Regional Science and Urban Economics 22 (1992) 229–241. North-Holland

The contribution of publicly provided inputs to states' economies*

Teresa Garcia-Milà

Universitat Autònoma de Barcelona, Barcelona, Spain
Institut d'Anàlisi Econòmica, CSIC, Barcelona, Spain

Therese J. McGuire

University of Illinois, Chicago IL, USA

Received August 1989, final version received September 1990

We specify a regional production function that, in addition to labor and private capital, includes two publicly provided inputs – highways and education. We employ a panel data set consisting of annual observations on the 48 contiguous states from 1969 to 1983 to estimate input elasticity coefficients under a specification that allows for differences over time and across states. We find that both of the publicly provided inputs have a significant and positive effect on output. Our results support the policy conclusion that publicly provided infrastructure is an important element of economic growth.

1. Introduction

The public sector affects and interacts with the private economy and the economic well-being of individuals in many ways. The distribution of income, the overall price level, and the quality of health and other goods and services are affected by such government activities as taxes, public expenditures, regulation, and budget deficits. In this paper, we investigate the productive contribution of publicly provided goods and services, in particular, highways and education. We specify a production function for the economy that includes these publicly provided inputs and that enables us to investigate the relative impact of public and private inputs on output.

By measuring the productivity of public inputs we can evaluate the investment decisions of public officials and address the issue of the quality and adequacy of public infrastructure. One reason for concern about the lack of investment in or maintenance of roads and highways, and the quality of

Correspondence to: Prof. Therese J. McGuire, Institute of Government and Public Affairs, University of Illinois, 921 W. Van Buren St., Suite 230, Chicago, IL 60607, U.S.A.

*We are grateful to Dave Card, Rob Porter, Julio Rotemberg and an anonymous referee for helpful comments and suggestions.

public schools, is the potential for a detrimental effect on economic growth. That effect can be evaluated once the productivity of publicly provided inputs is known.

Determining the productivity of publicly provided inputs will enable us to address, at least partially, two current policy questions in the U.S. First, there has been great concern over the absolute and relative level of labor productivity in the U.S. in recent decades. In searching for the causes of the productivity slowdown, the standard explanations are being rejected [see Griliches (1988)], and an explanation involving investment in the quality of publicly provided infrastructure is gaining support [see Aschauer (1989) and Munnell (1990)]. The second policy issue is a possible deterioration in the quality of public schools. A primary reason for being concerned with the quality of public schools is the belief that a poorly educated labor force is less productive. The results presented here address both of these policy issues.

In an attempt to investigate whether public infrastructure affects productivity growth, Hulten and Schwab (1984) calculate regionwide production functions for manufacturing and estimate how much of the observed variation in the growth of real value-added can be explained by regional differences in three variables: capital growth, labor growth, and growth in total factor productivity. The authors find that the higher rate of growth of value added of the Sunbelt comes from strong growth in all three factors, while the growth in the Snowbelt is essentially due to total factor productivity growth. Their results lead them to conclude that labor and capital growth rate differences across regions explain most of the regional differences in output. They interpret these results as a lack of evidence for the hypothesis that the public infrastructure of the Snowbelt has declined enough to have adversely affected productivity. This interpretation of their results is rather broad. They do not actually measure public infrastructure, and the growth in total factor productivity is simply a residual. The authors interpret total factor productivity as being reflective of the quality of public infrastructure, however, total factor productivity may vary by region because of other factors such as resource availability and energy costs.

Further, their conclusion that capital and labor flowing out of the Snowbelt to the Sunbelt is the primary cause of regional differences in productivity is subject to several interpretations. One possible interpretation is that capital and labor have migrated from the Snowbelt because of dissatisfaction with the quality of public infrastructure. If that is the case, public infrastructure could be an indirect cause of regional differences in growth rates.

A production function with public capital has been estimated by Eberts (1986) for metropolitan areas. Public capital in his analysis includes highways, public hospitals, sewage and sanitation facilities and public service enterprises. He finds public capital to be productive with an elasticity much smaller than those for labor and private capital.

