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16. Abstract <p>Recent research has uncovered an apparent relationship between rates of productivity growth and levels of investment in core infrastructure by the public sector. If valid, these findings account for most of the widely reported slowdown in U.S. rates of productivity growth in recent decades, and lend a measure of intrinsic worth to government intervention in the national economy more fundamental than a merely countercyclical role. This review (a) outlines the central results of the dozens of research efforts mounted in the last decade that attempt to explain the U.S. productivity slowdown; (b) retraces the findings of the researchers most noted for their linking of infrastructure investment with productivity changes; (c) recapitulates the criticisms to which they have been subjected in recent months; and (d) summarizes the main issues that divide protagonists and antagonists in this arena. Finally, a set of empirical and theoretical issues are introduced that have not been given adequate attention by researchers on either side of the debate.</p>			
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**Public Investment and U.S. Productivity Change:
An Evaluation of Recent Research**

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**Public Investment and U.S. Productivity Change:
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Recent articles by Aschauer (1988, 1989a, 1989b, 1989c, 1990), Munnell (1990a, b; 1991a, b), Eberts (1986, 1988) and others (Eberts and Fogarty, 1987; Duffy-Deno and Eberts, 1989; Garcia-Mila and McGuire, forthcoming; Holtz-Eakin, 1988) have uncovered an apparent relationship between rates of productivity growth and an element of economic activity neglected up to now by researchers grounded in neoclassical production and economic growth theory: investment in core infrastructure by the public sector. If valid, these findings are arresting, for two reasons. They lend a measure of intrinsic worth to public sector intervention in national economic performance far beyond the countercyclical role assigned to it by Keynes, and they account for most of the widely reported slowdown in U.S. rates of productivity growth in recent decades.

This review will (a) briefly outline the central results of the dozens of research efforts mounted in the last decade that attempt to explain the U.S. productivity slowdown; (b) retrace the arguments and findings of the researchers most noted for their linking of infrastructure investment with productivity changes; (c) recapitulate the criticisms to which they have been subjected in recent months; and (d) summarize the main issues that divide protagonists and antagonists in this research area. Finally, as part of a sketch

of future directions for research into this vital public policy issue, a set of empirical and theoretical issues will be introduced that have not been given adequate attention by researchers on either side of the debate.

1. The Productivity Slowdown

Declining rates of U.S. productivity growth have been identified in recent years as perhaps the most important economic problem facing the nation. Because productivity growth is one of the major determinants of our standard of living, concern about its rate of growth is quite understandable. As Alicia Munnell (1990a) points out in a lively preamble to her discussion of recent research in this area,

If the efficiency with which resources can be used rises at 2.5 percent per year, people can expect their real wages and their living standards to double every 28 years, or roughly once a generation. In contrast, productivity growth of 0.5 percent means that children can expect living standards only 15 percent higher than those of their parents. (p. 3)

“In this regard”, Munnell continues, “the numbers look bad”. From 1948 to 1969, labor productivity--inflation-adjusted output to hours worked--in the private nonfarm business sector grew at an average rate of 2.5 percent annually. From 1969 to 1973, that rate declined to 2 percent per year, and to 0.5 percent annually from 1973 to 1979. Productivity has improved somewhat in the last decade to 1.2 percent per year, but this is still less than half that of its peak post-World War II performance.

To date, literally hundreds of studies have tried to isolate the causes of falling productivity¹, but these still remain a mystery. The majority of those engaged in productivity research have begun with the hypothesis that falling rates of U.S. productivity growth must be caused by the deteriorating productivity of labor or capital inputs. Investigators focusing on labor issues have asserted that the productivity of the American workforce has declined either because of changes in its demographic structure, or falling levels of education, or both.

The demographic argument is that as baby boomers moved into the workforce during the 1970s, its age and gender mix changed. The percentage of adult males dropped from 55 percent of the total in 1970 to 47 percent in 1979. The workforce thereby became younger and more feminine, and--presumably--less experienced and accordingly less productive. To test this hypothesis, several analysts constructed quality-adjusted labor force variables where workers in each age-sex demographic group are weighted by the wage for that group (Perry, 1971; Denison, 1974, 1979, 1985; Darby, 1984, Munnell, 1990, *op. cit.*), but this explained only a small fraction of the decline in labor productivity after 1969.

Fraumeni and Jorgenson (1981), and Denison (1985) asked whether declines in educational status on the part of new entrants into the workforce contributed to falling productivity. They found that the U.S. work force was

¹See Baily (1986) for a more comprehensive review of the literature. In a review of the most recent and widely publicized effort at evaluating the issue (i.e., Baumol, *et. al.*, 1989), Williamson (1991) states that the analysis of the determinants of declining productivity still leaves "too many questions unanswered." (p. 67)

becoming better educated, and that productivity gains had been made by many workers with increased education levels. However, other researchers (Freeman, 1976; Smith and Welch, 1978; Baily, 1981, *op. cit.*) found that the rates of return to additional education in recent years actually fell. This leaves the education-productivity hypothesis with some highly contentious ambiguities.

Other economists have turned their attention to presumed deficiencies in the productivity of capital. Hudson and Jorgenson (1974), and later, Jorgenson (1988) responded to the run-up in energy prices in the 1970s by asking whether these increases decreased the rate of capital investment in strategically important U.S. industries, thereby slowing the rate of productivity growth. Capital investment during the 1970s did not actually slow down, however, and Baily (1981, *op. cit.*) therefore argued that it was the flow of services from capital that deteriorated. This was due in part to rising energy costs (Griliches, 1988), diversion of capital investment away from productive activities to pollution prevention and worker safety regulations (Crandall, 1980; Denison, 1985, *op. cit.*; Norsworthy, Harper, and Kunze, 1979), and the scrapping of domestic manufacturing capital rendered unprofitable by foreign competition. Unfortunately, there is no strong evidence supporting these hypotheses. Berndt (1980), for example, concluded that energy price variations have not affected productivity to a significant degree because energy costs are a small percentage of a given firm's total costs. Denison (1985, *op. cit.*) also showed that productivity began to decline before energy prices began to increase. Rising energy prices were probably a contributing factor to the continuation of declining productivity, but only to the extent of about .01 percent.

