Infrastructure and Regional Economic Performance: Comment

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Widely disparate results have flowed from various attempts to analyze the impact of public investment in tangible infrastructure. Charles Hulten purports to see estimates of "much larger elasticities [of output] with respect to public capital (often exceeding the corresponding private elasticity)" in time series than in analyses of state data (Hulten 1990, p. 105). The substantial body of data for 48 states over the years 1970 to 1986 put together by Munnell and her associate offers a unique opportunity to reveal divergences of estimates from the same data set.[1] Results from overall regressions, pooled cross sections, and pooled time series of these data do indeed reveal sharp differences, but in quite the opposite direction from those suggested by Hulten.

Munnell reports the results of what may be called "overall" regressions, where the observation vectors consist of differences from the means of public and private capital stock, labor, and output series for all 48 states for all 17 years. Regressions on these vectors thus combine cross-section and time-series variance and covariance. In fact, though, as we shall note, it is the cross sections that dominate.

On the basis of her overall regressions, Munnell reports that private capital, labor, and public capital all contribute to state output and that unemployment, even given the number of workers in nonagricultural employment, reduces it. In unconstrained Cobb-Douglas (log-linear) regressions (Munnell 1990a, Table 5), Munnell finds elasticities of state output of 0.31 to private capital, 0.59 to labor, and 0.15 to public capital, all with huge, significant t-statistics. In log-linear regressions breaking down public capital, Munnell finds similar significant positive elasticities for two of its components—0.06 for highways and 0.12 for water and sewer systems—but only a small, not significant coefficient of 0.01 for "other state and local capital, primarily buildings" (Munnell 1990a, Table 6). And breaking down her observation set into four regions, she reports uniformly positive but varying elasticities of output to public capital—0.07 for the Northeast, 0.12 for North Central states, a very high 0.36 for the South, and 0.08 for the West (Munnell 1990a, Table 7).

Munnell also reports results of estimates of translog production functions (Munnell 1990a, Table 9). They yield similar positive elasticities for public capital, 0.16 as the coefficient of the log of public capital, but positive coefficients for the squared terms, suggesting increasing returns to scale for factors greater than their means, particularly for private capital and labor. And finally, the results show negative coefficients for the cross-product terms involving private capital, suggesting that both public capital and labor are substitutes for private capital.

Munnell's results essentially are replicated here in corresponding Tables 5A, 6A, 7A and 9A.[2] In Table 5B, however, pooled time series regressions give strikingly different results. The observation vectors here involve differences for each state from the mean of all its own observations. The variance and covariance are thus exclusively over time; differences between states play no part. In these time series the private capital and labor coefficients are in the usually expected range, 0.292 and 0.768, respectively. The public capital coefficient, however, is virtually zero in the unconstrained regression, indeed (not significantly) negative, −0.026. Where the coefficients of private capital and labor are constrained to sum to unity, a significantly positive coefficient for public capital again is found. In view of the results of the unconstrained regression, however, that would appear to entail public capital proxying for private capital (with which it is correlated) to bring forth the increasing returns that are evident here, as elsewhere.

What is going on becomes clearer in Table 5C, which offers the pooled cross-section results. These observation vectors involve differences for each state for each year from the mean of observations of all states for that year. The variance and covariance underlying the regressions are thus pure cross section, involving only differences between states. The coefficients in Table 5C are very similar to the results of replicating Munnell's overall regressions. The public capital coefficient (elasticity), in particular, is a highly significant 0.165 in the cross section versus 0.155 in the overall regression.

Similar comparisons of regional regressions are offered in Tables 7A, 7B, and 7C. The time series regression of Table 7B again shows non-significant and, in fact, small negative coefficients for public capital, except in the West, where the coefficient is a significantly positive 0.121. The cross-section results of Table 7C show somewhat higher coefficients for public capital than do the overall regressions of Table 7A in all the regions other than the West, where the coefficient is close to zero.

Finally, turning to the translog production functions shown in Tables 9A, 9B and 9C, it must first be noted that the coefficient of the public capital term is again virtually zero in Table 9B's time series. Further, the positive coefficients of the squared terms, as in the overall and cross-section regressions of Tables 9A and 9C, offer evidence of increasing returns, particularly in labor and public capital. But the time series suggest that public capital is a substitute for both private capital and labor. Unemployment, by the way, has a negative coefficient in almost all regressions, a finding not without interesting policy implications.

The regressions reported in Table E1 show the results of a more direct examination of the role of public capital in distributed-lag investment functions. They show the characteristic accelerator role for investment along with differences between sums of coefficients in time series (0.721) and cross sections (0.825), reported in firm data long ago (Eisner 1978, among others). Little evidence is shown of a role for public capital except, perhaps, the negative coefficient (−0.070) in the time series. This would seem to suggest that public capital is a substitute for private investment, perhaps making it more productive, so that less of it is needed for any given increase in output.

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[1] Editor's note: This article comments on research by Alicia H. Munnell with the assistance of Leah M. Cook. Their results were published in a paper, "How Does Public Infrastructure Affect Regional Economic Performance?" that appeared in the September/October 1990 *New England Economic Review* and in the proceedings of this Bank's economic conference No. 34, entitled *Is There a Shortfall in Public Capital Investment?* The paper explores the impact of the stock of public capital on economic activity at the state and regional level. Munnell concludes that those states that have invested in infrastructure tend to have greater output, more private investment, and higher employment growth. The Munnell tables referred to are reproduced at the end of this article, along with Eisner's results.