In a study of the regions of Japan, Mera (1973) investigates the impact of various measures of the social capital stock on three sectors of the economy. He finds public capital to be productive and to have an effect similar to the effect of private capital.

Unlike Hulten and Schwab, we are able to address directly the issue of the impact of public infrastructure on productivity by estimating its output elasticity. We construct private capital, highway capital, and publicly provided education series for the states, and estimate statewide production functions with gross state product as our measure of output. This differs from Eberts who constructs data for manufacturing only, at the metropolitan level. Our specification employs a unit of analysis at which many of the important public decisions are made, and broadens the analysis beyond manufacturing to the entire economy. Unlike previous studies we include education as a publicly provided input.

We find that both of the publicly provided inputs have a significant and positive effect on output. Our results support the policy conclusion that publicly provided infrastructure is an important element of economic growth.

The remainder of the paper is organized as follows. In section 2, we specify the production function and derive implications about the efficiency and productivity of public and private inputs. In section 3, we describe our panel data set and present results from estimating the production function. Section 4 is an evaluation of efficiency through comparison of wages and average productivities of the states. Our conclusions are presented in section 5.

2. A production function with public inputs

To evaluate the impact of publicly provided inputs on the economy of a state we specify a production function that relates a measure of aggregate output to a set of publicly provided inputs and aggregates of private inputs. These inputs include private capital in structures, private capital in equipment, labor, highway capital, and a variable representing expenditures on education.

The relationship we analyze is a long-run regional production function, not the production function of any single firm. Our private inputs and output are statewide aggregates across the many firms comprising the state. The publicly provided inputs are measured as the total available to any or all firms in the state. This statewide (regional) focus has implications, described below, for interpretation of the coefficients of the production function.

Although it is possible that other publicly provided goods and services are productive, we choose to concentrate on highways and education as these two have a direct impact on productivity. Highway capital is important for transporting intermediate and finished goods and for commuting to work. Education affects the production possibilities of a state in two ways. First, education increases the productivity of labor by generating human capital. Second, the working environment of a state is enhanced by having good schools and universities; high-quality labor is attracted to states with good public schools, and a better educated population tends to be characterized by lower crime rates and higher participation in political and community affairs. These additional benefits of education can increase the productivity of a state.[1]

For the functional form we choose a Cobb–Douglas production function which takes the following form:[2]

$$q = AK1^a K2^b L^c H^d E^e, \tag{1}$$

where q is aggregate output; $K1$, capital in structures; $K2$, capital in equipment; L, labor; H, highway capital; and E, education. Given that the exponent coefficient for each input is the elasticity of output with respect to the input, a, b, c, d, and e give the relative contribution of each input to output. The constant A is a shift factor that can take account of state-specific and time effects on the overall productivity of the inputs.

Typically, when regional production functions are estimated public inputs are not included and the coefficients estimated for private capital and labor are used to determine factor shares. The coefficients we estimate for private capital and labor will not be the same as coefficients derived from other studies where public inputs are not included. Of particular interest in this analysis will be the values for d and e, the elasticities of the publicly provided inputs.

The sum of the exponent coefficients yields the degree of statewide economies of scale. As described above, our input and output measures are generated by aggregating over all firms in the economy. Because of the possibility of externalities arising from proximity of firms to one another (agglomeration economies or congestion), the regional production possibilities might differ from (be greater than or less than) the production

[1] Azariadis and Drazen (1988) and Lucas (1988) incorporate similar dual effects of education in models of economic growth.

[2] The literature on the estimation of production functions, and in particular of the Cobb–Douglas functional form, is extensive. As examples, see Nerlove (1965), Zellner et al. (1966), and Fuss et al. (1978). While much of the literature addresses the problems and inadequacies of the Cobb–Douglas functional form, many of the estimates have employed a Cobb–Douglas specification. Our use of the Cobb–Douglas functional form facilitates comparisons between our estimates, which include publicly provided inputs, and many of the existing estimates in the literature, which only include private inputs.

possibilities derived from individual firm level production functions. The Hicks aggregation theorem implies that the degree of economies of scale derived from the statewide production function will be a weighted average of the within-firm returns to scale corrected for the between-firm or external economies that firms confer on one another [Hicks (1946)]. In other words, if the sum of the exponent coefficients is greater than one, then either most firms are experiencing increasing returns to scale or economies of agglomeration exist or both.

