects of Public Capital (impact of a 1 standard deviation increase in KG/K from .446 to .582)*										
	OLS		WLS [√y]		WLS [√Y]		WLS [√E]		SUR	
	DY	DE	DY	DE	DY	DE	DY	DE	DY	DE
g_t	.115	.034	.115	.039	.135	.052	.139	.050	.115	.034
Growth impact	.016	.005	.016	.005	.018	.007	.019	.007	.016	.005
Relative growth impact	.941	.357	.941	.379	1.144	.501	1.118	.480	.941	.357
*Evaluated at the average value of KG/K = .514.										

Table A.3

effect is calculated for the mid-point value of .514 for the public capital stock. As shown in the table, the growth effect ranges between 1.6 and 1.9 percent per year for output and 0.5 and 0.6 percent per year for employment. Relative to the standard deviations for output growth (of 1.7 percent per year) and for employment growth (of 1.4 percent per year), these 1 standard deviation increases in the public capital ratio generate as much as a 1.118 standard deviation increase in output growth and a 0.507 standard deviation increase in employment growth. Note, however, that these impacts are *static* in nature and, as such, represent only the initial effect on output and employment; the subsequent, or *dynamic* impacts depend critically on the degree to which (1) output and employment growth are related to the initial levels of output and employment, and (2) the extent to which output and employment growth interact with one another over time. These issues lie beyond the present paper but are discussed extensively in Aschauer (1997c).

B. Government Consumption Spending

A small, but significant role for flow government expenditure in the determination of productivity growth has been detected in the empirical analysis contained in Aschauer (1997a). Specifically, using essentially the same data set as the present paper, the level of government spending (relative to private capital) which maximizes productivity growth is estimated to equal 3.0 or 4.0 percent. As the level of government spending ranges from 4.0 percent to 29.3 percent in the sample, all of the observations are clustered above the growth maximizing level, and, in this sense, government spending can be said to be excessive. Stated differently, the estimates contained in that paper suggest that for all of the 48 states over the 1970s and 1980s a decrease in flow government spending would have resulted in an increase in productivity growth.

Table B.1 allows for a separate effect of government consumption expenditure--defined as general government spending *minus* public capital outlays--on output and employment growth. Generally, government consumption spending is negatively associated with both output and employment growth; for example, the OLS/SUR point estimates are -.179 for output growth and -.058 for employment growth. These point estimates imply that a 1 standard deviation increase in government consumption spending would reduce output growth by 0.8 percent per year and employment growth by 0.2 percent per year, or .471 and .143 standard deviations of output growth and employment growth, respectively. However, the point estimates are sensitive to the particular method of estimation--for instance, ranging from -.179 to .002 for output growth--and are insignificantly different from zero at conventional levels. Thus, in the present study there is little substantive role for government consumption spending in the determination of output and employment growth. Furthermore, not much is gained by the addition of government consumption to the estimating equations; compared to the equations contained in Table A.1, the adjusted coefficients of determination remain at about the same levels, and the point estimates for the coefficients of the relevant variables are left substantially unaffected. For example, the OLS/SUR estimate of the growth maximizing level of public capital is now .604 for output, nearly identical to the previous estimate of .603, and .559 for employment, somewhat smaller than the previous estimate of .568.

Output and Employment Growth Effects of Public Capital and Consumption

$$DX = l_X \cdot \left(\frac{KG}{K}\right) \cdot \left(1 - \frac{1}{2 \cdot m_X} \cdot \left(\frac{KG}{K}\right)\right) + a_X \cdot z + c_X \cdot \left(\frac{CG}{K}\right) + e_X$$

$$X = Y, E$$

	OLS		WLS [√y]		WLS [√Y]		WLS [√E]		SUR	
	DY	DE	DY	DE	DY	DE	DY	DE	DY	DE
l_X	.785 (.279)	.307 (.133)	.798 (.273)	.301 (.132)	.705 (.171)	.309 (.078)	.697 (.175)	.313 (.078)	.785 (.155)	.307 (.073)
m_X	.604 (.045)	.559 (.047)	.596 (.044)	.553 (.050)	.634 (.026)	.622 (.026)	.640 (.027)	.622 (.025)	.604 (.022)	.559 (.026)
c_X	-.179 (.320)	-.058 (.136)	-.163 (.326)	-.045 (.138)	.002 (.163)	-.069 (.074)	-.012 (.160)	-.074 (.071)	-.179 (.183)	-.058 (.086)
Y	.052 (.034)	.072 (.019)	.054 (.033)	.075 (.018)	.081 (.028)	.093 (.015)	.071 (.033)	.087 (.017)	.052 (.029)	.072 (.013)
E	-.105 (.042)	-.110 (.021)	-.105 (.041)	-.113 (.021)	-.151 (.038)	-.131 (.038)	-.141 (.043)	-.124 (.021)	-.105 (.031)	-.110 (.014)
U	.292 (.246)	.237 (.096)	.332 (.248)	.246 (.101)	.058 (.220)	.200 (.079)	.039 (.221)	.205 (.076)	.292 (.151)	.237 (.013)
R^2	.533	.868	.561	.898	.821	.930	.812	.920	.533	.868
SER x10(-3)	10.726	5.042	10.696	5.082	8.613	4.254	8.634	4.243	10.726	5.042
SSR x10(-3)	4.602	1.017	4.577	1.033	2.967	.724	2.982	.720	4.602	1.017

Notes: standard errors are in parentheses; all equations include individual state and decade fixed effects.

Table B.1

C. Financing Public Capital: Debt and Taxes

In order to fully understand the relationship between government capital and economic growth, it also is important to take into account the means by which the capital is financed--both the original acquisition of capital and the maintenance of capital over its useful lifetime. Here, we assume that the original acquisition of capital is financed through the issuance of municipal bonds while the maintenance of capital is financed by taxes. These financial variables--debt and taxes, respectively--are then allowed to have an effect (presumably negative) on both output and employment growth. Finally, the *net* effect of public capital on the economy can be calculated by subtracting, in an appropriate manner, these financial impacts from the gross impact of public capital.

Table C.1 shows estimates of the impact of public capital, debt, and taxes on output growth and employment growth, respectively. In all equations, public capital, debt and taxes are important determinants of both output growth and employment growth. The output growth maximizing level of public capital ranges between .667 and .720 while the employment growth maximizing level of public capital ranges between .614 and .699--with both sets of estimates lying somewhat higher than the estimates contained in Table A.1 for the basic model (which omitted financial variables). Output and employment growth are negatively associated with public debt, with estimated coefficients lying between -.102 and -.57 for output growth and .045 and -.050 for employment growth. These point estimates--specifically, the OLS/SUR estimates--indicate that a 1 standard deviation increase in public debt (relative to private capital) is associated with a .706 of 1 standard deviation reduction in output growth (1.2 percent per year) and with a .248 of 1 standard deviation reduction in employment

Output and Employment Growth Effects of Public Capital, Taxes and Debt

$$DX = l_X \cdot (\frac{KG}{K}) \cdot (1 - \frac{1}{2 \cdot m_X} \cdot (\frac{KG}{K})) + a_X \cdot z + b_X \cdot (\frac{BG}{K}) + t_X \cdot (\frac{T}{K}) + e_X$$