Some researchers have looked to the apparent decrease in the rate of private research and development investment. Griliches (1988) concluded recently, however--as did Dean and Kunze (1988) and Baily and Chakrabarti (1988)--that insufficient R&D was not a factor. Finally, perhaps because so many hypotheses have been promoted and then discarded for lack of empirical support, Baily and Gordon (1988) make the argument that the productivity slowdown is spectral--merely an artifact of mismeasurement. They assert that price indices used to deflate nominal output are highly inaccurate for some industries, especially in services, and that these errors might account for as much as one-fifth of the post-1969 slowdown. They also maintain that these measurement errors have gotten worse since 1973.

Most economists, however, do not believe that the productivity slowdown is illusory, and the search continues for a less equivocal explanation. This may be forthcoming from recent studies of the public sector of the U.S. economy. The evidence adduced has caused academic researchers, policy analysts, and policy makers alike to ask whether recent changes in *the composition of public spending in the U.S.* have made a decisive contribution to the productivity slowdown.

2. Public Capital and the Productivity Slowdown: Point-Counterpoint

a. The Protagonists--Aschauer, Munnell, and Eberts

Even though the make-up of public sector economic activity has long been viewed as fundamental to economic performance in the development of nations and regions (e.g., David, 1969; Fogel, 1964; Hansen, 1965; Royd and Walton, 1972; Hirschman, 1957; Lakshmanan, 1989; Rosenstein-Rodan 1961;

Rostow, 1960; and Sokoloff, 1989), the most widely cited productivity studies (see Solow, 1957; Kendrick, 1980; Jorgenson and Griliches, 1967; Denison, 1979; U.S. Bureau of Labor Statistics, 1983; Jorgenson, Gollop, and Fraumeni, 1987) ignored the potential connection of public capital to productivity. In 1988, David Aschauer of the Federal Reserve Bank of Chicago published findings that showed a strong, and to him, causal relationship between the two.

Aschauer's (1988) point of departure is that if there is an equivalence between alternative methods of public finance, as argued by proponents of the "new classical" school of macroeconomics (e.g., Barro, 1974: 1981; 1988), "it makes sense to concentrate on the *real* aspects of fiscal policy--the temporal pattern of government purchases, changes in distortional tax rates, and . . . *alterations in the composition of public spending* --as potentially powerful channels of influence on the private sector economy." (1987, p. 3, my italics) In this connection, he introduces two hypotheses: first, investments in highways, airports, power plants, and water and sewer systems cause increases in the profitability of private capital; second, increases in profitability cause increases in the economy-wide level of private capital investment. In this and two subsequent articles (1989a, 1989b) he tests several versions of these two hypotheses.

In the first (1988, *op. cit.*), he confirms a positive and statistically significant relationship between public capital investment and the profitability of privately owned capital. He suggests that this implies a strong causal link between changes in the ratio of public-to-private capital and declining rates of profit: "[since 1953,] gross and net rates of return to private capital have been depressed, relative to the level which would have arisen if

the public capital ratio had been steady" (p. 14), and decreases in the rate of public capital investment account for "much of the apparent downward trend" (p. 15) in the profit rate. In his second publication (1989a), he directly tests whether public investment causes an increase in the productivity of capital, and subsequent increases in private sector capital investment. His first model relates public capital inputs and--among other variables--the ratio of public-to-private capital to average productivity of capital in the U.S. (i.e., output per unit of capital). This model shows a statistically significant and strongly positive relationship between private capital productivity and public-to-private capital ratios: a one percent increase in the ratio of public-to-private capital increases output per unit of capital by .39 percent. The second model regresses total factor productivity (TFP) on the ratio of public capital stock to a weighted combination of private labor and capital inputs (where the weights are the rent shares appropriated by labor and capital from flows of public capital services). Aschauer finds that a one percent increase in this ratio--implying a higher proportion of public capital in the production mix--is associated with a .49 percent increase in total factor productivity. This is a huge effect: the elasticity of TFP to increases in the ratio of public capital to privately owned inputs by itself explains almost 60 percent of the slowdown in total factor productivity growth from 1970 to 1986. As we shall see, both of these estimates have become lightning rods for critics of Aschauer's work.

Aschauer's third effort in this series (1989b) tests a corollary of one of his central hypotheses. He asks whether public capital spending causes a "crowding out" of private investment, and how this conditions the positive relationship he found earlier between public investment and the rate of return to private capital. As it turns out, when public capital investments are

first made, they are near-perfect substitutes for private capital: "higher investment by the government sector crowds out private investment nearly one-to-one given the return to capital." (p. 12) Higher accumulations of public capital, however, act as a complement to private capital, "[raising its] productivity . . . , which, in turn, crowds in private investment." (*ibid.*) Overall, then, increased levels of public investment result in less than equal decreases in private investment. The total capital stock (both private and public) rises, and private investment increases in later periods. Not surprisingly, these findings are highly controversial.

In the penultimate article (1989c) in this series, Aschauer compares levels of public capital investment and productivity growth in the G-7 nations. In this case, productivity is measured as labor productivity, i.e., the percentage growth rate of gross domestic product (GDP) per employed person in the Group of Seven industrialized countries from 1966 to 1985. He hypothesizes that a positive relationship exists between labor productivity and ratios of public and private capital investment to GDP. He finds that a one percent increase in the share of GDP devoted to public capital investment is associated with a .44 percentage point rise in labor productivity growth, remarkably close to Aschauer's 1988 (*op. cit.*) estimate of the elasticity of capital productivity to public investment. Additionally, the ratio of government consumption spending to GDP has a marginally significant negative correlation with productivity growth. A one percentage point increase in the share of GDP devoted to government consumption of goods and services is associated with decreases in labor productivity growth of one-tenth of one percent. The policy implications are that "in conjunction with the positive association between productivity growth and public investment .

. . . countries can achieve substantial productivity gains by holding fixed tax revenues and altering the composition of government spending away from public consumption and toward public nonmilitary capital accumulation.” (p. 6) This is a far-reaching recommendation, one that has been criticized and discussed by economic development researchers and practitioners at all levels of government--international, national, and regional.

Aschauer’s major findings, then, are that a positive and statistically significant relationship exists between government expenditures on public capital and

- (1) (gross and net) average rates of return to private capital;
- (2) capital productivity (output per unit of capital);
- (3) total factor productivity; and
- (4) labor productivity (output per worker hour).

Further government consumption spending (i.e., on goods and services) and military spending are significantly and negatively related to these measures of productivity growth. Expenditures on “core” civilian infrastructure--streets and highways, airports, electrical and gas facilities, mass transit, water and sewers--are positively and significantly related to output-to-capital ratios.

