Why Is Infrastructure Important?

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As the decade of the 1990s begins, new challenges present themselves to the citizenry of the United States. Among the most important are concerns about the environment, economic productivity, and international competitiveness, and a rearrangement of standing strategic military relationships. Our future quality of life, economic prosperity, and security depend crucially on how we choose to meet these new challenges.

The apparent failure of the communist economic system and the associated relaxation of Cold War tensions offer the potential for a significant reallocation of the nation's resources from military to other uses. A crucial question then arises whether these resources should be channeled to the private sector, effecting overall government expenditure reduction, or kept within the public sector, thereby inducing an alteration in the composition of government spending.

The first direction, expenditure reduction, certainly has merit to a broad class of individuals. Many would point to the fact that total federal government outlays, expressed relative to gross national product, rose from 14.8 percent in 1950 to 21.6 percent in 1980 and, in 1989, to 21.8 percent. Others would point to the persistence of federal budget deficits. To both groups, expenditure reduction would be of benefit to economic performance, either by reducing the overall scale of government activity in the economy or by allowing a reduction in interest rates and an expansion in domestic investment activity.

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But the second direction, expenditure reorientation, may also have merit. It could well be the case that quality of life and economic performance would be best served by retaining the resources within the public sector and expanding expenditure in certain critical areas. One candidate area is infrastructure, the public stock of social and economic overhead capital. Indeed, it has been claimed in the popular press that "it's hard to escape America's crumbling infrastructure" and that "even though the deterioration of U.S. highways, bridges, airports, harbors, sewage systems, and other building blocks of the economy has been exhaustively documented in recent years, there has been scant progress" in addressing the postulated need to renew the public capital stock (*Industry Week*, May 21, 1990).

This paper reviews some of the ways in which infrastructure may be "important," and, by implication, considers the validity of any case to increase investment in infrastructure facilities. The first section discusses linkages between infrastructure and overall quality of life, while the second section looks at the potential importance of public infrastructure spending to the aggregate economy. The third section concludes the paper.

Infrastructure and Quality of Life

In the early 1960s, "quality of life" emerged as a central focus of public policy. The persistence of such social problems as urban and regional poverty, poor race relations, inadequate health care, and insufficient housing, as well as a growing recognition of environmental degradation, motivated social scientists to search for improved methods of assessing social trends and appropriate institutional responses.

One reflection of this research endeavor was the attempt by a number of economists to extend the national product accounts to include measurements of social as well as economic performance.[1] A second reflection was the "social indicator movement" begun by Bauer (1966) to provide a set of indicators of the current status of the quality of life in the United States, social indicators that were analogous to the existing set of economic indicators. The number of social indicator studies rose rapidly from the publication of Bauer's book, and beginning in 1972 the United States government published a serial entitled *Social Indicators*.[2]

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[1] See, for example, Juster (1972).
[2] The serial was discontinued in 1983.

One interesting outgrowth of this social indicator movement was the heroic attempt by Terleckyj (1975) to devise an "analytical framework for systematically assessing existing possibilities for social change measured by a set of quantitative indicators" with a focus on the "possible sources of change in specific social conditions that represent major aspects of the quality of life." His approach involved the consideration of various policy actions and their ultimate impact on social concerns, including health, public safety, and education. The elements of the list of social concerns each required major public activities (such as the provision of infrastructure) as well as private activities. The effects of the activities were measured by quantitative responses of indicators, such as average life expectancy (yielding information about the effects on health), number of violent crimes per 100,000 population (public safety), and the number of individuals completing college (education).

Unfortunately, Terleckyj's framework cannot be readily applied today to assess the potential gains to the quality of life from public infrastructure improvements. Much has changed since 1975 in terms of the role of various infrastructure services as an "input" into certain activities, the costs of those and related private services, and underlying resource constraints. It should also be pointed out that many of the projections in Terleckyj's framework were based on rather questionable (though understandable) assumptions and involved little direct empirical knowledge and, correspondingly, much judgment.

Instead, the best that can be accomplished here is to adapt Terleckyj's conceptual framework to trace out a number of the linkages between infrastructure investments across functional categories and various aspects of life quality, such as health, safety, recreation, and general aesthetics; economic opportunity; and leisure. The hope is that the major linkages between infrastructure and quality of life are captured. The exercise cannot aspire to be quantitative.

Table 1 indicates some of the more important linkages between infrastructure and quality of life. To focus on the potential gains from infrastructure investment, the set of candidate projects is limited, at least conceptually, to those that yield a Pareto improvement along the various quality-of-life dimensions. For instance, the construction of a freeway may reduce congestion and thereby support better health (improved air quality due to less smog), greater safety (fewer accidents), recreational activities (better access), economic opportunity (improved access to suburban jobs), and leisure (more discretionary time). But the particular highway construction may also involve disamenities to certain segments of the population and, by diverting commuters from mass transportation to automobiles, may increase air pollution. In the table, the investment is interpreted broadly to include the measures necessary to forestall any negative impacts—in the freeway example, the building

Table 1
Infrastructure and Quality of Life

Infrastructure Investment	Attributes of human habitat					
	Health	Safety	Recreation	Aesthetics	Economic Opportunity	Leisure
<u>Transportation</u>						
Highways	Increased air quality	Reduced accidents	Increased access		Increased employment Increased access	Increased discretionary time
Mass Transit	Increased air quality	Reduced accidents	Increased access		Increased employment Increased access	Increased discretionary time
Airport		Reduced accidents	Increased access		Increased employment	Increased discretionary time
<u>Waste Management</u>						
Municipal waste facilities	Reduced viral infection, etc.			Reduced odors, litter, and turbidity	Increased employment	
Solid waste facilities	Reduced toxicity			Reduced odor	Increased employment	
<u>Law Enforcement</u>						
Police stations, courts, prisons	Reduced drug use	Reduced crime			Increased employment	
<u>Fire Stations</u>		Reduced risk				
<u>Hospitals</u>	Increased access				Increased employment	

Table 2
Ability of Assessed River/Stream Miles and Lake Acres to Support Designated Use, 1984

Percent	Rivers and Streams	Lakes
Supporting	73	78
Partially supporting	14	16
Not supporting	6	5
Unknown	7	1

Source: EPA (1985).

of fences and landscaping to eliminate negative aesthetic effects as well as the granting of subsidies to maintain mass transit ridership.

At present, concern is widespread about whether existing and projected infrastructure facilities can adequately support quality of life requirements and improvements in the ways indicated in Table 1. Since apprehension appears to be greatest in the areas of the environment and transportation, the following discussion focuses on water quality, solid waste disposal, mobility needs, and traffic congestion.

Water Quality: Health and Aesthetics

The construction grants program associated with the Clean Water Act of 1972 spurred the expenditure of over $40 billion on the building and updating of sewage treatment facilities, seen to have had "significant positive impacts on the Nation's water quality." For example, in Virginia the annual flow of wastewater rose by 33 percent between 1976 and 1983, yet a significant simultaneous reduction in pollution occurred, as oxygen-dissolving organic wastes fell by 22 percent. In North Carolina, the extent of degraded stream mileage was reduced from 3,000 miles to 1,000 miles within the same period (U.S. Department of the Interior, Environmental Protection Agency (EPA) 1985).

Despite this and other evidence of progress, inadequate municipal wastewater treatment remains a significant problem in many areas of the country. Many streams and lakes are incapable of supporting a variety of their designated commercial or recreational uses. As Table 2 shows, in 1984, 6 percent of the evaluated river and stream mileage and 5 percent of the lake acreage in the United States were deemed unfit to support designated use; another 14 percent and 16 percent, respectively, were capable only of partial support of assigned uses. Table 3 indicates the likely sources of the use impairment of streams, rivers, and lakes in 1984. As can be seen, municipal point sources accounted for nearly

Table 3
Sources of Use Impairment of Rivers, Streams, and Lakes, 1984

Percent	Rivers and Streams	Lakes
Point Source		
Municipal	11	31
Industrial	36	10
Nonpoint Source	30	52
Natural	2	4
Other	21	3

Source: EPA (1985).

one-third of the total use impairment for lakes and a non-negligible fraction of use impairment for rivers. In the same year, elevated toxicity levels were reported in the waters of 37 states, and municipal facilities were found to be the source of 9 percent of the discovered toxics (arising largely as the result of the receipt and inadequate subsequent processing of untreated industrial wastes). According to the EPA, "many municipalities have yet to construct sewage treatment facilities that can meet permit requirements." In other municipalities, particularly in the Northeast, storm and sanitary sewers are combined in the same system and result in waste discharges during periods of heavy rainfall (combined sewer overflows). Connecticut reported that combined sewer outflows (CSOs) are the state's "primary sewer system infrastructure problem," and Maine indicated that "progress in reducing the impacts of CSOs will be slow in many communities because of the great expenses involved in upgrading sewage collection systems and because of cutbacks in the construction grants program" (EPA 1985).

Solid Wastes: Health and Aesthetics

The ability of municipalities to deal with garbage is an escalating problem. In 1960, the solid waste generated in the United States amounted to 2.65 pounds per person per day, while by 1986 it had reached 3.58 pounds per person per day. This is over one pound per person per day more than is produced in West Germany, a country that by most measures is at an equal state of industrial development. Solid wastes in the United States amounted to 87.5 million tons per year in 1960 and 157.7 million tons per year in 1986. The latter amount would be sufficient to fill a "convoy of 10-ton garbage trucks, 145,000 miles long, which is over half the distance between the earth and the moon" (Executive Office of the President, Council on Environmental Quality 1989).

At the same time that garbage is being generated at unprecedented rates, the number of facilities capable of handling the waste is shrinking. In 1978, approximately 20,000 municipal landfills were operating in the United States; by 1986, fewer than 6,000. The Council on Environmental Quality forecasts that by 1993 about 2,000 of the remaining landfills will be at capacity and "many more will be closed due to inadequate safety or environmental practices as new standards take effect. Some states such as Florida, Massachusetts, New Hampshire and New Jersey are expecting to close about all of their currently operating landfills in the next few years."

Furthermore, a significant fraction of existing landfill facilities do not meet federal and state environmental standards. Only 25 percent of the facilities monitor groundwater for possible pollution and more than 50 percent make no attempt to control for water pollution caused by rainwater runoff from the landfill site (EPA 1986). An EPA evaluation of case studies of 163 municipal solid waste landfills disclosed that 146 were contaminating groundwater, 73 were contaminating surface waters, and at several sites even drinking water was found to be contaminated (EPA 1988a). The EPA has reported to Congress that fully 22 percent of the sites on the Superfund National Priorities List are municipal landfills. These statistics "suggest that a large portion of landfill municipal solid waste ends up in places where it might contaminate groundwater." In addition to the health risks posed by the landfills, aesthetic problems are common; about 875 of the nation's 5200 operating municipal landfills have been cited in recent years for high odor levels (Executive Office of the President, Council on Environmental Quality 1989).

