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Is There a Shortfall in Public Capital Investment?

Proceedings of a Conference
Held in June 1990

Alicia H. Munnell, Editor

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Is There a Shortfall in Public Capital Investment? An Overview

*Alicia H. Munnell**

A nation can use its current output to provide for the future in numerous ways: it can undertake private capital investment, add to the stock of public capital, enhance income-producing assets abroad, invest in human capital through education and health programs, conserve natural resources and the environment, and invest in science and technology. During the 1980s none of these approaches were pursued vigorously and most of the country's increase in output went for consumption rather than the enhancement of future production; the adverse effects of debt-financed consumption on private investment, net foreign investment, and human capital have been well documented.

In the past few years, however, academic work, commission reports, and natural disasters have highlighted the fact that the nation has also been neglecting its stock of public capital. Stories abound of deteriorating roads, bridges, and sewer systems, which have often led to serious collapses or other disasters. Almost everyone has experienced the frustration and delay of congestion on overburdened roads and airports.

Political developments have also raised the importance of public capital investment on the national agenda. At the federal level, dissolution of Cold War tensions has spurred debate on the reallocation of spending from military to other uses, although this has been mitigated somewhat by recent developments in the Persian Gulf. The impending re-authorization of the federal highway bill also has sparked a great deal

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of interest. Fiscal problems at all levels of government have led policymakers and citizens to rethink spending priorities.

This conference aimed to determine the extent to which the United States may be underinvesting in public infrastructure, explain the potential economic consequences, and suggest mechanisms to help alleviate any adverse trends. The conference focused on public investment in physical capital only to make the topic manageable, and should not be interpreted to mean that investment in human capital is in any way less important.

The conference consists of six sessions: The first three sessions discuss various topics related to the importance of infrastructure, while the last three tackle some practical policy issues in this area. The first session addresses the broad question of why infrastructure is important by discussing the impact of public capital on quality of life, the environment, and output. The second introduces a new data set on state-level public and private capital stocks to examine the impact of public capital on output, investment, and employment growth at the state level. The third session explores directly the question of whether public infrastructure is undersupplied.

In the second, policy-oriented set of papers, the first explores the extent to which the private sector can compensate for the lack of public investment. The next two papers focus on incentives. One addresses the issue of the efficiency of current infrastructure investment and pricing, specifically as related to highways and airports. The other analyzes the optimal financing of public infrastructure and investigates the incentives imbedded in existing federal programs for public capital investment.

All conference participants agreed that public capital investment plays an important role in enhancing both the quality of life and private economic activity. All concurred that public capital, like private capital, belongs in an economic production function, and that the decline in public capital investment may have played some role in the productivity downturn. A sharp disagreement arose over the estimated economic importance of public infrastructure. The great majority of participants rejected the estimates of the marginal productivity of public capital in the range of 50 percent to 60 percent that emerge from the time series analysis.

Despite the general acceptance of the economic and social importance of public capital investment, two quite different perspectives on the need for more infrastructure investment emerge from the discussion. On one side are those who see a strong link between public capital investment and economic and social well-being; they view the current stock of public capital as inadequate and believe that additional investment is required. On the other side are those who are primarily concerned with the efficient use of existing infrastructure; they basically

oppose increasing investment until the engineering, pricing, and financing of infrastructure are closer to the optimum.

Why Is Infrastructure Important?

David Aschauer sets the stage for subsequent discussion and much controversy by laying out the case for the importance of infrastructure to the quality of life, the environment, and private economic activity.

In the first part of his paper, Aschauer presents an informal discussion of the linkages between public capital investment and various aspects of well-being, such as the human habitat, economic opportunity, and leisure time. The major point of this section is that many observers question the ability of existing and projected infrastructure facilities to adequately support quality-of-life requirements; their apprehensions are most pronounced in the areas of the environment and transportation.

As evidence on the environmental front, Aschauer notes that, despite large-scale expenditure following the passage of the Clean Water Act in 1972, many streams and lakes in the United States remain incapable of supporting their designated commercial or recreational uses. The problem rests, in large part, with municipal wastewater treatment facilities, which account for about one-third of the use impairment of the waters. These treatment facilities also raise the toxicity levels of lakes and rivers. The Environmental Protection Agency (EPA) says that many municipalities have yet to construct sewage treatment facilities to meet permanent requirements.

A second area where inadequate infrastructure has an adverse impact on both health and aesthetics is the treatment of solid waste. Garbage is being generated at unprecedented rates, while the number of facilities to handle the waste is shrinking. Between 1978 and 1986, the number of operating landfills declined from 20,000 to 6,000. Forecasts predict that by 1993 more than 2,000 of the remaining landfills will be closed due to inadequate safety and environmental practices or capacity constraints. These trends suggest increased health risks to residents and damage to the environment.

In the area of transportation, inadequate public transportation poses a serious barrier to employment for those without cars. Aschauer notes that disabled citizens cite a lack of transportation as the primary obstacle to obtaining jobs and being fully productive members of society. Moreover, in many cities job opportunities in the suburbs remain unfilled because of the lack of transportation from the urban core.

Increased congestion in the ground and air transportation networks

both impairs people's leisure and raises business costs. The Federal Highway Administration forecasts a 436 percent increase in urban freeway congestion by the year 2005 if improvements to the interstate system are not forthcoming. Similarly, the Federal Aviation Administration forecasts a significant increase in the number of airports suffering serious delays during the next decade. In short, transportation is another area requiring additional investment, or else inadequate infrastructure likely will continue to detract from the quality of life.

