

THE IMPACT OF TRANSPORTATION INVESTMENTS ON FACTOR PRODUCTIVITY IN TEXAS

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Final Report



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by

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16. Abstract This study attempts to replicate the analyses of Aschauer, Munnell and others regarding the impacts of public infrastructure investments on private factor productivity at the national level using a 1974 data set for the state of Texas using a newer public capital stock data set developed by NCHRP Study 2-17(3).					
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EXECUTIVE SUMMARY

Traditional project evaluation procedures do not account for all of the benefits and costs associated with transportation investments. Better understanding of the impacts of transportation investments on the macroeconomy is needed. Quantitative linkages between transportation investments and economic performance as measured by factor productivity and competitiveness should also be evaluated in addition to the traditional direct user benefits..

Analytic work by Aschauer, Munnell and Eberts has indicated that there are positive relationships between investments in infrastructure and factor productivity at the national, regional and state levels. These analyses were based on widely available information on total output, employment, private capital stocks and the size of the nation's public infrastructure capital stock. One criticism of these studies has been that the 1974 data set used in these analyses does not correctly measure the transportation capital stock.

The data set provided by the NCHRP study number 2-17(3) "Macroeconomic Analysis of the Linkages Between Transportation Investments and Economic Performance" (Co-Principal Investigators: Michael E. Bell, Ph.D., The Johns Hopkins University, Institute for Policy Studies, and Therese J. McGuire, Ph.D., The University of Illinois, Institute of Government and Public Affairs; final report submitted September 1994) was used to analyze the relationships between public, notably highway, capital and Gross State Product and private factor productivity for Texas. The key objective of the NCHRP 2-17(3) study was to prepare a refined and updated transportation and other public capital stock data set. However, the relationships generated from this data set for Texas were not statistically significant. The main reason for failure to achieve statistically significant results appears to be a lack of sufficient observations due to the short length of time covered by the NCHRP 2-17(3) data set (data for individual state public capital stocks are available for the years 1977-1990 only) combined with the absence of adequate ways to control for significant Texas-specific business cycle volatility during the period covered by this data set. However, even without the relatively unique Texas business cycle following the collapse of energy prices in the 1980's, the NCHRP 2-17(3) data set does not provide enough annual observations to establish statistically significant relationships between infrastructure investments and factor productivity on a time-series basis for any individual state.

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CHAPTER 1 INTRODUCTION

Research Objectives

The overall objective of this research is to improve the understanding of the linkages between transportation investments and economic performance in Texas. The data set from the final report of NCHRP 2-17(3) "Macroeconomic Analysis of the Linkages Between Transportation Investments and Economic Performance" (Co-Principal Investigators: Michael E. Bell, Ph.D., The Johns Hopkins University, Institute for Policy Studies, and Therese J. McGuire, Ph.D., The University of Illinois, Institute of Government and Public Affairs; submitted September 1994) was used to examine the relationship between output, factor productivity, and public capital in the state of Texas, on a time-series basis. The goal was to replicate Alicia H. Munnell's study (1990b) using newly released data, notably estimates of private capital stock, as well as a gross state product and private public capital stocks for each of the 50 states, including Texas.

Research Background

Aschauer (1988, 1989a, 1989b, 1989c, 1990), Munnell (1990a, 1990b) and Eberts (1988) have uncovered a relationship between rates of productivity growth and investment in core infrastructure by the public sector. These findings account for most of the widely reported slowdown in U.S. rates of productivity growth in recent decades.

Aschauer (1988) posed two hypotheses: (1) investments in highways, airports, power plants and water and sewer systems cause increases in the rate of return to private capital; and (2) increases in profitability cause increases in the level of private capital investment. He regressed the average rate of return (gross and net) to private capital on time, the labor-capital ratio (aggregate employment to total capital stock), the public capital-private capital ratio and the capacity utilization rate. He confirmed a strong positive relationship between public capital investment and rates of return and contended that this indicates a strong causal link between falling profit rates since 1953 and the roughly contemporaneous decline in the public capital-private capital stock ratio. He also asserted that gross and net rates of return to private capital have been depressed relative to the level which would have obtained if the public capital ratio had been steady and that the falling rate of public capital investment accounts for much of the downward trend in the profit rate.