In the future, the closing down of landfills will require different techniques for managing solid wastes: source reduction, through improved product design and manufacture to reduce the quantity and toxicity of waste at the end of a product's useful life; heightened emphasis on recycling; and increased incineration. Dramatic examples show the effectiveness of the first two of these options: in the past twenty years the weight in aluminum beverage cans has been reduced by 20 percent, and certain municipalities, such as Wilton, New Hampshire, have been able to recycle in excess of 40 percent (by weight) of total solid waste at a profit (Council on Environmental Quality 1989). In 1988, 134 municipal incinerators were operating, with 22 more under construction and 9 in final planning stages. The main difficulty with incineration appears to be the generated fly and bottom ash; in 1986, incinerators were producing in excess of three million tons of potentially hazardous ash a year.

Mobility Needs: Economic Opportunity

A key function of the nation's public mass transportation system is to provide basic mobility for those who are unable to utilize automobile transportation—the "transit dependent." According to the Urban Mass Transit Administration (1988b), "an improved quality of life requires increased mobility and access; this is particularly true for the transportation disadvantaged and those who are disabled and elderly." Indeed, disabled citizens cite a lack of appropriate transportation as the "chief barrier to getting jobs and being fully productive members of their communities" (U.S. Department of Transportation 1990).

Respondents to the Census Bureau's *American Housing Survey* (1973 and 1983) typically place public transportation at the top of the list of "inadequate neighborhood services." Also, the apparent trend in attitudes is increasingly unfavorable; whereas 36.1 percent of owner-occupied households and 24.3 percent of renter-occupied households reported in 1973 that public transportation was inadequate to meet their needs, 51.1 and 32.9 percent, respectively, so reported by 1983.

In addition, many communities, such as Chicago and Philadelphia, cite a growing transportation problem due to changing geographical commuting patterns. Traditional commuting to the central business district from the suburbs continues to place heavy demands on the transit system, but in many localities job opportunities in the suburbs are left unexploited because of lack of transportation from the city core. In the words of an Argonne National Laboratory report,

> public policy should recognize that reverse [commuting] service has been particularly poor and, generally speaking, ridership has been limited to those with no other transportation alternatives. These "captive riders" are disproportionately minorities, older workers, women, and the working poor. Few would deny that these riders need some basic level of service. All too often, however, that need goes unmet.

Congestion: Leisure

Usage of the nation's surface and air transportation network has grown tremendously in the past three decades. On the roads, travel by occupants of passenger vehicles has risen from 592 million miles in 1960 to 1,372 million miles in 1987; during the same period, motor vehicle freight carriage has climbed at a 4.5 percent annual rate, from 201 to 674 billion ton-miles. On the airways, growth in passenger travel and freight carriage has been more rapid, at 8.6 percent per year for both categories of air network use (Central Intelligence Agency 1989; U.S. Department of Transportation, Federal Highway Administration 1980 and 1987.)

One undesirable effect of increased usage of the country's transpor-

Table 4
Forecast of Urban Highway Delays

Forecast	Urban Freeway		Signalized Arterial	
	Vehicle Hours (Millions)	% Change	Vehicle Hours (Millions)	% Change
1985 Delay	722	—	146	—
2005 Delay	3869	+436	496	+241

Source: U.S. Department of Transportation, Federal Highway Administration (1987).

tation facilities has been surface and air traffic congestion. The General Accounting Office (1989) reports that "traffic congestion is an escalating transportation problem in this country. An increasing proportion of both rural and urban interstate freeways are operating under crowded conditions." Indeed, while in 1980 only 32 percent of urban interstates were in a congested state, by 1987 this statistic had pressed upward to 46 percent (65 percent at peak hour time periods) (U.S. Federal Highway Administration 1980 and 1987). A survey of participants in a national transportation outreach program discovered that 80 percent of the 20,000 respondents felt that traffic congestion was a problem in their communities (*Beyond Gridlock* 1988). In Atlanta and San Francisco, opinion polls indicate that traffic congestion has now eclipsed crime, unemployment, and air pollution as the highest priority public policy issue by a two-to-one margin (U.S. Department of Transportation 1989). And, according to the Department of Transportation (1990), the 21 primary airports that handle 80 percent of the nation's air travel are considered "seriously congested," experiencing 20,000 hours of flight delays annually.

Without doubt, the congestion problem will become increasingly severe in coming years. Table 4 shows the results of a Federal Highway Administration forecast of urban highway delays in the year 2005 if the highway system is not expanded to meet projected usage. Urban freeway delays are projected to reach nearly four billion hours annually—a 436 percent increase from 1985—and urban arterial delays are expected to climb to about one-half billion hours—a 241 percent increase. The Federal Aviation Administration forecasts that air passenger enplanements will climb at a 4.3 percent annual rate between 1989 and 2001, from 485 million to 815 million (U.S. Department of Transportation, Federal Aviation Administration 1989).

In the future, dealing with highway traffic congestion will require a many-faceted strategy. Increased capacity through construction of new routes, adding lanes to existing routes, and reconstruction will be one such facet, but others will be necessary as well. Transportation system management will need improvement so as to maximize the effective supply of existing capacity (for example, traffic signal coordination) and to lower traffic demand (by such programs as ride-sharing). The research, development, and implementation of advanced technologies utilizing computers and telecommunications offer great hope for reducing congestion; in the extreme, the "goal is to make roads so 'smart' that they can guide 'intelligent' vehicles without direction from the drivers" (General Accounting Office 1989). Significantly, all major automotive companies are currently developing electronic navigation systems.

The discussion above has only touched upon the many ways in which the current and future status of the nation's infrastructure may add to, or detract from, overall quality of life. Numerous additional cases can be found where quality of life has been or will soon be improved—or eroded—as a result of infrastructure capabilities. For example, the reported level of crimes against persons and households has abated, at least as measured by victimization rates, partly as "a result of increased incapacitation of larger numbers of career criminals"; between 1980 and 1987, the federal prison population rose by 83 percent while the percentage of the prison population granted paroles fell from 70 percent to 63 percent (U.S. Parole Commission 1989). Yet the "current level of prison overcrowding coupled with substantial growth in the future prison population" is likely to "create a crisis of major proportions in the Federal criminal justice system" unless added capacity is forthcoming. Similarly, the nation's highway system has become safer as a result of a variety of safety improvement projects carried out over the period from 1974 to 1987; as one example, during that time rail-highway crossing fatalities have been reduced by 89 percent (U.S. Department of Transportation 1989). Yet in 1989 nearly one-half of the nation's rural bridges were found to be "structurally deficient or functionally obsolete," with the potential for causing future injury and loss of life (*New York Times*, September 27, 1989).

In many other cases, rapid economic, demographic, and social change will strain the ability of available infrastructure facilities to maintain an adequate quality of life in the United States. Persistent water quality problems due to inadequate waste treatment; solid waste disposal difficulties because of the shrinkage of landfill capacity; heightened crime resulting from prison overcrowding and early release of criminals; additional loss of leisure time due to traffic congestion—all are to be anticipated unless more attention is directed to the nation's infrastructure requirements.

Infrastructure and the Economy

Quality of life issues will thus remain a central focus of infrastructure policy. During the 1980s, however, the adequacy of the stock of infrastructure has increasingly been called into question. The final report of the National Council on Public Works Improvement (1988) stresses the importance of infrastructure to the economy:

> The quality of a nation's infrastructure is a critical index of its economic vitality. Reliable transportation, clean water, and safe deposit of wastes are basic elements of a civilized society and a productive economy. Their absence or failure introduces a major obstacle to growth and competitiveness.

The potential importance of trends in infrastructure spending to the macroeconomy can be discussed by utilizing the framework in Arrow and Kurz (1970) and in Aschauer and Greenwood (1985). These authors expand on the standard neoclassical production function, expressed in labor-intensive form, to include the public stock of infrastructure capital:

$$y = f(k, k^g)$$

where y = private sector output, k = private capital, and k^g = public infrastructure capital (all expressed relative to employment).[3]

A clear implication of including public capital in the private production technology is that it may play a direct role in promoting private sector productivity. Indeed, some, albeit limited, empirical evidence suggests that the public capital stock is an important factor of production in the aggregate production technology. Aschauer (1989a) presents time series evidence for the post-World War II period in the United States that a "core infrastructure" of streets and highways, mass transit, airports, water and sewer systems, and electrical and gas facilities bears a substantially positive and statistically significant relationship to both labor and multifactor productivity. Munnell (1990) adjusts the standard U.S. Bureau of Labor Statistics (BLS) measure of labor input to account

[3] Here, the services of the private and public capital stock are assumed to be proportional to the existing stocks and the services of public capital are assumed to be offered to the private sector free of charge. While user charges are applied for a variety of government infrastructure services, such charges are typically less than the total cost of providing such services. For example, in 1987 state highway user tax revenues and tolls equaled $26.5 billion, while total highway disbursements equaled $46.3 billion (*Highway Statistics 1987*). In 1986, of the total federal airport and airway spending of $4 billion, $2.7 billion was funded from general revenues (Congressional Budget Office 1988). Hence, to a significant extent, public infrastructure should be considered an uncompensated intermediate factor of production in the private production function.

for changes in the age/sex composition of the labor force, updates the sample period to 1987, and obtains similarly strong results for the importance of public capital in private sector production. Munnell also computes adjusted measures of multifactor productivity growth and finds that after accounting for changes in the quality of the labor force and for changes in the growth rate of the core infrastructure capital stock, the fall-off in multifactor productivity growth during the 1970s and 1980s relative to the 1950s and 1960s is "much more in line with expectations" and that "much of the drop in published multifactor productivity numbers may reflect the omission of public capital from the calculation of inputs rather than a decline in technological innovation (p. 19)."

Aschauer (1989c) employs cross-country data for the Group-of-Seven nations over the period 1965 to 1985 and finds that upon controlling for private investment and employment growth, public nonmilitary investment bears a significantly positive relationship with growth in gross domestic product per employed person. On the other hand, public consumption—inclusive of military expenditure—bears a marginally significant negative relationship to productivity growth. It is also of interest that public investment spending as a share of gross domestic product fell during the late 1960s and early 1970s for five of the seven countries in the sample, the exceptions being Japan and Italy. The ratio of public investment to public consumption declined in all the Group of Seven countries.

