Infrastructure Investment: A Review Essay

Edward M. Gramlich


Stable URL: http://links.jstor.org/sici?sici=0022-0515%28199409%2932%3A3%3C1176%3AIIARE%3E2.0.CO%3B2-C

Journal of Economic Literature is currently published by American Economic Association.

Your use of the JSTOR archive indicates your acceptance of JSTOR's Terms and Conditions of Use, available at http://www.jstor.org/about/terms.html. JSTOR's Terms and Conditions of Use provides, in part, that unless you have obtained prior permission, you may not download an entire issue of a journal or multiple copies of articles, and you may use content in the JSTOR archive only for your personal, non-commercial use.

Please contact the publisher regarding any further use of this work. Publisher contact information may be obtained at http://www.jstor.org/journals/aea.html.

Each copy of any part of a JSTOR transmission must contain the same copyright notice that appears on the screen or printed page of such transmission.

JSTOR is an independent not-for-profit organization dedicated to creating and preserving a digital archive of scholarly journals. For more information regarding JSTOR, please contact support@jstor.org.
Infrastructure Investment: A Review Essay

By Edward M. Gramlich
The University of Michigan

I thank David Aschauer, Sheldon Danziger, Michael Deich, John Fernald, Charles Hulten, Alicia Munnell, Laura Rubin, Joel Slemrod, John Tatom, and two anonymous referees for helpful comments on earlier drafts.

Economists try not to be faddists but they often cannot help themselves. While work on a topic should mirror the prospective importance of the topic, that situation seems to occur with disappointing frequency. Instead, the usual pattern is that some reasonably important topic will be totally ignored for the longest time, then recognized, and then the subject of a flurry of work all out of proportion to its likely long run importance.

Nowhere has this speculative bubble of economic research been more clearly illustrated than with infrastructure investment. Macroeconomists have long felt that the stock of public capital is an important factor input in the production of total output. Macroeconomists have known that U.S. productivity growth slowed dramatically in about 1973 and macroeconomists should have known that United States investment in public capital has been down since the late 1960s. Yet analysis of the U.S. productivity slowdown completely ignored infrastructure investment for the first fifteen years of this slowdown, concentrating instead on energy prices, social regulation, the composition of the work force, research and development, different rates of obsolescence of the private capital stock, and any number of other matters. The public capital stock was hardly ever even mentioned as a potential factor in the productivity slowdown.

Aschauer changed all that. He wrote a series of papers (1989a, 1989b, 1989c) that put these two movements together econometrically—infrastructure investment turned down and aggregate productivity turned down slightly later, both in the United States and in some other developed countries. His work hit the magic button. Those who had worried about the productivity puzzle for fifteen years welcomed a new suspect. Those who were worried about low rates of U.S. national saving welcomed a new way to make their argument even more forcefully than with official figures on saving and investment, which do not count infrastructure investment as investment. Political liberals and liberal politicians saw a way to rescue government spending and projects from the assaults of Reaganism, and even a way to avoid oth-
erwise necessary budget cuts—just call the spending infrastructure investment. All of these planets came into proper alignment, and Aschauer's papers were followed by an unusual amount of attention, from politicians and economists. Beefing up infrastructure investment became simultaneously the liberals' political war cry of the early 1990s and one of the favorite topics for econometric research, by now the subject of at least forty other econometric studies using different data and techniques.

Now that the bubble has happened and may even be beginning to burst, it is useful to stand back and ask what has been learned from this discussion. It almost goes without saying that infrastructure investment was always more important than was indicated by its lack of attention up to 1989; never as important as the intense attention since 1989 would suggest. But in the process of debate, many other matters have been clarified—about how to identify a shortage of infrastructure investment, about whether there ever was an overall shortage, and about whether this possible shortage has been a factor in the aggregate productivity decline. In this essay I review all these questions. But I then go beyond this review to ask what I think is a much more fundamental question, the question that economists should have been focusing on all along. In a word, is the country doing something wrong, and if so, what? That is, what, if any, policies regarding infrastructure investment should be changed?

I. Basic Facts About Infrastructure Capital

There are many possible definitions of infrastructure capital. The definition that makes the most sense from an economics standpoint consists of large capital intensive natural monopolies such as highways, other transportation facilities, water and sewer lines, and communications systems. Most of these systems are owned publicly in the United States, but some are owned privately. An alternative version that focuses on ownership includes just the tangible capital stock owned by the public sector. Broader versions include successively human capital investment and/or research and development capital. Most econometric studies of the infrastructure problem have used the narrow public sector ownership version of infrastructure capital as their independent variable. This is in large part because it is very hard to measure anything else. It is difficult to measure privately owned infrastructure capital, and even if good measures were available, it would be difficult to distinguish private infrastructure capital from other private capital. It is difficult to distinguish human investment spending for health and education from consumption spending, difficult to know whether to count all research and development expenditures as investment, and difficult to know how to depreciate either of these types of spending in defining capital stocks. Hence for these purposes I follow others in using a relatively narrow public sector ownership definition of the stock of infrastructure capital.

Bureau of Economic Analysis (BEA) estimates of this nonresidential stock in 1991 in current dollars are shown in Table 1. The net stock of infrastructure capital, structures plus equipment, military and domestic, was $2755.8 billion, of which $2034.1 billion ($2755.8 - $514.1 - $207.6) was for nonmilitary structures and $2241.7 billion ($2755.8 - $514.1) was for nonmilitary structures and equipment. Most of this nonmilitary capital, 88 percent of the structures and 71 percent of the equipment, is owned by state
TABLE 1
PUBLIC INFRASTRUCTURE CAPITAL, 1991
(BILLIONS OF CURRENT DOLLARS)