In the second part of the paper, Aschauer shifts from quality-of-life issues to the impact of infrastructure on economic activity. He cites previous studies demonstrating the positive effect of public capital stock on output, both within this country and across countries. He further notes that public capital increases the rate of return to private capital, thus stimulating private investment; at the same time it substitutes for private investment, thus discouraging private initiatives.

Aschauer assembles these various forces into a simple model to simulate the effect of higher public investment on the aggregate economy. Specifically, he assumes that public investment during the period 1970 to 1988 remained near the average for 1953 to 1969, thereby eliminating most of the actual decline. The results suggest that the increased public investment would have raised the rate of return to private capital from 7.9 percent to 9.6 percent and the rate of productivity growth from 1.4 percent to 2.1 percent for the 1970–88 period. The impact on private investment is more complicated; initially higher public investment crowds out private investment, but eventually the higher rate of return dominates and simulated private investment exceeds actual levels. Aschauer emphasizes the tentative nature of these results and goes on to address criticisms that have been raised about his empirical work: that public investment is endogenous, that the estimated coefficient on public capital is too large to be reasonable, and that the model is too simple.

Aschauer then attempts to provide new evidence showing how public sector capital affects private sector productivity. This time he explores the relationship between private productivity and public capital investment across states, by including government capital as an intermediate input in a generalized Cobb-Douglas production function. To work around the lack of state capital stocks, Aschauer rewrites the production function so that the estimate of the relationship requires data on only the capital-output ratio, rather than the level of capital stocks. He then assumes, based on cross-country comparisons, that the capital-output ratio is constant over time. As a result, individual state capital-output ratios can be expressed as the ratio of investment to output times the rate of growth of output plus the depreciation rate, which Aschauer sets at 5 percent.

Aschauer estimates the production function using data averaged over the period from 1965 to 1983. His results show that state output per worker is positively and significantly related to public investment in core infrastructure, although the coefficient on the public investment variable (representing the marginal product) is extraordinarily high. More precisely, while the marginal product of private capital in his equations ranges between 9 and 12 percent, the marginal product of public capital exceeds 200 percent. Again, Aschauer addresses likely criticisms of this empirical exercise and attempts to demonstrate the robustness of his results by varying the assumed depreciation rate and using instrumental variables.

Aschauer concludes that given the importance of infrastructure, both for quality of life and economic competitiveness, and the dissolution of Cold War tensions, the time seems ripe for a reorientation of government spending priorities.

Henry Aaron, in commenting on Aschauer's work, notes that although Aschauer has made an important contribution to the productivity slowdown debate by including public capital as an explanatory factor, several serious questions surround his empirical work. Aaron cautions that if a result fits with our hopes and appears too good to be true, it probably is, and should be subjected to careful scrutiny.

Most fundamentally, Aaron rejects the estimates of the productivity of public capital in both Aschauer's earlier work and the paper presented at this conference. In the case of the earlier results, which show a productivity of public capital around 60 percent, Aaron attributes the implausible estimates to the pitfalls of time series analysis. Aggregate time series analysis based on variables expressed in levels is dominated by trend, and produces marvelous fits that do not really explain much of the relevant variance. Thus, unless the results are robust to estimation using other functional forms, the hypothesis should not be considered to have been proven. Another problem is that the production function model assumes competitive factor markets. Public capital, however, does not pass any market test in which productivity is balanced against a cost measure.

In terms of the current paper, Aaron attributes the startling results to an incredible list of assumptions required to estimate the model, and argues that more tests should have been run to assess the sensitivity of the results to other assumptions. He also raises another oft-cited criticism—reverse causation, whereby rapid output growth and high productivity lead to greater public investment, rather than public capital investment causing greater output per hour. While Aschauer attempts to treat this issue with instrumental variables, Aaron notes that he should have examined it through direct modeling and testing.

In a different vein, Aaron also questions much of the informal

reasoning in Aschauer's argument about quality-of-life effects. He sees much of the advocacy for more infrastructure as a reflection of the vested interests of those agencies and organizations that gain from greater capital spending. Furthermore, while Aaron believes that government spending can improve the quality of life, this claim does nothing to support the thesis that infrastructure contributes to national output as conventionally measured.

Richard Musgrave also questions Aschauer's high estimated coefficient on public capital and wonders about reverse causality, but focuses his efforts on trying to identify the unique characteristics of infrastructure and other issues. He concludes that infrastructure as an intermediate good is distinguished by its joint and cross-industry use, and then speculates whether these characteristics could lead to high productivity.

Musgrave also argues that much could be learned about the benefits of public capital through cost-benefit analysis. While this approach has its problems, it can, and should, be applied to estimate cost savings in production where public capital is an intermediate good. Musgrave also recommends that researchers attempt to quantify currently unrecorded pieces of GNP, such as quality of life indicators, and apply cost-benefit analysis to estimate the impact of infrastructure investment on these unrecorded aspects of national output.

Musgrave concludes with the thought that although it was appropriate to limit the conference to the subject of physical infrastructure, one must not forget that physical assets are only one part of the issue. Public investment in health and education is no less important and should be included in any more comprehensive analysis.

How Does Public Infrastructure Affect Regional Economic Performance?

Alicia Munnell's paper explores the impact of infrastructure investment on three measures of state-level economic performance. Since no comprehensive measures of public or private capital stocks are available at the state level, these data are constructed and used to estimate state production functions, to explore the relationship between public and private investment, and to analyze employment growth within a business location model.

The first step is to construct estimates of the public and private capital stocks by state. For public capital stocks, the perpetual inventory method is employed to generate an estimate of the net value of state and local government capital investments, which is then used to apportion Bureau of Economic Analysis (BEA) national stock estimates among the states. In the case of private capital, BEA stock estimates are distributed

among states based on measures of each state's activity in various sectors of the economy. The observations show significant variation and appear to contain real information.