Another implication of including public capital in the production technology is that changes in the public capital stock may influence the marginal productivity of private factors of production. Aschauer (1988) presents results based on an aggregate time series analysis which suggest that the rate of return to private capital in the nonfinancial corporate sector is positively affected by changes in the stock of public capital per worker. Employing data on manufacturing firms over the period 1970 to 1978, Deno (1988) finds similarly strong effects of public capital—highways, sewers, water facilities, as well as the total—in a translog profit function; in particular, he finds evidence of a complementary relationship between public and private capital. While Eberts (1986) also finds that the public capital stock makes a positive and significant contribution to manufacturing output, the magnitude of the effect is considerably smaller than indicated by Deno's results. Deno reconciles the difference by arguing that his own approach is more flexible, as it allows responses by firm output supply as well as factor demands to changes in public capital.

Given that public capital complements private capital, an increase in the public capital stock can be expected to stimulate private capital accumulation through its effect on the profitability of private capital.

Holding fixed the profit rate of private capital, however, higher public capital investment can also be expected to reduce private investment as national—private plus public—investment is pushed beyond the level that would be chosen by optimizing agents. Aschauer (1989b) finds that the U.S. time series data suggest both channels of the effect of public investment on private investment may well be operative. Specifically, he presents results that indicate a nearly one-to-one "crowding out" of private by public investment—holding fixed the rate of return to private capital—as well as a "crowding in" of private investment by public investment, as the rate of return to capital responds, over time, to the increases in the public capital stock brought about by higher public investment.

It is instructive to bring together some of these empirical results in order to consider the potential, simultaneous effects of higher public investment on the profitability of private capital, on private investment, and on productivity growth. This is accomplished by utilizing the aforementioned empirical estimates to construct a minimal model capable of simulating the effect of higher public investment on the aggregate economy. These simulations are to be taken as only suggestive of the true impact of changed public investment levels on these macroeconomic variables; many reasonable objections to the approach could be offered, such as that (1) movements in public nonmilitary investment are taken as exogenous, (2) the model parameters are based on estimates of disputable magnitude, (3) the model is too simple and ignores many aspects of the interaction between public investment and the economy, and (4) the Lucas (1976) critique of econometric policy evaluation casts doubt on the general validity of such exercises. These objections will be addressed below. Nevertheless, it is striking (at least to the author) how closely some of the simulation results appear to match the results obtained by other researchers from simulations of theoretical representative agent growth models (Baxter and King 1988).

The simulation assumes an increase in the level of public nonmilitary investment by an amount equal to 1 percent of the private capital stock during the period 1970 to 1986; this represents a 125 percent increase in the level of public investment over its actual average level during the period 1970 to 1986. Table 5 provides data on actual and simulated levels of the rate of return to private nonfinancial corporate capital (measured as the ratio of corporate profits net of depreciation, plus net interest payments, to the total value of the net capital stock); of net private investment in nonresidential structures and equipment (measured as a percentage of private capital stock); and of private business sector productivity growth (measured as growth in output per labor hour). The actual data document the inferior economic performance experienced during the period from 1970 to 1988 relative to the

Table 5
Simulated Impact of Public Investment on Private Economy

Time Period	Return to Private Capital (%)		Private Investment (% of Private Capital Stock)		Productivity Growth (% per Annum)	
	Actual	Simulated	Actual	Simulated	Actual	Simulated
1953–69	10.7	—	3.8	—	2.8	—
1970–88	7.9	9.6	3.1	3.7	1.4	2.1
1970–74	8.7	10.7	3.9	3.9	1.5	1.9
1975–79	8.5	9.9	3.2	4.2	1.3	2.2
1980–84	6.7	8.4	2.7	3.0	1.1	1.9
1985–88	7.8	9.6	2.8	3.8	1.8	2.7

Source: See Aschauer (1989a, 1989b) for details of method.

earlier period 1953 to 1969: a lower rate of return to private capital—7.9 percent as opposed to 10.7 percent; lower private investment—3.1 percent of the private capital stock rather than 3.8 percent; and lower labor productivity growth—1.4 percent per annum as opposed to 2.8 percent.

The simulated data, on the other hand, reveal some interesting potential relationships between public nonmilitary investment, private profitability, private investment, and private sector productivity growth. In the first five years of the expansion in public investment, the rate of return to private capital rises by 2 percentage points over its actual level, remaining at the 1953 to 1969 level of 10.7 percent instead of falling to 8.7 percent. This is the cumulative positive effect of the rising public capital stock on the productivity of private capital. During the same period, the private investment rate averages 3.9 percent of the private capital stock, the same as in the actual data. This reflects two offsetting forces; in the first three years of the higher public investment, private investment is pushed lower due to the direct crowding-out effect of higher public investment, while in the next two years private investment is brought above its historical level by the higher rate of return to private capital. In the same period, private sector productivity growth is enhanced, from 1.5 to 1.9 percent per year. As the private investment rate (as a percent of the capital stock) is seen to remain steady, this enhancement of productivity growth reflects the direct positive effect of a growing public capital stock on the productivity of labor.

In the later years of higher public investment, the rate of return to private capital remains between 1 and 2 percentage points higher than in the historical data. This stabilization of the return to capital arises because the private investment rate climbs to a level up to 1 percentage point higher than in the historical data, and the growing private capital stock has a negative effect on the rate of return to private capital, roughly offsetting the positive effect of the expanding public capital stock. Productivity growth now rises by a more substantial amount—nearly 1 percent per year above historical values—because the direct effect of the growth in the public capital stock is augmented by the indirect effect of a higher return to capital, raising private investment, which, in turn, stimulates productivity growth.

On net, the simulation suggests the possibility that the performance of the economy might have been greatly improved by an increased investment in public facilities. Comparing the period 1970 to 1988 to the earlier period 1953 to 1969, the rate of return to capital would have been only 1.1 percentage points lower instead of 2.8 percentage points; private investment would have been only 0.1 percentage point lower rather than 0.7 percentage point; and annual productivity growth would have been 0.7 percentage point per year lower instead of 1.4.

As was mentioned above, these results must be interpreted with much caution, and a truly accurate picture of the relationship between public investment and the economy must await further research. First, a logical case can be made that public investment, rather than being exogenous, may well be responding to changes in the private economy. For instance, one could argue that slower growth in productivity, per capita income, and tax revenue will induce the government to reduce spending on public capital projects. In the extreme, this argument concludes that the fall-off in public investment in the 1970s and 1980s was a result, rather than a cause, of the slump in productivity growth during the same period.

Yet this argument must confront the simple facts that public nonmilitary investment expenditure, as a ratio to output, reached a peak in the period between 1965 and 1968, while the usual dating of the onset of the productivity decline is around 1973. Some would argue that the productivity slump began as early as 1965, and others such as Darby (1984) deny its very existence, but such economists are in the distinct minority. As demonstrated in Aschauer (1989a), those functional categories of public capital that one would expect, on an a priori basis, to be most productive—in particular, a core infrastructure of surface and air transportation facilities, water and sewer systems, and electrical and gas facilities—turn out to have the strongest statistical significance in estimated productivity relations. Finally, Holtz-Eakin (1989) has looked in some detail at the statistical association between public capital accumulation and private productivity growth; he finds that a substantial portion of the correlation reflects causation from the former variable to the latter.

An argument can also be made that the estimated impact of public capital on productivity—one key parameter in the simulations above—is too large to be reasonable. For instance, Montgomery (1989) states that "the importance ascribe[d] to government investment . . . simply strains credulity." Also, in a contribution to *Setting National Priorities: Policy for the Nineties*, Schultze (1990) writes that the regression results in Aschauer (1989a) "imply . . . that a $1 increase in the stock of public infrastructure adds about as much to productivity as a $4 increase in the stock of private business capital" which, in his eyes, is indicative of "grossly inflated estimates of the returns to infrastructure investment."[4] Indeed, using the elasticity estimates contained in that paper and the ratio of business output to the net public capital stock, a rate of return to public capital in the range of 50 or 60 percent is generated. It should be noted that this estimate of the rate of return, while substantial, is in line with estimates of the rate of return to research and development (R&D) capital. For example, Griliches (1986) finds overall rates of return to R&D of between 30 and 60 percent, while Scherer (1982) estimates returns to R&D to be as high as 74 percent.

Further, while rates of return to public investment in the 50 percent range seem high relative to those estimated by conventional cost-benefit techniques,[5] this result conceivably could be caused by deficiencies in cost-benefit methods. Such defects could arise for a variety of reasons, including the use of an inappropriate rate of discount for public projects (Ogura and Yohe 1977),[6] the inherent difficulties involved in capturing general equilibrium effects in partial-equilibrium cost-benefit analysis (Hickling 1990), and the actual process of project selection (EPA 1984).

A third concern about the simulation exercise is that the model is too simple; indeed, it takes movements in employment and capacity utilization to be independent of changes in public investment spending. The rationale for doing so is that the exercise focuses on forces operating

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[4] However, Schultze (1990) also states that "carefully selected public investment in infrastructure can improve national productivity and output—the building of the interstate highway system, for example, was undoubtedly a major contributor to the rise in national productivity during the 1960s and 1970s."

[5] This is not to say that when benefit-cost analysis is applied small benefit-cost ratios are always obtained. A Federal Highway Administration investment analysis of increased spending on the federal-aid highway system reports that "given current investment levels . . . benefit-cost ratios range from an average of 5.9 for all the systems in the rural areas to an average of 9.3 in the urbanized areas. Or, in more general terms, for every dollar invested, there is about a $6 to $9 return in benefits." (Federal Highway Administration 1987 no. 13). These ratios can be usefully compared to those of Schultze (1990).

[6] In many cases, a 10 percent discount rate is used to discount benefit streams that are inflation-adjusted, and so represents a very high discount rate. See, for example, the calculation of the present value of benefits and costs in *Public Works Infrastructure: Policy Considerations for the 1980's* (Congressional Budget Office 1983).

on the supply side as opposed to the demand side of the economy. Yet traditional disequilibrium macroeconomic models would allow a direct, demand-side effect of government spending on output and capacity utilization. Even equilibrium macroeconomic models can allow for significant positive output effects of public investment, at least in the long run. Baxter and King (1988) show that a unit increase in public investment spending may result in sizable output multipliers, substantially in excess of unity. Aschauer (1990b) provides evidence that public nonmilitary investment has a much more stimulative impact on output than either public consumption or military investment; the output multipliers attached to the former type of expenditure lie in the range of 4, while those associated with the latter two types lie well below unity.