Given the estimated statewide production function, and given relevant price data, we could determine whether states choose inputs efficiently. Equality between the value of the marginal product of an input to its cost indicates productive efficiency. Assuming diminishing marginal productivity, if the value of the marginal product exceeds (is less than) the cost of the input, then the state is under-(over-)investing.

There may be a presumption that private inputs are chosen optimally by competitive firms, but this will not necessarily be the case for at least two reasons. First, if the between-firm externalities noted above are strong, then competitive firms acting unilaterally are not likely to choose the optimal level of inputs. Second, because of tax and investment incentives, firms may not face prices for inputs that represent the true opportunity costs of employing the inputs.

Because we include public inputs in our production function, this efficiency analysis could be performed for publicly provided inputs as well. Given the political process that leads to determination of levels of publicly provided inputs, there is little hope that these decisions are made efficiently. An estimated production function could be used to determine whether public decisions concerning investment in publicly provided inputs are efficient or inefficient and, if inefficient, the direction of the suboptimality. Specifically, given the proper data, we could determine whether states optimally choose levels of highway capital and education expenditures.

3. Data and estimation results

The data consist of 14 annual observations for the 48 contiguous states. As a measure of output we use gross state product (GSP), and the two private capital series are constructed using investment series in structures and equipment, respectively. We need to generate the capital stock values as no such series is available by state. To determine an initial capital stock for each state we allocate the U.S. capital stock in a base year to each state using a fraction which relates to each state's share of total U.S. investment.

Labor is the number of employees by state as measured by the Bureau of Labor Statistics. To generate the highway capital series we treat annual expenditures on highways by state and local governments as a measure of investment in new capital and maintenance of existing capital. An initial highway capital stock for the U.S. is allocated to each state using a state's share of total highway mileage. Our highway variable is highway capital per square mile.

Our education variable is total state and local expenditures for K-12 and postsecondary education. To capture the delayed impact of education on human capital we use the average of education expenditures over the previous four years and the current year to construct a given year's education variable.

The observations for GSP and labor are from 1970 to 1983. The observations for capital in structures, capital in equipment, highways, and education are from 1969 to 1982. These four variables are lagged one year with respect to GSP to capture their availability at the beginning of the year in which GSP is produced.

GSP, the capital series, and education are measured in 1972 dollars. The source for labor is the Bureau of Economic Analysis, Department of Commerce (BEA), which employs data generated by the Bureau of Labor Statistics. The source for highways and education expenditures is the Bureau of the Census, *Governmental Finances*, which is an annual publication. The source for the GSP and private investment data is the BEA. Details of the data construction are presented in the appendix.

Our goal is to estimate a long-run production function for the states, controlling for relevant state-specific effects, business cycle effects, and changes in technology. Because we have few time observations relative to the number of cross-section observations, we do not include state dummy variables in order that the cyclical variation overtime does not dominate the long-run relationship we hope to estimate. To account for potentially important differences across the states we include the population of the state and a measure of the average industrial mix of the state over this time period.[3] The size of a state in terms of population may have scale economy or congestion effects. The industrial mix of a state may affect overall productivity as some industries have grown faster or experienced greater increases in labor productivity than others.

To take acount of business cycle effects, which are likely to be important in the period of analysis, and of time dependent technological changes, we incorporate yearly dummy variables. This specification enables us to stress the cross-section variation while controlling for time variation. We use OLS

[3]The population data are from Census and we have observations for all states for all years. The industrial mix variable is manufacturing's share of total output, an average over the time period for each state. The 48 observations are repeated for each year so that it is a state-specific but time invariant variable.