Munnell then introduces these stock estimates as inputs in a pooled cross-section production function based on data for 1970 to 1986. The results indicate that public capital has a significant, positive impact on output at the state level. The regression coefficients also show rough equivalence between the marginal products of private and public capital; specifically, the coefficients imply a marginal productivity of 35 percent for both private and public capital. They also suggest slightly increasing returns to scale across the three inputs. When public capital was disaggregated, water and sewer systems had the largest impact on output, followed by highways, with other public capital exhibiting a very small impact.

The next section examines the relationship between public and private investment in which two opposing forces are at work. On one hand, public capital enhances the productivity of private capital, raising the rate of return and encouraging more private investment. On the other hand, public capital serves as a substitute for private capital. An attempt is made to combine these opposing influences in a stock-adjustment model, where the desired stock of private capital is related to the level of output, the stock of labor, and the stock of public capital, and also to the marginal productivity of private capital. The results, while not robust, indicate that, on balance, public capital investment stimulates private investment. Munnell notes that these results should be interpreted only as an additional bit of evidence supporting public capital's economic importance and as an invitation to future researchers.

Finally, a business location model that includes a measure of public capital stock is used to analyze employment growth. This type of model assumes that firms strive to maximize profits and will choose a location based on their profitability at alternative sites. Any characteristics of the location that affect production costs or sales will influence this decision. The specification used by Munnell analyzes the average annual percent change in private employment in the state as a function of variables reflecting the labor market, energy costs, cost of land, market size, tax burden, and public capital stock. Munnell notes that the results are generally in line with what one would expect, with public capital having a positive influence on employment growth, all else equal.

Taken together, the results of these three exercises indicate that public capital has a positive impact on private sector output, investment, and employment. Some areas need significantly more research and refinement, but these results are another piece in the emerging picture of public capital's economic importance. Munnell concludes that more spending on public investment, which clearly would remedy serious

safety hazards and improve the quality of life, may also induce greater productivity and growth.

In his comments, Charles Hulten, while finding the coefficient on public capital in the production function quite plausible, and substantially more so than the results of aggregate time series estimates, notes several problems. First, since the nation's infrastructure networks are largely complete, the estimated coefficient on public capital may overstate the benefits from *additional* public investment. Second, without resource costs one cannot discern whether the allocation of public capital is efficient. Third, only a state's own public capital stock enters into the production function, which ignores the benefits that a state may derive from the public capital stocks in neighboring jurisdictions. Fourth, the equations include no adjustment for congestion. Finally, the production function is only one equation within a simultaneous system, and thus the correlation between public capital and private output might come from other parts of the economic system, which brings up the perennial issue of the direction of causation.

Ann Friedlaender sketches out an alternative framework that could be used in this type of research, a framework that would address the problem of resource costs. She advocates estimating a cost rather than a production function. This model would incorporate input price effects into the analysis, as well as allowing analysis of the efficiency of capital allocation. While admitting that the data requirements of this approach are substantial, she offers reasonable guidelines for estimating certain data, such as the cost of private and public capital by state. Friedlaender also proposes that one could add demand effects into the analysis through the use of a benefit function. She concludes that such an approach is feasible and could yield interesting results to supplement the existing evidence on the importance of infrastructure to regional output, investment, and employment.

Is Public Infrastructure Undersupplied?

George Peterson addresses directly the question of whether public infrastructure is undersupplied. He begins by tracing the historical pattern of infrastructure spending over a longer period than previous studies. While public capital spending has indeed declined from its peak in the 1960s, this decline is only one downturn in a longer history of cyclical behavior. Moreover, the fact that infrastructure investment has declined does not in itself indicate that it is undersupplied. Thus, more information is required to determine whether there is a shortfall in public capital.

As one piece of evidence, Peterson basically accepts the Aschauer

argument that the marginal productivity of public capital is extremely high compared to private capital. This suggests an undersupply even if the infrastructure has no value in providing services directly to the consumer. Peterson then looks to the taxpayer-voter for further evidence that infrastructure may be undersupplied.

Peterson obtains a partial answer through voters' revealed preferences as expressed in bond elections and other referenda. The answer is partial because only 25 percent of infrastructure spending passes through this process. Nevertheless, if public officials were trying to satisfy the median voter, as theory suggests, they would submit frequent bond proposals for consideration in order to assess voter demand. As a result, bond elections should be closely contested with bond approval rates and margins close to 50 percent. Instead, he finds that 80 percent of infrastructure bond proposals were approved between 1984 and 1989, and that the margin of approval exceeded 66 percent on average. This experience suggests an undersupply. But why? What forces could frustrate the demands of both business, which can gain as much from public capital investment as from its own investment, and the electorate, which appears disposed to approve higher levels of public capital outlays?

Peterson suggests three possible explanations. The first emphasizes spillover effects. As long as some of the benefits from public capital investment spill over to users outside the local taxing district, and these users do not contribute to the costs of the projects, local taxpayers, who consider only their own benefit-cost trade-off, will choose to provide a suboptimal level of infrastructure capital. This problem could be solved through a user fee system, where all users, regardless of where they live, pay a fee to cover the marginal costs they impose on the network. In those instances when user fees are impractical, an alternative solution is intergovernmental matching grants.

A more innovative explanation is Peterson's notion that the undersupply might be traced to the "fear of rejection" on the part of public officials. Since the taxpayer revolts of the 1970s and early 1980s, the very act of referendum voting—and the possibility it brings of public repudiation—appears to intimidate officials. Rather than designing proposals to satisfy the median voter, they aim at garnering as large a majority as possible in order to minimize the chance of rejection. As a result, public capital spending proposals are simply not brought to the attention of voters.