Aschauer (1989a) attempted to test the thesis that public investment causes an increase in the marginal productivity of capital and thereby spurs increased private sector capital investment. He estimated 2 models relating (1) output per unit of capital to time, public capital inputs, labor-capital and public capital-private capital ratios and capacity utilization rates; and (2) total factor productivity to time, the ratio of public capital inputs to a weighted linear combination of labor and capital inputs, and capacity utilization rates. Model 1 showed a statistically significant and strongly positive relationship between output-to-capital and labor-to-capital and public-to-private capital ratios. A 1% increase in the labor-capital ratio increases output per unit of capital by 0.35%, while the elasticity of output with respect to the public-to-private capital stock ratio is 0.39. Model 2 showed a statistically significant and positive relationship between public capital and total factor productivity. A 1% increase in the public capital stock increases total factor productivity by 0.49%. He also found that government consumption and military spending do not contribute to increases in productivity; structures (as opposed to equipment) are the most important contributors to productivity; and public sector investment in 'core' infrastructure (streets and highways, airports, electrical and gas facilities, mass transit, water and sewers) has an output-to-capital elasticity coefficient of 0.24 and is highly significant.

Aschauer (1989b) found that public capital acts as a complement to private capital in the production and distribution of goods and services and works to raise the productivity of private capital.

Aschauer (1989c) compared levels of public capital investment and productivity in the Group of Seven nations. Productivity was measured as labor productivity growth, i.e. the percentage growth rate of GDP per employed person from 1966 to 1985. Explanatory variables were the annual percent change in employment growth, the ratio of private net investment to GDP (lagged 1 year), the ratio of public nonmilitary net investment to GDP (lagged 1 year), and rates of change in capacity utilization. He found that, holding other variables out of the equation, a 1% increase in the share of GDP devoted to public capital accumulation is associated with a 0.73% increase in labor productivity growth; including the ratio of private capital to GDP and the capacity utilization rate lowers the elasticity of labor productivity growth to public investment from 0.73 to 0.44.

Aschauer (1990) attempted to measure the relationship between state growth rates (percent change in per capita output) and levels of highway capacity from 1960 to 1985. Per

capita output is a function of initial levels of output, vehicle density and highway capacity. He finds that a one standard deviation increase in the log of highway capacity induces a 0.13% increase in the growth rate of per capita income. A 1% erosion of pavement quality induces a 0.009% decrease in per capita income growth. Highway capacity and pavement quality are significantly related to per capita income growth. When vehicle density is included in the regression it is insignificant and does not alter the signs and significance of the other variables.

Aschauer's major findings were: (1) There is a positive and statistically significant relationship between expenditures on public capital at the national level and (a) gross and net average rates of return to private capital; (b) output per unit of capital; (c) total factor productivity; and (d) labor productivity growth (the percentage growth rate of GDP per employed person). In addition he found significant and positive relationships between highway capacity and state growth rates (measured as percentage changes in per capita gross state product). (2) There is an elasticity of output with respect to the public-private capital stock ratio of about 0.4. (3) Public capital acts as a complement to private capital in the production and distribution of goods and services, raises the productivity of private capital, and crowds in private investment. (4) Nonmilitary expenditures on 'core' infrastructure (streets and highways, airports, electrical and gas facilities, mass transit, water and sewers) have positive and statistically significant effects on output-to-capital ratios.