Finally, the lessons of the Lucas critique must be heeded. It is highly unlikely that the mix and level of public investment spending that was optimal in the past forty years will be optimal in future years. To give a simplistic example, even if it were established beyond doubt that the interstate highway system was a key determinant of productivity growth in the 1960s and 1970s, such knowledge would not necessarily imply that a similar effect on productivity would be obtained from the construction of another 40,000 miles of controlled access highways (even if such construction were feasible).

In all, the discussion above should not be taken as an attempt to prove that the level of public investment is clearly inadequate or that public capital is capable of influencing productivity to the degree indicated by the above simulation results. Instead, it should be viewed as an attempt to convince the reader that further research into the importance of public infrastructure spending to the private economy is well justified. In this vein, the subsequent section yields additional evidence on the role of infrastructure in influencing private sector production.

New Evidence

The empirical analysis to follow employs cross-sectional state-level data on gross state product and public infrastructure expenditure, averaged over the roughly 20-year period from 1965 to 1983. The use of cross-sectional, time-averaged data reflects a deliberate attempt to focus on long-run as opposed to short-run relationships between output and infrastructure spending.[7] This emphasis on the long-run relationships in

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[7] Other studies utilize state-level data on infrastructure capital and/or spending; see Garcia-Mila and McGuire (1987) and Helms (1985). However, by utilizing pooled cross-

the data also allows us to obtain reasonable proxies for steady-state, capital-output ratios across states as well as to cast the analysis in a way that may reduce the potential for various simultaneity biases.

Conceptual Issues

Consider a government sector that absorbs resources and provides services to individuals within its jurisdiction. Some services may be oriented toward consumption, such as the establishment and operation of a community park, while others are oriented toward production, such as the building and maintenance of streets and highways. The productive services, in turn, act as intermediate inputs into the production function of the jurisdiction; we have

$$Y = F(K,G,N;Z) = ZK^aG^bN^{1-a-b}$$

where Y = level of output within the jurisdiction, K = private fixed capital, G = level of government productive services, N = population or labor force, and Z = index of technological progress. At this point, we assume that the production function displays constant returns to scale over all inputs, inclusive of government services.

We next transform the production technology so as to relate the logarithm of output per person to the logarithm of the private capital-output ratio and to the logarithm of the ratio of government productive services to output. Upon rearrangement and the taking of natural logarithms, the production function may be written as

$$y/n = [z + a(k/y) + b(g/y)]/(1 - a - b)$$

where lower-case variables denote the logarithms of the respective upper-case variables. This formulation of the production technology is advantageous because good state-level data on capital stocks are currently unavailable. Written in this form, the estimation of the production relation requires information about the capital-output ratio only, for which we now provide a reasonable proxy.

To this end, we extrapolate from the apparent long-run behavior of capital-output ratios for those countries for which good capital stock data are available. Romer (1989), citing Maddison (1982), asserts that no long-run trend is to be found in capital-output ratios for such countries.

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state time series data, these studies tend to confound long-run and short-run effects of government spending.

Analogously, we assume that for individual states

$$D(k/y) = O$$

where Dx = percentage rate of change in X within a specified time period. This implies that the steady-state capital-output ratio is given as the following function of the investment to output ratio, I/Y, the rate of growth of output, Dy, and the depreciation rate, d:

$$K/Y = (I/Y)/(Dy + d).$$

Given an assumption for the depreciation rate applicable to capital structures and equipment, information about the investment to output ratio and the rate of output growth translates into information about the capital-output ratio in a particular locale.

For the main part of the analysis below, we assume a depreciation rate for structures and equipment of 5 percent per year.[8] This depreciation rate is a weighted average of assumed depreciation rates for residential structures of 2.5 percent, for nonresidential structures of 5 percent, and for equipment of 10 percent, the weights being given by the percentage of the aggregate United States capital stock composed of each type of capital.[9] Similarly, the weighted (by individual states' shares of total output) average capital-output ratio equals 1.67, which compares favorably with the aggregate ratio of private equipment and structures to output during this time period. For instance, in 1978—a year when the actual unemployment rate of 6 percent was at or very near standard estimates of the natural unemployment rate—the aggregate capital-output ratio equalled 1.63. Further, substantial variation in estimated capital-output ratios occurs across states, with the ratios ranging from 2.32 to 1.10 and having a standard deviation equal to 0.22. In utilizing these proxies for capital-output ratios in the subsequent empirical analysis, the implicit assumption is that only a minor portion of the true variability in capital-output ratios across states can be attributed to variability in depreciation rates.

We next assume that capital is mobile and flows across jurisdictional boundaries such that, at least in the long run, the marginal product of private capital is equalized across jurisdictions. Since the marginal

[8] We note, however, that the empirical results are not too sensitive to reasonable alterations in the average depreciation rate (say between 4 percent and 6 percent).

[9] For example, in 1970, the aggregate private fixed capital stock equalled $4,312 billion (1982), of which $2,100 billion (49 percent) was in the form of residential capital, $1,272 billion (29 percent) in nonresidential structures, and $940 billion (22 percent) in equipment. Employing these weights yields an average depreciation rate of 4.9 percent.

product of capital and the elasticity of output with respect to capital are related by

$$a = (K/Y)F_K,$$

differences in output elasticities will necessarily be reflected by differences in capital-output ratios. Similarly, the marginal product of government services and the elasticity of output with respect to such services is expressed as

$$b = (G/Y)F_G.$$

We also assume that the government sector chooses a level of services so as to equate the marginal productivity of services in a particular jurisdiction to that in other jurisdictions; consequently, differences in levels of government services, relative to output, will also reflect differences in production technologies across jurisdictions.

Substitution of the elasticity conditions into the production function then yields

$$y/n = [z + F_K(K/Y)(k/y) + F_G(G/Y)(g/y)] / [1 - F_K(K/Y) - F_G(G/Y)]$$

which is the basic expression to be estimated below.

Estimation

We now estimate the above production relation by using average data from 1965 to 1983 for the 50 states. Table 6 shows nonlinear estimates of the production relationship between per capita output, the capital-output ratio (assuming a 5 percent depreciation rate), and government spending.[10] All regressions are corrected for a heteroskedastic error structure.[11] At this point, we ignore the possible endogene-

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[10] For the entire period 1965 to 1983, the only employment data available are for the nonagricultural sector. It is expected that the relationship between total employment and total population is closer than is that between total employment and nonagricultural employment, so the empirical analysis uses population as a proxy for total employment.

[11] The estimated errors of the various regressions showed a strong and persistent relation to population. If we assume that the true error variance is related to population as in

$$e^2 = c(0) * N^{c(1)} u^2$$

where u is a homoskedastic error term and estimate using the residuals from the unweighted regressions, we obtain estimates of c(1) near −.7 with associated standard errors of approximately .2. For instance, in an equation including core infrastructure as the government spending variable, we obtain c(1) = −.659 (s.e. = .197). Accordingly, the

Table 6
Production Relationships of Per Capita Output, Capital-Output Ratio, and Government Spending
Dependent Variable ≡ y/n

INSTR	(1)	(2)	(3)
F_K	.114	.116	.093
	(.037)	(.039)	(.042)
F_{G1}	2.226	2.230	1.960
	(.389)	(.398)	(.496)
F_{G2}	−.250	−.254	.136
	(.160)	(.204)	(.422)
ne	.117	.126	.142
	(.029)	(.028)	(.028)
mw	.140	.142	.137
	(.022)	(.023)	(.023)
w	.102	.108	.135
	(.031)	(.031)	(.035)
ha	.281	.284	.327
	(.166)	(.167)	(.168)
$\bar{R}^2$	.988	.988	.988
SER	.086	.087	.088

Note: Standard errors in parentheses. Equations also include constant term.

Column (1) employs G1 ≡ core infrastructure spending, G2 ≡ total government spending minus core infrastructure spending.

Column (2) employs G1 ≡ core infrastructure spending, G2 ≡ total government spending minus welfare, net interest payments, and core infrastructure spending.

Column (3) employs G1 ≡ core infrastructure spending, G2 ≡ educational expenditure.

F_k ≡ marginal product of private capital.

Dummy variables: ne = Northeast, mw = Midwest, w = West, ha = Hawaii and Alaska.

ity of the government spending variables; this concern will be addressed shortly. The first column of Table 6 employs government spending on "core" infrastructure such as streets and highways, sewers and sanitation (G1), and all other government spending (G2). The marginal product of private capital, F_K, is estimated to be .114 (standard error = .037), which appears reasonable in light of the fact that the actual rate of return to the aggregate stock of nonfinancial corporate reproducible capital during this period ranged from .150 (in 1965) to .061 (in 1981).[12] The associated estimate of the elasticity of output with respect to

regressions make use of the weight $n^{.7}$ although using the square root of population yields essentially the same results.

[12] These rates of return are taken from the *Survey of Current Business* (April 1987).

reproducible capital, using an average capital-output ratio of 1.67 (thereby assuming an average depreciation rate of 5 percent), is then calculated to equal .19.

The estimate of the marginal product of core infrastructure spending is 2.226 (s.e. = .389), while that of all other government expenditure combined is −.250 (s.e. = .160). Thus, the level of per capita output is positively and significantly related to core infrastructure and negatively though insignificantly related to other government spending. It can also be seen that the marginal product of other government spending lies significantly below that of core infrastructure spending. In a paper with a production framework similar to the above, Barro (1989) argues that optimizing governments will choose a level of productive services so as to set the elasticity of output with respect to government productive services, e_{G1}, equal to the share of such services in total output, s_{G1}. In Barro's framework, a level of productive services such that $e_G = s_G$ maximizes the marginal product of private capital, which, in turn, raises the rate of economic growth to an optimal level. More generally, however, the fulfillment of this condition ensures that the government will be maximizing the net (of government) product available for private use. On the other hand, if $e_{G1} > (<) s_{G1}$, then the government has under- (over-) expanded in the sense that the net output to the private sector will be lower than if $e_{G1} = s_{G1}$. Using the estimated marginal productivity of 2.226, we find the elasticity of output with respect to infrastructure services equals .055, substantially above the (nominal) share of infrastructure spending in output, which equals .025.

The equation estimated in the first column also indicates that the level of per capita output is particularly low in the South, even after accounting for differences in the intensity of capital and government services in production, as dummy variables for the Northeast, the Midwest, the West, and for Hawaii and Alaska are all significantly positive.