Table 1

Estimation results.[a]

	Regression 1		Regression 2	
Constant	−2.325	(7.46)	−4.598	(12.11)
ln *K1*[b]	0.104	(6.37)	0.027	(1.55)
ln *K2*	0.373	(13.03)	0.449	(15.99)
ln *L*	0.356	(11.90)	0.465	(15.31)
ln *H*	0.045	(8.65)	0.044	(8.89)
ln *E*	0.165	(8.00)	0.072	(3.34)
POP	0.6×10^{-8}	(4.19)	0.3×10^{-8}	(1.96)
MIX	−0.004	(7.86)	−0.004	(8.87)
MED			0.087	(9.41)
T70	0.147	(6.66)	0.177	(8.43)
T71	0.113	(5.62)	0.139	(7.32)
T72	0.119	(6.22)	0.141	(7.83)
T73	0.125	(6.90)	0.142	(8.29)
T74	0.062	(3.63)	0.076	(4.69)
T75	0.017	(1.03)	0.030	(1.92)
T76	0.032	(1.96)	0.041	(2.71)
T77	0.051	(3.16)	0.058	(3.82)
T78	0.069	(4.30)	0.071	(4.72)
T79	0.052	(3.29)	0.051	(3.40)
T80	0.014	(0.91)	0.012	(0.82)
T81	0.023	(1.49)	0.021	(1.45)
T82	−0.015	(0.99)	−0.016	(1.07)
R^2	0.995		0.995	

[a]The dependent variable is the natural log of gross state product. The number of observations is 672. The absolute values of the *t*-statistics are in parentheses and displayed to the right of the corresponding coefficient.

[b]*K1* is capital structures; *K2*, capital in equipment; *L*, labor, *H*, highway capital; *E*, education; *POP*, population; *MIX*, industrial mix; *MED*, median years of schooling; and *T70* through *T82* are time (yearly) dummy variables.

to estimate the logarithmic transformation of eq. (1). The results are displayed in table 1, regression 1.[4]

The estimated coefficients on the five input variables and on population and industrial mix are highly significant, and the hypothesis that all of the coefficients of the time dummies are zero is strongly rejected.[5] The R^2 indicates that the set of variables explains most of the observed variation in GSP. The relative sizes of the coefficients on the input variables lead us to conclude that education plays an important role in determining the econo-

[4]In work not reported here we estimate an equation where we control for the possible endogeneity of labor by using labor lagged one year as an instrument. The results of this specification do not alter any of our conclusions.

[5]The value of the relevant *F*-statistic is 7.99, well above the 1 percent critical point of 2.2 for the *F*-distribution with (13,651) degrees of freedom.

mies of the states. Highways does not appear to have a relatively large impact on GSP. The estimated coefficient on labor is lower than many estimates reported for the value of labor's share. This lower estimate can be explained by the fact that we have accounted for the contribution of not only labor and capital but also public inputs and that our measure of output is tax inclusive.[6] The sum of the coefficients is 1.04 which is close to one but statistically significantly greater than one.[7] This finding of slight economies of scale is contrary to the often used assumption of constant returns to scale.[8]

While the sum of the estimated exponent coefficients reflects both potential agglomeration economies and scale economies, the size of a state in terms of population may also induce agglomeration economies or congestion. We allow for this size effect to impact the constant term only, not the slope coefficients, so that the relationship between the inputs is not allowed to change but the inputs are jointly more or less productive. Population enters as a significant positive factor indicating that states with larger populations have a productive comparative advantage.

The industrial mix variable is significant and its negative coefficient indicates that states with relatively large manufacturing shares are less productive. Relative to other industries manufacturing grew slowly during this time period so that those states with a concentration of fast growth industries enjoyed higher output, all else equal.[9] The estimated coefficients for the time dummies move roughly with the business cycle.