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Munnell (1990a) examined two of Aschauer's most important results: the positive relation between the stock of public capital, public-private capital ratios, and output per unit of capital, and the relationship between the growth of multifactor productivity and the stock of nonmilitary capital. She re-estimated these relationships with labor productivity as the dependent variable. Her findings were consistent with Aschauer: total nonmilitary public capital and core infrastructure enter the production function with coefficients of 0.31 and 0.39, respectively, implying that a 1% increase in these would increase labor productivity by 0.31% and 0.39%, respectively.

Munnell (1990b) analyzed the impact of public capital on output, private investment, and employment growth at the regional and state level. Her procedure involved four steps: (1) construction of public and private capital stock measures for regions and states; (2) estimation of an aggregate production function to see whether the positive relation between public capital and output holds at these sub national levels; (3) determination of the degree to which public and private capital investment are substitutes or complements; and (4) estimation of the effect of public capital spending by state on firm location and state employment growth. With respect to

(2) she reproduced--with smaller elasticity coefficients--Aschauer's and her own results at the state level: a 1% increase in public capital at the state level raises state output by 0.15%. This is roughly half that for private capital and less than half that found by Aschauer and Munnell for public capital at the national level. In (3) Munnell found that public capital positively affects the marginal productivity of private capital and that public and private capital are substitutes. In (4) Munnell estimated a regional disequilibrium adjustment model to find very small relationships between employment growth and levels of public capital investment--elasticities on the order of 0.0001 to 0.0003.

Eberts (1986, 1988) used translog production functions to estimate the contribution of public capital stocks in 38 SMSAs. Public capital makes a positive and statistically significant contribution to manufacturing output, although the coefficient of elasticity is much lower than Aschauer's and Munnell's: about 0.02. He also found that public capital's contribution is much less than that of private capital and labor. Third, he asserted that public and private capital are 'q-substitutes' meaning that increases in the level of public capital decrease the price of private capital by increasing its relative abundance. The other input pairs--private capital and labor, and public capital and labor--are 'q-complements' in that increase in the supply of one factor in each pair increases the price of the other.

Eberts (1991) described five channels through which public infrastructure investment affects regional growth and development: (1) Infrastructure contributes directly to output as an input in private production. (2) Infrastructure investment affects the supply side of regional economies by augmenting the productivity of other production inputs. This is particularly relevant to transportation infrastructure investment and the ability of workers to get to their jobs. (3) Infrastructure moves through the supply side as an attractor of new firms and households. Some studies have shown that the presence of the interstate highway system has a positive effect on the growth of new firms in emerging urban centers in the South (Wheat 1976). (4) On the demand side of regional economies, infrastructure investment creates jobs and income, at least in the short term. Eberts estimated an elasticity of income with respect to public infrastructure in metropolitan areas at 0.1--that is, a 10% rise in public investment leads to a 1% increase in per capita income. (5) Particularly in the North, public capital formation precedes, and thus in our terms causes, private capital formation, which suggests that public investment has been used as an effective instrument in inducing local economic development.

Schultze (1990) believed that Aschauer's coefficients of the elasticity of output with respect to public capital stocks were much too large. Aschauer's point estimate of 0.39 was

highly inflated by a strong correlation between the time pattern of national productivity growth and the time pattern of the growth in public investment. The growth rate of public capital peaked and began to decline at about the same time as productivity growth began to sag. Investment in public infrastructure can have strong and timely impacts on national productivity, such as that witnessed during the building of the interstate highway system in the 1960s and early 1970s, but the kind of payoffs promised by Aschauer's study are not to be had.

Jorgenson (1991) argued that any evaluation of the productivity of infrastructure investment must be made at the level of the individual project, through cost-benefit techniques. Jorgenson made two points regarding Aschauer's evidence on the return to public capital. The first was a measurement issue. Unlike privately produced inputs in production (labor and private capital), the contribution of public capital cannot be measured on the basis of prices generated from market transactions. This causes a great deal of difficulty in evaluating the relative contribution of public capital to productivity. The wide variation in the point estimates of the elasticity of output to public capital--ranging from about 0.4 in Aschauer and Munnell to 0.02 in Eberts' studies--is partially a result of the problems inherent in correctly pricing public infrastructure. The proper context in which to evaluate the effects of public capital is at the microeconomic level, with the tools of cost-benefit analysis. second, Jorgenson, like Schultze, believed that the large coefficients of output elasticity found by Aschauer and Munnell are a product of 'common trends' between data on aggregate output and infrastructure investment. Private capital investment and labor inputs also show common trends with public capital investment.