Peterson's third explanation suggests that the political process systematically underweights the benefits from infrastructure that accrue to businesses. He contends that the principle of "one person, one vote" provides no mechanism for aggregating the interests of both business and taxpayers.

Peterson concludes that infrastructure undersupply is as much a problem of politics as of economics. He argues that traditional decision-making processes are badly designed to handle joint consumer and producer demand for public goods. He also rejects the trend toward creating authorities and other institutions that can invest in infrastructure without submitting to the referendum process. Rather, he advocates the formation of business and consumer alliances that together take the case for infrastructure spending directly to the public.

Alan Blinder, while agreeing that infrastructure is undersupplied, and that the causes include public officials' fear of rejection and externalities, questions the argument that business needs are not well represented in the political process. Each of us is both a producer and a consumer, and there is no evidence that people vote only their consumer interests. Furthermore, in an age when business has successfully lobbied to further its interests on regulatory, antitrust, and trade protection issues, why should one believe that it is completely mute on the infrastructure front?

Because of the growth in both the economy and population that has occurred during this century, Blinder considers it inappropriate to compare only the absolute levels of capital spending across time. He notes that Peterson's median voter model implicitly assumes that the number of bond referenda proposed derives from previous approval rates. That may be a "good" model, but it does not embody rational expectations. Furthermore, while Blinder agrees that user fees are an appropriate way to deal with externalities, he cautions that user fees may not do the job if a free rider problem exists within a jurisdiction.

Joel Tarr focuses on the cyclical nature of infrastructure spending in an attempt to place the current developments in a historical context. He explains that both public and private capital spending have exhibited irregular cycles of spending bursts followed by periods of retrenchment and stability. Further, spending has shifted over time among levels of government and between private and public providers.

State governments were especially active from the 1820s through the 1840s, but curtailed their activities after depressions. Cities then assumed the role of primary infrastructure provider during the 1860s and early 1870s, after states suffered from over-investment, high taxes, corruption, and subsequent borrowing limitations.

At this point, private provision again became important, especially in water supply, as many municipal governments experienced defaults on their obligations and were hampered by spending limitations imposed by state governments. By the 1890s, however, municipalities regained their position as primary provider, which they held until World War I; after the war the states resumed the dominant role with heavy involvement in transportation investment.

The federal government was not deeply involved in providing capital investment until the 1930s. It dominated through World War II. Since then, federal financing of capital spending has exhibited the familiar cycles of boom and bust.

Tarr then discusses the common characteristics of previous infrastructure spending bursts. Concerns over deterioration of facilities and adequacy of services have generally not been sufficient to spur investment. Earlier periods of rapid investment were characterized by a variety of demand- and supply-side conditions: major urbanization; critical technological developments, such as the automobile, the airplane, or advances in bacterial science; and new funding mechanisms, such as the gas tax.

Tarr concludes that current social, political, fiscal, and technological forces are unlike any previous period of growth in infrastructure investment, and thus suggests that those interested in expanding investment should investigate a variety of flexible approaches to achieve this goal.

What Are the Prospects for Privatizing Infrastructure?

Jose Gomez-Ibanez, John Meyer, and David Luberoff explore one alternative by investigating the prospects for privatizing infrastructure investment. Specifically, they analyze whether the private sector can do a more effective job of investing in and pricing infrastructure services. They focus on highways and wastewater treatment facilities as two areas where private participation appears most promising.

They make clear at the beginning that they would expect privatization to have little impact on the total quantity of infrastructure. In fact, they contend that the nation would probably end up with more infrastructure under public provision than under private. Their argument is that private infrastructure investment is likely to displace some other capital project, since it is financed from a limited pool of private savings. Public provision, in contrast, has some possibility of increasing total investment to the extent that the project is funded by user charges or taxes that are paid from a reduction in current consumption rather than from saving.

Rather than altering the quantity of infrastructure, privatization affects the distribution of burden between users, taxpayers, and wage earners. The conventional argument in favor of privatization is that the private sector is inherently more efficient and thus could build and operate facilities at a lower cost than the public sector. This argument has been augmented in recent years by the concern that the public sector may be unable to finance facilities because of taxpayer resistance.

The commonly cited cost advantages of privatization are not entirely clear, the authors argue. Some of the reduction in cost reflects transfers among groups rather than real savings for society as a whole. For example, landowners may be more likely to donate rights-of-way to private road projects, but this is merely a transfer from landowners to road builders and does not change the amount of land needed for the project or the resource costs to society as a whole. On the other hand, private firms do have some real cost advantages: they have a stronger incentive and more flexibility to use resources productively, they can often build facilities more quickly, and they may be better able to exploit economies of scale, scope, and experience.

Proponents of privatization bemoan provisions of the Tax Reform Act of 1986 that restrict the use of tax-exempt financing for private projects; they claim that the higher financial costs for private providers make it difficult for them to compete fairly with the public sector. Gomez-Ibanez, Meyer, and Luberoff argue, however, that even without tax exemption the costs of private and public providers do not differ markedly, since private providers can deduct interest payments as a business expense.

Cost, however, is often neither the only, nor the most important factor in the decision whether a particular project should be provided privately or publicly. Siting is often a major problem for highways as well as solid waste disposal facilities. Private providers may have some advantages in siting by allaying concerns of local residents and forming alliances with them before the project falls under the public spotlight, while public agencies are generally required to conduct site searches openly from the start. The private sector may also be more skilled in public relations—better able to market the benefits and minimize the risks of a project. Private involvement, however, does not eliminate the pressures or opportunities for government oversight or public involvement in siting decisions, since private facilities still require zoning permits and environmental approvals. Moreover, the public may be concerned that private firms may not take their environmental and other community responsibilities seriously. Public agencies may have an advantage simply because they have more established institutions and procedures for dealing with these issues. On balance, the authors do not find that the private sector offers any major advantages in siting.