There are two potentially serious criticisms of our use of the education expenditures variable in a production function. First, one could argue that there are better measures of the human capital available in a state. Because people are quite mobile between states, the education provided by one state benefits other states and may not perfectly characterize the education of its current labor force, many of whom may have been educated elsewhere. Median years of schooling completed by the population aged 25 and older may be a better measure of the quality of the existing labor force. In the second regression reported in table 1 we include a variable for median years

[6]Without taking into account public inputs, Kydland and Prescott (1982) calculate a value for labor's share of 0.64 for total U.S. in 1976, while Hulten and Schwab (1984) report values for manufacturing between 0.57 and 0.79 for several U.S. regions between 1951 and 1978.

[7]The F-statistic for the null hypothesis that the sum of the exponent coefficients is equal to one is 25.95. The F-statistic is distributed with degrees of freedom (1,651) with a critical value of 3.84 at a 5 percent significance level. We thus reject the hypothesis that the sum is equal to one. These results on increasing returns to scale are in contrast to the results of Eberts (1986) and Segal (1976) who both find constant returns to scale at the metropolitan level.

[8]Kydland and Prescott (1982) and Mera (1973), among others, assume constant returns to scale. Romer (1986), on the other hand, argues for increasing returns in a model where knowledge is productive.

[9]A similar result for industrial mix is obtained in Wasylenko (1986).

of schooling.[10] We include both education and median years of schooling since education expenditures are hypothesized to have an effect beyond the generation of human capital, namely, the quality and attractiveness of the working environment is enhanced in states that spend more on public education.[11] The results indicate that both education and median years of schooling are significantly and positively related to output, and that the importance of the education variable in terms of its relative elasticity is diminished. The estimates for the other input elasticities are also affected by the inclusion of the median years of schooling variable.

The results of regression 2 must be interpreted with caution because our measure of the human capital of the existing labor force, median years of schooling, is based on only two observations for each state, is a rough summary of the distribution of years of schooling, and may not reflect the quality of the labor force.

The second major criticism of our use of education expenditures in a production function estimation is that education expenditures may be endogenous, that the demand for education expenditures depends on income, our left-hand side variable.[12] This is a serious econometric problem that we had hoped to solve by using median years of schooling as an instrument for education, but the correlation between median years of schooling and education is -0.044 and thus median years of schooling is not a proper instrument. We were unable to devise other instruments and are thus forced to acknowledge that the positive and significant coefficient on education may be reflecting both demand for and productivity of education.[13]

4. Toward an efficiency analysis

A major motivation for estimating statewide production functions is to be able to evaluate the choices of levels of inputs using the criterion of productive efficiency. For each state we could determine if an input is chosen efficiently by comparing the value of the marginal product of an input to its unit cost. Given a Cobb–Douglas production function, the efficiency con-

[10]The variable is defined as the average of the 1970 and 1980 values for median years of schooling for individuals aged 25 or older. The source is the Census of Population, 1970 and 1980.

[11]It could be argued that we should simply replace education with median years of schooling, if the latter is a better measure of human capital. We are unconvinced by this argument and our results indicate that both variables are important.

[12]Other right-hand side variables are also subject to this problem. The estimation of production functions where inputs are likely to be chosen simultaneously with output has a long history. See Lucas (1970) for an example.

[13]Recall that our education variable is lagged one year and therefore is the average of the expenditures on education for the previous five years, not including the current year. This definition mitigates the problem of endogeneity of the education variable.

dition can be expressed as the equality between the average product and the ratio of the input cost to the output price times the elasticity coefficient. In the estimation discussed above and in the efficiency comparisons that follow, we assume that all states have the same output price and the same elasticity coefficients for the inputs.[14] Under these assumptions, efficiency would require that average products and input costs move together.

If we find that the average product and input cost for an input are not perfectly correlated, then one possible explanation is that the levels of the input have not been chosen efficiently. Another possible explanation for such a finding is that our assumptions are invalid and the output prices and elasticity coefficients *do* vary across the states, resulting in the possibility of a less than perfect correlation between average product and input cost. While we cannot distinguish between these two explanations, we can describe the implications of our maintained hypotheses for two inputs – one public and one private – for which we have input cost data.