The next column once again employs core infrastructure expenditure (labeled, as before, G1), but now limits other government spending (G2) to goods and services expenditures by also subtracting transfer spending on welfare and net interest payments. The results are essentially the same as for total government spending; the estimated productivity of core infrastructure spending equals 2.230 (s.e. = .398) while that of other spending is insignificantly negative. The third column employs core infrastructure (G1) and total education spending (G2); the estimated marginal productivity of core infrastructure is reduced to 1.96 (s.e. = .496), while the estimated productivity of educational spending is insignificantly positive at .136 (s.e. = .422). One possible interpretation of the small coefficient on education spending is that governments have overexpanded in the provision of educational services. Another interpretation, however, is that because of labor mobility, the productive returns to the educational services provided in one state are likely to arise in a different state, thereby reducing the magnitude of the estimated productivity coefficient.[13]

It should be emphasized that the above results, which suggest that government spending on core infrastructure is of more importance than other types of spending in explaining state-level variations in output, are tentative and open to valid criticism along a number of dimensions. As the theme of this conference is physical infrastructure, we will address a number of the likely criticisms, focusing on the core infrastructure expenditure category alone.

The likelihood of simultaneity bias is the first and no doubt foremost difficulty in interpreting the above results as indicating an insufficient level of infrastructure spending across states' economies. One might argue, for instance, that government spending on infrastructure is a "luxury" good, so that increases in per capita output and income induce increases in the share of output devoted to infrastructure uses.[14] A second potential difficulty with the above results is that they may not be robust to reasonable changes in the assumed depreciation rate for private capital stocks and, therefore, to changes in the proxy for the capital-output ratio.

Table 7 attempts to allay these concerns by providing instrumental variables estimates for three assumed depreciation rates ranging from 4 percent to 6 percent. Two instruments were chosen for infrastructure spending: federal grants to state and local governments (as a percentage of total state and local revenues), GRNTR, and the initial year (1965) stock of debt of state and local governments (also as a percentage of total revenues), DEBTR. Federal grants have been shown by a number of authors, beginning with Bahl and Saunders (1965), Osman (1966), Gabler and Brest (1967), and Gramlich (1968), to influence total state and local spending and, potentially, to stimulate state and local own-source spending. However, as argued by Oates (1968), since most grants are of a matching variety, federal grants may themselves be a function of state and local spending. The appropriate instrument would then be the matching rate, but unless the grants were of a variable-matching form

[13] In a cross-country analysis of educational spending in a similar framework, Aschauer (1990c) finds that the rate of return to education is statistically significant and lies some 60 percent above the rate of return to private physical capital. However, we would expect much less labor mobility in the cross-country model than in the cross-state model herein.

[14] It should be noted, however, that the reverse regression of infrastructure spending on per capita output yields a *negative* coefficient equal to −.018 (s.e. = .007), so this argument would seem to imply a downward bias in the estimated relationship between infrastructure expenditure and per capita output.

Table 7
Production Relationships for Per Capita Output, Capital Output Ratios, and Infrastructure Spending under Varying Depreciation Rates
Dependent Variable ≡ y/n

Depreciation Rate INSTR	(4%) GRNTR	(4%) DEBTR	(5%) GRNTR	(5%) DEBTR	(6%) GRNTR	(6%) DEBTR
F_K	.134	.162	.155	.175	.169	.182
	(.029)	(.034)	(.031)	(.039)	(.034)	(.044)
F_G	2.286	2.196	2.376	2.162	2.471	2.140
	(.375)	(.551)	(.373)	(.576)	(.380)	(.606)
ne	.131	.125	.114	.120	.101	.117
	(.024)	(.030)	(.024)	(.032)	(.025)	(.034)
mw	.183	.160	.174	.151	.165	.142
	(.019)	(.022)	(.019)	(.022)	(.018)	(.023)
w	.150	.182	.146	.183	.143	.185
	(.023)	(.024)	(.022)	(.025)	(.022)	(.026)
ha	.290	.297	.291	.302	.295	.310
	(.145)	(.154)	(.141)	(.159)	(.140)	(.165)
$\bar{R}^2$	.998	.997	.998	.997	.998	.997
SER	.987	.102	.086	.103	.086	.103

Note: Standard errors in parentheses. Equations also include constant terms. See the text and Table 6 for definitions.

(as with public welfare) no scope would remain for variation across states in this variable. We attempt to walk the fine line between the two extremes of endogeneity and of insufficient variation across states by expressing federal grants as a ratio to state and local revenue.

Recognizing that some will object to the use of the federal grants variable in this manner, we also utilize initial state and local debt relative to total revenues as an instrument for infrastructure spending. The idea is that the initial stock of debt is dependent upon past government spending and tax policies and that accumulated debt, to some extent, will impinge upon future spending. Of course, one can object to this instrument as well; past governments may have issued debt in the (correct) anticipation of future increases in per capita output, income, and tax revenue, rendering the debt ratio endogenous with respect to future output.[15]

[15] We refer the reader to the "tax smoothing" theory of government debt issuance in the macroeconomics literature. Basic references are Aschauer (1990a), Barro (1979) and Lucas and Stokey (1983).

If one is willing to accept either the federal grant or the initial debt variable as a valid instrument, however, then upward simultaneity bias does not appear to be a significant concern. Using either of the instruments leads to estimated marginal productivities of infrastructure services between 2.1 and 2.5, somewhat higher than the previous estimates.[16] The correlation (positive, as expected) of the grant variable with infrastructure spending is somewhat closer than the correlation (negative, as expected) of the initial debt variable, leading to tighter coefficient estimates with the grant variable.[17] Also, the results are robust to alterations in the assumed depreciation rate and, thereby, to variations in estimated capital-output ratios. As the assumed depreciation rate rises from 4 percent to 6 percent—and the associated capital-output ratios decline—the estimated productivities of physical capital increase. Hence, calculated elasticities of output with respect to private capital remain in a fairly close and reasonable range, between .250 and .259 in the case of grants as the chosen instrument and between .266 and .313 for initial debt.

Another concern about the above specification and results may revolve around the specification of returns to scale in production. It may well be that government infrastructure services are "nonrival" in the sense that the facilities are available to all users simultaneously; in such a case, it would be the total amount of government spending, or services, that is relevant for production and not the amount per person or worker. In order to capture this possibility, we rewrite the original production technology so as to read

$$Y = ZK^aG^bN^{1-a-b(1-c)}.$$

Here, if $c = 0$, the production technology is characterized by constant returns to scale across all productive inputs, private and public. If $c = 1$, it is characterized by constant returns across private inputs, with the implication of increasing returns across private and public inputs together. A logarithmic transformation and substitution of output elasticities, as before, then yields

$$y/n = [z + F_K(K/Y)(k/y) + F_G(G/Y)((g/y) + cn)] / [1 - F_K(K/Y) - F_G(G/Y)].$$

[16] The two-stage estimation procedure actually employs the other right-hand-side variables in the instrument list as well.

[17] Specifically, the coefficient estimates linking the grants and initial debt variables to core infrastructure spending equal .098 (s.e. = .015) and −.007 (s.e. = .002), respectively. The simple correlations of grants and initial debt with core infrastructure spending equal, in turn, .765 and −.439.

Table 8
Production Relationships for Per Capita Output, Capital-Output Ratios, and Infrastructure Spending, Allowing for Increasing Returns to Scale
Dependent Variable ≡ y/n

INSTR	GRNTR	DEBTR
F_K	.125	.142
	(.029)	(.031)
F_G	4.257	4.585
	(.558)	(.490)
c	.533	.511
	(.086)	(.068)
ne	.125	.115
	(.022)	(.022)
mw	.151	.142
	(.017)	(.016)
w	.128	.122
	(.019)	(.019)
ha	.382	.406
	(.123)	(.111)
$\bar{R}^2$	.999	.999
SER	.073	.072

Note: Standard errors in parentheses. Equations also include constant term. See the text and Table 6 for definitions.

Table 8 provides estimates of the production relation allowing for the possibility of increasing returns to scale across all inputs. Evidence of increasing returns to scale can readily be seen; the estimated value of c is in the range of .5 and lies more than two standard errors from either zero (constant returns to scale across all inputs) or unity (constant returns across private inputs only). The estimated productivity of infrastructure services is now in the range of 4.5, implying an elasticity of output with respect to infrastructure of around .11.[18]

Finally, the literature contains evidence of the existence of "agglomeration economies" such that localities with a more concentrated population are associated with higher levels of per capita output and

[18] Note that the production relation could have been estimated in a less constrained form that allows population to interact freely with per capita output. However, the computed likelihood ratio statistics, distributed as a chi-square random variable with one degree of freedom, do not allow a rejection of the form shown above. For the case of grants as the instrumental variable, the likelihood ratio statistic equals 1.63, while in the case of initial debt as the instrumental variable, it is 2.26. These values are to be compared to the 10 percent critical value of the chi-square(1) distribution, 2.71.

Table 9
Production Relationships for Per Capita Output, Capital-Output Ratios, and Infrastructure Spending, Adjusting for Population Density
Dependent Variable ≡ y/n

INSTR	GRNTR	DEBTR
F_K	.128	.144
	(.032)	(.032)
F_G	4.118	4.499
	(.721)	(.651)
c	.529	.510
	(.090)	(.070)
d	.004	.002
	(.012)	(.011)
ne	.120	.112
	(.027)	(.027)
mw	.150	.142
	(.017)	(.016)
w	.129	.123
	(.020)	(.019)
ha	.379	.404
	(.124)	(.112)
$\bar{R}^2$	.999	.999
SER	.074	.073

Note: Standard errors in parentheses. Equations also include constant term. See the text and Table 6 for definitions.

income. Table 9 allows for the possibility that population density may play a separate role in the determination of output across states. As can be seen, however, population density has little marginal explanatory power for output per capita. While having the proper sign for the agglomeration economy argument, the coefficient linking population density to output is quantitatively small—a 1 percent increase in density being associated with a .002 increase (initial debt as instrument) or a .004 increase (grants as instrument) in output across states—and is insignificantly different from zero at conventional levels.

Conclusion

In attempting to answer the query "Why is infrastructure important?" this paper has pointed out some of the possible gains to the quality of life and to economic performance that might arise from increased infrastructure investment. Numerous past infrastructure investments have been responsible for significant improvements in the overall quality of life in terms of health, safety, economic opportunity, and leisure time and activities. Similarly, recent empirical evidence, as well as that established in the preceding section of this paper, suggests that infrastructure expenditures may well have been a key ingredient to the robust performance of the economy in the "golden age" of the 1950s and 1960s.

