The Case of Korea

Iltae Kim
Professor, Department of Economics
Chonnam National University, Korea

Bong-Jin Kim
Visitng Scholar, Graduate School of Economics
Kyushu University, Japan

Abstract

This paper estimates a stochastic production frontier using time-series data for the aggregate Korean economy in 1977-2005 to examine whether public infrastructure stock reduces aggregate technical inefficiency in the gross domestic product. A stochastic production frontier is estimated in first-differenced form, and the one-sided residuals are regressed against the stock of public infrastructure per labor. We show that estimated the extent of technical inefficiency is negatively related to public infrastructure and suggest that public infrastructure stock reduces technical inefficiency in gross domestic production function, but does not directly affect gross domestic product. Our results suggest that public infrastructure enhances economy-wide technical efficiency.

The public infrastructure stock increases private sector output both directly and indirectly. The public infrastructure comprises government or local government capital goods. It includes high-ways, streets and roads, mass transit and airport facilities, electric, gas, and water supply facilities and distribution system, wastewater treatment facilities. In conventional view on public infrastructure, one effect of public infrastructure arises, because public infrastructure stock provides intermediate services to private sector firms, or the marginal product of public infrastructure stock in the private sector is positive. On the other hand, another effect stems from an assumption that public and private infrastructure are complements in production.

There are numerous previous empirical studies investigating the role of technical progress and public infrastructure as an input in the production process since Arrow and Kurz (1970). These results reports that the values of the marginal product of infrastructure are positive and statistically significant, but often implausibly large and that the model includes various econometric problems. Specifically, Aschauer (1989) and Munnell (1990) reported that output elasticities with respect to public capital are 0.39 and 0.34, respectively. These findings are higher than the consensus output elasticity for private capital of 0.30 and invoke a useful discussion on the importance of public infrastructure. Recently Achim and Stephan (2001) proposed a simultaneous-equation approach to estimate the contribution of infrastructure accumulation to private production using panel data of large German cities for the years 1980, 1986, and 1988. Their results show that the simultaneity between output and public capital is weak, and feedback effects from output to infrastructure are also negligible. These studies assume that an increase in public infrastructure upwardly shifts an average production function in a neutral respect. This implies that, in determining the level of private output, such infrastructure should not be included as an direct input in an average production function.

To reconcile this problem, as an alternative approach, public infrastructure plays an role on reducing the technical inefficiency of private sector production, or decreasing the difference between actual and potential output. For example, Mullen, Williams, and Moomaw (1996) presented a model of a translog stochastic production frontier to estimate the direct (output) and indirect (efficiency) effects of public capital for manufacturing across USA. states and over time using panel data. Their result reveals that public capital increases both output and productive efficiency in manufacturing and that the estimated, direct output elasticity of public capital is very small. Delorme, et al. (1999) analyzed a stochastic production frontier including a public capital for the private USA. economy using time-series and reported that estimated technical inefficiency is negatively correlated with the stock of public capital.

There are several researches about infrastructure stock in Korea. First, (2002). Other researches estimated the effects of infrastructure on Korean economy. For example, Park and Jun (1994) investigated the marginal effect of infrastructure on manufacturing productivity using polynomial distributed lag model and annual data 1970-1992. Their results pointed out that the stock of infrastructure has significantly positive effect on manufacturing productivity. Park, Jun and Park (1996) examined the marginal effect of infrastructure on regional economic productivity using OLS (Ordinary least squares) model and regional panel data 1972-1991. Their results showed that the stock of infrastructure also has significantly positive effect on regional economic productivity. Kim, Lee, and Koo (1997) also examined the marginal effect of social overhead capital on manufacturing productivity in regional economy using stochastic frontier model and regional panel data 1977-1992. Their results also show that social overhead capital stock significantly increases regional economic productivity.

This paper is organized as follows. In Section 2, first, we examine the previous finding by estimating an average production function including public capital as an input and then estimate a model of stochastic production frontier. Finally, section 3 contains concluding remarks.