We calculate average products and obtain measures of per unit input costs for the labor and education inputs for 1980 for each state.[15] We choose these two inputs because we consider education to be highly labor intensive and the only state-specific measure of input costs we have is wages. We do not have what we consider appropriate measures of the costs of the other three inputs. The two wages are the average wage for all industries, which we compare to the average product of labor, and the average wage for the state and local government sector, which we compare to the average product of education.

The average product for labor and its wage are strongly, positively correlated (a correlation of 0.904, which is statistically significant at a 1 percent significance level), while the average product of education and its corresponding wage have a positive, but much weaker correlation (0.134, not statistically significant at conventional significance levels). The coefficient of variation of the ratio of the average product of labor to its wage is 0.05 while the coefficient of variation of the ratio of the average product of education to its wage is 0.17. These results indicate that the average product of labor and its wage are much more closely related than the average product of education and its wage.

We have mentioned above two possibilities for why variation across the states in the unit input cost may not completely explain the observed variation in the average product of an input. The first explanation involves our assumptions about the output price and elasticity coefficient being constant across states. If these assumptions are invalid, the unobserved variation across states in output prices and elasticity coefficients may result

[14]The assumption of a constant output price across the states is dictated by a lack of data.

[15]The source for the wage data is the Burea of Economic Analysis, U.S. Department of Commerce. The data consist of wages by industry by state for 1980.

in efficiency conditions requiring either low or high correlation between average product and input cost. Thus, our finding of a high correlation between average product and input cost for labor and a low correlation between average product and input cost for education may be due to the unobserved variation in output prices and elasticity coefficients.

The second explanation for our finding of a low correlation between average product and input cost for one input and a strong correlation for the other involves the relative efficiency in the choice of the two inputs. This comparison of the data indicates that education more so than labor might be inefficiently chosen. One explanation for this result is that the labor choice is made by cost minimizing firms while the level of education expenditures is determined by the political process, a process which involves considerations other than productive efficiency.[16]

5. Conclusion

This paper is an attempt to determine the contribution to output of two publicly provided inputs, highways and education, and to evaluate whether states make optimal decisions regarding expenditures on these two components of the public budget. We estimate long-run statewide production functions using a Cobb–Douglas specification with five inputs: capital in structures, capital in equipment, labor, highway capital, and education expenditures. Our panel data set consisting of annual observations on the 48 contiguous states from 1969 to 1983 is used to estimate input elasticity coefficients under a specification that allows for differences in overall factor productivity over time and across states.

Our results indicate that both highways and education are productive inputs with the latter having a stronger impact on output. This conclusion is valid even when we control for human capital by including median years of schooling as an explanatory variable. We conclude that public inputs should be included when specifying aggregate production functions. An efficiency analysis of the two inputs, labor and education, leads us to believe that the chosen levels of state and local education expenditures may be suboptimal.

Appendix: Construction of capital series for equipment, structures and highways

The only data available by state for private capital are annual observations on investment in structures and equipment, respectively, beginning in 1965. These data are used by the Bureau of Economic Analysis of the

[16]The political process may involve bureaucratic waste or excess, and/or the consideration of other goals such as satisfying consumer voters. In particular, education provides consumption as well as production benefits.

Department of Commerce in their regional economic model of the U.S. The first step in converting the investment data into capital stock variables was to obtain values for the total net capital stocks of equipment and structures in the U.S. in 1979 from a 1982 Department of Commerce publication called *Fixed Reproducible Tangible Wealth in the U.S., 1925–79.* We determined that coverage of equipment using the capital stock source was more extensive than the coverage of equipment from the investment source by almost 25 percent. We thus multiplied the initial equipment capital stock for the U.S. by 0.75 so that it would be compatible with our state specific investment data. The capital stock and investment coverage for structures appeared to be quite similar so that no corresponding adjustment to the aggregate capital stock of structures was required.

The 1979 net capital stocks for equipment and structures for the U.S. were allocated to the individual states by multiplying the two aggregate stocks by state-specific fractions (weights). A state's fraction was determined by dividing the appropriately depreciated sum of investment in the state from 1965 to 1979, by the sum of the same aggregated over the 51 states. For example, the fraction of the 1979 U.S. stock of equipment allocated to Wyoming was Wyoming's share of the aggregate depreciated investment in equipment from 1965 to 1979. In this way capital stocks in equipment and structures for 1979 were calculated for each state.