[2] Our one major discrepancy is with regard to Durbin-Watson (D-W) statistics, which are of uncertain meaning in this combination of cross section and time series. In fact the statistic must surely depend on the order of the observations. I took the 17 observations for each state in turn, and got very low D-W statistics. The fact that Munnell reports D-Ws close to 2 suggests to me that her regression program took first the 48 different state observations for one year and then 48 state observations for the next year, and so forth. (This is correct—Ed.) Also contributing to my very low D-Ws is the nature of the pooled regression. Since regression planes differ by states, each state's residuals from the pooled regression will be particularly autocorrelated.

Conclusion

Where does all this leave the ongoing debate on the role of public capital? First, it is clear, on the one hand, that those states that have more capital have greater output, even after taking into account both their amounts of labor (nonagricultural employment) and private capital. On the other hand, no evidence was found that states that have more public capital one year than another have more output during the year with more public capital.[3] This latter finding is hardly any comfort to those who would argue that increasing public capital will increase output and income. But it is also hardly surprising. In the first place, who would reasonably expect that adding a new sewer system or a new highway to a state's public capital stock at the beginning of a year would add to the state's output that year?[4] If the additions affect conventional output, the impact would rather be expected with considerable and possibly variable lags.

Furthermore, a large part of the output of public capital—the environmental benefits of water and sewage systems, the time savings of better transportation, the pleasures of public parks, and the greater comforts of public buildings—are not included in conventional measures of output or gross state product. They may make significant contributions in other measures such as Nordhaus and Tobin's MEW (measure of economic welfare) or Eisner's TISA (total incomes system of accounts), or in broader measures still.

The cross-section results do indicate a significant and substantial association between public capital and state output. Serious questions remain, however, as to which is cause and which is effect. Does public capital contribute to more output? Or do states that have greater output and income, as a consequence of having more private capital and labor, tend to acquire more public capital, perhaps for all of the non-measured benefits suggested above?

[3] This inference is supported by the results of regressions in first differences (Table 5D). The coefficient of public capital is virtually zero but the coefficients of private capital are also close to zero, indeed slightly negative (−0.032 with a t-statistic of 1.407 in the overall regression), and results were little different in the pooled cross sections and time series.

[4] It must be said that introducing lags of up to six years failed to uncover a significantly positive sum of coefficients for public capital in time series regressions. The variations of public capital over time, simply enough, do not account for any of the variance of state output over time beyond that explained by private capital, nonagricultural employment, and the rate of unemployment.

The Tables

Table 5
Output as a Function of Private Capital (K), Labor (L), and Public Capital (G), 48 States, 1970–86 (Munnell Table)

Equation for Output (lnQ)						$\bar{R}^2$	SE	DW
			Private Capital Only					
1) No Constraint:	lnMFP	+ alnK	+ blnL		+ dU%	.992	.092	2.0
	6.75	.36	.69		−.006			
	(69.2)	(38.0)	(82.4)		(4.0)			
2) a + b = 1:	lnMFP	+ a(lnK − lnL)	+ lnL		+ dU%	.990	.103	2.1
	7.32	.30	1.0*		−.002			
	(74.2)	(31.9)			(1.0)			
			Including Public Capital					
3) No Constraint:	lnMFP	+ alnK	+ blnL	+ clnG	+ dU%	.993	.088	1.9
	5.75	.31	.59	.15	−.007			
	(39.7)	(30.1)	(43.2)	(9.0)	(4.7)			
4) a + b = 1:	lnMFP	+ a(lnK − lnL)	+ lnL	+ clnG	+ dU%	.992	.090	2.0
	6.33	.34	1.0*	.06	−.007			
	(59.6)	(39.6)		(15.9)	(4.6)			
5) a + b + c = 1:	lnMFP	+ a(lnK − lnL)	+ lnL	+ c(lnG − lnL)	+ dU%	.990	.102	2.0
	6.82	.27	1.0*	.08	−.002			
	(45.8)	(23.3)		(4.4)	(1.0)			

Note: Q = gross state product; MFP = the level of technology; K = private capital stock; L = employment on nonagricultural payrolls; G = stock of state and local public capital; and U% = state unemployment rate; t-statistics in parentheses; number of observations = 816. $\bar{R}^2$ = adjusted coefficient of determination; SE = standard error of estimate; DW = Durbin-Watson statistic.

*Constrained to equal 1.