$X = Y, E$

	OLS		WLS [√y]		WLS [√Y]		WLS [√E]		SUR	
	DY	DE	DY	DE	DY	DE	DY	DE	DY	DE
l_x	.873 (.164)	.387 (.093)	.901 (.156)	.415 (.099)	.664 (.164)	.285 (.075)	.643 (.169)	.278 (.073)	.873 (.107)	.387 (.057)
m_x	.672 (.053)	.614 (.035)	.667 (.051)	.616 (.035)	.710 (.054)	.699 (.052)	.720 (.059)	.693 (.053)	.672 (.026)	.614 (.026)
b_x	-.156 (.047)	-.045 (.025)	-.157 (.049)	-.045 (.027)	-.103 (.050)	-.050 (.025)	-.102 (.047)	-.049 (.025)	-.156 (.036)	-.045 (.019)
t_x	-.580 (.320)	-.275 (.089)	-.593 (.326)	-.215 (.151)	-.309 (.251)	-.161 (.118)	-.316 (.245)	-.160 (.115)	-.580 (.184)	-.275 (.068)
Y	.066 (.027)	.089 (.018)	.069 (.026)	.096 (.018)	.084 (.022)	.096 (.012)	.075 (.025)	.090 (.014)	.066 (.023)	.089 (.012)
E	-.075 (.037)	-.113 (.024)	-.077 (.037)	-.121 (.024)	-.117 (.037)	-.118 (.019)	-.109 (.040)	-.112 (.031)	-.075 (.027)	-.113 (.014)
U	.376 (.182)	.275 (.089)	.422 (.190)	.291 (.093)	.150 (.188)	.233 (.075)	.119 (.189)	.229 (.070)	.376 (.128)	.275 (.068)
R^2	.680	.870	.710	.893	.857	.938	.850	.933	.680	.870
SER x10(-3)	9.529	5.101	9.512	5.278	7.914	4.012	7.901	3.962	9.529	5.101
SSR x10(-3)	3.632	1.041	3.619	1.114	2.505	.644	2.497	.628	3.632	1.041

Notes: standard errors are in parentheses; all equations include individual state and decade fixed effects.

Table C.1

growth (0.3 percent per year). Similarly, output and employment growth are inversely related to government revenues, with estimated coefficients ranging between -.309 and -.593 for output growth and -.160 and -.275 for employment growth. The OLS/SUR estimates suggest a very sizable role for taxes in determining output and employment growth; specifically, a 1 standard deviation increase in revenues (relative to private capital) is coupled with a 1.160 standard deviation (1.9 percent per year) decrease in output growth and a .681 of 1 standard deviation (0.9 percent per year) decrease in employment growth.[4]

Table C.2 presents estimated values of the degree to which the actual average public capital ratio falls short of the growth maximizing level of public capital, g_m along with the gross and net growth effects of public capital, g_l and g_t, respectively. The net growth effect is calculated as

$$g_t = g_l + b + t \cdot (d + \overline{DY}) \tag{15}$$

where the gross growth effect, g_l , is calculated as in equation (14), while b and t represent the estimated coefficients on public sector debt and taxes, respectively. Finally, d represents an assumed physical depreciation rate for public capital, taken to equal 2.5 percent per year. As calculated, the net growth effect indicates the effect of a 1 unit increase in public capital on economic growth: the gross effect, given by g_l, plus the (negative) effect of bond finance, b, plus the (negative) effect of tax finance of on-going public investment needed to maintain the public capital stock against physical depreciation and against growth in output (and private capital), $t(d + DY)$. As the table shows, the gross and net growth effects of public capital on both output and employment growth are sizeable.

Output and Employment Growth Effects of Public Capital, Taxes and Debt

$$g_m = m - (\frac{\overline{KG}}{K})$$

$$g_l = l \cdot [1 - (\frac{1}{m}) \cdot (\frac{\overline{KG}}{K})]$$

$$g_t = l \cdot [1 - (\frac{1}{m}) \cdot (\frac{\overline{KG}}{K})] + b + t \cdot (d + \overline{DY}) = 0$$

$$h_m: \quad m - (\frac{\overline{KG}}{K}) = 0$$

$$h_l: \quad l \cdot [1 - (\frac{1}{m}) \cdot (\frac{\overline{KG}}{K})] = 0$$

$$h_t: \quad l \cdot [1 - (\frac{1}{m}) \cdot (\frac{\overline{KG}}{K})] + b + t \cdot (d + \overline{DY}) = 0$$

	OLS		WLS [√y]		WLS [√Y]		WLS [√E]		SUR	
	DY	DE	DY	DE	DY	DE	DY	DE	DY	DE
g_m	.226	.168	.221	.170	.264	.253	.274	.247	.226	.168
g_l	.294	.106	.299	.115	.245	.103	.245	.099	.294	.106
g_t	.108	.047	.113	.059	.129	.045	.127	.051	.108	.047
	Value of χ^2 statistic: (p-values in parentheses)									
h_m	41.403 (<.001)	43.620 (<.001)	42.092 (<.001)	43.606 (<.001)	59.640 (<.001)	54.855 (<.001)	56.309 (<.001)	52.215 (<.001)	74.088 (<.001)	92.106 (<.001)
h_l	26.511 (<.001)	11.933 (.001)	27.405 (<.001)	11.678 (<.001)	21.687 (<.001)	23.445 (<.001)	21.038 (<.001)	24.191 (<.001)	60.128 (<.001)	27.268 (<.001)
h_t	2.701 (.100)	1.965 (.161)	2.883 (.090)	2.403 (.121)	3.391 (.066)	1.739 (.187)	3.415 (.065)	1.649 (.199)	6.874 (.009)	4.923 (.027)

Table C.2

The gross growth effects are somewhat larger than those contained in Table B.2, lying in a range of .245 to .299 for output growth and .099 and .115 for employment growth; as the bottom panel of the table indicates, these effects also are significantly different from zero. The net growth effects are in the range of .108 to .129 for output growth and .045 to .059 for employment growth; these effects, too, can be seen to be significantly different from zero at conventional levels (as a failure to reject the hypothesis of a zero effect would normally require a probability value of perhaps .90 or .95, far above the highest values of .100 for output growth and .199 for employment growth in the bottom row of the table).

Figures C.1 and C.2 illustrate the range of the net growth effect for the individual states in the sample over the 1970s and 1980s. For output, the net growth effect takes on a maximum value of .436 and a minimum value of -.328; the output growth effect is positive for 77.1 percent of the sample (74 of 96 observations). For employment, the growth effect is highest at .206 and lowest at -.172; the employment growth effect is positive for 74.0 percent of the sample (71 of 96 observations).

Table C.3 presents estimates of the effect of a 1 standard deviation increase in public capital and output after taking into account the adverse tax and debt effects associated with financing public capital. These growth effects are between 0.3 and 0.9 percent per year for output and 0.1 and 0.2 percent per year for employment--considerably below the analogous values in Table A.3. Nevertheless, these impacts are still sizeable, amounting to as much as .529 of 1 standard deviation for output growth and .143 of 1 standard deviation for employment growth.

MARGINAL OUTPUT GROWTH EFFECT OF PUBLIC CAPITAL
(tax & debt finance)