Other important issues are those of pricing and rate regulation. User charges seem to be appropriate financing mechanisms for both solid waste disposal and highways. While the choice of provider need not dictate the type of financing, the question arises whether a private firm or a public agency is more likely to charge the appropriate or socially desirable price. An argument in favor of private firms is that they are more likely to price services at marginal cost and to adjust

charges to reflect the costs imposed by different types of users. The most important disadvantage of a private provider is that it may be tempted to exploit any monopoly power it might enjoy. Some states have turned to regulation to mitigate this problem; this strategy, however, may be inefficient because it could stifle market signals to increase capacity. In other words, the regulatory process, while necessary, could undermine many of the advantages of private involvement in infrastructure provision.

The authors then try to make some overall assessments about the winners and losers from privatization, with the caveat that the incidence of gains and losses depends in large part on the individual project. Organized labor and landowners are the most likely losers in private provision, due to the private firm's greater incentives to capture economic rents. The clearest winners are federal and state taxpayers. Investors might gain if they can hold onto economic rents or efficiency gains rather than passing them on to facility users; the outcome will depend on the competitiveness of the market for the particular service. Thus, privatization is a more attractive policy for the public where the potential efficiency gains are great and the private operator faces effective competition.

The discussants find little with which to disagree. Sir Alan Walters adds that another argument for private provision is reducing the power of unions, thereby not only lowering wages but also reforming what he views as deleterious work practices. He also points out that the authors focus only on new construction and do not consider privatization of existing assets; this is probably a sensible tack since the likelihood of privatizing the Interstate Highway System is minimal. Nevertheless, an analysis of the efficacy of a completely privatized road system would have been interesting.

Walters does question the authors' argument that while privately provided infrastructure is likely to displace other private investment, publicly provided infrastructure, if funded by user charges or tax revenues rather than debt, is likely to generate additional investment. Walters believes that while the form of finance will affect the timing of savings, total investment will remain unchanged.

Gail Fosler states that the authors provide a useful discussion of the advantages and limitations of privatization; this effort adds an important perspective to the work of those advocating privatization as the solution to America's infrastructure problem. She notes the fact, implicit in their selection of highways and solid waste disposal facilities as examples, that privatization of infrastructure investment and public services generally has not progressed very far.

This raises the question: If private provision of infrastructure is such a good idea, why is it not done more frequently in the United States?

Fosler concludes that the incentives required for private participation are extremely high. History shows that infrastructure activities are provided privately only when they are very profitable, and that they are often profitable when they enjoy significant noncompetitive market advantages. As a result, the efficiency gains from private provision are limited.

Fosler also reaffirms the authors' point that siting is a critical issue, and speculates that even if funding were available for all infrastructure spending it would probably not all be spent because of the politics of development. Fosler closes with the point that beyond providing infrastructure, the private sector has an important role in helping to shape the political process, so that the required levels of public spending and taxation are forthcoming from the government with as little economic distortion as possible.

How Efficient Is Current Infrastructure Spending and Pricing?

Clifford Winston argues that the focus of the current policy debate should be shifted from the question of how much to increase infrastructure spending—be it public or private—to a discussion of efficient pricing and investment guidelines. He believes the nation does not need to increase public capital outlays as much as it needs to price and spend more effectively. Users of infrastructure impose costs on themselves and others by increasing congestion and by wearing out the infrastructure. Thus, an efficient infrastructure policy will maximize the gap between social benefits and costs, including the costs that users impose on others, through pricing specifications that regulate demand and investment guidelines that specify design.

Winston lays out an efficient spending policy for both highways and airports. Current policy finances highway construction and repair through the fuel tax; this levy does not accurately reflect the pavement damage and congestion caused by different types of vehicles. Pavement damage varies with weight per axle, and thus users should be charged according to this measure. The current fuel tax provides the opposite incentive, because it encourages the use of small, fuel-efficient engines. Smaller engines, however, cannot pull as many axles as their larger counterparts. Thus, the fuel tax indirectly encourages shippers to use the least number of axles, and the most weight per axle, to transport a given load, thereby creating the most pavement damage per haul.

Pavement damage also depends on the thickness of the pavement. Previous analysis conducted by Winston found that optimal thicknesses

are significantly higher than current thicknesses. Increasing pavement thickness would reduce annual maintenance expenditures and, by lowering the marginal cost of a standard axle load, would soften the impact of taxes promoting efficient pavement wear.

Winston also examines the problem of congestion and finds that while congestion pricing has been advocated by economists for many years, it has been ignored or dismissed by policymakers. He addresses critics of congestion pricing by arguing that equity objections can be overcome if revenues are used properly and by citing existing systems that implement congestion pricing without disrupting travelers.

Winston then turns to airports and discusses the need for efficient pricing and investment in this area. Many observers argue that airport congestion and flight delays stem from capacity constraints. If increasing capacity through construction is the only method used in addressing the congestion problem, Winston claims that society will face a difficult and expensive task. Building new airports involves enormous costs and long lead times, and the predicted growth of air traffic volume is tremendous. He argues that efficient pricing and investment can provide immediate, low-cost relief.