Table 5A

Output as a Function of Private Capital (K), Labor (L), and Public Capital (G), 48 States, 1970–86 (Replication of Table 5, Munnell)

Equation for Output (lnQ)											$\hat{R}^2$	SE	DW
					Private Capital Only								
1) No Constraint:	α	+	alnK	+	blnL	+	dU%						
	1.948		.355		.695		−.006				.992	.092	.176
	(39.792)		(38.054)		(82.424)		(4.093)						
2) a + b = 1	α	+	a(lnK − lnL)	+	lnL	+	dU%						
	2.472		.299		1.0*		−.002				.555	.103	.174
	(70.407)		(31.891)				(1.038)						
					Including Public Capital								
3) No Constraint:	α	+	alnK	+	blnL	+	clnG	+	dU%				
	1.643		.309		.594		.155		−.007		.993	.088	.180
	(28.536)		(30.100)		(43.203)		(9.036)		(4.754)				
4) a + b = 1:	α	+	a(lnK − lnL)	+	lnL	+	clnG	+	dU%				
	1.793		.343		1.0*		.057		−.007		.660	.090	.177
	(34.084)		(39.662)				(15.887)		(4.619)				
5) a + b + c = 1:	α	+	a(lnK − lnL)	+	lnL	+	c(lnG − lnL)	+	dU%				
	2.352		.269		1.0*		.084		−.002		.564	.102	.179
	(53.230)		(23.344)				(4.390)		(1.036)				

Note: Q = gross state product; α = intercept; K = private capital stock; L = employment on nonagricultural payrolls; G = stock of state and local public capital; and U% = state unemployment rate; t-statistics in parentheses; number of observations = 816. $\hat{R}^2$ = adjusted coefficient of determination; SE = standard error of estimate; DW = Durbin-Watson statistic.

*Constrained to equal 1.

Table 5B

Output as a Function of Private Capital (K), Labor (L), and Public Capital (G), 48 States, 1970–86, Time Series

Equation for Output (lnQ)									$\hat{R}^2$	SE	DW
			Private Capital Only								
1) No Constraint:	alnK	+	blnL	+	dU%						
	.288		.756		−.006				.999	.038	.608
	(11.655)		(27.869)		(6.233)						
2) a + b = 1:	a(lnK − lnL)	+	lnL	+	dU%						
	.295		1.0*		−.005				.937	.039	.669
	(11.807)				(5.542)						
			Including Public Capital								
3) No Constraint:	alnK	+	blnL	+	clnG	+	dU%				
	.292		.768		−.026		−.005		.999	.038	.613
	(11.625)		(25.527)		(.902)		(5.358)				
4) a + b = 1:	a(lnK − lnL)	+	lnL	+	clnG	+	dU%				
	.282		1.0*		.050		−.006		.938	.038	.617
	(11.276)				(3.473)		(6.415)				
5) a + b + c = 1:	a(lnK − lnL)	+	lnL	+	c(lnG − lnL)	+	dU%				
	.302		1.0*		−.076		−.004		.938	.038	.643
	(12.182)				(3.999)		(4.852)				

Note: Q = gross state product; K = private capital stock; L = employment on nonagricultural payrolls; G = stock of state and local public capital; and U% = state unemployment rate; t-statistics in parentheses; number of observations = 816. $\hat{R}^2$ = adjusted coefficient of determination; SE = standard error of estimate; DW = Durbin-Watson statistic.

*Constrained to equal 1.

Table 5C
Output as a Function of Private Capital (K), Labor (L), and Public Capital (G), 48 States, 1970–86, Cross Sections

Equation for Output (lnQ)					$\hat{R}^2$	SE	DW
		Private Capital Only					
1) No Constraint:	alnK +	blnL +		dU%			
	.355	.694		−.004	.992	.092	.161
	(37.875)	(82.160)		(2.195)			
2) a + b = 1:	a(lnK − lnL) +	lnL +		dU%			
	.299	1.0*		.0005	.560	.102	.152
	(31.889)			(.236)			
		Including Public Capital					
3) No Constraint:	alnK +	blnL +	clnG +	dU%			
	.304	.589	.165	−.006	.993	.087	.154
	(29.073)	(42.743)	(9.421)	(3.422)			
4) a + b = 1:	a(lnK − lnL) +	lnL +	clnG +	dU%			
	.342	1.0*	.056	−.005	.663	.089	.159
	(39.557)		(15.676)	(2.848)			
5) a + b + c = 1:	a(lnK − lnL) +	lnL +	c(lnG − lnL) +	dU%			
	.263	1.0*	.098	−.0003	.572	.101	.148
	(22.486)		(4.997)	(.141)			

Note: Q = gross state product; K = private capital stock; L = employment on nonagricultural payrolls; G = stock of state and local public capital; and U% = state unemployment rate; t-statistics in parentheses; number of observations = 816. $\hat{R}^2$ = adjusted coefficient of determination; SE = standard error of estimate; DW = Durbin-Watson statistic.
*Constrained to equal 1.