As we shall discuss in more detail below, it is the magnitude of these relationships that Aschauer’s critics have found to be controversial, not their existence. Aschauer’s estimate of the elasticity of capital and labor productivity with respect to the ratio of public-to-private capital stocks is

around .4, implying that nearly 60 percent of the drop in total factor productivity growth between 1970 and 1986 can be attributed to declining investment in public capital. Second, he argues that public capital investment acts both as a substitute and a complement for its private counterpart. Initially, it is a near-perfect substitute, crowding out private capital investment at a one-to-one rate. In later periods, however, it raises the marginal productivity of private capital, and thus “crowds in” private investment.

The focus shifts now to the work of two other researchers who have established links between productivity growth and public infrastructure investment. Munnell (1990a, 1990b) begins her follow-up to Aschauer’s work by examining two conclusions from his earlier studies: the correlations between (1) the output-to-capital ratio (i.e., the productivity of capital) and the public-to-private capital stock ratio, and (2) total factor productivity and the stock of nonmilitary public capital. She re-estimates these relationships with labor productivity as the dependent variable, and finds that 1 percent increases in both the stocks of core infrastructure capital and total civilian public capital raise labor productivity by .31 and .39 of a percent. These estimates are almost identical to those of Aschauer’s. Her conclusion, like his, is that the decline in labor productivity has not been due to “some mystical element” in multifactor productivity or technical progress, but rather to declining levels of investment in public infrastructure.

In an article published later in the same year, Munnell (1990b) analyses the impact of public capital investment at the subnational level. She constructs public and private capital stock measures for regions and states.

Using these, she estimates an aggregate production function to see whether and how public capital is related to output (measured as Gross State Product or GSP), private investment, and employment growth. Albeit with smaller elasticities, she reproduces Aschauer's (1989a, *op.cit.*) and her own (1990a, *op.cit.*) earlier results: a one percent increase in state-level public capital stocks is associated with an increase in state GSP of .15 percent. This is roughly half the magnitude of the correlation she found between changes in stocks of private capital and GSP, and less than half that found by Aschauer and Munnell for national public capital stocks (.39).

Munnell also finds that public and private capital are substitute goods. She cautions, however--contrary to Aschauer's assertions that public capital is a one-to-one substitute for private capital investment--that a careful estimation of the actual magnitude of the substitution effect remains to be done. Last, she estimates a regional disequilibrium adjustment model of the type used by Wheat (1986) to gauge the effect of public capital spending by state governments on firm location and state employment growth. She finds very small relationships between employment growth and levels of public capital investment--elasticities on the order of .0001 to .0003, with only marginally significant t-statistics.

Munnell thus confirms the most important of Aschauer's results and extends them to regions and states. Similarly, in a series of articles and public testimony (Duffy-Deno and Eberts, 1989; Eberts, 1986, 1988, 1991; and Eberts and Fogarty, 1987), Randall Eberts and two collaborators have also established a statistical relationship between productivity and public capital in the context of local, i.e., city economies. Eberts' work, however, has a qualitatively

different cast. He and his colleagues move away from the productivity issue, *per se*, to the effects that investment in public infrastructure has on productivity as an intermediate link in the development of regional economies. This grounds their work in the theoretical and empirical literature of regional economic growth and development, in which infrastructure investment has long been assumed to have an important role in the economic performance of places.

In two early research papers, Eberts (1986, 1988) estimates the contribution of public capital stocks to economic performance in 38 SMSAs. First, while the magnitude of this relationship is much smaller than that found by Aschauer and Munnell (about .02), public capital is positively and significantly related to manufacturing output. Public and private capital are also found to be “q-substitutes”. This means that increases in the level of public capital stocks decrease the price of private capital by increasing its relative abundance, which eventually stimulates private capital investment. This finding is in rough consonance with Aschauer’s and Munnell’s.

In a recent discussion of these results, Eberts (1991) describes five channels through which public infrastructure investment affects regional development processes. Three of these move through the supply side of regional economies. First, infrastructure contributes directly to output as an input in private production. This is Aschauer’s and Munnell’s focus, but Eberts points out that this effect depends on the type of infrastructure in which local governments invest, and on a given region’s level of economic development (Hansen, 1965, *op. cit.*). For example, he finds that when the stock of public infrastructure increases relative to private capital and labor

inputs in older metropolitan areas of the Northeast and across the Manufacturing Belt, these additional increments exhibit diminishing--sometimes even negative--marginal returns.

Second, infrastructure investment affects the supply side of regional economies by augmenting the productivity of other production factors. An obvious example of this is when investment in transportation infrastructure increases the speed with which workers can get to their jobs. Third, infrastructure moves through the supply side as an attractor of new firms and households. This is consistent with other studies that showed the presence of the interstate highway system having a positive affect on the location and growth of new firms in emerging urban centers (e.g., Wheat, 1976).

On the demand side of regional economies, infrastructure investment first creates jobs and income, at least in the short term. Here, Eberts estimates that a 10 percent rise in public infrastructure investment leads to a 1 percent increase in per capita income in metropolitan areas. Finally, as a region's economy grows and per capita income increases, its inhabitants demand more public infrastructure and the public service flows it provides. New infrastructure then provides the basis for further regional growth by eliminating transportation and communication bottlenecks.

b. The Antagonists--Schultze, Hulten and Schwab, and Jorgenson

Eberts' conclusions, along with Aschauer's and Munnell's, make up the the core arguments in the case for regarding public infrastructure investment

as an irreducible ingredient in policies aimed at improving national, state, and local economic performance. Recently, however, a group of prominent economists have criticized the evidence upon which they have built their case. The most prominent of these are Charles Schultze of the Brookings Institution, Dale Jorgenson of Harvard University--perhaps the best-known analyst of productivity in the U.S.--and Charles Hulten and Robert Schwab of the University of Maryland.

Schultze (1990) believes that Aschauer's elasticity of output with respect to public capital stocks is much too large. If public capital is a one-for-one substitute for private capital--a finding that he *prima facie* refuses to accept--Aschauer's point estimate of .39 (1989a, *op. cit.*), implies that a \$1 increase in the value of the stock of public capital "adds about as much to productivity as a \$4 increase in the stock of private business capital". (p. 63) He contends that this estimate is inflated by a strong correlation over time between decreases in productivity growth and declines in public capital spending, but does not believe that this constitutes a causal relationship. Schultze admits that investment in public infrastructure can have timely and positive impacts on national productivity, such as that witnessed during the building of the interstate highway system in the 1960s and early 1970s. However, "the kinds of payoffs promised by [Aschauer's] study are not to be had."