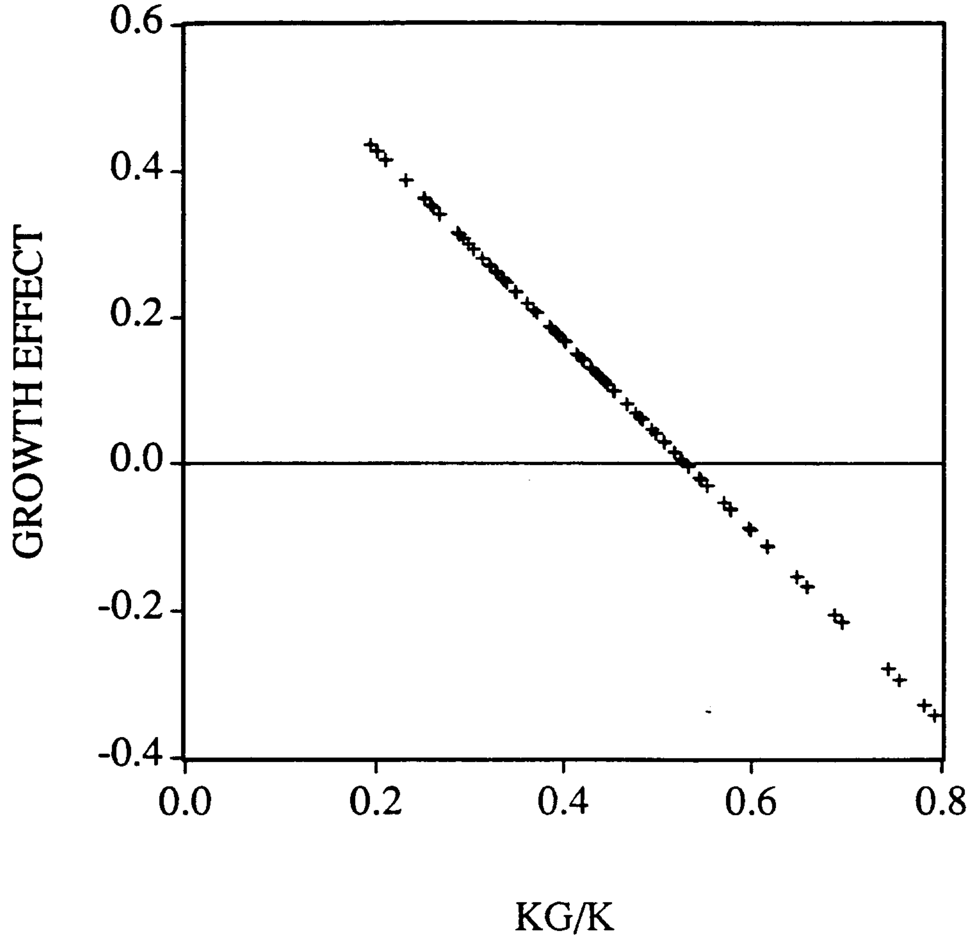

Figure C.1

MARGINAL EMPLOYMENT GROWTH EFFECT OF PUBLIC CAPITAL
(tax & debt finance)

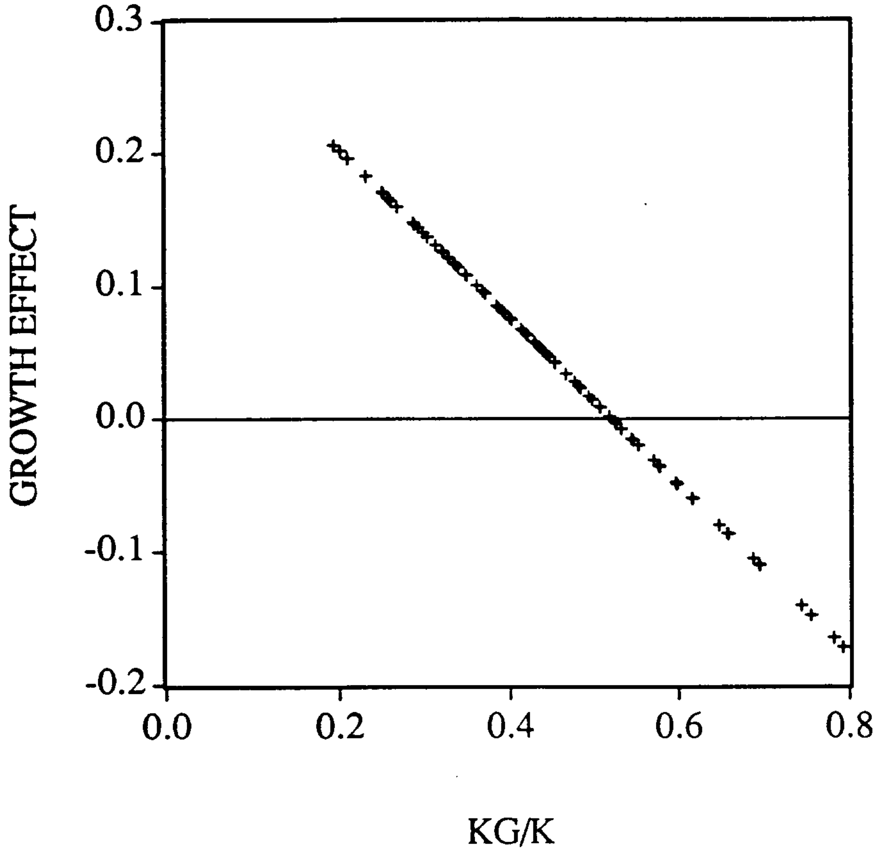

Figure C.2

Output and Employment Growth Effects of Public Capital, Taxes and Debt (impact of a 1 standard deviation tax & debt financed increase in KG/K from .446 to .582)*										
	OLS		WLS [√y]		WLS [√Y]		WLS [√E]		SUR	
	DY	DE	DY	DE	DY	DE	DY	DE	DY	DE
g_t	.029	.011	.020	.012	.065	.017	.066	.015	.029	.011
Growth impact	.004	.001	.003	.002	.009	.002	.009	.002	.004	.001

*Evaluated at the average value of KG/K = .514.

Table C.3

D. Public Capital and Economic Growth in the 1970s and 1980s

It is of interest to know if the growth impact of public capital--found to be positive for the average state over the entire period from 1970 to 1990--has been increasing or decreasing over time. One approach to addressing this question would involve assuming stable relationships between public capital and output and employment growth and calculating the growth effects on the basis of a changing public capital ratio over time. Table D.1 contains such calculations where the sample has been split into the separate decades of the 1970s and 1980s. As has been well documented in other studies--see, for example, Aschauer (1989)--the public capital stock failed to keep pace with the private capital stock during the 1970s and 1980s and, as a result, the public capital ratio slid from .472 in the 1970s to the .42 in the 1980s. Using this fact, the empirical results from Table C.1 allow us to calculate a corresponding increase in the gross and net growth effect of public capital for both output (from .256 to .327 and .071 to .142, respectively) and employment (from .090 to .122 and .031 to .063, respectively). Consequently, it would appear that the net growth effect of public capital doubled for *both* output and employment, rationalizing on statistical grounds the notion--prevalent in the policy discussions of the 1980s--of an " infrastructure crisis" in the United States.

Another approach to answering the previously stated question, however, also would allow for a change in the relationship between public capital and growth by estimating decade specific coefficients pertaining to public capital in the empirical specification. Table D.2 shows the results of such an estimation strategy. As can be seen from the table, from the 1970s to the 1980s, the estimate of l increases substantially for both the output growth and the employment growth expressions; a test

Marginal Growth Effects of Public Capital: Stable Relationship between *DX* and *KG/K* (1970s vs. 1980s)					
		DY		*DE*	
	KG/K	g_l	g_t	g_l	g_t
1970s	.472	.256	.071	.090	.031
1980s	.420	.327	.142	.122	.063

Table D.1

Output and Employment Growth Effects of Public Capital (1970s vs. 1980s)		
	DY	DE
l_x (1970s)	.538 (.135)	.217 (.076)
m_x (1970s)	.773 (.069)	.640 (.051)
l_x (1980s)	.883 (.134)	.337 (.076)
m_x (1980s)	.656 (.029)	.620 (.035)
b_x	-.179 (.035)	-.046 (.020)
t_x	-.369 (.204)	-.063 (.116)
Y	-.017 (.026)	-.046 (.020)
E	-.004 (.028)	-.089 (.016)
U	.278 (.114)	.235 (.065)
R^2	.739	.881
SER $x10(-3)$	8.610	4.899
SSR $x10(-3)$	2.817	.912

Notes: standard errors in parentheses; all equations include individual state and decade effects.