Currently the most common method of assessing landing fees is by aircraft weight. This fee is inefficient, since the principal cost imposed by an aircraft takeoff or landing is the delay it causes other aircraft. Instead, Winston argues, congestion pricing should be implemented and runway capacity of existing airports should be expanded to the point where the marginal cost of an additional runway is equated with the marginal benefit of reduced delay. While less empirical work has been done on the effects of efficient policies on other infrastructure areas, the available information suggests that significant benefits could be derived.

In the final section of the paper Winston addresses common criticisms of efficient pricing and investment—technological infeasibility and the political difficulties of implementation. He also assesses the alternatives to efficient infrastructure policy—traditional approaches, privatization, and significantly increasing infrastructure spending. He cites evidence that efficient policies can be implemented with existing, proven technologies and believes that political hurdles could be overcome. In comparing efficient policies with the alternatives he finds efficient pricing and investment clearly preferable.

Alan Altshuler responds that despite the merits of the efficient pricing and investment argument, he does question the political feasibility of implementing this kind of policy. Winston's evidence in support of his claims is only mildly suggestive, he says. Moreover, Winston does not carefully weigh the evidence contrary to his premise.

Altshuler judges that congestion pricing of roadways is still a

political nightmare, and he will continue to view it as such until toll-road authorities have replaced commuter discounts with peak-period surcharges. Business, labor, and civic groups have consistently been hostile and quite vocal about proposed policies of this nature, and very successful in fighting their implementation. Altshuler also disputes Winston's claim that user fee systems can be structured to avoid regressivity, and to calm the ruffled feathers of vested interests.

He believes, however, that a shift in truck taxation from number of axles to axle weight is quite plausible, since it would entail only a minor revision of a long-standing arrangement. Airport congestion pricing policies are increasingly being implemented, according to Altshuler, but he doubts that they will be sufficient to alleviate airport congestion in the face of rapid predicted traffic growth, even if used in conjunction with runway expansion and air traffic control improvements. In sum, although specific initiatives may be feasible, Altshuler sees little reason to believe that economic efficiency will triumph in infrastructure policy; the values on which our political system is grounded routinely conflict with efficiency.

Michael Bell's comments begin by highlighting what he sees as the value in Winston's approach. Bell believes Winston takes an important step by considering not only the condition of the infrastructure but also its performance, since it is the services rendered by the facility that are important, and not the facility itself. Winston also explicitly links spending on new construction with operation and maintenance requirements, a very important, but often neglected, approach. Finally, Bell says that Winston raises legitimate questions about privatization, which is often seen as a panacea.

Bell believes that Winston's analytic approach could be extended in the following ways: expanding the definition of the output or product of public infrastructure spending, and including environmental costs as part of the social costs and thus incorporating these costs into the efficient pricing scheme.

Bell ends his discussion by raising two concerns about efficient pricing strategy. One is the same point made by Altshuler—however theoretically reasonable or technically feasible an idea may be, the public may not accept it. This applies especially to congestion pricing. Second, even if technically feasible means of pricing were accepted and implemented for roads and airports, the task still remains of adapting these types of fees to environmental projects. This could be difficult because of distributional issues, the costs of administering such policies, and the weakening of economic tools as they are implemented through the political process.

How Should Public Infrastructure Be Financed?

Edward Gramlich further pursues the issue of getting the incentives right by evaluating the various mechanisms for funding public investment. He concentrates on state and local government spending, since the federal government undertakes little direct capital investment. The federal role in providing grants to states and localities for capital investment is central to the discussion, however.

Gramlich discusses three types of public capital investment and the appropriate funding schemes for each category. He begins with public capital investments that serve local needs with minimal spillovers to other communities and have no distributional implications. Here he argues that services should be financed by user fees; these fees apportion payment in accordance with benefits received and ensure efficient use. Some exceptions to this rule may arise in cases where, on equity grounds, officials want even those unable to pay to have access to, say, a park; the guiding principle, however, is that services that are enjoyed locally should be paid from a local revenue source.

Gramlich then discusses the second category of government investment, the case where spillovers occur, such as in national roads, wastewater treatment, or air pollution control. If feasible, the user fee is again the preferred funding mechanism. If user fees are costly to assess or inequitable, other options include the creation of a regional authority or the introduction of matching grants from the federal government. In the case of federal grants, the federal matching rates should correspond to the share of benefits accruing to out-of-jurisdiction users.

While many federal grant programs were designed with this principle in mind, their matching rates are much higher than appropriate, with the consequence that they must be capped to limit use. Gramlich proposes revamping the programs by reducing the matching rates significantly, while at the same time removing the caps. Changing the structure of these programs would go a long way to providing proper subnational government spending incentives and reducing federal grant spending.

The final category of investments entails both spillovers and long-run distributional considerations; the primary examples are public schools and higher education systems. These types of investments require different funding mechanisms. User fees are not appropriate for local schools, since education is a fundamental right of citizenship. Moreover, states have frequently been instructed by the courts to offset variations in the revenue-raising capability of communities in order to ensure that children in low-income communities are not educationally disadvantaged. The federal government currently has a limited grant

program to assist poor school districts, again characterized by a cap and a high federal matching share. Gramlich notes that the problem created by variations in community wealth is exacerbated by the federal deductibility of local property taxes. Thus, to improve schooling for children in underprivileged areas requires strengthening state equalization grants for education, reforming federal grants to poor school districts by removing existing caps and lowering the matching rate, and eliminating the federal tax deduction for property taxes.

Higher education is another area where long-run distributional implications come into play. In this case it is possible to impose user fees—tuitions—to cover the full cost of the service. This happens in some states, but typically only out-of-state students are charged the appropriate fee. Whether or not user fees cover the full costs, higher education has become very expensive, thus altering the issue somewhat: if fees do not cover the full cost, how can states afford the programs, or if fees are full cost, how can families afford it?