Jorgenson (1991) bases his critique of Aschauer's work on his judgment that ". . . this type of macroeconomic analysis yields results that are not sufficiently precise to be useful for policy analysis . . . [because] *the statistical foundations are too fragile to provide credible magnitudes for the key elasticity*" (p. 5, my italics). He raises three issues in support of this view.

First, on the microeconomic side, cost-benefit studies like those reviewed by the Congressional Budget Office (1988) have shown in many cases “modest or even negative payoffs” from infrastructure investment (p. 2). The source of this contradiction, Jorgenson believes, is that unlike private labor and capital, public capital’s contribution to production cannot be measured on the basis of prices generated from market transactions. He asserts that the variation in the estimates of the elasticity of output to public capital--from about .4 in Aschauer and Munnell to .02 in Eberts’s studies--is at least partially a result of the difficulty involved in correctly pricing public infrastructure. The proper context in which to evaluate the effects of public capital, then, is at the level of the individual project, using cost-benefit analysis.

Second, on the macroeconomic side, Jorgenson echoes Schultze’s conviction that Aschauer’s return to public capital is “astonishingly large”. Like Schultze, he believes this is produced by “common trends” between data on aggregate output and infrastructure investment. Private capital investment and labor inputs also show common trends with public capital investment. He cites Hulten and Schwab (*c.f.*, below), who remove this correlation by first-differencing the data to render it non-stationary. They re-estimate Aschauer’s models and find that the relationship between economic performance and public capital almost entirely disappears. Finally, Jorgenson attacks Aschauer’s cross-country comparisons (*op. cit.*, 1989c). He cites a study by Levine and Renelt (1990) where a cross-section analysis of 72 countries shows a positive but statistically insignificant relationship between “government investment in the national product” and economic growth rates. Moreover, the interval estimates for these regression coefficients include both positive and negative values.

Hulten's and Schwab's (1991) critique of Aschauer's findings is similar to Jorgenson's, with some additions. They first echo caveats expressed by Eberts (*op. cit.*) that the contributions of public capital to overall productivity vary from circumstance to circumstance and are thus difficult to measure: "Additional investment in public capital will give a large boost to growth in some situations, but have only a small impact in others. Similarly, some investments will generate significant externalities while others will yield direct benefits." (p. 9) For these reasons, they write, the landmark studies of productivity conducted over the last three decades have ignored public capital as a factor of production.

Hulten and Schwab then use the same data over the same time period to reproduce Aschauer's results. The aspect of Aschauer's results about which they are most bothered--and this troubles Jorgenson, as well--is that they stem from relating the level of public capital stocks to the level of private capital or output in a given period. This gives rise to what Hulten and Schwab believe is a spurious time-series correlation. They compensate by detrending the data and recasting the analysis in terms of whether changes in the level of public capital stock explain changes in output levels. In this model, a 1 percent increase in the stock of public infrastructure raises output per unit of capital by only .03 percent, or 13 times less than Aschauer's original estimate. They maintain, along with Jorgenson, that these results show a "rather fragile" relationship at the aggregate level between infrastructure investment and economic activity.

Finally, Hulten and Schwab make explicit reference to the issue of reverse causation. It is just as likely that increases in output “cause” increases in infrastructure investment, as growth in a given locale causes the demand for new roads, schools and water systems to increase. They admit that there may be important feedback effects that allow growth to continue in expanding regions because of continued infrastructure investment, but Hulten (1979), in an analysis of the direction of causality in this circumstance, found that these effects tend to overstate the causal relation between public capital formation and output growth.

c. Rebuttal and Reply

The substance of the attack mounted by the critics of Aschauer, Munnell, and Eberts, then, is that spurious correlation of time-series data and reverse causation produce the apparently strong relationships between public capital investment and productivity. In four of the five articles authored by Aschauer on this subject, he meets one or both of these objections head-on. With respect to spurious correlation, he notes (1989c, *op. cit.*) that his findings--as is claimed by Schultze, Jorgenson, Hulten, and Schwab--might simply be due to weakened public investment in periods of low productivity and (presumed) reductions in tax revenues, and increased public investment in times of prosperity and revenue growth. He uses several expedients to rule this out.

First--as did Hulten and Schwab--he lags the public and private investment variables by one year, thereby de-trending the data. Second, Aschauer purges the public investment variable of its direct relationship with

the level of economic activity by regressing it on the rate of growth of GDP. When he regresses the residuals from this equation on labor productivity and the other variables from his original model, a one percent rise in the ratio of public nonmilitary net investment to GDP is associated with a .42 percent increase in labor productivity (GDP per employed person). This magnitude is practically identical to that found in the uncorrected model.

In another case, Aschauer (1990) addresses the reverse causation problem as part of his attempt to measure the relationship between rates of state economic growth and levels of investment in highway capacity. Aschauer finds that a one standard deviation increase in the log of state highway capacity induces a .13 percent increase in the growth rate of per capita income. If reverse causation is present, this apparent relationship between economic growth and public capital investment could simply be attributable to high levels of investment in highways by states with high growth rates of per capita income. To rid his estimates of simultaneity bias, and “establish the direction of causation from highway investment to economic growth” (p. 15), he re-estimates the model using Two-Stage Least Squares (TSLS). This results in no change in his estimate of the elasticity of per capita income growth to highway investment.

Aschauer makes one final point regarding the question of reverse causality (1989c, op. cit.). If reverse causality explains the infrastructure investment-economic performance relationship, it must also account for the positive association between public investment expenditures and productivity, and the negative association between public consumption expenditures and productivity. In the first instance, public investment

appears to be a “normal” good, while in the second, public consumption is an “inferior” good. None of the critics have come to grips with this issue.