2. Model and Analysis

Our analysis examines the finding that public infrastructure affects real gross domestic product (GDP) in Korea economy. Following several studies, for example, Ratner (1983), Aschauer (1989), Munnell (1990), Gramlich (1994), Otto and Voss (1996), and Delorme, et al. (1999), this paper introduces an aggregate Cobb-Douglas production function augmented by Hicks neutral technical change with a constant-returns-to-scale technology. This model also includes the capacity utilization rate to control the phase of the business cycle because the dependent variable in this model (output per worker) varies procyclically over time. Annual data from the period 1977-2005 are used in the empirical analysis, and are described in <Table 1>.

The model can be written

, (1)

where , , , and are also defined in <Table 1>. The variables and are liner and quadratic time-trends, respectively. Following Dardy (1984) and Tatom (1991), and Delorme, et al. (1999), these variable represent proxy nonlinear technical change, is a normally distributed random variable, and is the N observations.

In econometric problem, it indicates that aggregate time-series variables are frequently non-stationary in level form. Such data may result in a spurious non-stationarity among the variables exits, from estimates of the parameters of the model in (1), we infer that public infrastructure affects GDP even if it does not.

Variable	Mean	Definition and Source
	369,827	Real Gross Domestic Product, in 10 billions of won (Korea, 2000); in Korea Statistical Information Service
	116,594	Real Fixed Capital, in 10 billions of won (Korea, 2000); in Korea Statistical Information Service
	18,003	Number of Domestic Labor Input, employed persons (thousand); in Korea Statistical Information Service
	76.22	Output as Percentage (%) of Capacity in Manufacturing; in Korea Statistical Information Service
	192,382	From 1978 to 1999 data is National Public Infrastructure Real Stock, in 10 billions of won (Korea, 2000); Kim and Kwon (2002), p. 73 and form 2000 to 2005 year data is calculated using construction investment of social overhead capital in Korea Statistical Information Service as following Kim and Kwon (2002).

To examine the integrated properties of the data, this paper uses augmented Dickey-Fuller (ADF) tests for unit roots in levels and in first differences of each variable in (1) using two lagged differences. Each ADF regression is estimated with and without a constant and a linear time trend. From the ADF tests, there exists a unit root in levels, but no unit root in first differences. This paper is therefore justified in assuming that the levels of the variables are integrated of order 1. This implies that these variables must be differenced once to maintain stationarity. If the values of ADF test statistic are less than test critical values, the null hypothesis is rejected. The result of ADF tests is reported in <Table 2, 3, 4, 5, 6>. From Table 2 in the first column (1), because the values of ADF test statistic of ; 1.969 are higher than test critical values of ; -3.689, -2.971, -2.625 and so the null hypothesis is not rejected and then the variable, has a unit root in levels. and From Table 2 in second column (2), because the values of ADF test statistic of ; -4.592 are lower than test critical values of ; -3.699, -2.976, -2.627, and so the null hypothesis is can be rejected and then the variable, has no a unit root in first differential levels.

test critical values 1% level	-3.689	
5% level	-2.971	
10% level	-2.625	

(2) Null Hypothesis:　has a unit root		
	t-statistic	Prob*
ADF test statistic	-4.592	0.001
test critical values 1% level	-3.699	
5% level	-2.976	
10% level	-2.627	

* Mackinnon one-sided p-values.

Null Hypothesis:　has a unit root		
	t-statistic	Prob*
ADF test statistic	-0.448	0.887
test critical values 1% level	-3.689	
5% level	-2.971	
10% level	-2.625	

Null Hypothesis:　has a unit root		
	t-statistic	Prob*
ADF test statistic	-4.094	0.003
test critical values 1% level	-3.699	
5% level	-2.976	
10% level	-2.627	

* Mackinnon one-sided p-values.

Null Hypothesis:　has a unit root		
	t-statistic	Prob*
ADF test statistic	-0.581	0.859
test critical values 1% level	-3.689	
5% level	-2.971	
10% level	-2.625	

Null Hypothesis:　has a unit root		
	t-statistic	Prob*
ADF test statistic	-4.649	0.001
test critical values 1% level	-3.699	
5% level	-2.976	

Null Hypothesis: has a unit root		
	t-statistic	Prob*
ADF test statistic	-1.302	0.613
test critical values 1% level	-3.699	
5% level	-2.976	
10% level	-2.627	

Null Hypothesis: has a unit root		
	t-statistic	Prob*
ADF test statistic	-2.628	0.059
test critical values 1% level	-3.699	
5% level	-2.976	
10% level	-2.627	

* Mackinnon one-sided p-values.