Using the base year (1979) state-specific capital stock, a capital stock series from 1969 to 1983 for each state was constructed by adding or subtracting appropriately depreciated investment values. The depreciation rates used for equipment and structures were 0.146 and 0.0361, respectively. Both figures were taken from Hulten and Schwab (1984).

The construction of the highway capital series proceeded much like the private capital series except that different data sets were involved. As a measure of state-specific highway investment we employed expenditures on highways taken from the annual publication, *Governmental Finances*, published by the Census Bureau. From a 1980 Department of Commerce publication, *A Study of Public Works Investment in the U.S.*, we obtained a value for total federal, state, and local capital stock in highways, roads and bridges in 1967. This total for the U.S. was allocated to the states by multiplying the total by each states's share of total rural plus municipal highway mileage. The source for the state-specific mileage figures was *Highway Statistics, 1967*, an annual publication of the Federal Highway Administration of the U.S. Department of Transportation.

Using the 1967 state-specific highway capital stock, a highway capital stock series for each state from 1969 to 1983 was constructed by adding appropriately depreciated investment values to the depreciated initial capital stock. The rate of depreciation used was 0.03, an educated guess based on the average life of structures being approximately 40 years (with a depreciation rate of 0.0361) and the average life of highways being approximately 60 years.

References

Aschauer, David Alan, 1989, Is public expenditure productive?, Journal of Monetary Economics 23, no. 2, March.

Azariadis, Costas and Allan Drazen, 1990, Threshold externalities in economic development, Quarterly Journal of Economics 105, no. 2, May.

Eberts, Randall W., 1986, Estimating the contribution of urban public infrastructure to regional growth, Working paper no. 8610 (Federal Reserve Bank of Cleveland, Cleveland, OH) Dec.

Fuss, Melvyn, Daniel McFadden and Yair Mundlak, 1978, A survey of functional forms in the economic analysis of production, in: Melvyn Fuss and Daniel McFadden, eds., Production economics: A dual approach to theory and applications (North-Holland, Amsterdam).

Griliches, Zvi, 1988, Productivity puzzles and R&D: Another nonexplanation, Journal of Economic Perspectives 2, no. 4, Fall.

Hicks, J.R., 1946, Value and capital, second edition (Oxford University Press, Oxford).

Hulten, Charles R. and Robert M. Schwab, 1984, Regional productivity growth in U.S. manufacturing: 1951–78, The American Economic Review 74, no. 1, March.

Kydland, Finn E. and Edward C. Prescott, 1982, Time to build and aggregate fluctuations, Econometrica 50, no. 6, Nov.

Lucas, Robert E., Jr., 1970, Capacity, overtime, and empirical production functions, The American Economic Review 60.

Lucas, Robert E., Jr., 1988, On the mechanics of economic development, Journal of Monetary Economics 22.

Mera, Koichi, 1973, II. Regional production functions and social overhead capital: An analysis of the Japanese case, Regional and Urban Economics 3, no. 2.

Munnell, Alicia H., 1990, Why has productivity growth declined? Productivity and public investment, New England Economic Review, Jan./Feb.

Nerlove, Marc, 1965, Estimation and identification of Cobb–Douglas production functions (Rand McNally, Chicago, IL).

Romer, Paul M., 1986, Increasing returns and long-run growth, Journal of Political Economy 94, no. 5.

Segal, David, 1976, Are there returns to scale in city size?, The Review of Economics and Statistics 58, no. 3, Aug.

Wasylenko, Michael, 1986, The effect of business climate on employment growth, in: Robert D. Ebel and Therese J. McGuire, eds., Final report of the Minnesota Tax Study Commission, Vol. 2 (Butterworth Legal Publishers, London).

Zellner, A., J. Kmenta and J. Drèze, 1966, Specification and estimation of Cobb–Douglas production function models, Econometrica 34, Oct.