Munnell (1991a), for her part, directly acknowledges that the “question remains whether public capital investment causes more output or higher levels of output and productivity lead to greater investment” (1991b, pp. 3-4). However, if simultaneity bias does exist, it does not necessarily invalidate her and Aschauer’s results. She cites an analogy: “The more affluent I am, the greater my investment portfolio; but this dependence does not diminish the contribution of the returns on these investments to my future income.” (p. 4)

More rigorously, she reports two regression experiments performed subsequent to her study of state growth and public capital. She confronts the reverse causation question by regressing the average level of output for each of the 48 states from 1970 to 1986 on the average level of private capital, the average labor input, and “public capital at the beginning of the period”. (p. 5, her emphasis). “This procedure forecloses the possibility of any feedback of output growth on public capital investment. Yet public capital shows a large, positive, and statistically significant effect on output”. (*ibid.*)

Second, she notes that pooled cross section analyses such as hers and Aschauer’s may produce upwardly biased coefficients if capital and other unobserved endowments (captured in the catch-all multifactor productivity term in traditional production function analysis) are correlated. Specifically, this will be the case if the variance of initial state endowments of wealth, technology, and managerial capacity is greater than the variance of capital and labor over time. High-endowment states will have more output and more

capital than those with low endowments, other things equal. To avoid this problem, she groups states by their unobserved levels of endowment, using levels of per capita gross state product as a proxy, and estimates separate regressions for high-, medium-, and low-endowment states. The results again show a positive and statistically significant effect on private output in all three groups--.14, .11, and .22, respectively, for low-, medium-, and high-endowment states. (p. 5) While she does not claim that either of these experiments completely dispels the problem of reverse causation, she believes that the relationships she, Aschauer, and Eberts have uncovered are more robust than the critics have asserted. Finally, Eberts discusses the matter of reverse causality. He comments that “. . . even when one takes account of [this] possibility . . . we still find that public infrastructure causes output and is thus a productive input in the production process . . . I have found that . . . particularly in the North, public capital formation precedes, and thus in our terms causes, private capital formation . . . (1991, *op. cit.*)

3. Public Capital and the Productivity Slowdown: Problems for Future Research

What are the unresolved issues that divide the protagonists and antagonists in the infrastructure investment-economic performance debate? Again, the most important objection raised by Schultze, Jorgenson, Hulten, and Schwab is that the elasticities of public capital investment with respect to output per unit of capital and private capital investment are too large and vary too widely between studies. Common trends in the data on aggregate output, private capital, labor inputs, and infrastructure investment produce spurious correlations. Hulten and Schwab take account of these and estimate

an output elasticity coefficient that is roughly thirteen times smaller than that reported by Aschauer and Munnell. Finally, no matter what the strength of the relationships, they cannot be interpreted as revealing the direction of causality. Increases (decreases) in per capita income and productivity could be causing increases (decreases) in infrastructure investment.

Aschauer, Munnell, and Eberts all report regression results that appear to account for at least a portion of the spurious correlation and simultaneity bias in their estimates. They are satisfied that the results continue to demonstrate the existence of a statistically significant and positive relationship between public capital and private sector economic performance. It should be noted that their attempts to deal with the simultaneity and spurious correlation questions are neither acknowledged nor evaluated by their antagonists in the debate.

The foregoing summary suggests three issues that will be critical for future research on infrastructure and productivity. Above and beyond the problems of reverse causation and spurious correlation, the first involves formidable technical complications arising from measurement error, the specification of appropriate functional forms, and the choice of estimating techniques.² How will measurement errors be approached? There are no error-free techniques for estimating the value of the public capital stock, and no matter how large the sample, Ordinary Least Squares (OLS) estimators will not even be asymptotically consistent in the presence of large measurement errors. This issue has not been explicitly faced in any of the studies reviewed.

² This discussion is excerpted entirely from a more technically detailed treatment in Luker and Pinnoi (1991).

Researchers have a greater measure of theoretical guidance and control over the specification of appropriate functional forms, but the room for error is large. In most infrastructure-productivity studies, for instance, Cobb-Douglas production functions (special cases of Constant Elasticity of Substitution [CES] forms) are used because of their computational simplicity. But when three inputs are modeled, as is the case with infrastructure-productivity studies, the CES restriction becomes implausible. Perhaps because of this, Eberts (1986, *op. cit.*) and Costa, *et.al.* (1987) used Variable Elasticity of Substitution (VES) forms such as Translogs and Generalized Leontiefs. Apparently, however, formal misspecification tests were not carried out in any of the studies reviewed.

As for estimating techniques, several investigators (e.g., Eberts, 1986, *op. cit.*; Munnell, 1990, *op. cit.*; Garcia-Mila and McGuire, forthcoming) fitted pooled time series-cross section data for states and SMSAs to aggregate production function technology. Because the assumptions for pooling data are rather strict, formal tests should be conducted to see whether the data is suitable for this procedure. It does not appear that these were performed in any of the studies reviewed. It is also important to note that both Munnell and Garcia-Mila and McGuire used OLS for their time series-cross-section models. OLS produces inefficient estimators and is not recommended for pooled data. One of two methods is generally acceptable: Kmenta's (KM), or the Error Components Model (ECM). Eberts (1986, *op. cit.*) used the KM technique. To date, infrastructure-productivity problems have not been modeled using ECM on pooled data, despite some advantages over KM. When there are a large number of cross-section units, for instance, ECM requires the estimation of fewer auxiliary parameters. Since the error

structure is assumed to be comprised of three additive terms--individual-specific, time-specific, and general error terms--the effects of each can be decomposed, controlled, and estimated. Although ECM assumes away the problems of autocorrelation and heteroskedasticity that the KM method explicitly takes into account, recent advances (Baltagi and Griffin, 1988; Baltagi and Li, 1990; Bhargava et.al., 1982; Mazodier and Trognon, 1978; and Randolph, 1988) in EC modeling provide several ways to test for and circumvent this problem.

The second issue for those wishing to extend the infrastructure-productivity research program involves choosing analytical strategies that directly confront the controversies generated so far. One approach might be to methodically reproduce Aschauer's, Munnell's, and Eberts's results, using their original data sets, functional forms, and variable specifications. This analysis could try to establish which estimating procedures and techniques for correction of bias (from the problems of simultaneity and common time trends in the data) are used by all participants in the debate, which are different, and whether and how these differences produce conflicting sets of evidence.

A second strategy might be to investigate the "systematic and intriguing pattern" seen by Munnell (1991a, p. 14) in estimates of the elasticity of private capital to public investment:

the coefficients at each level of government seem to be very similar across studies. The variation occurs as the unit of observation moves from the Nation to the State to cities. As the geographic focus of the studies narrows, the

estimated impact of public capital becomes smaller
The most obvious explanation is that, because of leakages or spillovers, one cannot capture all the payoffs to an infrastructure investment by looking at a small geographic area. This is only a notion, but since similar studies at similar geographic levels produced similar results, it seems that searching for explanations of the differences between groups may be more productive than the critics' current activity of merely dismissing a growing pile of fairly consistent results. (ibid.)