Hulten and Schwab's (1991) first criticism of Aschauer's findings was that when evaluating the relationship of infrastructure to economic performance, it is the flow of services from public capital that must be measured.

Hulten and Schwab also pointed out that the complexities of the role of public capital in economic growth make it difficult to document its exact contribution with a great deal of precision: additional investment in public capital will give a large boost to growth in some situations, but have only a small impact in others. Similarly, some investments will generate significant externalities while others will yield direct benefits.

Hulten and Schwab separately analyzed Aschauer's results by first reproducing them using the same data over the same time period. What they find most bothersome was that these results, in a time-series context, essentially related the level of one variable with the level of

another, causing a spurious correlation. They de-trended the data by recasting their analysis in terms of whether the changes in levels of public capital stock explain changes in levels of outputs. In this model, a 1% increase in the stock of infrastructure increases output by only 0.03%, or 13 times less than Aschauer's original estimate. They stated that these results show a 'rather fragile' relationship between infrastructure and economic activity, at least at the aggregate level.

Munnell (1991a) made 4 points in response to Schultze, Jorgenson, and Hulten and Schwab: First, in spite of difficult problems with data and model specifications, 'study after study' has revealed strong and statistically significant relationships between the stock of public capital and private economic activity. Second, to argue that the flow of services from public capital stocks should be the variable of choice is 'fair enough' but not possible to operationalize. Third, the variation in the elasticity coefficient estimates of the response of private capital to public investment, rather than demonstrating an unreliable and apparently random or 'fragile' statistical relationship, actually reveal a 'systematic and intriguing pattern' (these estimates shift from about 0.4 at the national level, to 0.15 at the state level, to 0.02 at the metropolitan level). As the geographic focus of the studies narrows, the impact of public capital becomes smaller. The most obvious explanation is that, because of leakages or spillovers, one cannot capture all the payoffs to an infrastructure investment by looking at a small geographic area. Fourth, Munnell addressed the question of causality: 'The question remains whether public capital investment causes more output or higher levels of output and productivity lead to greater investment.' Clearly there is a mutual influence, but the presence of simultaneity does not invalidate the reported coefficients.

Munnell reported two regression experiments performed subsequent to her study of state growth and public capital. First, she directly addressed the simultaneity issue by regressing the average level of output for each of the 48 states over the 1970-1986 period to the average level of private capital, the average labor input, and public capital at the beginning of the period. This procedure forecloses the possibility of any feedback of output growth on public capital investment. Yet public capital shows a large, positive and statistically significant effect on output--0.17. Second, she noted that cross section analyses may produce upwardly biased coefficients if capital and other unobserved endowments (captured in the catch-all multifactor productivity or 'A' term in traditional production function analysis) are correlated. This will be the case if the variance of initial state endowments of wealth, technology and managerial capacity is greater than the variance of capital and labor over time. High-endowment states will have more output and more capital than those with low endowments. To avoid this problem, she grouped the 48 states by their unobserved endowments, using levels of per capita gross state product as a

proxy, and estimates separate regressions for high, medium and low endowment states. The results showed a positive and statistically significant effect on private output in all 3 groups: 0.14 for low endowment states, 0.11 for medium endowment states, and 0.22 for high endowment states.