Yet much remains to be done if we desire a future with a cleaner environment, with safer urban streets, with increased mobility and economic opportunity for the disadvantaged, and with an economy well equipped to compete in the international arena. Such a future, it appears, is desired by the general public at the present time; according to the National Opinion Research Center's 1989 general social survey, over 70 percent of the respondents believe that as a nation we are spending too little to improve the environment and to reduce crime, while only 15.4 percent feel we are spending too little on the military. It seems that the time is ripe for a reorientation of government spending priorities, with a renewed emphasis on infrastructure investment, to meet the challenges of the 1990s and the twenty-first century.

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Discussion

*Henry J. Aaron**

The economy periodically produces puzzles that help to keep economists employed. One of the best full-employment puzzles of recent decades is the growth slowdown, dated variously as starting from the late 1960s to the early 1970s. The reasons why growth slowed both in the United States and in most other developed industrial countries, and the importance of various phenomena in explaining the slowdown, are matters of enormous consequence not just for economists but for economic policy.

David Aschauer has made one of the more fascinating and important contributions to this debate. He has called attention to the rather extraordinary disregard by economists and others of the possible role of public investment in explaining the slowdown. He has produced a series of papers in support of his contention that a sharp deceleration of public investment, especially investment in what he calls "core infrastructure," is very nearly sufficient to explain why growth slowed in the United States. What began as a solitary exercise bids fair to become a veritable subspecialty, as scholars around the nation address the issue he has raised. Few economists are able with a full lifetime of scholarly effort to shake up the profession as much as Aschauer has done in just a few years of professional life.

The paper presented at this conference continues his efforts to marshall support for this thesis. Characterizing the paper as an effort to

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*Director of Economic Studies, The Brookings Institution. These comments incorporate ideas of my Brookings colleagues Martin Baily, Barry Bosworth, and Clifford Winston, and especially Charles Schultze.

marshall evidence is an unusual way to introduce discussion of a paper for an economics conference. But it is intentional, as this paper has the flavor of a brief, rather than of a dispassionate evaluation of evidence. Aschauer has had a valuable insight but has greatly exaggerated its quantitative importance; this paper does little to advance the thesis he propounded elsewhere.

My comments consist of three parts. The first assesses Aschauer's initial effort to show that retardation in public sector investment, especially in core infrastructure, is largely sufficient to explain the growth slowdown of the 1970s and 1980s. The focus here is the original paper (Aschauer 1989) and Munnell's subsequent update and extension (Munnell 1990). The second part focuses on the paper for this conference (Aschauer 1990) and the third concludes by musing a bit on the course that the debate on the Aschauer thesis has taken so far.

The Aschauer Thesis

The Aschauer thesis consists of several elements. The first is that a properly specified aggregate production function should include not just privately owned capital but also publicly owned capital that contributes to production counted in gross national product. The second element is that when one specifies such a production function and estimates it with aggregate time series data, the resulting coefficients on publicly owned capital are large and indicate a very high marginal product. The third element is that not all publicly owned capital is equally important in this aggregate production relationship. In particular, core infrastructure—consisting of highways, mass transit, airports, electrical and gas facilities, water works, and sewers—is the element of public capital that contributes the most to private productivity. Other public capital and public labor seem to contribute little to productivity growth.

Aschauer's results are truly startling. According to a simulation reported in Table 5 of the paper presented here, a $500 billion increase in the 1988 stock of public sector capital would have boosted productivity 14.0 to 14.8 percent. Given gross domestic nonfarm business product in 1988 of $3,418 billion (1982 dollars), the increase attributable to public sector investment would be $479 billion to $509 billion, or about one dollar increase in annual output per dollar of investment. Part of that gain, to be sure, is the result of induced private investment.

The implied power of public sector investment is even more impressive than this calculation suggests. Since Aschauer finds that only "core infrastructure," which represents only 55 percent of public sector capital, matters in his productivity equations, the increase in the relevant capital stock is $275 billion, implying a payoff of nearly $2 in output for each additional $1 of core infrastructure.

When one confronts so startling a result, especially one that flows from aggregate time series regressions based on levels of variables (on which more presently), one should remember the warning Richard Goode (1966, p. 213) sounded when confronted with a less startling result:

> No evidence is sufficient to establish an implausible result unless the unreliability of the evidence would be more remarkable than the result which it endeavors to establish.[1]

The remainder of this section argues that the result Aschauer presented in his earlier paper and Munnell has updated is less plausible than the possibility that the evidence they present is flawed. No doubt others have presented some or all of these criticisms, as Aschauer has tried to deal with some of them.

Aggregate Time Series

Economists seem to be divided into two categories: those who regard aggregate time series regressions on variables expressed in levels as a form of preliminary data analysis and those who take such regressions seriously. The size of the first group has grown and that of the second has shrunk with time, for several reasons. Various analysts have pointed out that time series typically contain little information, usually no more than a few real "observations" that are generated at turning points or clear-cut inflection points. Time series are dominated by trend and produce marvelous fits that tend to distract one from their meager power to explain much of the relevant variance. The econometric devices used to avoid these problems are many and varied: detrending, differencing, ratioing, and various econometric tricks.

Aschauer's original paper (1989) uses none of these devices. It reaches the conclusion that the elasticity of output with respect to public capital is in the range of 0.38 to 0.56. Using a slightly longer series, Munnell (1990) narrows the range to 0.31 to 0.39 and settles on 0.34. Ordinarily, estimates of labor and private capital elasticities of output are in the range of 0.7 and 0.3 respectively. If one assumes that the

[1] The result Goode confronted was the finding of Richard Musgrave and Marion Krzyzaniak that the corporation income tax is shifted more than 100 percent to consumer prices, so that an increase in corporate profits taxes is good for corporations because it boosts profits. The quotation from Goode is a paraphrase of an earlier statement by David Hume.

elasticities of labor and private capital sum to 1 and that the elasticity of public capital is 0.34, then returns to scale are increasing and the elasticities of private and public capital are about the same size. If one assumes that returns to scale are constant, payments to capital and labor exceed their productivity. Adjusting their elasticities so that the sum, including the elasticity on public capital, equals 1, then the elasticity of output with respect to private capital is reduced to 0.22, about two-thirds that of public capital.

With these elasticities in mind, one can turn to the implied marginal productivities. The stock of nonfarm, nonresidential private capital in 1988 was $4,202 billion. The stock of government nonmilitary capital was $1,711 billion, but, as noted, only the 55 percent of that stock that represents core infrastructure, or about $940 billion, showed up as contributing to current output.[2] Thus a 1 percent change in the stock of private capital, or about $42 billion, could be expected to boost output by 0.22 to 0.30 percent, or by $8.9 billion to $12.1 billion in the first year. The implied annual return is 21 percent to 29 percent.

In contrast, a 1 percent increase in core infrastructure, or about $9.4 billion, could be expected to increase output by $13.7 billion, an implied annual return of about 146 percent, or five times that of private capital. Just to be clear, this estimate implies a payoff period for public sector infrastructure investment of just over eight months.

Another way of looking at this result is to consider by how much the stock of infrastructure would have to increase to achieve an efficient allocation of capital between private and public ownership. Since the marginal product of any input, X, is related to its elasticity of output, E_x, by the relation $E_x = (X/Y)F_x$, where Y is output and F_x is the marginal productivity of X, the ratio of the stock of private capital to the stock of core infrastructure, when their marginal productivities are equal, is simply the ratio of their elasticities.

If the 1988 stock of private capital is held at its historical value of $4,202 billion, and if the elasticities of output with respect to private capital and core infrastructure are taken as 0.30 and 0.34 respectively, then core infrastructure would have to increase from $940 billion to $4,763 billion or just over fivefold to equalize the marginal productivity of private capital and core infrastructure.[3]

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[2] Other public capital, such as school buildings, probably contributes to output, but the effects are so deferred that variations in the stock of such capital do not show up as explaining any significant part of current output, a point that Aschauer notes. Furthermore, this capital may be taken into account indirectly when the labor supply is based on education-level-adjusted counts of the work force.

[3] If one uses the smaller elasticity of output with respect to private capital implied by constant returns to scale, the stock of core infrastructure would have to increase to $6,494.5

Various readers will greet such calculations quite differently. To some, they are simply confirmation of a fact that they knew all along—that the American public sector is starved and that we are making mistakes of Brobdingnagian proportions in not expanding public sector investments enormously. But unless one has in mind paving Texas, it is hard to imagine where one would find room for or what one would buy with the nearly $5 trillion of core infrastructure that Aschauer's estimates suggest is needed in order to bring public investment into balance with private capital. To others, the results will be a reminder that functional forms that seem reasonable cannot be trusted when one moves far outside of the range over which the equation was estimated. Still others, some of whom may count themselves members of the first two groups, will conclude that these results indicate something is grossly wrong with the underlying model.

Because time series normally do not contain much information, and variables expressed in levels normally are dominated by trends, it is important to see whether time series regressions on data in levels hold up under various transformations and in the presence of other plausible variables. Table 1 presents a series of equations, estimated by my colleague Charles Schultze, that illustrate the consequences for the regressions Aschauer has presented of this kind of sensitivity analysis.

Equation 1 is a near replication of Equation 1.1 in Aschauer (1989), Table 1. The coefficient for public capital in Aschauer, estimated over the period 1949–85, was 0.39, in contrast to the coefficient of 0.41 reported here, estimated over the period 1951–85. Equation 2 introduces a new variable, the exchange value of the dollar against the yen, for whose inclusion no good theoretical case can be made but whose coefficient is nevertheless highly significant by any reasonable test. This variable also happens to have a time pattern somewhat like that of public sector investment. The coefficient of public capital is reduced from 0.41 to 0.34. I believe that Equation 2 illustrates a simple point: the statistical support for the significance of an extremely improbable variable, the yen/dollar exchange rate, is just as strong as the support for a result the magnitude of which I regard as equally implausible.

Equations 3 through 5 are based on the first differences of the variables. Equation 3, which includes the same variables as Equation 2, produces similar values of the various coefficients, except that t values are reduced with the removal of trend; in addition, the coefficient on public capital drops a bit more, to 0.27. There is no reason for attaching

billion, a nearly sevenfold increase. If, on the other hand, one does the calculation with respect to all public, nonmilitary capital, marginal productivities would be equalized when public capital goes up to "only" 278 percent of its current size, or not quite triples.