<table>
<thead>
<tr>
<th>Item</th>
<th>Federal</th>
<th>State and Local</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonmilitary structures</td>
<td>242.8</td>
<td>1791.3</td>
<td>2034.1</td>
</tr>
<tr>
<td>Highways</td>
<td>16.9</td>
<td>708.0</td>
<td>724.9</td>
</tr>
<tr>
<td>Education</td>
<td>1.2</td>
<td>318.8</td>
<td>320.0</td>
</tr>
<tr>
<td>Other buildings</td>
<td>33.7</td>
<td>224.3</td>
<td>258.0</td>
</tr>
<tr>
<td>Hospitals</td>
<td>11.7</td>
<td>50.0</td>
<td>61.7</td>
</tr>
<tr>
<td>Water and Sewers</td>
<td>—</td>
<td>295.5</td>
<td>295.5</td>
</tr>
<tr>
<td>Conservation</td>
<td>143.4</td>
<td>35.9</td>
<td>179.3</td>
</tr>
<tr>
<td>Industrial</td>
<td>25.7</td>
<td>—</td>
<td>25.7</td>
</tr>
<tr>
<td>Other</td>
<td>10.1</td>
<td>158.7</td>
<td>168.9</td>
</tr>
<tr>
<td>Nonmilitary equipment</td>
<td>61.0</td>
<td>146.6</td>
<td>207.6</td>
</tr>
<tr>
<td>Military</td>
<td>514.1</td>
<td>—</td>
<td>514.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>817.9</strong></td>
<td><strong>1937.9</strong></td>
<td><strong>2755.8</strong></td>
</tr>
</tbody>
</table>


and local governments. While the infrastructure problem usually is described as a problem needing federal government attention, these figures indicate that, if infrastructure investment is a problem, it may be much more a state and local problem than a federal problem. This issue will be discussed in the policy section below.

The categories shown in Table 1 suggest why economists might have trouble analyzing infrastructure capital. The services of capital such as highways and schools are generally not sold on the market (though highway user fees could be used more extensively than now, and indeed user fees will be a big focus in the policy discussion below). While infrastructure capital is purchased on the market at the time of initial construction or installation, it is rarely sold, implying that economic rates of depreciation are almost never directly measured. Depreciation measures used in the construction of infrastructure stocks are physical measures based on service lives of different types of public structures. It would in principle be possible to measure rates of utilization of infrastructure capital—how many vehicles use roads, etc.—but in practice these measures are available only for some components of the public capital stock. And like other public goods, a large share of the benefits of infrastructure capital involve improved security, time saving, improved health, a cleaner environment, or improved outdoor recreation, magnitudes that are difficult to measure and that are not included in official measures of national output. Hence it will also be difficult to relate infrastructure investment to its goals, or changes in them. No wonder there are empirical controversies.

Measures of the stock of infrastructure capital are shown in Figures 1 and 2. Figure 1 shows total nonmilitary infrastructure capital ($2241.7 in Table 1) per capita, in 1987 dollars. The federal component of this capital, mainly for conservation structures and other buildings, has been close to $1000 per capita for more than four decades. Because this capital affects mainly the utility value of outdoor
recreation, which is not counted in national output, and because it has been so constant for so long, not permitting serious time series inferences, it has generally been ignored in previous analyses of infrastructure investment and I will follow suit.

The stock of real state and local infrastructure capital per capita did grow steadily up to the early 1970s, but has leveled off since then. The implied investment numbers leading to this pattern for stocks have showed a decline in investment since the early 1970s, both absolutely and as a share of GDP (Clifford Winston and Barry Bosworth 1992; Hulten and Robert Schwab, forthcoming). Because 1973 was the watershed year beginning the overall national productivity decline, it is not surprising that simple time series analyses find a correlation between the stock of infrastructure capital and overall productivity. I will discuss a number of econometric issues in interpreting this correlation below; for now I continue just looking at the numbers to give the general patterns.

Figure 2 decomposes the total state and local capital stock into its biggest components: highways, educational buildings, and all other—water and sewer systems, hospitals, and miscellaneous other structures. The "other" component has not been constant but has grown at a relatively steady rate over four decades, so it would again be hard to make time series inferences about the causes of productivity movements on the basis of this series. The real action comes from the two biggest components of state and local infrastructure capital; highways, streets, and educational buildings, between them accounting for 53 percent of the state and local stock in 1991.

Figure 3 shows separately the highways and streets component of the state and local capital stock. This stock rose sharply from 1955 to 1975, the period when the U.S. interstate highway system was being built, and has since leveled off as interstate construction has slowed and the previously built highways have depreciated. An additional factor is the price of gasoline, which rose sharply in the mid 1970s and could have cut into the demand for highways, though over this time both the auto stock and the
number of miles driven per capita has still increased. The price of gasoline apparently did cut into the number of trucks, trailers, and buses on the roads, also shown in the Figure. While one could get a shortage out of this pattern by extrapolating previous rates of investment spending, the rise in gasoline prices and the fall in numbers of heavy vehicles suggests that such an extrapolation may not be in order. It is certainly not obvious from these overall numbers that there is a highway shortage.

Figure 4 takes a similar look at public schools and other educational buildings, the second largest component of the state and local capital stock. Again the stock rose rapidly from 1950 to 1975, following by four years the rapid rise in the school and college age population also shown in the Figure. For the past two decades the school and college age population has plummeted, the share of pupils educated in public schools has been very stable, but the stock of public educational buildings has declined only gradually. If these numbers suggest one question, it is not whether there has been underinvest-

ment in educational structures, but rather whether there is now too much educational capital stock—perhaps the value of educational structures should have declined even more rapidly as the publicly educated school and college age population declined. As for productivity studies, it is also clear that educational buildings should not be part of the independent variable, because while these structures may have a very important long run productivity impact, they certainly do not have a short run impact on aggregate supply. To the extent that the rise and fall of educational structures is responsible for a correlation with national productivity trends, the correlation is probably bogus.

These simple comparisons cannot resolve difficult policy questions by themselves, but they do suggest a number of pitfalls as one gets into more careful analysis. The net real stock of state and local structures per capita has risen sharply and then leveled off. But the rise was due in part to the building of the interstate highway system and in part to the building of educational structures to meet rapid increases in the school and college age population. Apart from these movements, the federal stock of infrastructure capital has been very stable and the other components of state and local capital have grown at stable rates. It is hard to find a great need for infrastructure capital based on these numbers alone, and one might be somewhat suspicious of correlations of these numbers and national productivity without some careful corrections.