Null Hypothesis: has a unit root		
	t-statistic	Prob*
ADF test statistic	-2.352	0.163
test critical values 1% level	-3.689	
5% level	-2.971	
10% level	-2.625	

Null Hypothesis: has a unit root		
	t-statistic	Prob*
ADF test statistic	-6.181	0.000
test critical values 1% level	-3.699	
5% level	-2.976	
10% level	-2.627	

* Mackinnon one-sided p-values.

To investigate the relationships among the variables and to examine the presence of cointegrating vectors in the non-stationary time- series data, from Johansen (1988) and Johansen and Juselius (1990), this paper performs the appropriate test statistics. The results of these tests reject the null hypothesis of no cointegration, since the values of the relevant test statistics are less than 5% critical values in <Table 7>. On first line in <Table 7>, the null hypothesis is that variables have no cointregration. If trace statistics (max-eigen statistics) are less than 0.05 critical values, the null hypothesis is rejected. That is to say, the variables have a cointegration less than 3, because trace statistics (max-eigen statistics); 33.031 (21.585) are higher than 0.05 critical values; 29.797(21.313).

Cointegration Rank Test (Trace)

Hypothesized NO. of CE(s)	Eigenvalue	Trace statistic	0.05 Critical Value	Prob**
None*	0.805	105.513	69.818	0.000
At most 1*	0.648	61.275	47.856	0.001
At most 2*	0.550	33.031	29.797	0.020
At most 3	0.330	11.445	15.494	0.185
At most 4	0.017	0.448	3.841	0.484

Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized NO. of CE(s)	Eigenvalue	Max-Eigen statistic	0.05 Critical Value	Prob**
None*	0.805	44.237	33.876	0.002
At most 1*	0.648	28.244	27.584	0.041
At most 2*	0.550	21.585	21.131	0.043
At most 3	0.330	10.957	14.264	0.156
At most 4	0.017	0.488	3.841	0.484

Trace test indicates 3 cointegrating eqn(s) at the 0.05 level
Max-eigenvalue test indicates 3 cointegrating eqn(s) at the 0.05 level
*denotes rejection of the hypothesis at the 0.05 level
**Mackinnon-Haug-Michelis p-values.

It is well-known that if a unit root exists, the model uses the difference form. However, when both a unit root and a cointegration exist, if time-series have a stationary linear combination, the model can use level form, while if time-series have a non-stationary linear combination, the regression of such data may result in bias in level form, and then the model uses the difference form. Thus, the production function to be estimated is correctly specified in first differences since the variables in (1) are integrated of order 1. Consequently, The model can be rewritten as a first differenced version of (1) where is a normally distributed random variable.

<Table 8> reports Ordinary least squares(OLS) estimates of the production function in first differenced form (2). The estimated coefficients on the capital stock and capacity utilization rate variable are positive and significantly different from zero, while the coefficients on trend variable are negative but statistically insignificant. In particular, estimated coefficients on the public infrastructure stock variable are positive (0.011) and t-statistics (1.786) are significantly different from zero. Therefore, this result confirms the widely reported previous empirical result that public capital increases real output in the Korean economy.

Variable	Coefficient
Intercept	0.043^{***} (3.081)
	0.147^{***} (2.830)
	0.525^{***} (2.553)
	0.230^{***} (2.975)
	0.011^{*} (1.786)
T	-0.000 (0.354)
D.W.	2.038
	0.837

1) OLS estimates.

2) Absolute values of estimated t-statistics are in parentheses under the coefficient estimates.(critical value *** 1%, ** 5%, * 10%)

3) The results of wald-coefficient tests support the null hypothesis of .