Table 1

Dependent Variable lnO − lnK	Independent Variables: Constant	Time	CU	lnL − lnK	lnYen,−1,−2			$lnK_G - lnK$	$\bar{R}^2$
(1)	−1.72	0.007	0.48	0.37				0.41	.979
	(−18.5)	(2.8)	(7.6)	(3.3)				(16.3)	
(2)	−2.07	0.010	0.43	0.45	0.09			0.34	.985
	(−16.0)	(4.3)	(7.5)	(4.6)	(3.6)			(11.9)	
Δ(lnO − lnK)			ΔCU	Δ(lnL − lnK)	ΔlnYen,−1,−2	D66	D74	$\Delta(lnK_G - lnK)$	
(3)	0.01		0.26	0.50	0.15			0.27	.922
	(2.7)		(2.5)	(2.8)	(4.0)			(3.0)	
(4)	0.02		0.32	0.54		−0.006	−0.006	0.13	.882
	(2.4)		(2.6)	(2.2)		(−1.1)	(−1.0)	(0.8)	
(5)	0.02		0.25	0.66	0.15	−0.004	−0.006	0.09	.924
	(3.1)		(2.2)	(2.9)	(4.1)	(−0.9)	(−1.2)	(0.6)	

Variable List: O = nonfarm business product; K = nonfarm business fixed capital; time = 1 for initial year and increases 1 per year; Yen = yen/dollar exchange rate; K_G = public nonmilitary fixed capital; D66 = 1 for 1966 and later years, zero otherwise; D74 = 1 for 1974 and later years, zero otherwise.

Period is 1951–85 for equations (1) and (4); 1952–85 for equation (2); and 1953–85 for equations (3) and (5).

t statistics are in parentheses.

any greater weight to the values in Equation 2 than to the values in Equation 3.

Equation 4 replaces the exchange value of the dollar against the yen with a pair of time dummies for years after 1966 and 1974. The coefficient of public capital drops to 0.13 and is not significantly different from zero by any normal test. The fact that the drop in the rate of infrastructure investment coincides with these two dummies and that these dummies cut the coefficient of infrastructure in half simply calls attention to the meagerness of the amount of information in the regression.

With the inclusion of both the exchange value of the dollar against the yen and the pair of time dummies in Equation 5, the coefficient on public capital drops still further to 0.09, and the t value is so low that one suspects that if this were the equation originally estimated, Aschauer and many others would be doing something different from what they are doing now.

The point of this little exercise is not to claim the superiority of Equations 2 through 5 to Equation 1. Rather, the point is that none of them is worth much in trying to unravel why growth has slowed, and to reinforce my earlier observation that time series regressions based on data expressed in levels should not be taken very seriously. When the results seem outlandish, some very careful analysis with other functional forms and other variables is necessary. If the results are not robust—and Aschauer's are not—then the hypothesis under examination cannot be regarded as even provisionally confirmed and no policy recommendations of any sort can rest on the results.

Similar caution is necessary with international cross-sectional data, as indicated by Tanzi (1990). He finds that the ratio of public sector investment to total investment adds nothing to the investment/GDP ratio in explaining the growth of GDP in a regression based on twenty-three developing countries. Adding one country, Botswana, generates a positive coefficient, but the t value indicates that the effect of public sector investment is statistically insignificant. The problem in such regressions is that the results frequently depend sensitively on which countries are included.

Absence of Competitive Test

The Solow-type production functions, of which Aschauer's estimates are an extension, rest on a sound foundation of microeconomic theory. In particular, they rest on assumed competitive markets in which factors are remunerated based on their marginal productivities. No such test exists for public infrastructure. Public capital does not pass any market test in which productivity is balanced against a market measure.

This fact implies that one cannot know whether the value of public capital, as measured by the discounted present value of what it would earn if remunerated based on marginal productivity, is accurately indexed by the series published by the U.S. Department of Commerce, which is based on cost. Studies of various categories of government investments are replete with examples of both enormously profitable and horrendously ill-conceived investments. If the published series differed from the true series by some constant ratio, this error would cause no problems in log linear regressions. But the difference between the official series and some "true" series is probably not constant over time. Hence, it is uncertain what productivity is really being regressed against.

The absence of a competitive test raises more profound problems, as indicated by the paper presented by Clifford Winston at this conference and in much greater detail elsewhere (Small, Winston, and Evans 1989). Winston finds that the United States builds roads inefficiently and prices them inefficiently. Public expenditures on roads and private expenditures on transportation are both higher than they would be if roads were constructed differently (basically, thicker) and truck fees were based on weight per axle, rather than fuel consumption. If road construction and pricing were both optimal, taking account of the response of road users to the fees and to reduced congestion, *total expenditures on roads should be reduced in the long run, not increased.* Any increase in outlays, beyond the levels Winston estimates, would reduce social welfare, and those levels are below current outlays. Thus in one major area of core infrastructure, which carries the load in Aschauer's equations, the marginal welfare effect of increased spending on public capital, *after one rationalizes current outlays,* is actually negative.

Several other issues arise concerning the original regressions that also come up with respect to the paper for this conference, to which I now turn.

The Two Papers

Aschauer's paper for this conference really combines two essays, distinct in content and style. The first is an informal brief for infrastructure investment. The second reviews earlier statistical findings and presents new results that the author contends support his claim that the rate of return to infrastructure investment is very high.

Needs and Indicators

The informal brief begins with the unassailable assertion that government expenditures of various kinds improve the quality of life by slowing or reversing environmental degradation, by contributing to public safety, by extending recreational opportunities, by improving public health, and by providing other valuable services. Despite this valid insight, this section is unsatisfactory for two reasons. First, most of the claims, even if sustained, do not indicate that infrastructure investment would contribute anything to national product as conventionally measured, although it is quite reasonable, even praiseworthy, to broaden readers' understanding of the contributions that public investment can make to an individual's well-being. Second, this section simply repeats claims that public investments are good for us. These claims were made nearly two decades ago and could be verified, but are not.

Furthermore, the reasoning in this section is highly informal and some of it is probably wrong. For example, this section calls for more road construction on the almost certainly false assumption that it would produce less smog. (Can there be much doubt that, say, eliminating urban roads and passenger cars would be a far more effective way to reduce smog than to build more roads and thereby to encourage more auto use?) This section also repeats claims of organizations that have vested interests in the subjects under study, such as the Federal Highway Administration's projections of disastrously increased congestion if its budget is not increased. This section also endorses measures to curtail solid waste, which may or may not be a good idea; but they would almost certainly reduce national output as conventionally measured, because they would convert costs of disposal from final outputs into intermediate inputs. Investments in national parks would presumably reduce national output as conventionally measured if these resources were shifted from capital goods that yielded a flow of marketed services.

My point is not that investments to improve the quality of the environment or to reduce crime or to expand public recreation or to reduce congestion on the roads are useless. Many of them are extremely useful, even vital. Public investment decisions should not be guided solely by how they affect measured national output. Some of the best features that public investment can provide do not and never will appear in measured output. A good case can be made for boosting public investments. But a good case does not rest on repetition of ex parte claims. In addition, the argument that public sector investments contribute massively to measured national output is not strengthened by arguing that such investments contribute to items that do not appear in measured output.

Statistical Findings

The second part of Aschauer's paper, an attempt to review earlier evidence and to introduce new findings in support of the key role of public sector investment in determining economic growth, begins with the simulation of the effects of increased public sector investment referred to earlier. As indicated, the simulated effect of increased investment appears implausibly large.

Then Aschauer turns to new empirical evidence relevant to the productivity of public sector investment. This evidence consists of regressions relating output per unit of labor input to the private capital-output ratio and the public capital-output ratio, where the values for each of these variables are averages spanning the period 1965 through 1983 for the 50 states. The marginal productivity of core infrastructure is estimated to be 19 to 21 times larger than the marginal product of private capital.

Before one bases policy on such estimates, one must ask once again whether the model from which the results emerge makes sense and, even more importantly in this case, whether the data used to estimate the model are appropriate. Starting with the model, the lack of detailed state-by-state data leads to the following assumptions:

- The capital-output ratio differs among states, ranging from 2.32 to 1.10, but is constant in each state. (The justification for the assumption of constancy is that no long-term trend has been found in capital output ratios among countries.)
- The depreciation rate is the same across states.
- The employment-population ratio is the same in each state.
- The marginal product of private capital is the same in all states.
- The marginal product of public capital is the same in all states.
- The rate of technical progress is uniform across all states.

This list of assumptions strains credulity, even for economists who are trained to tolerate implausibility in the name of tractability. Each assumption is almost certainly false. Tests showing the sensitivity of results to these assumptions are shown only for variations in the rate of depreciation, where variations do not matter much. But no reason is given to expect that the results will be so insensitive to other assumptions.

The issue of reverse causation is treated with instrumental variables, but it cries out for direct modeling and testing (assuming that one is willing to make all of the foregoing assumptions). In particular, it seems plausible that opportunities for stronger than average growth in per capita income would be associated both with rapid population growth and with high rates of public sector investment, especially in core infrastructure. Even use of data averaged over nearly two decades is insufficient to deal with this problem, as the multi-decade growth of the Sun Belt over the period in question suggests. This bias may well account for the enormous coefficients on public sector investment. But these coefficients do more to underscore the pitfalls of reduced form estimation than they do to buttress the case that public sector investment is a major influence on economic growth.

The policy implications also should give pause. Few would probably question that the road-building program of the 1950s and 1960s contributed to economic growth. The message of this analysis, however, is that economic growth slowed largely because the program of road construction ended. In view of the fact that the bulk of the productivity slowdown has occurred in mining, construction, and services and little or no slowdown has occurred in manufacturing, it is hard to understand how highways could bear so much of the blame.

The Course of the Debate

The debate on the Aschauer thesis is remarkable in two respects. The first is that it has taken so long for someone to focus the attention of the economics profession on the role of public investment in determining productivity. Students of why ideas remain dormant and when and under what circumstances they emerge from shadow should find enormously fascinating how it was that public investment remained almost unmentioned in discussions of productivity in general and of the productivity slowdown in particular. That it remained for a graduate student to spotlight this issue in the mid 1980s, more than a decade after the growth slowdown began, is downright bizarre.

Aschauer deserves enormous credit for calling the attention of a blinkered profession to something that should have immediately commanded its attention. Clearly something peculiar was going on. Everyone has known that the public sector invests a lot and that the things it invests in matter for private production. But we did not use that knowledge to help explain the productivity slowdown. Perhaps attention to this issue awaited the release of official statistics on tangible wealth (Musgrave 1986). Whatever the explanation, the almost complete omission of changes in public sector investment from most of the efforts to explain the growth slowdown is peculiar, and everyone is in Aschauer's debt for redressing that oversight. No doubt public capital belongs in any sensible aggregate production function.