After examining the issue of who should pay for which facilities, Gramlich then addresses timing questions. He emphasizes that in financing any project the cohort that reaps the benefits should pay the costs. Thus, capital expenditures should be financed by long-term bonds with maturities close to the life of the asset purchased. User fees or taxes should then pay annual depreciation plus interest and principal on the bonds. The good news is that, for the most part, this is already happening.

At both the federal and state levels much infrastructure investment is financed through dedicated trust funds. Trust funds are a useful way to link marginal benefits and costs when dedicated taxes or user fees can be assessed and when no externalities are present. Gramlich offers some suggestions for reform of the trust funds to best meet their intended purposes.

Gramlich's first discussant, Rudolph Penner, finds little with which to disagree and expands on the problem of capped grants. Many federal grants provide large windfalls to someone who would have engaged in the same activity regardless of the subsidy, rather than affecting the individual's marginal decision. This action, while irrational by textbook standards, is quite pervasive and thus deserves some attention. If the design of grant systems is fundamentally flawed, it severely limits the ability of higher-level governments to induce lower-level governments to provide optimal levels of public capital investment.

Penner has found that many phenomena that appear perverse to economists are often quite understandable and reasonable to legislators and others. He offers as an explanation of the popularity of these capped grants the fact that they convey a great deal of power to the bureaucracy and to the appropriate subcommittees. They also reduce the uncertainty

facing politicians about the total amount required to fund a grant program. While the current situation is far from perfect, Penner believes it can improve. In large part improvement requires educating non-economists to the principles of economics (such as marginal decisions and horizontal equity). These issues are not intuitive to many people, but they need to be understood since they form the theoretical underpinnings of the proposed changes.

James Poterba, while generally agreeing with Gramlich's position, believes that some of his recommendations are open to debate. He begins by noting that reforms of infrastructure finance are not merely accounting conventions; changes in financing mechanisms will also directly affect the level of spending. For example, one study showed that transit workers in urban mass transit systems with earmarked taxes received higher wage increases than those in systems without earmarked taxes. Similarly, Poterba's own work revealed that states with capital budgets spent 15 percent more on capital investment than states where capital and operating outlays were combined.

Poterba makes the same point as Penner: something must be going on to explain the pervasiveness of capped grants in the face of all the evidence of their inefficiency. He agrees with Penner that political factors are at work, but believes that the most important of these is the perceived need for equitable treatment of different jurisdictions. With open-ended grants, rich areas may contribute several times as much as their poorer neighbors to matching programs; the result is that absolute transfers from the federal government to the richer areas will be larger than those to poorer areas, thereby widening the inequities.

Poterba argues that capped grants may actually be efficient, citing literature from regulatory economics as evidence. For example, if federal grant-givers envision a minimum threshold of highway spending in each jurisdiction, then high subsidy rates on expenditures up to some level will ensure that most areas will take advantage of the program up to that point. Even if closed-ended grants are an efficient way to achieve an objective, Poterba emphasizes that this does not automatically imply that existing grant programs are well designed.

Poterba also raises a point about the applicability of user fees in certain situations. Regarding Gramlich's recommendation of user fees for solid waste disposal, for example, Poterba notes that user charges are generally more successful when levied at the time a consumer purchases a good than when charged to someone disposing of it. Finally, Poterba believes that calls for more efficient infrastructure financing will receive serious attention, especially given the current climate of fiscal austerity at both the federal and state levels.

Conclusion

Infrastructure is important for the environment, the quality of life, and economic performance. The United States has cut back sharply on infrastructure investment in recent years. At the same time, few of the incentives that affect the decision to invest in new public capital or to use infrastructure services appear consistent with those advocated by economists. The question is what government officials should do now. Here opinion is sharply divided.

Those worried about the incentives to spend, the efficiency of design, and the appropriateness of the prices charged, want all efforts focused on eliminating current distortions and inefficiencies. They tend to believe that once the perversities in the existing system are removed, the present stock of infrastructure may meet most of the nation's needs. Additional investment at this time will divert attention and alleviate pressure to make the needed reforms.

While acknowledging the inadequacies in current funding, pricing, and design, other observers still see a need for more immediate investment. Dilapidated bridges and roads, large wastewater treatment requirements, and other needs make additional public capital investment essential. The positive impact of infrastructure on output and economic growth provides a further spur. Moreover, many question the likelihood that efficient pricing mechanisms will be adopted in the near future.

Resolving this infrastructure debate will be essential in order to determine the manner and appropriate level of highway and other capital spending during the 1990s.

Why Is Infrastructure Important?

*David Alan Aschauer**

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
Transportation						
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
Waste Management						
Municipal waste facilities	Reduced viral infection, etc.			Reduced odors, litter, and turbidity	Increased employment	
Solid waste facilities	Reduced toxicity			Reduced odor	Increased employment	
Law Enforcement						
Police stations, courts, prisons	Reduced drug use	Reduced crime			Increased employment	
Fire Stations		Reduced risk				
Hospitals	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

	Urban Freeway		Signalized Arterial	
Forecast	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

[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

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[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-

[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

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

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[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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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

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[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

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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								$\bar{R}^2$
	Constant	Time	CU	lnL − lnK	lnYen,−1,−2			lnK_G − lnK	
(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	Δ(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

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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.

How Does Public Infrastructure Affect Regional Economic Performance?

Alicia H. Munnell
*with the assistance of Leah M. Cook**

Bridge collapses and water main explosions focus national attention on the crumbling condition of the nation's infrastructure. Catastrophic infrastructure failures are always a momentary spur to debate on the nation's capital investment policies. But increasingly these negative developments have been accompanied by economists' claims that public capital investment makes a significant contribution to national output, productivity, growth, and international competitiveness.