In general, the most important objection raised by Schultze, Jorgenson, and Hulten and Schwab is that the coefficients on output and private capital investment elasticity with respect to public capital are too large and vary too widely between studies to be taken seriously. They base this view on 3 arguments: (1) Neither Aschauer, Munnell nor Eberts attempted to account for common trends in the data on aggregate output, private capital, labor inputs and infrastructure investments. This produced spurious correlations, which cannot be interpreted as revealing a definite direction of causality: productivity growth could just as well be working back through increased per capita incomes to increase infrastructure investment as the other way round. By de-trending the data, Hulten and Schwab estimated a coefficient of output elasticity 13 times smaller than the estimates calculated by Aschauer and Munnell. (2) Measurement problems make evaluating the effect of public capital on economic performance at the national level virtually impossible. Jorgenson maintained that this is because the prices of public capital are not determined by market forces. (3) Because the role of public capital in private capital formation and productivity is so dependent on the type of public investment and the geographic, temporal and economic circumstances in which it occurs, its impact should be measured on a case-by-case basis with the tools of cost-benefit analysis. With respect to (1), Munnell responded that these coefficients are consistent with the observed division over time of factor shares of income between labor and capital; they are consistent with the relative sizes of private and public capital stocks in the U.S.; and the apparently random values of the coefficients across studies reveals a possibly significant, systematic variation across geographic foci that should be the subject of further investigation. Munnell and Eberts agree that the impact of infrastructure investments is spatially and temporally conditional, and that disaggregated studies are in order.

CHAPTER II MODEL AND DATA

The analysis builds on the earlier work by Munnell (1990b) and examines the impact of public capital in the framework of neoclassical production function. The public capital is treated as another input in the production function, yielding the following equation:

$$1) Q = (\text{MFP}) * f(K, L, G),$$

where Q is output, MFP is the level of technology, K is the private capital stock, L is labor and G is the stock of public capital. Assuming a generalized Cobb-Douglas form of technology yields a more specific relationship between inputs and outputs:

$$2) Q = \text{MFP} * K^a L^b G^c$$

Translation of this equation into logarithms produces a linear function that can be estimated as:

$$3) \ln Q = \ln \text{MFP} + a \ln K + b \ln L + c \ln G$$

The coefficients a, b, and c are the output elasticities of the factor inputs - they indicate the percentage change in output for a given percentage change in factor input.

Constant returns to scale over the private inputs has been the traditional assumption underlying most analysis of the Cobb-Douglas production function. However, the inclusion of private capital raises new questions about returns to scale. Given this, Munnell has also estimated several constrained forms of the above equation. First, constant returns to scale are assumed to hold only for the private inputs (private capital and labor). This is captured by setting $a + b = 1$, and the equation looks as follows:

$$4) \ln Q = \ln \text{MFP} + a(\ln K - \ln L) + \ln L + c \ln G$$

The other option is that constant returns to scale applies to the entire production function, i.e. $a + b + c = 1$. Imposing this constraint produces the following equation:

$$5) \ln Q = \ln \text{MFP} + a(\ln K - \ln L) + \ln L + c(\ln G - \ln L)$$

The following data for the state of Texas from the final report of NCHRP 2-17(3) "Macroeconomic Analysis of the Linkages Between Transportation Investments and Economic Performance" have been used in estimating the equations:

1) Gross State Product (revised series): 1977 - 1989

The data set provides data on the gross state product in constant 1982 dollars. Since other time series are provided in constant 1987 dollars, the gross state product was translated into 1987 dollars using the GDP deflator. The GDP deflator was obtained from the web-site of the NASA JSC Cost Estimating Group (<http://www.jsc.nasa.gov/bu2/Inflation.html>). The base year is 1992, the 1982 value is 0.6972, and the 1987 value is 0.8293. Thus, gross state product in 1982 dollars was multiplied by 1.2728 ($0.8293/0.6972$) to convert to 1987 dollars.

2) Private Capital Stock: 1977 - 1989

The data set contains two estimates of state-level private capital stocks by industry: using employment shares as allocators and using gross state product minus indirect business taxes (GSP - IBT) as allocators. Using employment shares, state-level private capital stock was allocated to 19 industries, and the allocation by GSP - IBT shares included 12 industries. The total state-level private capital stock was obtained by summing up industries' capital stocks. The equations were estimated with private capital stock obtained both by using employment shares and GSP-IBT shares as allocators.