The issue is not the sign of the coefficient of that variable—on that, everyone agrees. The issue is the size of the coefficient, both in retrospect and in prospect. Charles Schultze, who once remarked that nothing was wrong with supply-side economics that dividing by ten would not cure, updated that comment by saying nothing is wrong with the Aschauer thesis that dividing by four would not cure.

The second peculiarity of the debate about the Aschauer thesis is the credulous acceptance of the results by people who normally react with sophisticated skepticism to econometric discoveries that the world is really so very different from what we had supposed. One possible explanation raises a fundamental issue in the analytical method. We all pride ourselves on our bulldog persistence in subjecting every result to remorseless scrutiny. But the truth is that each of us approaches any problem with a set of maintained hypotheses. When statistical results are consistent with these hypotheses, we tend to think they must be right and we are less likely to continue investigation than if the results conflict with our "priors." When the results conflict with these hypotheses, we are more likely to continue looking.

I think that something of that reaction explains the acceptance of results that seem to me to be implausibly large, although of the right sign. Aschauer's results have been most welcome among those who are sick and tired—with good reason, in my view—of continuous and unsupported allegations that everything the government does is wasteful or harmful. We know that is not true. So when a study comes along showing only the dollars and cents value—not soft quality-of-life or income-distribution stuff, but the real McCoy—of a large class of what the government does, we clasp it to our bosom. So do organizations such as the American Road and Transportation Builders Association (Mudge and Aschauer 1990) who stand to gain hugely from a large program of road-building that, according to Winston, may well have no good economic justification whatsoever.

The lesson, I suggest, is that we should be especially careful when we come upon a result that nicely fits our hopes and yearnings. Confronted with a result that appears just too good to be true, the safest reaction is that it probably is. Confronted with a policy backed by extravagant promises, it is prudent to recall the maxim, "Married in haste, we may repent at leisure."

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Discussion

*Richard A. Musgrave**

Based on his earlier work and an extension thereof, Aschauer estimates the productivity-raising power of infrastructure investment to be huge, as much as quadrupling that of private investment. At a time when it is customary to view public sector activity as inherently wasteful, this is indeed a startling result. But while I do not share that presumption, I feel uneasy with so high a ratio. Obviously, infrastructure investment should be allowed for in productivity analysis, and it is indeed surprising this has not been done in past analysis. We are indebted to the work of Aschauer and Munnell for having drawn our attention to this omission. Nevertheless, Aschauer's striking result remains to be explained. Reference to similar results for R&D investment is not convincing, since R&D's linkage to new technology gives it a special role. Nor can one readily reject the hypothesis that the finding reflects reverse causality or, as I prefer, a timing coincidence between high productivity growth and high infrastructure investment. Finally, why should Aschauer's results differ so sharply from Munnell's more modest conclusions?

A closer look at the econometric procedure and its limitations is thus in order, but I will leave this to more qualified critics. Instead, let me recall Fritz Machlup's insistence (from the Hopkins days) that econometric results are never better than the analytical reasoning by which they can be supported. Therefore, let me assume that Aschauer's results are correct and, taking the title of his paper literally, ask why it

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is that infrastructure investment should be more productive than investment in an ordinary but honorable facility such as a mousetrap plant. What are the peculiar characteristics that explain so large a difference?

Being a scholarly type, I thought it best to begin by ascertaining just what people mean when they refer to infrastructure investment. To my surprise and dismay I found no such entry in any of the standard sources such as the *Palgrave*, the *Encyclopedia of the Social Sciences*, or even the *Encyclopedia Britannica*. I was puzzled further to find our conference topic given as the shortfall in public investment, while the session subtitles all refer to various aspects of infrastructure investment. Are we to conclude that all infrastructure investment is public and that all public investment is infrastructure? This is hardly the case. What, then, are the peculiar characteristics that render an investment "infrastructure" and might endow it with such unusual productivity?

None of the standard distinctions between types of investment seem to draw the line. Infrastructure may take the form of human investment (health and education) or it may be in physical assets (roads). The asset may be in the form of a durable consumer good (access roads to a recreation lake) or an intermediate or capital good (freight-intensive highways). Next, the asset or the services it renders may be private in nature so they can be provided through the market (a toll bridge) or they may be public in nature, thus calling for budgetary provision (a cross-country highway).

Looking for a better explanation, is infrastructure characterized by entering at the beginning or foundation of the production process, as the term seems to suggest? Are we to go back to Quesnay and consider land and natural resources the ultimate infrastructure? Or, does the concept have a place in the mystique of Marxian capital theory and the process by which labor inputs ripen into final output? Neither tack seems helpful. A highway used for retail delivery at the very end of the production process is no less infrastructure than one used for delivering raw materials that enter at the beginning.

Having gotten nowhere with these familiar distinctions, let me suggest that the peculiar thing about infrastructure of the intermediate good type is that it enters as a common input into many uses. By the term "many," I do not refer simply to the fact that the service is used by many firms. This is necessary if the structure is to be public, so that joint use precludes exclusion and preference revelation. But the service may also be private in nature so that price exclusion is appropriate. The term "many" as used here instead refers to the condition that a wide range of industries is involved. Thereby infrastructure investment may affect the productivity of private capital and labor across the board, bearing, as Aschauer puts it, on the health of the aggregate economy.

Given that infrastructure investment is thus characterized by its joint and cross-industry use, does it also follow that therefore it must be especially productive? This is the question that has to be answered before accepting the econometric result. As the perfect marketeer will tell us, investment will be carried to the point where the same return is obtained at the margin. True enough, but what happens at the optimal margin may not be what happens in the real world. The question then is why a deficient level of infrastructure investment should leave an especially heavy loss of producer surplus, or why catching up to the optimal level should secure an unusually large gain. Could the cross-industry use of such investment result in a kinked efficiency-of-investment schedule, so that the return over the range of investment deficiency was unusually high, without the same holding for further increments of investment? I am aware that I have raised questions rather than given answers, but these are issues, I think, that need to be further explored.

While I have suggested that cross-industry use is a distinguishing feature of infrastructure investment, it does not follow that all industries should participate equally. Some lines of output may be more infrastructure-intensive than others, and various types of infrastructure investment may be more important for one industry or another. A more disaggregated approach may thus be helpful, and by focusing on inter-industry cross-section analysis, the problem of timing coincidence between productivity and investment growth may be avoided.

Before leaving the intermediate goods case, a word about the role of cost-benefit analysis. This is briefly touched upon in Aschauer's paper and the usual doubts are raised. The fashion has been to stress these shortfalls, but I wonder whether the difficulties of drawing inferences from econometric analysis are not as great or greater. After all, cost-benefit analysis applied to the case of intermediate goods does not have to face the ultimate problem of evaluating consumer preference for final output. All that is needed is to estimate cost savings in production. Cost-benefit analysis remains an essential part of the problem and I would have liked to see a paper at this conference on that topic. While much and perhaps more than necessary has been said about the proper rate of discount, much remains to be done in improving the application of cost-benefit analysis to particular situations.

So much for infrastructure investment in intermediate goods. The remainder goes to provide for durable consumer goods of various sorts. Such goods enter by adding directly to consumer welfare, rather than via raising private sector productivity. They may provide positive benefits as does maintenance of a recreation lake or they may go to prevent or limit external costs generated by private sector activity, costs that do not come to be accounted for in the calculus of the market. While

I have not seen a direct estimate, I gather that as much as one-half of infrastructure investment may be directed toward the provision of consumer benefits, and this is where the quality-of-life issues, dealt with in the first part of Aschauer's paper, enter.

Given the growing impact of environmental damage on the quality of life, it becomes increasingly important not only to measure economic performance in terms of recorded GNP but also to supplement the measurement by a calculation of benefits and costs not yet accounted for. Towards this task, the kind of statement developed by Terleckyj and published annually by the United Nations is a good first step, but a first step only. Measuring the reduction in air pollution or in the crime rate is useful, as is measuring the effectiveness of various programs in securing such results. But these are first steps only. In order to decide how much public investment is called for, or to assess the size of the prevailing deficit therein, dollar values must be placed on these outcomes. Once more cost-benefit analysis becomes essential, including now its most difficult task of assessing consumer evaluation.

Does the nature of infrastructure investment bear upon the political economy of its provision and potential deficiency? Looking at the supply side, I see no particular reason why infrastructure-producing industries such as construction companies should be any less successful in pressing their services upon governmental providers than other suppliers to governmental agencies. However, a difference may be found on the demand or user side. The cross-industry use of infrastructure facilities may render it more difficult to generate pressure groups than is the case for intermediate goods, which are used primarily by firms within a given industry. Moreover, the consumers of the final product into which the intermediate good enters may not be aware of its importance to them and thus fail to render political support. Even where infrastructure supplies final services, these may be remote in nature, as in the case of environmental improvements, and again suffer weakened support. Thus various political reasons may cause adequate support to be lacking. Interjurisdictional benefit or cost spillovers pose a further problem.

Given these difficulties of fiscal choice, cannot the problem be resolved more readily by privatization, leaving the choice of provision to the market? Consider a setting that is rival in consumption, so crowding occurs but is subject to decreasing cost, thus calling for a natural monopoly. Landfills and toll bridges and, for that matter, most public utilities are cases in point. These are situations where private provision is possible but the public hand is needed by way of regulation, so as to provide efficient utilization and pricing. Or, public provision is a possibility. Which route is preferable depends on the particular case, but the public hand has to be involved in both. In other situations this option does not exist. This is the case where use is non-rival so that exclusion and provision by sale (instead of budgetary finance) would be inefficient. The benefits of cleaned air should not be rationed by requiring people to wear gas masks unless they pay a fee. Or, the use of uncrowded highways should not be restricted by tolls, even where a toll charge is feasible. The range over which privatization-cum-control offers a feasible alternative is thus limited, and it would be interesting to know what shares of the problem are open to the various solutions.

Quite possibly, the emergence of "quality of life" problems adds to the share calling for budgetary action. Rather than suggesting privatization, de-privatization may be called for. Air pollution, to take a most obvious example, treats the use of air as if it were a private resource, thereby disregarding external costs and damages to the community. Once more, the appropriate measure may take the form of public provision or of regulation. The one therefore cannot be discussed without the other.

This conference, quite appropriately, was limited to the case of physical infrastructure, thereby reducing an otherwise unmanageable topic to a manageable range. But it may also be noted in concluding that physical assets are but part of the problem. Human investment in health and education may be no less important, as both intermediate and consumer goods, and cannot be excluded from a more comprehensive analysis. Going even further, the very existence of the state, the judicial system, and for that matter the prevailing work ethic are important features of the overall environment in which the economic process is conducted and may be said to provide its infrastructure.