Table 5D
Output as a Function of Private Capital (K), Labor (L), and Public Capital (G), 48 States, 1970–86, First Differences

Equation for Output (lnQ)						$\hat{R}^2$	SE	DW
			Private Capital Only					
1) No Constraint:	α +	alnK +	blnL +		dU%			
	.011	−.033	.830		−.006	.690	.021	1.766
	(8.287)	(1.449)	(23.273)		(8.215)			
2) a + b = 1:	α +	a(lnK − lnL) +	lnL +		dU%			
	.033	−.215	1.0*		−.014	.505	.026	1.438
	(33.849)	(8.040)			(18.447)			
			Including Public Capital					
3) No Constraint:	α +	alnK +	blnL +	clnG +	dU%			
	.011	−.032	.831	−.007	−.006	.690	.021	1.766
	(7.763)	(1.407)	(22.491)	(.144)	(7.862)			
4) a + b = 1:	α +	a(lnK − lnL) +	lnL +	clnG +	dU%			
	.027	−.219	1.0*	.305	−.015	.525	.026	1.517
	(19.403)	(8.352)		(5.684)	(19.303)			
5) a + b + c = 1:	α +	a(lnK − lnL) +	lnL +	c(lnG − lnL) +	dU%			
	.028	−.096	1.0*	−.491	−.009	.587	.024	1.420
	(29.920)	(3.672)		(12.313)	(9.910)			

Note: Q = gross state product; α = intercept; K = private capital stock; L = employment on nonagricultural payrolls; G = stock of state and local public capital; and U% = state unemployment rate; t-statistics in parentheses; number of observations = 768. $\hat{R}^2$ = adjusted coefficient of determination; SE = standard error of estimate; DW = Durbin-Watson statistic.
*Constrained to equal 1.

Table 6

Output as a Function of Private Capital (K), Labor (L), and Disaggregated Public Capital (H, WS, O), 48 States, 1970–86 (Munnell Table)

Equation for Output (lnQ)							$\hat{R}^2$	SE	DW
			State and Local Capital						
lnMFP +	alnK +	blnL +	clnH +	dlnWS +	elnO +	fU%			
5.72 (42.0)	.31 (28.1)	.55 (35.4)	.06 (3.8)	.12 (9.6)	.01 (.7)	−.007 (5.2)	.993	.085	1.9

Note: Q = gross state product; MFP = the level of technology; K = private capital stock; L = employment on nonagricultural payrolls; H = stock of highways; WS = stock of water and sewer systems; O = other state and local public capital, primarily buildings; and U% = state unemployment rate; t-statistics in parentheses; number of observations = 816. $\bar{R}^2$ = adjusted coefficient of determination; SE = standard error of estimate; DW = Durbin-Watson statistic.

Table 6A

Output as a Function of Private Capital (K), Labor (L), and Disaggregated Public Capital (H, WS, O), 48 States, 1970–86 (Replication of Table 6, Munnell)

Equation for Output (lnQ)							$\hat{R}^2$	SE	DW
			State and Local Capital						
lnMFP +	alnK +	blnL +	clnH +	dlnWS +	elnO +	fU%			
1.926 (36.684)	.312 (28.142)	.550 (35.380)	.059 (3.821)	.119 (9.597)	.009 (.692)	−.007 (5.255)	.993	.085	.188

Note: Q = gross state product; MFP = the level of technology; K = private capital stock; L = employment on nonagricultural payrolls; H = stock of highways; WS = stock of water and sewer systems; O = other state and local public capital, primarily buildings; and U% = state unemployment rate; t-statistics in parentheses; number of observations = 816. $\bar{R}^2$ = adjusted coefficient of determination; SE = standard error of estimate; DW = Durbin-Watson statistic.

Table 6B

Output as a Function of Private Capital (K), Labor (L), and Disaggregated Public Capital (H, WS, O), 48 States, 1970–86, Time Series

Equation for Output (lnQ)											$\hat{R}^2$	SE	DW
				State and Local Capital									
alnK	+	blnL	+	clnH	+	dlnWS	+	elnO	+	fU%			
.235 (8.966)		.801 (26.923)		.077 (2.457)		.079 (5.245)		−.115 (6.325)		−.005 (5.287)	.999	.037	.627

Note: Q = gross state product; K = private capital stock; L = employment on nonagricultural payrolls; H = stock of highways; WS = stock of water and sewer systems; O = other state and local public capital, primarily buildings; and U% = state unemployment rate; t-statistics in parentheses; number of observations = 816. $\bar{R}^2$ = adjusted coefficient of determination; SE = standard error of estimate; DW = Durbin-Watson statistic.

Table 6C

Output as a Function of Private Capital (K), Labor (L), and Disaggregated Public Capital (H, WS, O), 48 States, 1970–86, Cross Section

Equation for Output (lnQ)											$\hat{R}^2$	SE	DW
				State and Local Capital									
alnK	+	blnL	+	clnH	+	dlnWS	+	elnO	+	fU%			
.309 (26.634)		.548 (35.341)		.064 (3.913)		.116 (9.302)		.011 (.895)		−.006 (3.229)	.993	.085	.162

Note: Q = gross state product; K = private capital stock; L = employment on nonagricultural payrolls; H = stock of highways; WS = stock of water and sewer systems; O = other state and local public capital, primarily buildings; and U% = state unemployment rate; t-statistics in parentheses; number of observations = 816. $\bar{R}^2$ = adjusted coefficient of determination; SE = standard error of estimate; DW = Durbin-Watson statistic.