Table D.2

of the equality of the *l* coefficients over the 1970s and 1980s results in chi-square statistics (probability values) of 24.729 (<.001) for output and 9.890 (.003) for employment. The rise in the estimates of *l* implies that for a given public capital deficiency--say on the order of .30--the gross growth effect rose from .161 to .265 for output and from .065 to .101 for employment--increases of 49.8 and 44.1 percent, respectively.

This calculation is complicated, however, by the fact that there is some evidence of a *decline* in the output and employment maximizing levels of public capital over the course of the 1970s and 1980s--as the estimated value of *m* slid from .773 to .656 for output and from .640 to .620 for employment. Nevertheless, as the calculations in Table D.3 and the illustrations in Figures D.1 and D.2 indicate, the net growth effect for both output and employment increased from the 1970s to 1980s. For output, the marginal growth effect rose from a small .012 to .121, while for employment the growth effect rose from an almost negligible .008 to .060. Consequently, both approaches to answering our initial question arrive at the same answer--specifically, that the net effects of public capital on output and employment growth increased in a marked fashion over the two decades of the sample period under consideration.

E. Public Capital and Economic Growth in the Snowbelt and Sunbelt

It is also of interest to know if the growth effect of public capital is more of less the same across the various regions of the country. As with the preceeding discussion, there are (at least) two approaches that can be taken to obtain an answer to this question, depending upon whether the

Marginal Growth Effects of Public Capital: Changing Relationship between *DX* and *KG/K* (1970s vs. 1980s)					
		DY		*DE*	
	KG/K	g_l	g_t	g_l	g_t
1970s	.472	.209	.012	.057	.008
1980s	.420	.318	.121	.109	.060

Table D.3

MARGINAL OUTPUT GROWTH EFFECT OF PUBLIC CAPITAL
(1970s vs. 1980s)

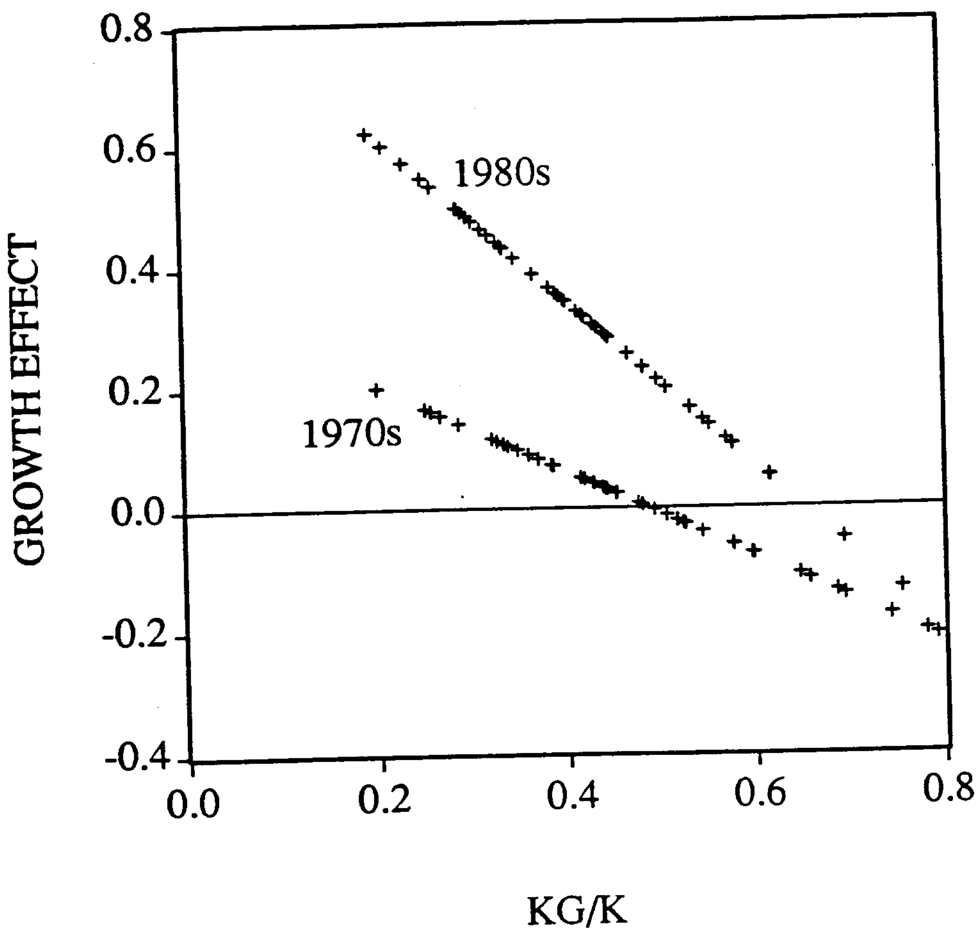

Figure D.1

MARGINAL EMPLOYMENT GROWTH EFFECT OF PUBLIC CAPITAL
(1970s vs. 1980s)

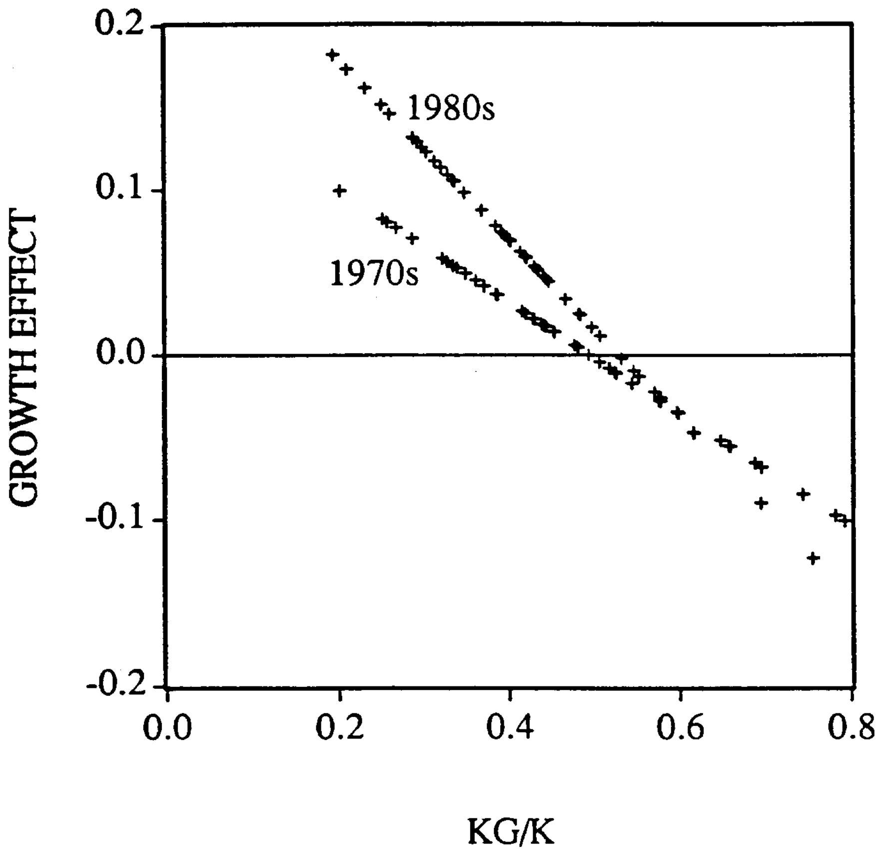

Figure D.2

relationship beween output and employment growth and public capital can be taken to be stable or changing (now, across regions as opposed to time). Table E.1 presents calculations of the output and employment effect of public capital in the Snowbelt (the 42 states in the northeastern and midwestern regions) and the Sunbelt (the 54 states in the southern and western regions) assuming that the growth relationship is stable. As is evident from the table, the public capital ratio is considerably higher in the Snowbelt than in the Sunbelt, which, given the common values for growth maximizing estimates of the public capital ratio of .672 for output and .614 for employment, implies correspondingly higher growth effects for the Sunbelt than for the Snowbelt. Specifically, the net output growth effect is calculated to be 18.2 percentage points lower in the Snowbelt than the Sunbelt, while the net employment growth effect is 4.4 percentage points lower. These calculations, therefore, would lead one to argue in favor of increased infrastructure investment in the Sunbelt relative to the Snowbelt due to the deficiency of public capital in the former relative to the latter region of the country.