II. Is There a Shortage of Infrastructure Capital?

I argue below that I think the most important question involving infrastructure investment is not whether there has
been a shortage of infrastructure investment, but rather whether government policies regarding infrastructure investment should be changed. I get to the underlying policy issue below, but for now I lead up to it by focusing on the question that has been the focus of the vast majority of papers about infrastructure—whether there is or has been a shortage of infrastructure capital. There have been four ways of trying to determine if there is, or was, such a shortage:

- Engineering assessments of infrastructure needs.
- Political measures based on voting outcomes.
- Economic measures of rates of return.
- Econometric estimates of productivity impacts.

I review each in turn.

A. Engineering Needs Assessments

The first clarion call regarding the infrastructure gap involved needs assessments (Associated General Contractors 1983; National Council on Public Works Improvement 1988). These assessments typically relied on engineering studies of the condition of and need for capital facilities. The studies specified some desired capital stock based on some arbitrary initial period when capital was presumed to be adequate, and then measured desired investment as the gap between this and the actual stock. There was almost no economic reasoning anywhere in the calculation—fixed proportions were assumed, there was no adjustment for excessive or underutilized initial capital, and there was no recognition that citizens may want to trade off the benefits of greater capital against the costs.

Many of these engineering-type studies involved highways, the largest and most volatile component of the infrastructure capital stock. Table 2, taken from George Peterson’s (1991) analysis of the 1980s, shows that these physical needs studies suggested smaller highway infrastructure gaps as time passed and as they were done more carefully. Even though the Associated General Contractors study found actual highway investment to be less than a third of the desired level in the early 1980s (comparing actual investment, $19.1 billion, with “needed” investment, $65.4 billion), by 1987 there was no highway spending gap at all using the U.S. Congressional Budget Office (CBO) (1983) estimates and only a slight gap using the FHA (1989) estimates (comparing actual investment, $29.0 billion, with either $27.2 billion or $34.5 billion).

More up to date FHA numbers are shown in Table 3. The Table gives estimates of the percentage of pavement mileage needing improvement and the percentage of peak hour vehicle miles traveled under congested conditions. In each case the physical needs measure—
TABLE 3
PAVEMENT RATINGS AND PEAK HOUR CONGESTION
(PERCENTAGE OF PAVEMENT MILES
OR VEHICLE MILES TRAVELED)

<table>
<thead>
<tr>
<th>System and year</th>
<th>Needing improvement*</th>
<th>Congested**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban interstate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td>16.8</td>
<td>30.6</td>
</tr>
<tr>
<td>1987</td>
<td>11.1</td>
<td>42.0</td>
</tr>
<tr>
<td>1991</td>
<td>7.7</td>
<td>47.2</td>
</tr>
<tr>
<td>Urban and other arterials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td>10.0</td>
<td>28.5</td>
</tr>
<tr>
<td>1987</td>
<td>8.7</td>
<td>30.0</td>
</tr>
<tr>
<td>1991</td>
<td>6.8</td>
<td>28.7</td>
</tr>
<tr>
<td>Urban collectors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td>14.9</td>
<td>6.0</td>
</tr>
<tr>
<td>1987</td>
<td>13.6</td>
<td>6.0</td>
</tr>
<tr>
<td>1991</td>
<td>11.3</td>
<td>7.5</td>
</tr>
<tr>
<td>Rural interstates</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td>13.3</td>
<td>3.0</td>
</tr>
<tr>
<td>1987</td>
<td>11.6</td>
<td>7.7</td>
</tr>
<tr>
<td>1991</td>
<td>7.6</td>
<td>8.8</td>
</tr>
</tbody>
</table>

* Percent of pavement mileage rated in poor condition.
** Percent of vehicle miles travelled where the peak vehicle-capacity ratio exceeds a threshold set by FHA (0.8).

the percentage of highway miles in poor condition—declined steadily between 1983 and 1991. It is now at very low levels in all categories. The story is less clear for measures of highway congestion, which did all rise between 1983 and 1991, but congestion is still only at a high level for urban interstate and other arterials. There could be all kinds of pricing or other incentive policy changes that could reduce traffic congestion on these types of roads.

There are other needs assessments for water and sewer systems, aviation, and mass transit (Winston and Bosworth 1992). The story seems to be always the same—while one could make some case for a shortage of infrastructure capital, the shortages are not dramatic and it is far from clear that any step up in present rates of investment is in order.

Hence in the end these needs assessments do not make a compelling case for there being an overall shortage of infrastructure capital. They make a series of arbitrary, noneconomic assumptions, and even then do not give clear evidence that infrastructure capital is significantly out of balance. Perhaps the most convincing evidence in favor of a shortage involves urban highway congestion, and there could be many other explanations for, and ways of resolving, urban highway congestion.

B. Political Voting Outcomes

State and local officials themselves report that their biggest hurdle in building new infrastructure capital is in gaining the approval of voters. Roughly 20 percent of all new state and local construction must now be approved by referenda, which suggests that referenda voting might prove a good way to identify and measure infrastructure shortages.

Peterson (1991) also analyzed the results of referendum voting. He constructed a model explaining the results of voter referenda on capital investment projects. He reasoned that if public officials could guess the tastes of their voters right on average, they would submit spending proposals that reflected these tastes correctly on average, and roughly half of these proposals would be approved. But political officials might not be able to guess the tastes of their voters correctly on average, and they might fear the loss in credibility and public esteem should their bond proposals fail at the polls. Hence they might be expected to let infrastructure construction fall behind its true desired level so they could submit capital spending proposals that should capture large majorities, anticipating that more than half of these proposals would generally be approved.
There could be, in this political sense, a slight infrastructure shortage, but not one that policy measures should try to correct as long as there is no unhappiness with this general procedure for making infrastructure decisions. Moreover, apart from some lack of information or perception problems, there should never be a gross shortage of infrastructure capital because if this capital ever did fall far short of its desired level, vote-maximizing politicians could be expected to submit proposals to raise spending and utility-maximizing citizens could be expected to approve the proposals.