Table 7

Output as a Function of Private Capital (K), Labor (L), and Public Capital (G), Four Regions, 1970–86 (Munnell Table)

Equation for Output (lnQ)						$\hat{R}^2$	SE	DW	n
			Private Capital Only						
	lnMFP +	alnK +	blnL +	dU%					
Northeast	9.31	.11	.95	−.01		.997	.068	1.5	153
	(28.2)	(3.3)	(28.9)	(3.2)					
North Central	6.90	.34	.72	−.003		.998	.048	2.0	204
	(27.9)	(14.2)	(41.2)	(1.8)					
South	6.03	.42	.62	−.01		.983	.098	1.7	272
	(31.1)	(22.4)	(30.3)	(4.7)					
West	4.92	.54	.58	−.02		.997	.058	1.7	187
	(31.6)	(36.9)	(51.4)	(7.9)					
			Including Public Capital						
	lnMFP +	alnK +	blnL +	clnG +	dU%				
Northeast	8.83	.09	.90	.07	−.01	.997	.067	1.5	153
	(22.7)	(2.7)	(22.2)	(2.3)	(3.7)				
North Central	5.68	.34	.62	.12	−.004	.998	.046	2.0	204
	(15.8)	(15.1)	(22.3)	(4.5)	(2.6)				
South	3.15	.38	.36	.36	−.02	.988	.082	1.7	272
	(10.1)	(22.8)	(12.0)	(10.8)	(6.8)				
West	4.53	.51	.53	.08	−.02	.997	.056	2.0	187
	(23.4)	(28.0)	(28.7)	(3.2)	(8.4)				

Note: Q = gross state product; MFP = the level of technology; K = private capital stock; L = employment on nonagricultural payrolls; G = stock of state and local public capital; and U% = state unemployment rate; t-statistics in parentheses. $\hat{R}^2$ = adjusted coefficient of determination; SE = standard error of estimate; DW = Durbin-Watson statistic; n = number of observations.

Table 7A

Output as a Function of Private Capital (K), Labor (L), and Public Capital (G), Four Regions, 1970–86 (Replication of Table 7, Munnell)

Equation for Output (lnQ)						$\hat{R}^2$	SE	DW	n
			Private Capital Only						
	α +	alnK +	blnL +	dU%					
Northeast	2.722	.109	.953	−.010		.997	.068	.14	153
	(25.097)	(3.302)	(28.847)	(3.239)					
North Central	1.892	.337	.724	−.003		.998	.048	.49	204
	(14.431)	(14.259)	(41.252)	(1.859)					
South	1.762	.424	.618	−.012		.983	.098	.07	272
	(19.034)	(22.379)	(30.315)	(4.661)					
West	.932	.541	.577	−.019		.997	.058	.33	187
	(10.689)	(36.923)	(51.441)	(7.913)					
			Including Public Capital						
	α +	alnK +	blnL +	clnG +	dU%				
Northeast	2.616	.090	.898	.073	−.012	.997	.067	.15	153
	(22.413)	(2.672)	(22.195)	(2.282)	(3.785)				
North Central	1.371	.342	.624	.120	−.005	.998	.046	.51	204
	(8.018)	(15.133)	(22.328)	(4.482)	(2.588)				
South	.688	.375	.356	.356	−.015	.988	.082	.10	272
	(5.455)	(22.808)	(11.987)	(10.782)	(6.807)				
West	.874	.506	.530	.079	−.019	.997	.056	.33	187
	(10.059)	(28.052)	(28.738)	(3.208)	(8.447)				

Note: Q = gross state product; α = intercept; K = private capital stock; L = employment on nonagricultural payrolls; G = stock of state and local public capital; and U% = state unemployment rate; t-statistics in parentheses. $\hat{R}^2$ = adjusted coefficient of determination; SE = standard error of estimate; DW = Durbin-Watson statistic; n = number of observations.

Table 7B

Output as a Function of Private Capital (K), Labor (L), and Public Capital (G), Four Regions, 1970–86, Time Series

Equation for Output (lnQ)												$\hat{R}^2$	SE	DW	n
				Private Capital Only											
	alnK	+	blnL	+	dU%										
Northeast	.201		1.058		−.007							.999	.034	.51	153
	(3.910)		(16.416)		(3.720)										
North Central	.138		.925		−.001							.999	.034	.80	204
	(2.600)		(13.959)		(.715)										
South	.452		.543		−.005							.997	.040	.42	272
	(8.928)		(9.299)		(2.993)										
West	.148		.842		−.005							.999	.029	.52	187
	(4.210)		(24.778)		(3.261)										
				Including Public Capital											
	alnK	+	blnL	+	clnG	+	dU%								
Northeast	.210		1.078		−.058		−.006					.999	.034	.52	153
	(4.025)		(15.961)		(.995)		(2.715)								
North Central	.141		.932		−.016		−.001					.999	.034	.80	204
	(2.584)		(13.122)		(.258)		(.632)								
South	.464		.560		−.044		−.004					.997	.040	.43	272
	(8.768)		(8.957)		(.770)		(2.615)								
West	.137		.780		.121		−.007					.999	.029	.57	187
	(3.969)		(19.949)		(2.962)		(4.266)								

Note: Q = gross state product; K = private capital stock; L = employment on nonagricultural payrolls; G = stock of state and local public capital; and U% = state unemployment rate; t-statistics in parentheses. $\hat{R}^2$ = adjusted coefficient of determination; SE = standard error of estimate; DW = Durbin-Watson statistic; n = number of observations.