As before, however, it is instructive to take into account the possibility of different sensitivities of economic growth to public capital in the two regions of the country. To this end, Table E.2 presents estimates of growth relations which allow for region specific *l* and *m* coefficients. As can be seen, both sets of coefficients carry point estimates which are higher for the Snowbelt than for the Sunbelt; for instance, the output and employment growth maximizing values for the public capital ratio are 8.7 and 6.1 percentage points higher, respectively, in the Snowbelt than in the Sunbelt. Consequently, the heightened sensitivity of economic growth to public capital in the Snowbelt can be expected to partly--if not fully--compensate for the Snowbelt's relative surfeit of public capital and tend to

Marginal Growth Effects of Public Capital: Stable Relationship between *DX* and *KG/K* (Snowbelt vs. Sunbelt)					
		DY		*DE*	
	KG/K	g_l	g_ι	g_l	g_ι
Snowbelt	.485	.151	-.029	.081	.022
Sunbelt	.416	.333	.148	.125	.066

Table E.1

Output and Employment Growth Effects of Public Capital (Snowbelt vs. Sunbelt)		
	DY	DE
l_x (Snowbelt)	.901 (.138)	.400 (.075)
m_x (Snowbelt)	.727 (.043)	.652 (.039)
l_x (Sunbelt)	.839 (.131)	.372 (.071)
m_x (Sunbelt)	.640 (.030)	.591 (.030)
b_x	-.124 (.038)	-.034 (.021)
t_x	-.723 (.192)	-.262 (.104)
Y	.046 (.025)	.082 (.372)
E	-.062 (.028)	-.109 (.015)
U	.439 (.128)	.297 (.070)
R^2	.680	.867
SER *x*10(-3)	9.526	5.174
SSR *x*10(-3)	3.449	1.017
Notes: standard errors in parentheses; all equations include individual state and decade effects.		

Table E.2

equalize growth effects across the two regions.

Table E.3 presents calculations making use of the coefficient estimates in Table E.2 which, indeed, show that the output and employment growth effects are nearly the same across regions once account is taken of the different sensitivities of economic growth to public capital. In particular, the output growth effect now is 0.6 tenths of one percentage point *higher,* and the employment growth effect only 0.8 tenths of a percentage point lower, in the Snowbelt than in the Sunbelt. Furthermore, as is evident from Figures E.1 and E.2, the net growth effects for the average state in both the Snowbelt and Sunbelt are positive, which justifies increased public capital investment in both regions of the country.

F. Core and Other Public Capital and Economic Growth

Previous studies of the relationship between public capital and the economy have tended to find support for the notion that "core" public capital--typically comprised of highways, water and sewer systems--is more important than "other" public capital. For instance, Aschauer (1997a) estimates that the output elasticity of core capital equals .444 while that of other capital equals .313; nevertheless, both sorts of capital are deemed to contribute in a significant fashion to productivity growth. Similarly, Morrison and Schwartz (1996) define public infrastructure to include "only highways, water, and sewers" and state that the estimated impact of public capital on costs of production in the manufacturing sector "is somewhat smaller if we include 'other' public capital, apparently largely containing government buildings which do not augment efficiency."

Marginal Growth Effects of Public Capital: Changing Relationship between *DX* and *KG/K* (Snowbelt vs. Sunbelt)					
		DY		*DE*	
	KG/K	g_l	g_t	g_l	g_t
Snowbelt	.485	.300	.140	.102	.055
Sunbelt	.416	.294	.134	.110	.063

Table E.3

MARGINAL OUTPUT GROWTH EFFECT OF PUBLIC CAPITAL
(Snowbelt vs. Sunbelt)

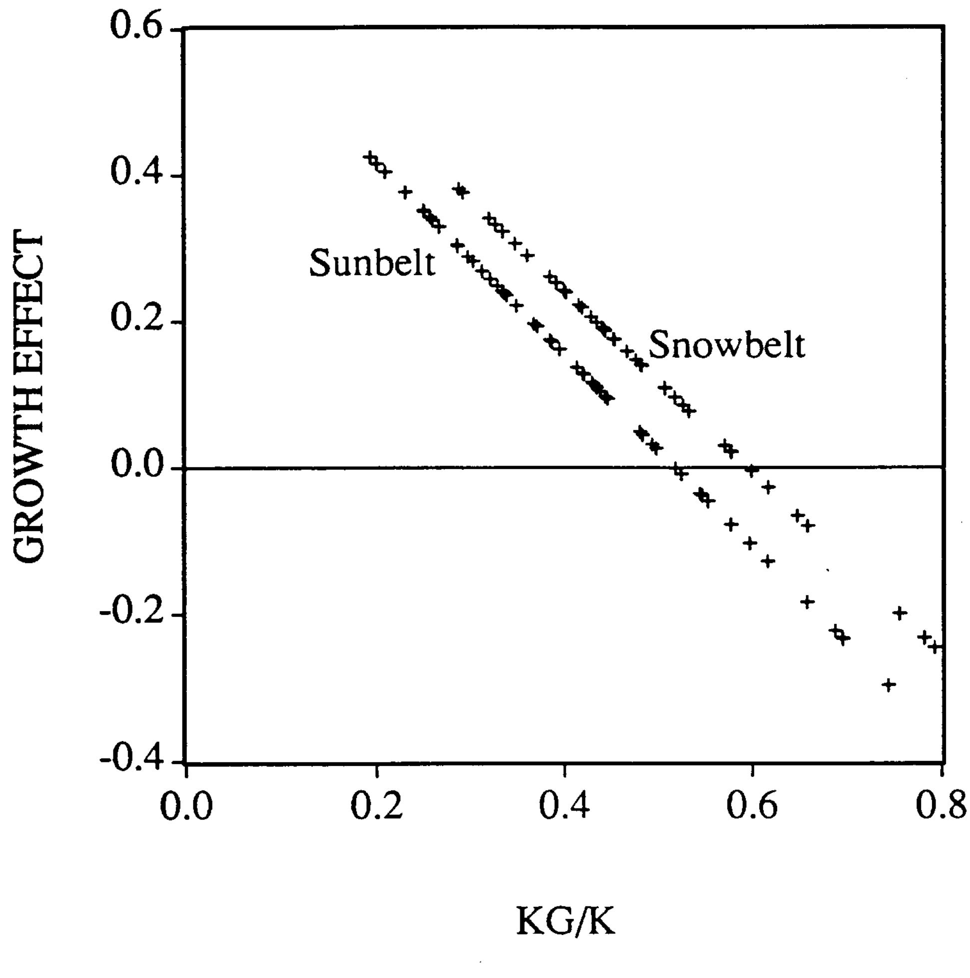

Figure E.1

MARGINAL EMPLOYMENT GROWTH EFFECT OF PUBLIC CAPITAL
(Snowbelt vs. Sunbelt)