To determine whether a large gap in infrastructure investment opened up in the 1980s, Peterson analyzed the results of bond voting over time. The results, for overall capital projects for the 1948-90 period, are shown in Figure 5. Over the entire period the approval share averaged 70 percent, well above half as Peterson predicted. From 1968 to 1978, the share of construction dollars approved was below this average every single year, indicating either that voters were in an anti-public spending mood or that officials had overextended the public capital stock. Evidence in favor of the anti-spending explanation comes from the large number of state tax or spending limitation measures passed in this period. But from 1979 to 1989, the approval share was above the historical average in all years but 1981 and 1983. One could take these outcomes as evidence that the public capital stock had fallen below the level desired by voters. But by the very end of the period, the approval share seemed once again poised to fall below its historical average, suggesting that if there ever was any underinvestment, it might have already been corrected.

As with the needs assessments, there is no clear evidence of an infrastructure shortage from these voting data. There is evidence that voters were more unfavorable to infrastructure projects in the 1968-78 era and more favorable since. This could be because infrastructure capital fell behind voters’ desire for it, or there could be other causes. But even if there was a persistent gap for a time, public officials and voters may have already corrected it.

C. Economic Rates of Return

The economic approach to infrastructure investment involves computing all the benefits and costs of projects and then their rate of return. If the effective real rate of return exceeds the going real interest rate, the investment is worthwhile. Alternatively, if the net present value of project benefits evaluated at the going real interest rate is positive, the investment is worthwhile.¹

While the methodology for computing real rates of return, and the implied present value of net program benefits, has

¹The latter statement assumes that the going real interest rate is the proper rate for evaluating project benefits. In an open economy, it is the proper measure of the opportunity cost of private capital; in a closed economy, the matter is more complicated but the going pre-tax real interest rate is at least a reasonable contender (Gramlich 1990).
TABLE 4
PERCENTAGE REAL RATES OF RETURN ON HIGHWAY INVESTMENT

<table>
<thead>
<tr>
<th>Investment</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Projects to maintain current highway conditions</td>
<td>35</td>
</tr>
<tr>
<td>New urban construction projects</td>
<td>15</td>
</tr>
<tr>
<td>Upgrading sections not meeting minimum standards</td>
<td>5</td>
</tr>
<tr>
<td>New rural construction projects</td>
<td>Low</td>
</tr>
<tr>
<td>Fix sections above minimum standards</td>
<td>Negative</td>
</tr>
</tbody>
</table>


been around in one form or another for decades, it is surprising how few careful calculations of rates of return are available for infrastructure investment. The Army Corps of Engineers and the Tennessee Valley Association have made estimates of net benefits and rates of return for various canal and dam projects, but these estimates are suspect in a number of ways (CBO 1988; Gramlich 1990). Here the usual suspicion is that these agencies load the dice in favor of infrastructure spending that is pejoratively called pork barrel spending. For our standard highway category, the most complete and acceptable calculations of prospective rates of return have come from the FHA for various types of highway expenditures done in the early 1980s. These have been analyzed by the CBO and are shown in Table 4.

A mixed picture emerges from the Table. Figure 3 showed how it was hard to make an aggregate case that highway investment was too high or too low—this investment seemed to be more or less in balance with the number of heavy vehicles that might use highways. Table 4 now shows that some types of highway investment still seem highly desirable, such as plain old maintenance and to a lesser extent urban construction. Others do not seem as desirable, such as rural construction and improvements beyond minimum service standards. This distinction between maintenance and new construction will be important in the policy discussion below. The overall mixed picture is probably not surprising, and indeed it is the reason why economists generally prefer more disaggregated approaches in dealing with alleged capital shortages.

But even on their own terms, numbers like those shown in Table 4 may not ultimately be very informative. For one thing, rates of return were calculated in the early 1980s, when highway construction was much lower than it is now (see Table 2). By now, the pickup in highway construction could have lowered many rates of return substantially. For another, the numbers shown in the Table are not nearly disaggregated enough. There are growing and declining areas of the country, and surely infrastructure capital is more than adequate in some areas and quite inadequate in others. It is fine to disaggregate into particular categories of infrastructure capital, such as maintenance and new construction, but it would be far more useful to give particular rates of return—that on road maintenance in New York and Los Angeles, on new construction in San Francisco and Chicago, and so forth. With all the pages written on infrastructure investment, one is struck by how little there is of this sort of truly useful disaggregated information.

There are, of course, some problems even with this microeconomic approach. The most important in interpreting both the rate of return studies and the econometric studies (dealt with below) is benefit externalities. One argument for doing overall macroeconomic studies is that it is so difficult to deal with externalities in the micro studies. True, but it is also hard to know how serious the bias is.
Douglas Holtz-Eakin (1992) shows that it is unlikely that externalities would be a major problem because regional benefits do not seem to be any higher than state benefits in econometric studies. Gramlich (1990) reports data from license plate studies showing that even on major interstate highways most drivers are from within the state, and suggesting that the external benefits from highways for out-of-state drivers are not very large. Moreover, there are negative as well as positive externalities. The above estimates of high rates of return for urban road construction might be especially suspect in this regard, for often these projects impose significant external pollution and social costs on urban neighborhoods, costs that are difficult to quantify in rate of return studies.

While the picture is mixed, there are some categories of highway investment, maintenance, and possibly urban roads, that seem quite economic and where added infrastructure investment might make sense on average. There are other categories such as rural construction where added investment probably does not make sense on average. There are undoubtedly important regional differences in the value of added infrastructure investment. From this, it is hard to avoid the conclusion that while there may not be an aggregate shortage of infrastructure capital, at any time there could well be, or have been, shortages of particular types of infrastructure capital.

D. Econometric Estimates of Productivity Impact

Although macroeconometric studies might seem to be one of the least efficient approaches for determining infrastructure gaps, econometrics is what economists like to do, and these studies have commanded the most attention. Aschauer's initial papers have been followed by his own supporting work (1990, 1993) and that of Holtz-Eakin (1988, 1992), Munnell (1990a), Narayana Kocherlakota and Ke-Mu Yi (1992), Fernald (1993), and Rafael Flores de Frutos and Alfredo Pereira (1993). These papers have in turn generated a raft of criticisms from such authors as Henry Aaron (1990), Charles Schultze (1990), Hulten and Schwab (1991a, forthcoming), Rubin (1991), Dale Jorgenson (1991), and Tatom (1991a, 1991b, 1993, forthcoming).