3) Labor: 1977-1989

The total non-farm employment in 1977-1989 was used as a measure of labor input.

4) State-level public capital stock: 1977 - 1989

The data set provides estimates of both total state public capital stock and public capital stocks for six categories of infrastructure (highways, air transportation, water transportation, sewerage, water supply, and transit). The total state public capital stock is not the sum of capital stock from these categories.

In addition, to reflect the cyclical nature of productivity, Munnell included the unemployment rate in the equations. The Texas unemployment rate was obtained from the Federal Reserve Bank of Dallas.

CHAPTER III: RESULTS

The regression (OLS) results are summarized in Table 1:

TABLE 1.
Regression Results: Output as a function of Private Capital (K),
Labor (L), and Public Capital (G), State of Texas, 1977-1989

Equation for Output (lnQ) - State Private Capital stock based on GSP - IBT shares as allocators:

	Private Capital Only					R ²	SE	DW
1) No Constraint	lnMFP +	a lnK +	b lnL +	dU%		0.953	0.02	1.02
	12.62	-0.01	0.89	-0.002				
	(8.89)	(-0.92)	(9.12)	(-0.34)				
2) a + b = 1	lnMFP +	a(lnK - lnL) +	lnL +	dU%		0.944	0.02	1.16
	10.82	-0.01	1.0*	-0.007				
	(108.55)	(-1.42)		(-1.45)				
	Including Public Capital							
1) No Constraint	lnMFP +	a lnK +	b lnL +	c lnG +	dU%	0.961	0.02	1.21
	7.18	-0.01	0.59	0.40	-0.005			
	(1.69)	(-0.93)	(2.48)	(1.35)	(-0.79)			
2) a + b = 1	lnMFP +	a(lnK - lnL) +	lnL +	c lnG +	dU%	0.947	0.02	1.04
	12.82	-0.01	1.0*	-0.08	-0.004			
	(4.17)	(-1.10)		(-0.65)	(-0.58)			
3) a + b + c = 1	lnMFP +	a(lnK - lnL) +	lnL +	c(lnG - lnL) +	dU%	0.961	0.02	1.21
	6.53	-0.01	1.0*	0.43	-0.006			
	(3.04)	(-1.07)		(1.99)	(-1.31)			

Note: Q = gross state product; MFP = the level of technology; K = private capital stock; L = non-farm employment; G = public capital stock; U% = state unemployment rate; t-statistics in parentheses.

* Constrained to equal 1.

The results in table 1 fall far short of statistical significance. Even though R² and the F-statistic were fairly high in each case, suggesting that the overall equations may provide a good fit,

t-statistics for private and public capital, and even the unemployment rate, were far smaller than necessary to indicate significant relationships. The Durban-Watson (DW) statistic is substantially less than 2 for each equation, pointing to considerable autocorrelation.

The same equations were also estimated with the state private capital stock variable allocated based on employment, rather than GSP-IBT, shares. The results were even less economically meaningful and statistically significant.

Naturally, the fact that the private capital stock has not provided any explanatory power (in all equations, its coefficient is slightly negative and statistically insignificant) merits further discussion. First, during the 1977-1989 period Texas experienced a business cycle almost exactly opposite to the United States as a whole. Due to a heavy dependence of the state's economy on energy prices, Texas saw an economic boom in the years when the rest of the U.S. experienced a recession (1980 -1981), whereas the years of the U.S. economic growth (1982, 1986-87) witnessed a decline in Texas. Given this, the state private capital stock estimates obtained by apportioning the national totals on an annual basis may be erroneous. The state's capacity utilization rate (as in Aschauer's times-series study of public capital productivity on the national level) could have provided an efficient way to control for the influence of business cycle on output and productivity, given Texas business cycle specifics. Unfortunately, the capacity utilization rate for the individual state of Texas is unavailable, and (following Munnell) the state unemployment rate, a considerably less efficient way to reflect the cyclical nature of productivity at an individual state level, had to be used instead. In addition, lack of available data prevented us from obtaining an estimate of the private capital stock in Texas using the data provided by the NCHRP 2-17(3) "Macroeconomic Analysis of the Linkages between Transportation Investments and Economic Performance" but following Munnell's procedures of apportioning the national total private capital stock among individual states.