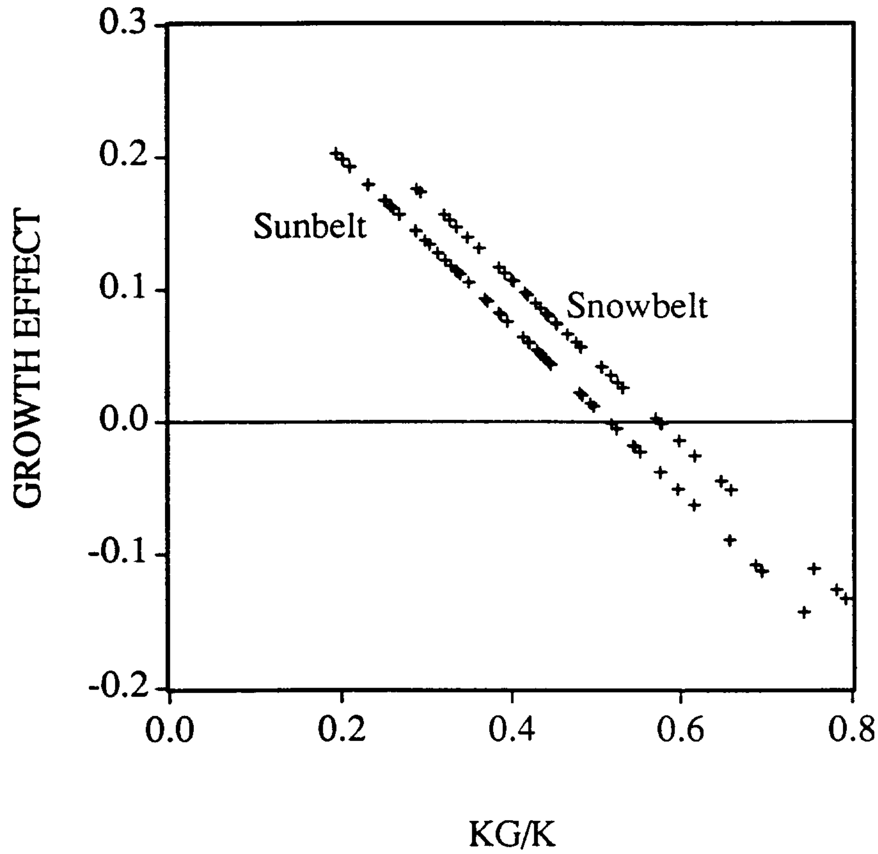

Figure E.2

However, one might expect certain portions of the other public capital category to be important for employment growth and output growth at the state level. For instance, a very large portion of other public capital is comprised of local and higher educational facilities, which can be expected to have a direct effect on employment growth and at least an indirect effect on productivity and output growth. While separate educational capital stock estimates are not presently available, Table F.1 indicates that in 1970 and 1980 state and local capital outlays for education equalled 46.7 and 30.2 percent of total outlays for other public capital. Similar arguments can be made for electric and gas utilities, for mass transit, for air transport, and for water transport which, taken together, represented 13.4 and 26.9 percent of total outlays for other public capital in 1970 and 1980. Indeed, the previous estimates notwithstanding, it would seem surprising if these public facilities were not in some way conducive to economic growth.

Table F.2 shows estimates of the output and employment growth relations where allowance is made for the separate impacts of core and other public capital. The estimates of coefficients pertaining to both types of public capital are highly statistically significant and are of a reasonable order of magnitude. In the output growth expression the estimates of both l and m are smaller for core capital than for other capital; the former tends to reduce, while the latter tends to increase, the growth effects of core capital relative to other capital. On the other hand, in the employment growth expression the estimate of l is smaller, but the estimate of m is larger for core capital; both tend to diminish the growth effects of core capital relative to other capital. Broadly speaking, one might use these results to quip--with anecedotal evidence for support--that "highways are important to the economy" and

State and Local Government Expenditures for Capital Outlay 1970 & 1980 (millions of $)		
	1970	1980
Core Public Capital		
•highways	10,762	19,334
•water	1,385	6,911
•sewer	1,201	3,784
Other Public Capital		
•education	7,621	11,327
•hospitals	790	2,559
•air transport	691	1,438
•water transport	258	878
•electric	820	4,980
•gas	50	181
•natural resources	789	1,017
•housing & urban renewal	1,319	2,689
•parks & recreation	684	2,072
•other	2,915	7,810
Source: *Governmental Finances* (annual).		

Table F.1

Output and Employment Growth Effects of Public Capital (Core vs. Other Public Capital)		
	DY	DE
l_x (Core)	.600 (.158)	.238 (.084)
m_x (Core)	.385 (.034)	.314 (.041)
l_x (Other)	.934 (.168)	.385 (.090)
m_x (Other)	.331 (.026)	.328 (.033)
b_x	-.212 (.040)	-.078 (.021)
t_x	-.399 (.192)	-.111 (.103)
Y	.088 (.025)	.101 (.013)
E	-.114 (.028)	-.134 (.015)
U	.299 (.128)	.225 (.068)
R^2	.659	.862
SER x10(-3)	9.833	5.263
SSR x10(-3)	3.674	1.053
Notes: standard errors in parentheses; all equations include individual state and decade effects.		

Table F.2

to productivity and output growth, but "schools are critical to attracting workers" and generating employment growth.

Figures F.1 and F.2 illustrate, and Table F.3 presents calculations of, the separate marginal growth effects of core and other public capital. The gross output and employment growth effects are positive for both core and other capital. However, once account is taken of the (presumed) financing of public capital by debt and taxes, the net output and employment growth effects are positive for other--but not core--capital. On the basis of these results, it would appear that other public capital, such as schools and hospitals, has been underprovided relative to core public capital, such as highways and water and sewer systems.

To some (including the author), this last statement may--at least at first blush--ring hollow. Intuitively, on *a priori* grounds, core capital might seem to be more important to economic performance than other capital. Yet a reconciliation between the empirical results and one's intuitive reaction might be found in the means of financing public capital.

Suppose, for instance, that core public capital is disproportionately funded by grants from the federal government; specifically, let the percentage differential in financing by grants be given by $f > 0$. Then, from the perspective of an individual state, the true differential in the net growth effects of core versus other public capital is better estimated as

MARGINAL OUTPUT GROWTH EFFECT OF PUBLIC CAPITAL
(Highway, Water & Sewer vs. Schools, Hospitals)