The basic idea is simple—just expand an aggregate production function to include the public capital stock. The production function is written as:

$$Q = AF(K, L)$$

(1)

where $K$ is the stock of private capital, $L$ is the labor force, and $A$ is an index representing total factor productivity. Aschauer and others then make $A$ a function of the services provided by the government capital stock ($G$), rewriting (1) as:

$$Q = A^*F(K, L, G)$$

(2)

where $A^*$ is total factor productivity purged of the influence of the government capital stock. Using the Cobb-Douglas form and writing (2) in logs gives:

$$\ln Q = \ln A^* + a \ln K + b \ln L + c \ln G.$$  

(3)

Because government capital is not paid for its services, interpretation of the production elasticities, $a$, $b$, and $c$, is tricky. If one assumes that private capital and labor are paid their marginal products and finds $c$ to be positive, $a + b = 1$ and $a + b + c > 1$, so that returns to scale are increasing. If one assumes returns to scale are constant and finds $c$ to be positive, $a + b + c = 1$ and $a + b < 1$, so that labor and capital are paid more than their marginal products. When Aschauer did his macro time series
regressions, he found $c$ to be positive, from $.38$ to $.56$, forcing this choice between increasing returns and large factor rents.

It is also possible to use (3) to determine the rate of return on government capital. Differentiating the Cobb-Douglas form of (2) yields:

$$c = F_G G/Q$$  \hspace{1cm} (4)

where $F_G$ is the marginal product of government capital. Given that $G$ was $\$1938$ billion in 1991 (Table 1) and $Q$ was about $\$4800$ billion (using private business output), estimates of production elasticity $c$ from $.38$ to $.56$ result in pretty stratospheric estimates of the marginal product of government capital, 100 percent per annum or more.\(^2\) That means that one unit of government capital pays for itself in terms of higher output in a year or less, which does strike one as implausible. When Holtz-Eakin (1988) and Munnell (1990a) followed similar procedures, they also got very high rates of return.

A number of logical criticisms have been made of this macro time series approach, and a number of econometric criticisms. On the logic side, a first question involves the definition of the variables. The usual version of public capital entered into these production regressions is the state and local stock, corresponding to the number that is $\$1938$ billion in Table 1.\(^3\) As was seen in discussing Table 1, 37 percent of the total stock involves highways, which could influence overall national output if better

\(^2\)The implied marginal product of government capital is slightly less when evaluated for earlier years, but only slightly less. For example, the $G/Q$ ratio is about $.4$ in 1991 and about $.5$ in 1970, roughly the midpoint of the time series estimation period for most authors. Had the calculations in the text been done in 1970, the marginal product of government capital would have been 75 percent or more, still pretty stratospheric.

\(^3\)Some authors add the nonmilitary federal stock but the conclusions are little changed.

highways lower the cost of trucking. But many of the benefits of highway investment will also involve the time saving of private individuals, which will generally not be reflected in national output. The 16 percent of the state and local stock representing education buildings, the 12 percent representing miscellaneous office buildings, the 3 percent representing hospitals, and the 2 percent representing conservation should not have much short term impact on the supply of aggregate output as it is now measured. Adding everything up, only about two-thirds of the existing state and local capital stock even purports to raise national output, so the stratospheric output rates of return for all public capital become all the more implausible.

This problem has been recognized and a number of authors have gone over to another concept called core infrastructure, defined as highways and water and sewer systems, about 60 percent of the state and local total. Both Aschauer (1989a) and Rubin (1991) have tried various definitions of the appropriate stock, and they do find that the core infrastructure component of the state and local stock has the highest production elasticity. But the rates of return for core infrastructure capital are still implausibly high, so this disaggregation is not the whole answer to the puzzle.

Another way to check on these results is used by Rubin and Fernald. If core infrastructure is to raise overall productivity, it ought to raise value added most in industries that directly benefit from the public capital stock, such as transportation. Rubin and Fernald do a number of tests of the impact of core infrastructure capital on productivity in various manufacturing industries. It is difficult to make an assessment here—Rubin does not find much pattern to the results but Fernald does.
It would also be possible to check on the results by converting production functions to cost functions, as was originally suggested by Ann Friedlaender (1990). While nobody has estimated cost functions for the same data sets used in the productivity studies, Aschauer (1993) reports on a number of cost function studies that show positive social rates of return on infrastructure capital, for manufacturing industries in this and other developed countries.

Another logical problem involves the high rate of return. It is hard to see how the rate of return on public capital measured from output changes could ever lie above that of private capital. The private capital rate shows how private investors are making decisions at the margin, comparing marginal output benefits of their capital with the opportunity cost of their own funds. For public capital, these same investors would compare marginal output benefits with the opportunity cost of somebody else’s funds. If public investment really were as profitable as claimed, would not private investors clamor to have the public sector impose taxes or float bonds to build roads, highways, and sewers to generate these high net benefits? The impact on business profits would be higher than for private capital and the cost to business far less. While it is hard to measure the clamor of private business investors, and even harder to determine whether inducing clamor is an efficient modus operandi for business investors, very little such pressure seems to have been observed, even when the implied econometric rates of return were allegedly very high. Most of the political arguments of private investors in the 1980s were that tax rates were too high, not that public investment was too low.

A final logical problem stressed by Hulten (forthcoming) might be described in various ways, either in terms of linkages or in terms of the old marginal-average problem. Simply saying that some capital has been productive in the past, which is all a production study can hope to say, does not mean that future investments will also be productive. It could be very beneficial to build up a network of highways and not very beneficial to expand this network. There could be many such examples for infrastructure investment, and there is a sense in which looking at past patterns might tell very little about future beneficial effects of public investment.

There are also a number of econometric problems with the macroeconomic time series method of estimating production functions. Perhaps the most serious involves common trends. We saw in Table 2 that the overall trend for state and local capital per capita mirrored the overall trend for national output per capita, rising rapidly up to the early 1970s and then much more slowly. There could be very different explanations for these trends—state and local capital could be influenced by the building of the interstate system and by the number of school and college age students; while overall productivity could have slowed for all the usual reasons—energy prices, environmental regulation, declining technology opportunities, and the like.