Table 7C

Output as a Function of Private Capital (K), Labor (L), and Public Capital (G), Four Regions, 1970–86, Cross Section

Equation for Output (lnQ)												$\hat{R}^2$	SE	DW	n
				Private Capital Only											
	alnK	+	blnL	+	dU%										
Northeast	.072		.987		−.004							.998	.063	.08	153
	(2.284)		(31.331)		(.862)										
North Central	.341		.712		.004							.998	.044	.37	204
	(15.281)		(42.220)		(1.521)										
South	.429		.608		−.017							.982	.099	.06	272
	(21.977)		(28.058)		(4.222)										
West	.556		.569		−.016							.997	.056	.25	187
	(37.476)		(49.871)		(5.383)										
				Including Public Capital											
	alnK	+	blnL	+	clnG	+	dU%								
Northeast	.025		.892		.139		−.008					.998	.058	.08	153
	(.819)		(25.099)		(4.694)		(1.690)								
North Central	.345		.607		.127		.003					.998	.041	.38	204
	(16.565)		(23.801)		(5.286)		(1.215)								
South	.380		.318		.383		−.024					.988	.080	.11	272
	(23.288)		(10.438)		(11.629)		(7.205)								
West	.537		.549		.036		−.018					.997	.056	.25	187
	(25.121)		(27.558)		(1.217)		(5.489)								

Note: Q = gross state product; K = private capital stock; L = employment on nonagricultural payrolls; G = stock of state and local public capital; and U% = state unemployment rate; t-statistics in parentheses. $\hat{R}^2$ = adjusted coefficient of determination; SE = standard error of estimate; DW = Durbin-Watson statistic; n = number of observations.

Table 9
Output (lnQ) and Translog Production Function, 48 States, 1970–86 (Munnell Table)

Equations for Output (ln Q):

Including Aggregate Public Capital	Coefficient (t-Statistic)	Disaggregating Public Capital	Coefficient (t-Statistic)
$\ln K-\overline{\ln K}$	.22 (18.9)	$\ln K-\overline{\ln K}$	.21 (16.1)
$\ln L-\overline{\ln L}$	.69 (37.5)	$\ln L-\overline{\ln L}$	.67 (35.7)
$\ln G-\overline{\ln G}$	.16 (9.1)	$\ln H-\overline{\ln H}$	.04 (2.7)
		$\ln WS-\overline{\ln WS}$	.15 (10.9)
		$\ln O-\overline{\ln O}$	−.02 (1.1)
$(\ln K-\overline{\ln K})^2$	.27 (11.7)	$(\ln K-\overline{\ln K})^2$	.27 (10.3)
$(\ln L-\overline{\ln L})^2$	.13 (3.2)	$(\ln L-\overline{\ln L})^2$	.17 (3.1)
$(\ln G-\overline{\ln G})^2$	.03 (.5)	$(\ln H-\overline{\ln H})^2$	.02 (.3)
		$(\ln WS-\overline{\ln WS})^2$	.01 (.4)
		$(\ln O-\overline{\ln O})^2$	.09 (3.9)
$(\ln K-\overline{\ln K})(\ln L-\overline{\ln L})$	−.39 (9.8)	$(\ln K-\overline{\ln K})(\ln L-\overline{\ln L})$	−.35 (7.9)
$(\ln K-\overline{\ln K})(\ln G-\overline{\ln G})$	−.14 (2.1)	$(\ln K-\overline{\ln K})(\ln H-\overline{\ln H})$	−.10 (1.6)
$(\ln L-\overline{\ln L})(\ln G-\overline{\ln G})$	.12 (1.4)	$(\ln K-\overline{\ln K})(\ln WS-\overline{\ln WS})$	.08 (2.1)
		$(\ln K-\overline{\ln K})(\ln O-\overline{\ln O})$	−.20 (4.4)
		$(\ln L-\overline{\ln L})(\ln H-\overline{\ln H})$	.11 (2.0)
		$(\ln L-\overline{\ln L})(\ln WS-\overline{\ln WS})$	−.05 (.6)
		$(\ln L-\overline{\ln L})(\ln O-\overline{\ln O})$	−.04 (0.8)
U%	−.006 (4.7)	U%	−.006 (5.2)
intercept	11.0 (1190.3)	intercept	11.0 (1168.1)
$\bar{R}^2$	.995	$\bar{R}^2$	.996
DW	1.7	DW	1.7

Note: Q = gross state product; K = private capital stock; L = employment on nonagricultural payrolls; G = stock of state and local public capital; H = stock of highways; WS = stock of water and sewer systems; O = other state and local capital, primarily buildings; and U% = state unemployment rate; overbar denotes mean; t-statistics in parentheses; number of observations = 816.