Following Schmidt (1986), this paper introduces a type of specification test which can be used to determine whether or not the effect of public infrastructure on gross domestic product is statistically significant because it reduces technical inefficiency in production. Thus, the stochastic production frontier to be estimated can be written as where is a normally distributed random variable, and is a one-sided error which displayed technical inefficiency in production. The argument discussed above, that public infrastructure reduces technical inefficiency, implies that there is an auxiliary relation

$$, \qquad (4) $$

where is predicted, and since the distribution of the dependent variable is truncated at zero.

Following Delorme, et al. (1999), the specification test proceeds in two stages. First, this paper estimates the production frontier by maximizing the log-likelihood function.

$$ \qquad (5) $$

where is the standard normal distribution function, is the variance of the composite error , and is the ratio of the standard error of technical inefficiency to the standard error of statistical noise. From the formula proposed by Jondrow, et al. (1982), we can compute estimates of the one sided error components, calculating the expectation of the , conditional on the fitted values of , These estimates are then used as the values of the dependent variable in the auxiliary equation given in (4) above.

Equation (4) is specified as a truncated normal regression model estimated by maximum likelihood method. If the value of the estimate of is not significantly different from zero, then we accept the null hypothesis that public infrastructure stock does not affect technical inefficiency. On the other hand, if the estimate of is significantly less than zero, we reject the null hypothesis and conclude that public infrastructure stock indeed decreases technical inefficiency, and so reducing the difference between potential output and actual output in gross domestic products for any given levels of capital stock and labor.

<Table 9> reports maximum likelihood estimates of the stochastic production frontier. The estimated coefficient on capital stock (0.174) and Laber (0.640) are positive and significantly different from zero. The estimated coefficient on the capacity-utilization rate (0.186) is also positive and significantly different from zero.

Variable	Coefficient
Intercept	0.060^{***} (5.242)
	0.174^{***} (3.492)

	(3.672)
	0.186^{*} (1.864)
T	-0.000 (0.916)
	1.966^{*} (1.911)
	0.022^{***} (3.713)

1) Maximum-likelihood estimates.
2) Absolute values of estimated t-statistics are in parentheses under the coefficient estimates.(critical value *** 1%, ** 5%, * 10%)
3) The results of wald-coefficient tests support the null hypothesis of .

In this paper, the estimate of indicates whether presence or absence of technical inefficiency in gross domestic product in Korea. The estimated coefficient on (1.966) is positive. Under the null hypothesis of no inefficiency, and all of the variance in the estimated equation would be attributed to statistical noise. According to conventional test criteria, the estimated t-statistic on implies that there is no technical inefficiency, at 5% level of significance.

To estimate equation (4), this paper uses the truncated-normal regression procedure implying that the one-sided residuals from the estimated production frontier are regressed against the omitted variable, the ratio of public infrastructure stock, . The results of estimating equation (4) are presented in <Table 10>. The estimated coefficient on public infrastructure is negative and significantly different from zero at critical values. These results show that the one-sided residuals are reduced by the stock of public infrastructure. This finding is consistent with the hypothesis that public infrastructure facilitates the gross domestic product by enhancing technical efficiency. That is to say, public infrastructure stock indirectly affects the gross domestic product, by lowering technical inefficiency in an aggregate production frontier which omits the stock of public infrastructure as a direct input.

Variable	Coefficient
Intercept	-0.031 (0.420)

	(1.516)
	0.008 (1.680)

1) Maximum-likelihood estimates.
2) Absolute values of estimated t-statistics are in parentheses under the coefficient estimates.(critical value *** 1%, ** 5%, * 10%)

3. Concluding Remarks

This paper introduces an aggregate stochastic production frontier using time-series data for the Korean economy in 1977-2005 to examine whether public infrastructure stock reduces aggregate technical inefficiency in the gross domestic product. A stochastic production frontier is estimated in first-differenced form, and the one-sided residuals are regressed against the stock of public infrastructure per labor. The results show that estimated technical inefficiency is negatively related to public infrastructure and suggest that public infrastructure stock reduces technical inefficiency in gross domestic production function, but does not directly affect gross domestic product. The results imply that public infrastructure enhances economy-wide technical efficiency.