One way to deal with common trends is to use some form of differencing. When Hulten and Schwab (1991a) and Tatm (1991b) first difference macro time series observations, they get much lower estimates of the marginal product or rate of return of public capital, often not even positive and always statistically insignificant. Munnell (1992) feels that this correction may be too radical, because differencing could destroy the long term relationships in the data. Tatm (forthcoming) on the other hand tests the variables for stationarity and finds that differencing is required to make valid
statistical estimates of the coefficients. Both authors agree that the proper approach is to test the variables for co-integration and adjust them before estimating the relationship. This is almost exactly what Tatam (1993) does, still finding essentially no productivity impact of infrastructure capital.

A second econometric problem involves missing variables, the obvious one being some measure of energy prices. These went up just when the stock of infrastructure capital and overall productivity stopped going up, and at a minimum one would think energy prices should be controlled for in aggregate production studies. When Tatam (1991b) makes such a control, in effect mixing production functions and cost functions, the estimated impact of infrastructure capital becomes weaker still. Tatam's approach can be criticized precisely because it does mix production functions and cost functions, and an obvious suggestion for future work is to try to pin this matter down by using measures of energy quantities in production functions.

A third econometric problem involves causality—does the levelling off of infrastructure capital reduce the growth of output, or does the reduced growth of output reduce the demand for infrastructure capital? Robert Eisner (1991) in particular has raised this question. Tatam (1993) does a series of lead-lag tests that indicate the causation may be more from output to infrastructure capital. Hulten (forthcoming) goes on to show that a plausible multi-equation growth model would make public capital an endogenous variable in the macro growth system, implying that its contribution to growth cannot be determined from a regression of output on public capital. To be sure, this type of criticism could be levelled at many production studies, many estimated production elasticities for private capital, and many lead-lag tests.

There is also another form of simultaneous bias. The idea of production studies is to relate the stock of infrastructure capital to aggregate supply, but when infrastructure investment rises, aggregate demand is what changes in the short run. Even if the true aggregate supply effect of core infrastructure were zero, a rise in infrastructure investment would raise aggregate demand and output in the short run, leading to an inappropriate inference of large productivity effects of infrastructure investment.

The idea of making public capital an endogenous variable in a macro growth system has been pursued by Flores de Frutos and Pereira (1993). They correct for both common trends and simultaneity and do find that public investment is clearly endogenous, driven positively by private output changes and negatively by private employment changes. But even with all these corrections, they still find very high rates of return on public capital, almost as high as those found by Aschauer.

Another way to correct for simultaneity was used by Fernald. He first disaggregated by industry, reasoning that individual industry productivity would not simultaneously determine the overall stock of public capital. He then focused only on roads, and he interacted this stock of roads with use of roads, as measured by industrial vehicle stocks. Again, even with all of these careful corrections, Fernald still found very high rates of return on public capital, as high as those found by Aschauer. These latest two studies destroy the notion that more careful econometrics leads inevitably to lower implied rates of return on public capital.

Some of these problems of econometric interpretation could be lessened by using pooled time series, cross section
data across states, as Munnell (1990b), Jose Costa, Richard Ellson, and Randolph Martin (1987), Eisner (1991), Randall Eberts (1986, 1990), Kevin Duffy-Deno and Eberts (1991), Holtz-Eakin (1992), and Hulten and Schwab (forthcoming) have all done. This approach generally gives more sensible estimates of the implied rate of return on infrastructure investment: now that rate of return ranges from the implied rate of return on private capital on the high side to zero on the low side (see Munnell’s summary, 1992). While this approach takes advantage of greater variation in the infrastructure (and other) independent variables, it may still overstate infrastructure impacts by confounding intrinsic state productivity differences with variation in infrastructure capital. It still is subject to the reverse causation criticism. It may also either understate or overstate infrastructure impacts by ignoring out-of-state benefit spillovers. Some of Ohio’s capital has impacts in states other than Ohio, but some of the contribution to Ohio’s output is from capital lying outside Ohio which may be correlated with that lying inside Ohio. It is very difficult to deal with problems of this sort.

If it makes sense to use data from different states, it also makes sense to use data from other countries, as Aschauer (1989b) did early on. As for the basic trends, Tatrom (forthcoming) shows that infrastructure investment in Canada, Japan, and five advanced European countries has followed the same basic pattern as in the United States—as a share of GDP, public capital formation has dropped off since the 1960s and 1970s. As for the econometric relationships, there is by now a massive literature that attempts to use production function analysis to find the determinants of growth rates across countries. Ross Levine and David Renelt (1992) have in effect summarized this literature by trying to make fair comparisons of the whole list of variables suggested to influence growth rates across 119 countries. It turns out that most of the variables alleged to influence growth rates do not pass tests of statistical robustness. One of the variables that definitely does not pass their robustness test, indeed never gets significantly positive coefficients, is the government capital stock. But a similar analysis focusing just on transportation infrastructure for 96 countries by David Canning and Marianne Fay (1993) find normal to high rates of return in developed countries, high rates of return in industrializing countries, and moderate rates of return in underdeveloped countries.

Hence, while the business of estimating time series econometric relationships has preoccupied a large segment of the profession for the past five years, one cannot help but feel that there are two kinds of research bubbles here, time series and cross section. For time series, as was asserted above, public investment should never have been totally ignored up to 1989, and probably should not have been the focus of so much attention since 1989. On the cross-section side, compared to more detailed studies of referenda voting and benefit-cost analyses, the attention to macro time series seems way out of proportion to what ever could have been learned from inevitably low-powered comparisons of time series trends, even if buttressed by cross-sectional data.

III. Policy Considerations

Not only have previous studies not provided very convincing answers to whether there is or has been an infrastructure shortage, but they may not have even focused on the right question in the first place. Even if there were no doubt of an infrastructure shortage, it is not clear what infrastructure policy or
policies should be changed. By the same token, finding no evidence of shortage would not mean that no policy should be changed. Hence rather than asking whether there is a shortage, it seems more helpful to ask what, if any, policies should be changed. In this section I switch the focus and analyze the infrastructure issue from this policy perspective.