One other might be to follow Eberts's (op. cit., 1991) suggestion that a regionally focused, simultaneous equations approach be taken to the infrastructure-productivity research program. This might involve the use of hybrid input-output/regional econometric models (Treyz, 1990; Bolton, 1985) to more precisely determine the net effect of infrastructure investment--acting as both a substitute and a complement to private capital and labor--on regional and local capital stocks.

At this juncture, however, the most important problem that researchers must face in the future is to make an *a priori*, explicit, and self-conscious effort to locate the infrastructure-productivity question in an appropriate and consistent theoretical and analytical context. It should be remembered that the initial work on public capital's role in national and regional economic performance was grounded in macroeconomics, a discipline that has traditionally been oriented to studying aggregate indicators of national economic performance. The aggregate production function technology used in most of the studies discussed so far is consistent with that framework. Yet as the debate has progressed and the studies have

proliferated, the dependent variables (e.g., average rate of return to private capital, output per unit of capital, total factor productivity, and labor productivity) have shifted from measures of productivity to output growth: manufacturing output at the SMSA level, growth rates of Gross State Product (GSP), state employment growth, and new firm location. In the latter cases, not only have growth rates of output and employment replaced productivity as dependent variables, but references to the literature of economic history and the theory of economic development have begun to replace those related to macroeconomic theory.

While they overlap in important ways, measures of growth in aggregate output and measures of productivity are, or should be, as analytically distinct as are the categories of economic growth and economic development. Economic growth--which can occur without large increases in productivity--is usually considered a necessary but not a sufficient condition for development. It involves, at its most basic level, increases in the volume of economic activity, without implying anything about the way in which that activity is being carried out. Economic development, on the other hand, is one outcome of growth, but more importantly, economic development implies economic change (Meier, 1989). In this setting, high rates of productivity growth are an indicator of change: society is becoming more efficient at producing goods and services, making possible higher real per capita incomes and rising standards of living. These are associated with higher levels of economic development, and enhanced levels of social and individual well-being for all of society's members.

The foregoing implies that the infrastructure-productivity link might indeed be more fruitfully studied within the theoretical and empirical context of development economics. This aside, what is important is that these distinctions are not merely pedantic. They are crucial in illuminating what might be a better way to frame the entire issue: if public infrastructure investment accelerates productivity change (and this still remains to be conclusively verified), how does this relationship affect economic growth and economic development? It is not unlikely that infrastructure investment could affect both, but Aschauer's (1990, *op. cit.*), Munnell's (1990b, *op. cit.*), and Garcia-Mila and McGuire's (*op. cit.*, forthcoming) replacement of productivity with rates of GSP, per capita income, and employment growth conflates the issues of growth and development.

This abrupt change in the object of inquiry leaves the analytical reader wondering what effects are actually being evaluated. Are they elasticities of state growth rates with respect to "publicly provided inputs to state economies", as, for example, Garcia-Mila and McGuire (p. 1) phrase it? Does this imply a study of the infrastructure-productivity link, or of infrastructure's impact on state growth rates? If the former, GSP growth is a highly imperfect proxy for productivity change. If the latter, it is woefully underspecified: over the last three decades, regional economics has produced dozens of studies of the forces that influence state growth aggregates. A representative sampling includes climate and the strength of state and regional markets (Wheat, 1986, *op. cit.*; Plaut and Pluta, 1983); wage levels, unionization, and tax rates (Carlton, 1983; Cushman, 1987; Bartik, 1983, 1989; Helms, 1985); state economic development incentives and programs (Walker and Greenstreet, 1990; Wasylenko, 1988); and the degree to which a state's

economy is dependent on primary resources (e.g., fossil fuels and agriculture) (Schmidt, 1989). None of the analysts who used GSP as a dependent variable--while purporting to measure infrastructure's relationship to productivity--systematically controlled for these factors. The immediate suspicion, given that most of this research has shown climate, market strength, wages, unions, and taxes exerting overwhelming influence on state growth rates, is that public infrastructure's contribution in models that included these variables would be, on the margin, relatively small.

It is a maxim in economics, however, that the most interesting phenomena happen at the margin. In this instance, if the elasticity of state growth rates is small with respect to infrastructure investment, could this nevertheless be the region where the effects of productivity changes on state growth rates--and, subsequently or simultaneously, on thoughtfully chosen indicators of economic development--might be fruitfully measured? Under this specification, infrastructure investment might have an intermediate effect on development through its enhancement of productivity in cities and sub-national and sub-state regions. This is only a notion, but unfortunately, notions are all we will have until those engaged in this research begin to explain how infrastructure investment might relate to both growth and development in a plausible theoretical sense. It is clear to this writer, at least, that unless a substantial effort is made to clearly delineate the objects of inquiry in this research program, investigators will continue to operate without a common frame of reference. Without this, there can be no real understanding of which variables, functional forms, and estimation techniques are appropriate, and the task of evaluating conflicting claims about the benefits of infrastructure investment will be largely inconclusive.

References

Aschauer, David Alan. (1988) "Government Spending and the Falling Rate of Profit", *Economic Perspectives*, v. 12, pp. 11-17.

_____. (1989a) "Is Public Expenditure Productive?", *Journal of Monetary Economics*, v. 23, pp. 177-200.

_____. (1989b) "Does Public Capital Crowd out Private Capital?", *Journal of Monetary Economics*, v. 24, pp. 171-188.

_____. (1989c) "Public Investment and Productivity Growth in the Group of Seven", *Economic Perspectives*, v. 13, no. 5, pp. 17-25.

_____. (1990) "Highway Capacity and Economic Growth", *Economic Perspectives*, v. 14, no. 2, pp. 14-24.

Baily, Martin Neil (1986) "What Has Happened to Productivity Growth?", *Science*, vol. 234, October, pp. 443-451.

_____ and Alok K. Chakrabarti (1988) *Innovation and the Productivity Crisis* (Washington, D.C.: The Brookings Institution)

_____ and Robert Gordon (1988) "The Productivity Slowdown, Measurement Issues, and the Explosion of Computer Power." In *Brookings Papers on Economic Activity*, vol. 19, no. 2, pp. 347-420.

Baltagi, B.H. (1981), "Pooling: An Experimental Study of Alternative Testing and Estimation Procedures in a Two-Way Error Components Model," *Journal of Econometrics*, 17, pp.21-49.

_____ and J.M. Griffin (1988), "A Generalized Error Component Model with Heteroscedastic Disturbances, *International Economic Review*, 29, pp. 745-753.