References

Achim Kemmerling and Andreas Stephan. (2001), *The Contribution of Local Public Infrastructure to Private Productivity and its Political-Economy: Evidence from a Panel of Large German Cities*, Discussion Paper FS IV 01-14, Wissenschaftszentrum Berlin.

Arrow, Kenneth and Mordecai Kurz. (1970), "*Public Investment, the Rate of Return, and Optimal Fiscal Policy*," Baltimore: John Hopkins Press.

Aschauer, David A. (1989), "Is Public Expenditure Productive?," *Journal of Monetary Economics* 23, March, 177-200.

Darby, Michael R. (1984), "The U.S. Productivity Slowdown: A Case of Statistical Myopia," *American Economic Review* 74, March, 301-322.

Delorme, Charles, D., Thompson, Herbert, G., and Ronald, S. Warren. (1999), "Public Infrastructure and Private Productivity: A Stochastic-Frontier Approach," *Journal of Macroeconomics* 21(3), Summer, 563-576.

Gramlich, Edward M. (1994), "Infrastructure Investment: A Review Essay," *Applications*, 68-119, Oxford University Press.

Holtz-Eakin, Douglas. (1994), "Public-Sector Capital and the Productivity Puzzle," *The Review of Economics and statistics* 76, February, 12-21.

Johansen, Soren. (1988), "Statistical Analysis of Cointegration Vectors," *Journal of Economic Dynamics and Control* 12, June/Sept, 231-254.

Johansen, Soren and Katarina Juselius. (1990), " Maximum Likelihood Estimation and Inference on Cointegration with Applications to the Demand for Money, " *Oxford Bulletin of Economics and Statistics* 52, May, 169-210.

Jondrow, James, C.A. Knox Lovell, Ivan S. Materov, and Peter Schmidt. (1982), "On the Estimation of Technical Inefficiency in the Stochastic Production Function Model," *Journal of Econometrics* 19, August, 233-238.

Kim, Myung-Soo. (2004), "Estimating Regional SOC(Social Overhead Capital) Stocks in Korea, *The Korean Journal of Public Finance* 19(1), 83-110. (in Korean)

Kim, Myung-Soo and Hyeock-Jin Kwon. (2002), *Estimation of Social Overhead Capital Stock*, KRIHS Annual Report 2002-39, Korea Research Institute For Human Settlements. (in Korean)

Kim, Sang-Ho, Lee, Young-Hun, and Jaewoon Koo. (1997), "Social Overhead Capital and Production Efficiency in Manufacturing", *Journal of Economic Theory and Econometrics* 8, 1-25. (in Korean)

Mullen, John K., Martin Williams, and Ronald L. Moomaw. (1996), "Public Capital Stock and Interstate Variations in Manufacturing Efficiency," *Journal of Policy Analysis and Management* 15, Winter, 51-67.

Munnell, Alicia H. (1990), "Why Has Productivity Declined? Productivity and Public Investment," Federal Reserve Bank of New England, *New England Economic Review*, January/February, 3-22.

Otto, Glenn D. and Graham M. Voss. (1996), "Public Capital and Private Production in Australia," *Southern Economic Journal* 62, January, 723-738.

Park, Chul-Soo and Il-Soo Jun. (1994), "An Analysis of the Contribution of Social Overhead Capital on Manufacturing Productivity," *Productivity Review* Vol. 9. No. 1, 83-103. (in Korean)

Park, Chul-Soo, Jun, Il-Soo, and Jae-Hong Park. (1996), "An Analysis of the Contribution of Public Capital Stock on Regional Economic Growth," *Regional Research* 12(1), 17-29. (in Korean)

Pyo, Hak K., Kim Jong Il and Lee Jin Nyun. (2003), "Estimates of Capital Stock by Industries and Types of Goods in Korea(1953-2000), *Analysis of Korea Economy* 9(1), 203-282. (in Korean)

Ratner, Jonathan B. (1983), "Government Capital and the Production Function for U. S. Private Output," *Economics Letters* 13, 213-217.

Schmidt, Peter. (1986), "Frontier Production Functions," *Econometric*

Federal Reserve Bank of St. Louis Review 73, May/June, 3-15.