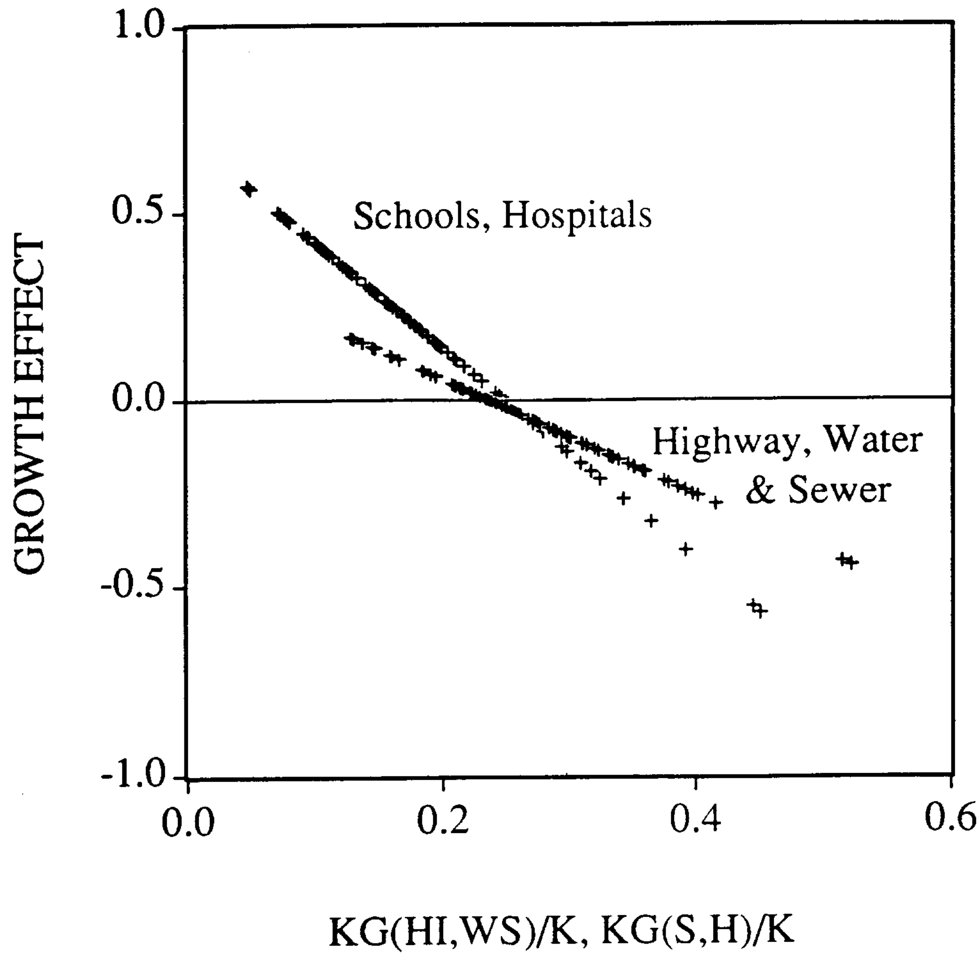

Figure F.1

MARGINAL EMPLOYMENT GROWTH EFFECT OF PUBLIC CAPITAL
(Highway, Water & Sewer vs. Schools, Hospitals)

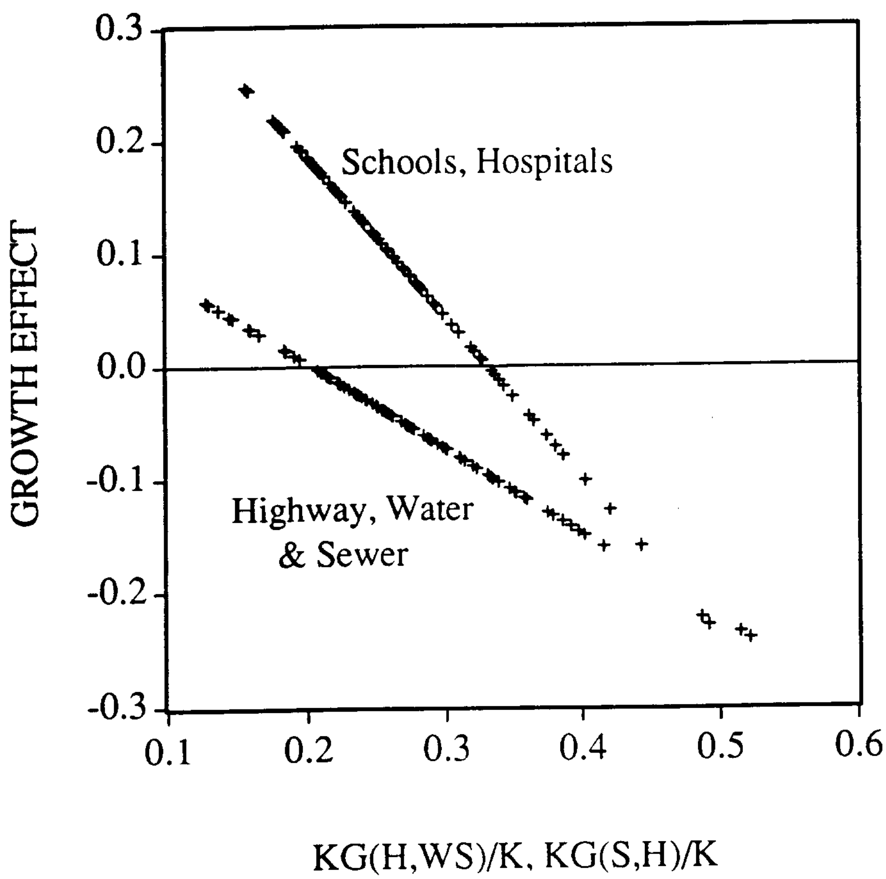

Figure F.2

Marginal Growth Effects of Public Capital (Core vs. Other Public Capital)					
		DY		*DE*	
	KG/K	g_l	g_ι	g_l	g_ι
Core	.267	.184	-.048	.035	-.049
Other	.179	.429	.197	.175	.091

Table F.3

$$g_t^{core} + f - g_t^{other} > g_t^{core} - g_t^{other}. \qquad (16)$$

and the previous calculation, based on the right hand side of equation (16), would understate the relative contribution of core capital to economic growth.

Additional light can be shed on this argument by considering federal grants to state and local economies over recent decades. Table F.4 gives data on federal grants for highways and water and sewer facilities from 1950 through 1980; highway grants substantially exceeded water and sewer grants even after the passage of the Clean Water Act of 1972 and an acceleration of Environmental Protection Agency grants for the construction of water treatment facilities. Thus, we would expect to find that a decompostion of core public capital into highway versus water and sewer capital would yield larger net growth effects for water and sewer capital than for highway capital to compensate for the disproportionate outside (of the jurisdiction) financing of highway capital.

Table F.5 gives estimates of the effects of highway capital and water and sewer capital on output and employment growth. To begin, note that in both expressions the estimates of m are considerably higher for highway capital than for water and sewer capital. On the other hand, the estimates of l are correspondingly higher for water and sewer capital than for highway capital.

Taken together, the estimates of l and m imply that the gross growth effects for highway capital are exceeded quite substantially by those for water and sewer capital; the former effects are calculated

Federal Grants to State & Local Governments (millions of $)		
	Highways	Water & Sewer
1950	432	1
1955	586	0
1960	2,942	40
1965	4,018	70
1970	4,334	328
1975	4,702	2,060
1980	9,209	4,748

Source: ***Budget of the United States Government****, Special Analyses*, "Federal Aid to State and Local Governments" (annual).

Table F.4

Output and Employment Growth Effects of Public Capital (Highways vs. Water & Sewers)		
	DY	DE
l_x (HI)	.398 (.141)	.144 (.082)
m_x (HI)	.265 (.035)	.203 (.055)
l_x (WS)	1.984 (.399)	.790 (.233)
m_x (WS)	.099 (.010)	.087 (.010)
l_x(Other)	.906 (.146)	.375 (.085)
m_x (Other)	.344 (.028)	.344 (.040)
b_x	-.241 (.036)	-.091 (.022)
t_x	-.359 (.165)	-.105 (.096)
Y	.071 (.022)	.094 (.013)
E	-.021 (.014)	-.033 (.008)
U	.355 (.115)	.235 (.067)
R^2	.731	.871
SER $x10(-3)$	8.729	5.101
SSR $x10(-3)$	2.743	.937
Notes: standard errors in parentheses; all equations include individual state and decade effects.		

Table F.5

to be .086 and -.003 for output growth and employment growth, respectively, while the latter are found to equal .798 and .256. Similarly, the net growth effects--as conventionally calculated, taking into acccount the adverse impacts of debt and taxes on states' economies--are much smaller for highway capital than for water and sewer capital. This result also is clear from an inspection of Figures F.3 and F.4 which illustrate the range of net growth effects over the entire data sample; these effects are uniformly negative for highway capital but, at least for the majority of the observations, positive for water and sewer capital.

IV. Conclusions and Directions for Further Research

This paper contains evidence of statistically important, positive effects of public capital on output and employment growth. Specifically, for the average state over the 1970s and 1980s, the *static* impact of a 1 standard deviation increase in general public capital is to increase output growth by around 1.6 percent per year and employment growth by some 0.5 of a percent per year. And, even after account is taken of the adverse effects which debt and tax financing of public capital have on the economy, the impact, though reduced in magnitude, is still positive, at 0.4 of a percent per year for output growth and 0.1 of a percent per year for employment growth.