_____ Y. Chang, and Qi Li (1990), "Monte Carlo Results on Several New and Existing Tests for the Error Component Model," Working Paper, Department of Economics, Texas A&M University.

Bartik, Timothy J. (1985) "Business Location Decisions in the United States: Estimates of the Effects of Unionization, Taxes, and Other Characteristics of States", *The Journal of Business and Economic Statistics* , v. 3, no. 1, pp. 14-22.

_____. (1989) "Small Business Start-Ups in the United States: Estimates of the Effects of Characteristics of States", *Southern Economic Journal*, v. 55, no. 4, pp. 1004-1018.

Bhargava, A. L. Franzini and W. Narendranathan (1982), "Serial Correlation and the Fixed Effects Model," *Review of Economic Studies*, 49, pp. 533-549.

Barro, Robert J. (1981) "Output Effects of Government Purchases" *Journal of Political Economy*, vol. 89, pp. 1086-1121

_____. (1988) "The neoclassical approach to fiscal policy",
Working Paper (University of Rochester, Rochester, NY)

_____. (1989) "A Cross-Country Study of Growth, Saving, and
Government." NBER Working Paper No. 2855, February.

Baumol, William J., Sue Anne Batey Blackman, and Edward N. Wolff.
(1989) *Productivity and American Leadership: The Long View* (Cambridge
and London: The MIT Press)

Berndt, Ernest (1980) "Energy Price Increases and the Productivity
Slowdown in United States Manufacturing", in *The Decline in Productivity
Growth*, Federal Reserve Bank of Boston Conference Series no. 22, pp. 60-89.

Bolton, Roger (1985) "Regional Econometric Models", *Journal of
Regional Science*, vol. 25, no. 4, pp. 495-520.

Carlton, Dennis (1983) "the Location and Employment Choices of New
Firms: An Econometric Model with Discrete and Continuous Endogenous
Variables", *The Review of Economics and Statistics*, v. 65, no. 3, pp. 440-449.

Congressional Budget Office (1988) *New Directions for the Nation's
Public Works* (Washington, D.C.: USGPO)

Costa, Jose da Silva, Richard W. Ellson, and, Randolph C. Martin
(1987), "Public Capital, Regional Output, and Development: Some Empirical
Evidence," *Journal of Regional Science*, 27(3), pp. 419-37.

Crandall, Robert (1980) "Regulation and Productivity Growth", in *The Decline in Productivity Growth*, Federal Reserve Bank of Boston Conference Series no. 22, pp. 93-111.

Cushman, David O. (1987) "The Effects of Real Wages and Labor Productivity on Foreign Direct Investment", *Southern Economic Journal*, v. 54, no. 1, pp. 174-185.

David, Paul (1969) "Transport Innovation and Economic Growth", *Economic History Review*, vol. 3, no. 32 (December)

Darby, Michael (1981) "The U.S. Productivity Slowdown: A Case of Statistical Myopia", *the American Economic Review*, vol. 74, no. 3, pp. 301-322.

_____ (1984) *Labor Force, Employment, and Productivity in Historical Perspective* (Los Angeles: UCLA Institute of Industrial Relations)

Dean, Edwin and Kent Kunze (1988) "Recent Changes in the Growth of U.S. Multifactor Productivity", *Monthly Labor Review*, May, pp. 14-22.

Denison, Edward (1974) *Accounting for United States Economic Growth, 1929-1969* (Washington, D.C.: The Brookings Institution)

_____ (1979) *Accounting for Slower Economic Growth: The United States in the 1970s* (Washington, D.C.: The Brookings Institution)

_____ (1985) *Trends in American Economic Growth: 1929-1982* (Washington, D.C.: The Brookings Institution)

Deno, Kevin T. (1988) "The Effect of Public Capital on U.S. Manufacturing Activity: 1970 to 1978", *Southern Economic Journal*, v. 55, no. 2 (October 1988), pp. 400-411.

Duffy-Deno, Kevin T. and Randall Eberts (1989) "Public Infrastructure and Regional Economic Development: A Simultaneous Equations Approach", Federal Reserve Bank of Cleveland, Working Paper No. 8909.

Eberts, Randall (1986) "Estimating the Contribution of Urban Public Infrastructure to Regional Growth", Federal Reserve Bank of Cleveland, Working Paper No. 8610.

_____ (1988) "Estimating the Contribution of Public Capital Stock to Metropolitan Manufacturing Production" Federal Reserve Bank of Cleveland, Working Paper (mimeo)

_____ (1991) "Infrastructure, Productivity, and Economic Growth", testimony before a hearing of the Subcommittee on Water Resources, Transportation, and Infrastructure of the Committee on Environment and Public Works, United State Senate, February 5, 1991.

Eberts, Randall and Michael S. Fogarty (1987) "Estimating the Relationship Between Local Public and Private Investment", Federal Reserve Bank of Cleveland, Working Paper No. 8703.

Fraumeni, Barbara M. and Dale W. Jorgenson (1981) "Capital Formation and U.S. Productivity Growth, 1948-1976", in *Productivity Analysis: A Range of Perspectives*, Ali Dogramaci, ed. (Norwell, MA: Kluwer-Nijhoff)

Fogel, Robert W. (1964) *Railroads and American Economic Growth: Essays in American Econometric History* (Baltimore: The Johns Hopkins Press)

Freeman, R.B. (1976) *The Overeducated American* (San Diego, CA: Academic Press)

Garcia-Mila, Teresa and Theresa McGuire (forthcoming) "The Contribution of Publicly Provide Inputs to States' Economies" *Regional Science and Urban Economics*

Griliches, Zvi (1988) "Productivity Puzzles and R&D: Another Non-Explanation", *The Journal of Economic Perspectives*, vol. 2, no. 4, pp. 9-22.

Hansen, Niles (1965) "Unbalanced Growth and Regional Development", *Western Economic Journal*, vol. IV, no. 1, pp. 3-14.

Helms, L. Jay (1985) "The Effect of State and Local Taxes on Economic Growth: A Time-Series Cross-Section Approach", *Review of Economics and Statistics*, v. 67 pp. 574-582.

Hirschman, Albert O. (1957) *The Strategy of Economic Development*
(New Haven: Yale University Press)

Hudson, E.A. and D. W. Jorgenson (1974) "U.S. Energy Policy and
Economic Growth" *Bell Journal of Economic Management Science*, Autumn,
pp. 416-514.