With the overall lack of statistical significance in the examined equations, the 0.40 coefficient on public capital is close to the 0.35 estimated by Aschauer (1989) in his time-series analysis of the national data and noticeably higher than the 0.15 produced by Munnell's pooled cross-section state data analysis. In addition, the impact of various components of public capital on the state's output was also examined. The NCHRP 2-17(3) "Macroeconomic Analysis of the Linkages Between Transportation Investments and Economic Performance" data set provides state capital stock series for each of the following six categories of infrastructure: air transportation, water transportation, sewer, water utility, transit, and highways. Since those categories do not make up the total state capital stock (educational and health-care facilities are

significant public infrastructure categories which are not separately estimated in the NCHRP 2-17(3) data set), the "other" category (total public capital stock minus the sum of the estimated six categories) represents the remainder of the public capital stock. Table 2 summarizes the regression results with public capital broken into air transportation, water transportation, sewer, water utility, transit, highways, and other.

TABLE 2.

Regression Results: Output as a function of Private Capital (K), Labor (L), and Disaggregated Public Capital (AT, WT, S, WU, TR, HW, O), State of Texas, 1977-1989
Equation for Output (lnQ) - State Private Capital stock based on GSP - IBT shares as allocators:

$\ln MFP + a$	$\ln K + b$	$\ln L + c$	$\ln AT + d$	$\ln WT + e$	$\ln S + f$	$\ln WU + g$	$\ln TR + h$	$\ln HW + i$	$\ln O + j$	$U\%$
32.44	0.01	0.16	-1.10	-1.78	0.15	-2.33	0.16	-0.18	4.21	-0.006
(6.41)	(1.51)	(1.07)	(-2.67)	(-2.65)	(1.49)	(-3.18)	(3.28)	(-0.28)	(4.12)	(-1.68)
R² = 0.999; SE = 0.007; DW = 2.24										
Note: Q = gross state product; MFP = the level of technology; K = private capital stock; AT = air transportation capital stock; WT = water transportation capital stock; S = stock of sewer systems; WU = water utilities capital stock; HW = stock of highways; O = other state capital, primarily buildings; and U% = state unemployment rate; t-statistics in parentheses										

Even though the disaggregation of public capital has somewhat increased the explanatory power of the equation, none of independent variables has recorded a t-statistic high enough to achieve at least 5-percent level of significance. Surprisingly, the coefficient on highways capital stock, as well as coefficients on some other public infrastructure categories, is slightly negative (-0.18). However, it is also "the least" significant, as its t-statistic is (-0.28) is much lower than for any other variable (the second lowest t-statistic is 1.07).

The relationship between public (notably highway) capital stock and labor productivity in the state of Texas was also examined. The simple Cobb-Douglas production function used earlier can be rewritten so that the productivity of labor becomes the dependent variable. That is,

$$6) Q/L = MFP * K^a L^{b-1} G^c$$

As before, translating this equation into logarithms produces a linear function that can be estimated:

$$7) \ln Q - \ln L = \ln MFP + a \ln K + (b-1) \ln L + c \ln G$$

Two equations were estimated - one using a total public capital, and one with public capital disaggregated into the stock of highways and all other public capital stock. The results are summarized in table 3.

TABLE 3.