Table 9A
Output (lnQ) and Translog Production Function, 48 States, 1970–86 (Replication of Table 9, Munnell)

Equations for Output (ln Q):

Including Aggregate Public Capital	Coefficient	Disaggregating Public Capital	Coefficient
$\ln K-\overline{\ln K}$	.256 (25.582)	$\ln K-\overline{\ln K}$	.259 (24.726)
$\ln L-\overline{\ln L}$	.671 (46.566)	$\ln L-\overline{\ln L}$	.668 (41.047)
$\ln G-\overline{\ln G}$	.132 (8.151)	$\ln H-\overline{\ln H}$	.020 (1.415)
		$\ln WS-\overline{\ln WS}$	.120 (11.006)
		$\ln O-\overline{\ln O}$	−.024 (1.685)
$(\ln K-\overline{\ln K})^2$	.269 (11.661)	$(\ln K-\overline{\ln K})^2$	.270 (10.325)
$(\ln L-\overline{\ln L})^2$	.125 (3.240)	$(\ln L-\overline{\ln L})^2$	.169 (3.101)
$(\ln G-\overline{\ln G})^2$	.027 (.464)	$(\ln H-\overline{\ln H})^2$	.017 (.350)
		$(\ln WS-\overline{\ln WS})^2$	.014 (.432)
		$(\ln O-\overline{\ln O})^2$	.093 (3.904)
$(\ln K-\overline{\ln K})(\ln L-\overline{\ln L})$	−.387 (9.822)	$(\ln K-\overline{\ln K})(\ln L-\overline{\ln L})$	−.351 (7.887)
$(\ln K-\overline{\ln K})(\ln G-\overline{\ln G})$	−.143 (2.053)	$(\ln K-\overline{\ln K})(\ln H-\overline{\ln H})$	−.095 (1.583)
$(\ln L-\overline{\ln L})(\ln G-\overline{\ln G})$	.122 (1.402)	$(\ln K-\overline{\ln K})(\ln WS-\overline{\ln WS})$	.083 (2.125)
		$(\ln K-\overline{\ln K})(\ln O-\overline{\ln O})$	−.200 (4.355)
		$(\ln L-\overline{\ln L})(\ln H-\overline{\ln H})$	.105 (1.973)
		$(\ln L-\overline{\ln L})(\ln WS-\overline{\ln WS})$	−.049 (.639)
		$(\ln L-\overline{\ln L})(\ln O-\overline{\ln O})$	−.038 (0.756)
U%	−.006 (4.717)	U%	−.006 (5.231)
intercept	10.504 (1148.738)	intercept	10.494 (1160.292)
$\bar{R}^2$	.995	$\bar{R}^2$	.996
DW	.236	DW	.263

Note: Q = gross state product; K = private capital stock; L = employment on nonagricultural payrolls; G = stock of state and local public capital; H = stock of highways; WS = stock of water and sewer systems; O = other state and local capital, primarily buildings; and U% = state unemployment rate; overbar denotes mean; t-statistics in parentheses; number of observations = 816.

Table 9B

Output (lnQ) and Translog Production Function, 48 States, 1970–86, Time Series

Equations for Output (ln Q):

Including Aggregate Public Capital	Coefficient (t-Statistic)	Disaggregating Public Capital	Coefficient (t-Statistic)
$\ln K-\overline{\ln K}$	.209	$\ln K-\overline{\ln K}$	.150
	(8.015)		(5.562)
$\ln L-\overline{\ln L}$	.851	$\ln L-\overline{\ln L}$	.864
	(27.416)		(28.216)
$\ln G-\overline{\ln G}$	−.007	$\ln H-\overline{\ln H}$	.083
	(.234)		(2.337)
		$\ln WS-\overline{\ln WS}$	.071
			(4.754)
		$\ln O-\overline{\ln O}$	−.081
			(4.629)
$(\ln K-\overline{\ln K})^2$	.386	$(\ln K-\overline{\ln K})^2$	−.282
	(1.209)		(0.785)
$(\ln L-\overline{\ln L})^2$	1.210	$(\ln L-\overline{\ln L})^2$	.726
	(3.405)		(1.997)
$(\ln G-\overline{\ln G})^2$	1.254	$(\ln H-\overline{\ln H})^2$	1.601
	(3.622)		(5.947)
		$(\ln WS-\overline{\ln WS})^2$	−.097
			(.908)
		$(\ln O-\overline{\ln O})^2$	.180
			(1.355)
$(\ln K-\overline{\ln K})(\ln L-\overline{\ln L})$	−.020	$(\ln K-\overline{\ln K})(\ln L-\overline{\ln L})$	−.679
	(.034)		(1.062)
$(\ln K-\overline{\ln K})(\ln G-\overline{\ln G})$	−1.360	$(\ln K-\overline{\ln K})(\ln H-\overline{\ln H})$	−1.970
	(2.571)		(3.310)
$(\ln L-\overline{\ln L})(\ln G-\overline{\ln G})$	−1.425	$(\ln K-\overline{\ln K})(\ln WS-\overline{\ln WS})$	.846
	(2.725)		(3.012)
		$(\ln K-\overline{\ln K})(\ln O-\overline{\ln O})$	−.514
			(1.492)
		$(\ln L-\overline{\ln L})(\ln H-\overline{\ln H})$	−.249
			(.370)
		$(\ln L-\overline{\ln L})(\ln WS-\overline{\ln WS})$	−.606
			(2.238)
		$(\ln L-\overline{\ln L})(\ln O-\overline{\ln O})$	−.104
			(0.279)
U%	−.003	U%	−.003
	(2.996)		(2.735)
$\hat{R}^2$	.999	$\hat{R}^2$	.999
DW	.639	DW	.676

Note: Q = gross state product; K = private capital stock; L = employment on nonagricultural payrolls; G = stock of state and local public capital; H = stock of highways; WS = stock of water and sewer systems; O = other state and local capital, primarily buildings; and U% = state unemployment rate; overbar denotes mean; t-statistics in parentheses; number of observations = 816.