Hulten, Charles R. and Robert M. Schwab (1991) "Is There Too Little
Public Capital? Infrastructure and Economic Growth" Paper presented at the
conference on "Infrastructure Needs and Policy Options for the Nineties",
American Enterprise Institute, Washington, D.C., February 4, 1991. (mimeo)

Hulten, Charles R. (1979) "On the 'Importance' of Productivity
Change", *The American Economic Review*, vol. 69, March.

Holtz-Eakin, Douglas (1988) "Private Output, Government Capital, and
the Infrastructure 'Crisis'" Columbia University Department of Economics,
Discussion Paper No. 394

Jorgenson, Dale W. (1988) "Productivity and Postwar U.S. Economic
Growth", *The Journal of Economic Perspectives*, vol. 2, no. 4, pp. 23-42.

_____. and Zvi Griliches (1967) "The Explanation of
Productivity Change", *Review of Economic Studies*, July.

_____. , Frank Gollop, and Barbara Fraumeni *Productivity
and U.S. Economic Growth* (Cambridge, MA: Harvard University Press)

_____ (1991) "Fragile Statistical Foundations: The Macroeconomics of Public Infrastructure Investment" Paper presented at the conference on "Infrastructure Needs and Policy Options for the Nineties", American Enterprise Institute, Washington, D.C., February 4, 1991. (mimeo)

Kendrick, John W. (1980) "Productivity Trends in the United States", in *Lagging Productivity Growth: Causes and Remedies*, Shlomo Maital and Noah M. Meltz, eds. (Cambridge, MA: Ballinger Publishing Co.)

Lakshmanan, T.R. (1989) "Infrastructure and Economic Transformation", in *Advances in Spatial Theory and Dynamics*, A.E. Anderson, et. al., eds. (Amsterdam and New York: Elsevier Science Publishers)

Levine, Ross and David Renelt (1990) "A Sensitivity Analysis of Cross-Country Growth Regressions" Washington, D. C., The World Bank, August.

Luker, Jr., William A. and Nat Pinnoi (1991) "A Critical Review of Recent Research on Public Infrastructure and U.S. Economic Performance", paper presented at the Annual Meetings of the Western Economics Association, Seattle, WA, July 5, 1991. (mimeo)

Mazodier P. and A. Trognon (1978), "Heteroskedasticity and Stratification in Error Components Models," *Annales de l'INSEE*, 30-31, pp. 451-82.

Meier, Gerald M. (1989) "What Do We Mean by Economic Development?", in *Leading Issues in Economic Development*, Gerald M. Meier, ed. (Oxford: Oxford University Press)

Munnell, Alicia (1990a) "Why Has Productivity Growth Declined? Productivity and Public Investment" *New England Economic Review*, Jan/Feb 1990, pp. 3-22

_____. (1990b) "How Does Public Infrastructure Affect Regional Economic Performance?" *New England Economic Review*, Sept./Oct. 1990, pp. 11-33

_____. (1991a) "Infrastructure, Productivity, and Economic Growth", testimony before a hearing of the Subcommittee on Water Resources, Transportation, and Infrastructure of the Committee on Environment and Public Works, United State Senate, February 5, 1991.

_____. (1991b) "Comments on 'Is There Too Little Public Capital? Infrastructure and Economic Growth'" by Charles Hulten and Robert Schwab. Paper presented at the conference on "Infrastructure Needs and Policy Options for the Nineties", American Enterprise Institute, Washington, D.C., February 4, 1991. (mimeo)

Norsworthy, J.R., Michael Harper, and Kent Kunze (1979) "The Slowdown in Productivity Growth: Analysis of Some Contributing Factors" *Brookings Papers on Economic Activity*, vol. 2, pp. 387-421.

Perry, George L. (1971) "Labor Force Structure, Potential Output, and Productivity" *Brookings Papers on Economic Activity*, no. 3.

Plaut, Thomas and Joseph Pluta (1983) "Business Climate, Taxes and Expenditures, and State Industrial Growth in the United States", *Southern Economic Journal*, v. 50, no. 1, pp. 99-119.

Randolph, W.C. (1988), "A Transformation for Heteroscedastic Error Components Regression Models," *Economic Letters*, 27, pp. 349-54.

Rosenstein-Rodan, Paul (1961) "Notes on the Theory of the Big Push", in *Economic Development for Latin America*, Howard Ellis, ed. (New York: St. Martin's Press)

Rostow, W.W. (1960) *The Stages of Economic Growth* (Cambridge: Cambridge University Press)

Royd, J. Hayden and Gary Walton (1972) "Social Savings from Rail Passenger Services", *Explorations in Economic History*, Spring.

Schmidt, Ronald H. (1989) "Natural Resources and Economic Growth" *Economic Review of the Federal Reserve Bank of San Francisco* (January/February), pp. 18-28.

Sokoloff, Ken (1989) "Inventive activity in early industrial America: Evidence from patent records, 1790-1846", *Journal of Economic History*, vol. 48, pp. 813-850.

Solow, Robert (1957) "Technical Change and the Aggregate Production Function", *The Review of Economics and Statistics*, vol. 39, no. 3 (August), pp. 312-320.

Smith, James P. and Finis R. Welch (1978) "The Overeducated American: A Review Article" (Santa Monica, CA: The Rand Corporation)

Treyz, George, Dan S. Rickman, and Gang Shao (1991) "The REMI Economic-Demographic Forecasting and Simulation Model", Working Paper, Regional Economic Models, Inc., Amherst, MA

U. S. Bureau of Labor Statistics (1983) "Trends in Multifactor Productivity, 1948-1981" (Washington, D.C.: USGPO)

Walker, Robert and David Greenstreet (1990) "Regional Development Policy, Location, and Job Growth in Manufacturing: A Survey-Based, Econometric Analysis of Incentive and Assistance Programs", paper presented at the Annual Meetings of the Southern Regional Science Association, March, 1990.

Wasylenko, Michael (1988) "Empirical Evidence of Inter-Regional Business Location Decisions and the Role of Fiscal Incentives in Economic Development", paper presented at the Symposium on Industry Location and Public Policy, University of Tennessee, Knoxville, Tennessee.

Wheat, Leonard (1986) "U.S. Manufacturing Employment Growth, 1963-1977: How the South and West Grew", *Journal of Regional Science*, vol. 20, no. 4, pp. 635-660.

_____. (1976) *Urban Growth in the Nonmetropolitan South* (Lexington, MA: Lexington Books)

Williamson, Jeffrey G. (1991) "Productivity and American Leadership: A Review Article", *Journal of Economic Literature*, vol. XXIX (March), pp. 51-68.