A common way in which decisions about whether to invest in infrastructure capital are made is the one described above—states and localities propose bond issues and voters decide whether to build the structure. Because voters are deciding, it is hard to say there is a structural policy defect here. But voters are influenced by the financial and other terms of the deal, and these are set by governments and could be altered. The most important way in which this is done now is by federal grants, but other restrictions on whether and under what circumstances state and local governments can impose user charges can also be altered.

A. Federal Grants

Federal grants for construction purposes have followed a long swing process, ascending from less than 1 percent of GDP in the 1950s up to about 1.5 percent by 1978. At that point they began a long descent and grants are now back to close to the same percentage of GDP as in the 1950s.\(^4\)

The standard argument for federal infrastructure grants is benefit spillovers: citizens outside of the jurisdiction receive some benefits from infrastructure projects, and if these citizens’ votes are not reflected in decisions, too little infrastructure capital will be supplied. The most precise way to deal with the problem is by a series of Coasian bargains between governments, but given that there are something like 80,000 state and local governments in the United States, there would be very high transactions costs to arrive at such a set of bargains. It would be simpler, the argument goes, just to have the federal government provide matching grants for infrastructure projects, with the federal match in some general way representing the appropriate contribution of outsiders.

If this is the argument for federal grants, the actual terms of federal grant programs leave much to be desired. It is helpful to distinguish types of capital. One type is new capital with large costs and potentially enormous technological benefits, say as for the super-conductor, super-collider. For such capital technological spillovers are substantial, justifying federal support. Federal matching shares should reflect the benefits, technological and other, that flow beyond state lines. It is of course difficult to determine such benefits for these advanced technology projects, but present federal matching shares on this type of capital, generally about 90 percent, are probably way too high. Rather than keeping federal matching shares this high and having states lobby intensely for projects, as now happens, one quasi-market approach for determining proper federal matching shares would be to let states bid on projects. If the state of Massachusetts really wanted the super-conductor, super-collider, let it outbid Texas. Such an approach should save on federal tax dollars and improve the statewide allocation of government projects.

A second type of infrastructure capital, by far the most common, is capital like that already in place—widened or expanded roads, improved water and sewer plants, and on down the list. Studies have shown that for most infrastructure proj-

\(^4\) In doing these calculations, it is important to distinguish federal grants for construction purposes from other federal grants, these days largely consisting of open-ended grants for medicaid and public welfare.
pects of this kind the majority of the benefits, 70 percent or so, are realized by those inside the state (Gramlich 1990). Given this, the proper federal matching grant would pay about 30 percent of the costs for the typical project. Instead, the typical federal infrastructure grant pays about 80 percent of the cost of a project up to some limit, then none of the costs. In the usual case where the grant limit is small relative to typical state spending on the project, the federal money provides no price subsidy at all at the margin, and much too large an inframarginal income subsidy. These capped grants then achieve the worst of both worlds—they cost the federal government too much, hence raising the federal deficit and probably lowering national saving, and they do nothing about external benefits at the margin. The correction is obvious—lower federal matching shares and remove the caps.

The problems with overly generous inframarginal matching could be even worse than they seem. Suppose state or local officials know that there is too little of some type of public infrastructure nationally, and they think that Congress will rise to the bait and pass a new grant program. Rather than simply building the facility in short supply, the generous federal matching gives these officials a powerful incentive to wait and see if they can get a federal grant, rather than just going ahead with their own project. Exactly this seems to have happened, first with a countercyclical public works grant program passed in the late 1970s (Gramlich 1978) and later with pollution-control grants (James Jondrow and Robert Levy 1984).

Another problem involves the distinction made earlier between new construction and maintenance. Basically, maintenance investment seems to have higher rates of return but new construction gets higher federal matching subsidies. In fact, often highway maintenance projects get little or no federal matching while new interstate construction projects get the generous treatment described above. The solution is obvious here too—while matching shares are lowered for new construction, they might actually be raised up to their proper low level for highway maintenance.

A further problem involves the financing of the federal grants. At the national level there are five dedicated trust funds—for airports, highways, aquatic resources, harbors, and inland waterways. The Department of Transportation (1990) has recently suggested creating others for the coast guard and railroads. Into each trust fund goes the dedicated revenue, such as that from the gas tax for highways, and out come the federal grants for the relevant projects. Many states have similar arrangements to finance their own infrastructure projects.

This trust fund arrangement can be useful in limiting federal subsidies by forcing the dedicated tax to pay for all or most of the spending in question. At the same time, if the arrangement is misapplied, it can lead to inefficient outcomes. One example of such a misapplication is the gas tax, which could also be rationalized as an energy conservation measure that should not have its returns sent to the highway trust fund and devoted to the construction of further highways. Recent budget bills have devoted much of the gas tax revenues to general federal revenues and not to the highway trust fund, but it was twenty years into America's energy crisis and fifteen years into America's budget crisis before this daring step was taken.

A second example of such a misapplication is that four of the trust funds, all but the one for aquatic resources, do not even limit federal subsidies by forcing trust fund revenues to cover all of the federal spending for the facilities in ques-
tion (David Montgomery 1989). At a minimum they should do that. At present, whenever there is a hold-down on federal infrastructure grants for budget reasons, the revenues build up in the trust fund, again achieving the worst of both worlds—the funds are there, activating lobbyists in favor of increased spending, even though spending is already subsidized by federal general revenues. The solutions are obvious here too—finance all grants from the trust funds, and devote most gas tax revenues to general revenue.

B. User Fees

The above comments suggest some general reforms in federal grant programs for infrastructure investment. But if it were possible to impose user fees on infrastructure facilities, which it certainly is for highways and other transportation infrastructure, many higher education structures (the user fee is commonly known as tuition), hospitals, many water and sewer systems, some conservation structures, and some industrial structures, it would be possible to do even better than to have revamped federal grants finance the infrastructure investment.