Table 9C

Output (lnQ) and Translog Production Function, 48 States, 1970–86, Cross Section

Equations for Output (ln Q):

Including Aggregate Public Capital	Coefficient (t-Statistic)	Disaggregating Public Capital	Coefficient (t-Statistic)
$\ln K-\overline{\ln K}$	.236	$\ln K-\overline{\ln K}$	.220
	(24.057)		(20.484)
$\ln L-\overline{\ln L}$	.670	$\ln L-\overline{\ln L}$	.690
	(48.636)		(45.366)
$\ln G-\overline{\ln G}$	.151	$\ln H-\overline{\ln H}$	.057
	(9.743)		(3.833)
		$\ln WS-\overline{\ln WS}$	.110
			(10.689)
		$\ln O-\overline{\ln O}$	−.034
			(2.528)
$(\ln K-\overline{\ln K})^2$	.341	$(\ln K-\overline{\ln K})^2$	.396
	(14.157)		(13.385)
$(\ln L-\overline{\ln L})^2$	.006	$(\ln L-\overline{\ln L})^2$	.188
	(.167)		(3.540)
$(\ln G-\overline{\ln G})^2$	−.072	$(\ln H-\overline{\ln H})^2$	−.035
	(1.290)		(.658)
		$(\ln WS-\overline{\ln WS})^2$	.070
			(2.222)
		$(\ln O-\overline{\ln O})^2$	.085
			(3.860)
$(\ln K-\overline{\ln K})(\ln L-\overline{\ln L})$	−.428	$(\ln K-\overline{\ln K})(\ln L-\overline{\ln L})$	−.466
	(11.333)		(11.010)
$(\ln K-\overline{\ln K})(\ln G-\overline{\ln G})$	−.246	$(\ln K-\overline{\ln K})(\ln H-\overline{\ln H})$	−.293
	(3.477)		(4.283)
$(\ln L-\overline{\ln L})(\ln G-\overline{\ln G})$	.408	$(\ln K-\overline{\ln K})(\ln WS-\overline{\ln WS})$	.205
	(4.868)		(5.349)
		$(\ln K-\overline{\ln K})(\ln O-\overline{\ln O})$	−.291
			(6.750)
		$(\ln L-\overline{\ln L})(\ln H-\overline{\ln H})$	.377
			(6.887)
		$(\ln L-\overline{\ln L})(\ln WS-\overline{\ln WS})$	−.289
			(3.624)
		$(\ln L-\overline{\ln L})(\ln O-\overline{\ln O})$	.064
			(1.329)
U%	−.005	U%	−.004
	(3.352)		(2.832)
$\hat{R}^2$	.996	$\hat{R}^2$	.996
DW	.182	DW	.231

Note: Q = gross state product; K = private capital stock; L = employment on nonagricultural payrolls; G = stock of state and local public capital; H = stock of highways; WS = stock of water and sewer systems; O = other state and local capital, primarily buildings; and U% = state unemployment rate; overbar denotes mean; t-statistics in parentheses; number of observations = 816.

Table E1

Net Private Investment as a Function of Four Lagged Changes in Output and of Labor and Public Capital, 48 States, 1975–86

$$d\ln K = b_0 + \sum_{j=1}^{4} b_j \, d\ln Q_{-j} + b_5 \ln L_{-1} + b_6 \ln G_{-1} + U\%_{-1}$$

	Overall	Time Series	Cross Section
b_0 (Constant)	.008	.012	—
	(2.862)	(3.665)	
b_1 ($d\ln Q_{-1}$)	.239	.229	.303
	(5.583)	(5.226)	(5.051)
b_2 ($d\ln Q_{-2}$)	.178	.162	.175
	(4.030)	(3.491)	(2.786)
b_3 ($d\ln Q_{-3}$)	.261	.238	.308
	(6.090)	(5.416)	(4.910)
b_4 ($d\ln Q_{-4}$)	.112	.092	.039
	(2.675)	(2.213)	(.623)
$\sum_{j=1}^{4} b_j (\Sigma\, d\ln Q_{-j})$	.798	.721	.825
	(8.901)	(7.523)	(8.711)
b_5 ($d\ln L_{-1}$)	.003	.024	.004
	(.453)	(.849)	(.585)
b_6 ($d\ln G_{-1}$)	−.002	−.070	−.002
	(.222)	(1.746)	(.298)
b_7 ($U\%_{-1}$)	−.0003	−.0003	−.0007
	(.410)	(.227)	(.887)
$\hat{R}^2$	.199	.205	.181
SE	.035	.034	.034
DW	2.125	2.139	2.155

Note: Q = gross state product; K = private capital stock; L = employment on nonagricultural payrolls; G = stock of state and local public capital; and U% = state unemployment rate; t-statistics in parentheses; number of observations = 576. $\hat{R}^2$ = adjusted coefficient of determination; SE = standard error of estimate; DW = Durbin-Watson statistic.

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