Regression Results: Productivity of Labor as a function of Private Capital (K), Labor (L), and Public Capital (G), State of Texas, 1977-1989

Equation for Output ($\ln Q - \ln K$); State Private Capital stock based on GSP - IBT shares as allocators:

Total Public Capital (G)					R²	SE	DW
lnMFP +	a lnK +	(b-1)lnL +	c lnG +	dU%			
7.18	-0.01	0.59	0.40	-0.005	0.593	0.02	1.21
(1.69)	(-0.93)	(2.48)	(1.35)	(-0.79)			
Public Capital disaggregated into highways (H) and other (O)							
lnMFP +	a lnK +	(b-1)lnL +	c lnH +	d lnO +	fU%		
34.34	-0.01	0.44	-2.01	1.36	-0.008	0.929	0.01
(6.90)	(-2.03)	(4.00)	(-5.46)	(6.51)	(-2.75)		2.94

Note: Q = gross state product; MFP = the level of technology; K = private capital stock; L = non-farm employment; G = total public capital stock; H = highways capital stock; O = other public capital stock; U% = state unemployment rate; t-statistics in parentheses.

Not surprisingly, the relationship between total state public capital and labor productivity is the same as that between public capital and output, given that it is simply a rearrangement of the general equation. On the other hand, the disaggregation of public capital into highways and other capital results in a highly negative coefficient on highways and highly positive coefficient on other capital, where both have significant (at the 5% level) t-statistics. However, the coefficients on other variables are still not significant. The highly negative coefficient on highways again can be attributed to the volatility of Texas economy during the sample period, which turned out to be difficult to control for at a state level, given the short length of time-series (13 years) and the absence of a state capacity utilization rate.

CHAPTER IV CONCLUDING REMARKS

The 1994 NCHRP database doesn't provide enough observations to establish, with any degree of precision, the link between public investments in infrastructure and factor productivity and economic growth in the individual state of Texas. To examine whether the lack of statistical significance and mixed economic results are caused exclusively by the specifics of Texas business cycle during 1977-1989, the equations specifying the relationship between output, labor productivity and public and private capital were also estimated for the state of Michigan, chosen as a state whose business cycle closely follows that of the U.S. as a whole. While Michigan's coefficients on private capital and labor are in line with economic theory, the coefficient on state total public capital is negative (-0.40), and all the coefficients again lack statistical significance.

This indicates that obtaining meaningful and statistically significant time-series results for an individual state based on NCHRP 2-17(3) final report data set may be simply impossible. The main obstacle is the length of time series—only 13 years. The constraint here is public capital, with the data covering only 1977-1990 period. True, Munnell's data series were only slightly longer—17 years (1970-1986). However, Munnell estimated the above equations using pooled state output, capital, and labor data, without reporting results on an individual state basis. Aschauer (1988) did use a time-series approach for the United States as a whole where his number of observations was 37 (1949-1985) and the data on public capital stock were taken from Fixed Reproducible Tangible Wealth 1925-1985, a publication of the Department of Commerce. The critiques of Aschauer addressed, among other things, the quality of this public capital stock data. One of the key purposes of NCHRP 2-17(3) was providing estimates of public capital stock superior to the ones used by Aschauer and Munnell, especially with respect to apportioning national public capital totals among individual states. However, NCHRP 2-17(3) failed to provide state-by-state data on public capital stock for more than 14 years (1977-1990).

It appears that comprehensive examination of linkages between transportation and other public investments and economic growth and productivity at an individual state level requires a data base of Texas transportation infrastructure investment and capital stock. This database should be continuous beginning not later than 1950, as opposed to the 1994 NCHRP transportation capital stock database. The development of Texas transportation infrastructure investment and capital stock database would allow for a better understanding of the influence of transportation investment on economic growth and productivity and more efficient determination of the optimum level of taxation for spending on transportation infrastructure, both in terms of

new investment and in terms of optimal levels of maintenance that are justified. In addition, it would facilitate project evaluation and ranking, as well as economic/environmental impact assessment and transportation cost allocation.

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