What remains is to ascertain the *dynamic* impact of public capital on economic growth which depends on whether and how fast output and employment *converge* to their long run or steady state values. Many authors, using data on the U.S. states, have documented a convergence in per capita output and income. For example, Barro and Sala-i-Martin (1991, 1995) estimate a convergence rate

MARGINAL OUTPUT GROWTH EFFECT OF PUBLIC CAPITAL
(Highway vs. Water & Sewer)

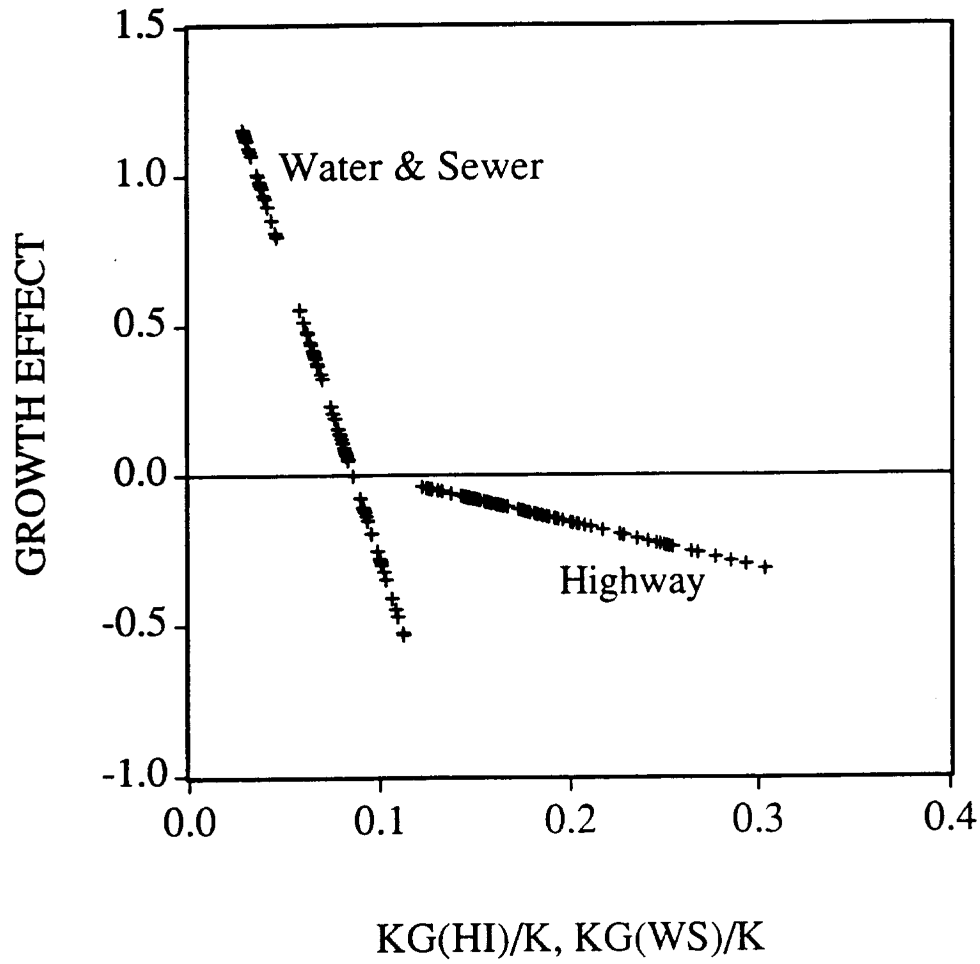

Figure F.3

MARGINAL EMPLOYMENT GROWTH EFFECT OF PUBLIC CAPITAL
(Highway vs. Water & Sewer)

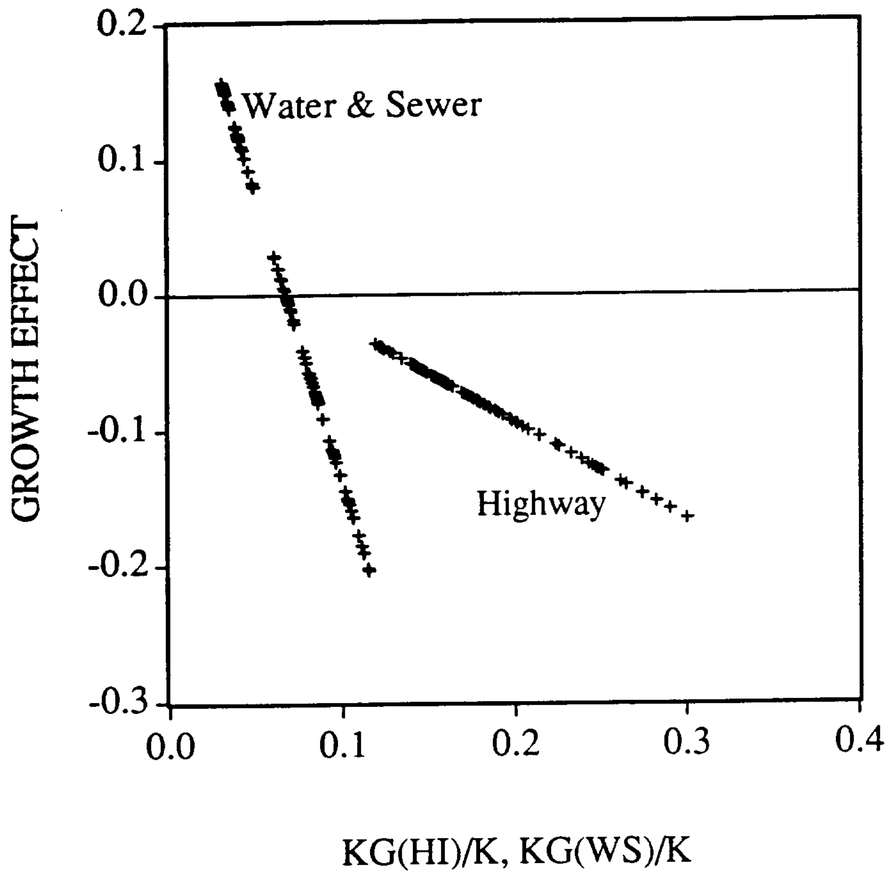

Figure F.4

for personal income per capita of between 1.75 and 2.20 percent per year over the period from 1880 to 1990; however, they also find that the convergence rate has become much less significant in the 1970s and 1980s.

Applying a convergence rate of 2 percent per year--a rough average of the convergence rates found by Barro and Sala-i-Martin--to the results of the present paper suggest that a 1 standard deviation increase in the public capital stock will cumulate to a sizeable 20 percent increase in output per worker. This quick calculation assumes, however, that employment growth is exogenous (and unaffected by public capital) and that, as a direct consequence, there is no dynamic interaction between output growth and employment growth as a particular state economy reacts to the public capital investment.

The estimates contained in the present paper, however, suggest that employment growth, as well as output growth, is, indeed, affected by the public capital stock. The estimates also show that there is a joint relationship between output growth and employment growth; in all of the equations estimated in this paper, output growth depends (negatively) on employment growth while employment growth depends (positively) on output growth. Thus, the findings of the present paper allow for a very rich set of possibilities for the dynamic impacts of public capital, impacts which will be the focus of the analysis in subsequent work.

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Endnotes

1. The relationship between the initial levels of output and employment and the growth rates of the respective variables becomes more important in a dynamic setting where it is important to gauge the degree to which output, employment, and output per employed person *converge* to their respective steady state values. This relationship is investigated in Aschauer (1997b).

2. Currently, reliable state level price deflators are not available.

3. Distinctly different data collection methodologies for agricultural and non-agricultural employment rationalizes the restriction to non-agricultural employment.

4. Note, however, that the task of achieving a particular percentage increase in (average) tax revenues requires a larger percentage increase in (marginal) tax rates due to a presumed adverse effect of the latter on the tax base.