Take the case of highway maintenance financing, perhaps the largest category of infrastructure investment where there are opportunities for desirable expansion. If these maintenance projects are eligible for federal grants, the federal government collects a gas tax, devotes a large share of it to the federal highway trust fund, and has the trust fund in turn provide grants with 80 percent federal matching to states, which probably match the federal money with revenues from their own gas tax. Suppose instead the gas tax were devoted to federal general revenues and budget deficit reduction, the federal highway trust fund were abolished, and the states were permitted to finance their own maintenance expenditures with revenues from tolls (which in general they cannot now levy if they have used federal money to build their interstate roads). The impressive list of advantages from such a change is as follows:

- Revenue. There would be a new source of revenue to pay for the highway maintenance, lessening budget problems at both the federal and state levels.
- Allocation. Over the long run the toll revenue from highway \( x \) could be devoted to restoring highway \( x \), thus giving public officials a better quasi-market guide on how to allocate their maintenance (and other) funds (Wallace Oates 1991).
- Politics. The nasty political debate about excessive taxation could be moderated. At least in this area it would be very clear where the toll revenues were going.
- Taxation by Willingness to Pay. This has always been the public finance dream, to devise financing schemes that tax citizens according to their willingness to pay for the facility. How better to do that than to use user fees?
- Spillovers. Rather than have federal grants, even reformed federal grants, employ inevitably crude estimates of out-of-state marginal benefits in constructing matching ratios, toll user fee finance of highway maintenance would automatically be paid by out-of-state users in proportion to their use.
- Conservation. Highway engineers report that interstate roads depreciate according to the cubic power of vehicle axle weight (Kenneth Small, Winston, and Carol Evans 1989). Rather than letting all vehicles use the road for free, tolls could be based
on true damage imposed on the road, hence encouraging heavy truckers to lighten their axle weight and extend the life of the road. Or, states could build thicker roads and charge truckers for that. Part of the economic saving here would be that less road maintenance would need to be done if tolls were set efficiently.

- Congestion. Tolls could be varied by the time of day or week, hence lessening congestion.

With so many advantages, it is hard to say no. There are clear opportunities to have user fees finance much infrastructure investment, simultaneously financing the investment and extending the life of the capital. States could be allowed to finance their road maintenance and new construction projects by tolls (generally not possible now), airports could be allowed to use ticket taxes (recently made possible) and landing charges (still not possible), higher education could charge tuition rates nearer to marginal costs (giving more aid to needy students), hospital and other structures could finance themselves with fees. There are a number of technological innovations in the collection of these fees that could keep down administrative costs (Winston and Bosworth 1992; Martin Neil Baily, Gary Burtless, and Robert Litan 1993). The revenue from the fees could also be devoted to properly designed trust funds to keep revenues and spending in balance. One radical version of this proposal is that infrastructure capital could simply be privatized, with the private owners given both the permission and incentive to set up their own fee schedules.

There are, of course, economic objections to comprehensive user fee financing of all infrastructure capital. Present day federal matching grants could still be more efficient if it were costly to collect the user fees, if there were externalities, if there were natural monopolies with spillovers, or to complete a national network of roads and/or airports. While one can think of types of capital for which these types of objections are relevant, these exceptions to the general rule would seem to be of modest enough importance that a more extensive set of user fees should still bring about large efficiency gains. A more extensive set of user fees may in the end result in more or less infrastructure investment—that prediction is difficult to make. But the mechanism for making infrastructure decisions would be much improved. States would have a new and powerful incentive to find the optimal stock of infrastructure capital.

There could also be political objections to user fee financing of infrastructure capital. If user fees are so wonderful, why are they not used more widely? Space constraints prohibit a deep discussion of the politics of paying for government spending, a topic with many well-known subtleties. But one thing that can be said is that if the world gradually adjusts its institutions in the direction of the optimal approach, the use of user fees in the United States is growing dramatically (CBO 1993).

IV. Conclusions

As for the alleged infrastructure shortage, the evidence reviewed in the paper is decidedly mixed. The needs assessment approaches and macro time series approaches used to justify big increases in infrastructure spending are flawed in many ways. One might make some more headway by looking at more disaggregated time series, bond referenda voting, and rates of return, where there is some evidence that some types of infrastructure could have been in short supply, but even here the evidence is inconclu-
sive and it is not clear that the overall shortage persists.

What should be done about any shortages? The best approach is not to try to analyze the numbers and tell how short the supply is and how much national or state spending or grants should be increased. A far more sensible approach is to set up institutional structures that permit state and local governments, the holders of almost all infrastructure capital, to find their own optimal stock. The way this might be done is to reform the present system of financing infrastructure investment. States could be forced to bid for costly, large-scale high technology projects. States could also be permitted or encouraged to impose user fees to finance their own capital and maintenance. And federal matching grants could be restructured and used much less intensively.

As for the contribution of economic researchers to this new understanding, there is some good news and some bad news. After years of ignoring the issue, economists led by Aschauer did finally find it, giving some more professional gloss to advocacy pieces that up to then were entirely from the infrastructure lobby. But the contributions of economists were not all they could have been—there seems to have been far too much attention to the details of macro production studies, which can never answer the relevant policy questions very well, and far too little attention to more disaggregated rate of return studies and studies of the impact of different types of policy changes.

While in some sense the problems outlined and discussed here are more at the state and local level than at the federal level, the federal government could help matters in various ways. The obvious way is to change policies to permit states to go on their own on infrastructure investment, cutting states loose from the federal grant system and giving states their own source of revenue and power to make key decisions. But there are some less obvious ways as well. Improved capital stock data would make it possible to conduct more disaggregated studies. Improved estimates of economic rates of depreciation of the infrastructure stock would also improve estimates of the size of this stock and the desirability of expansion. More importantly, the federal government might even give policy analysts something to study by doing experiments with policy changes of various sorts—permitting bidding for valued projects, permitting user fees, permitting privatization, permitting other sorts of incentive changes—to see how state and local governments and their voters will respond. Studying reactions of this sort can redirect the efforts of economists onto studies of just what policy changes are in order.

References
EBERTS, RANDALL W. “Estimating the Contribution of Urban Public Infrastructure to Regional Eco-


———. “Infrastructure Spending: Where Do We Go From Here?” in the National Tax Association Proceedings, forthcoming.


MONTGOMERY, W. DAVID. “Statement before the U.S. Senate Committee on Appropriations.” May 11, 1989.