These conclusions, which emerge from the work of Aschauer and others, have generally been based on observed patterns of national and international spending on public capital and various measures of economic performance. Reaction to these claims has been cautious; critics have charged that the empirical work overstates the impact on productivity by ignoring other factors, that the direction of causation between public investment and output growth is unclear, and that even if the historical empirical relationships were estimated correctly, they provide no clear indications for current policy.

This paper is not designed to answer all the criticisms but rather to offer one more brush stroke to the emerging picture of the relationship between public capital investment and private economic activity. It does this by exploring the impact of public capital on output, employment growth, and private investment at the state and regional level. The

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paper consists of four parts. Since no comprehensive measures of public or private capital are available at the state level, the first section explains the construction of such data and describes the distribution of these wealth measures by state and region. The second section uses these data to estimate an aggregate production function, in order to see whether the positive relationship between output and public capital, which has been documented at the national level, holds up for individual states and regions. The third section moves from the steady state to the adjustment process and explores the relationship between public investment and private investment, attempting to determine the direction and magnitude of the effect. Finally, the fourth section introduces the public capital data into a firm location model in order to see whether variations in public capital by state have had any impact on state-by-state employment growth.

The conclusion is that those states that have invested more in infrastructure tend to have greater output, more private investment, and more employment growth. This evidence supports results found in earlier studies. The empirical work also seems to indicate that public investment comes before the pickup in economic activity and serves as a base, but much more work is required to spell out the specifics of the link between public capital and economic performance.

Public and Private Wealth by State and Region

The U.S. Bureau of Economic Analysis (BEA) publishes annual data from 1925 to the present on the stock of private and public tangible wealth; these data include equipment and structures, but exclude land inventories and rental residential real estate. Despite the availability of public capital data, until recently this kind of input had been virtually ignored in the analysis of national production and growth. The oversight is difficult to explain, since the stock of public capital is not small. As shown in Table 1, in 1988 public capital amounted to almost $2.5 trillion, compared to $4.4 trillion in the private sector. Even ignoring investments devoted to military purposes, the stock of public capital amounted to $2.0 trillion, or 46 percent of the value of the stock of private capital.

Most of the $2.0 trillion of nonmilitary public capital consists of assets owned by state and local governments. Highways and streets account for 39 percent of the total state and local wealth, and water and sewer systems for another 16 percent; buildings (primarily schools and hospitals), other structures, and equipment make up the rest (Table 2).

No data are available on the stock of private or public capital on a state-by-state basis. Hence, it was necessary to devise some way of

Table 1
Private and Public Nonresidential Net Capital Stock, 1988

Capital Stock[a]	Billions of Dollars	Percent of Total
Total	6846.4	100
Total Private	4364.8	64
Nonfarm business	4202.3	61
Farm	162.5	2
Total Public	2481.6	36
Military	490.9	7
Nonmilitary	1990.7	29
Federal	272.2	4
State and Local	1718.5	25

Note: Numbers may not add to totals because of rounding.

[a]Figures include equipment and structures only. Land, inventories, and rental residential capital are excluded.

Source: U.S. Bureau of Economic Analysis, unpublished data.

dividing up the national totals published by the BEA. In the case of public capital, the approach taken was to create a state capital series based on annual state public investment data and BEA depreciation and discard schedules, and use this distribution of capital to apportion the BEA public capital totals. In the case of private capital, state investment data (except for manufacturing) were not available, so the approach followed was to apportion the BEA total on the basis of various measures of each state's activity in agriculture, manufacturing, and nonmanufacturing (see Appendix A).

Table 2
State and Local Fixed Nonresidential Net Capital Stock by Type of Asset, 1988

Capital Stock	Billions of Dollars	Percent of Total
Highways and Streets	670.7	39.0
Water and Sewer Systems	265.7	15.5
Buildings and Other Structures		
Schools, Hospitals and Other Buildings	514.2	29.9
Conservation and Development Structures	29.3	1.7
Miscellaneous	126.7	7.4
Equipment	111.8	6.5
Total	1718.5	100.0

Note: Numbers may not add to totals because of rounding.

Source: U.S. Bureau of Economic Analysis, unpublished data.

Table 3
Stocks of Public and Private Capital by Region, 1988

Region	Public Capital		Private Capital		Ratio of Private to Public Capital
	Per Capita (Dollars)	Percent of Total	Per Capita (Dollars)	Percent of Total	
Northeast					
New England	5,953	4.9	13,748	4.4	2.3
Mid Atlantic	7,193	17.1	13,829	12.9	1.9
North Central					
East North Central	6,205	16.5	15,866	16.6	2.6
West North Central	7,501	8.4	18,455	8.1	2.5
South					
South Atlantic	5,788	15.3	14,520	15.1	2.5
East South Central	6,106	5.9	16,080	6.1	2.6
West South Central	6,330	10.7	25,165[a]	16.8	4.0
West					
Mountain	7,679	6.5	19,603	6.5	2.5
Pacific	6,573	14.8	15,256	13.5	2.3
Continental United States	6,509	100.0	16,551	100.0	2.5
Addendum					
Total Capital[b] (Billions of Dollars)	1,585.5		4,031.4		

[a]The high per capita private capital figure for the West South Central region is the result of a very large share of the nation's manufacturing and mining capital being allocated to Louisiana and Texas. The mining is understandable, since this sector consists largely of oil and gas production. Louisiana and Texas account for almost half of the nation's production of oil and gas, and oil and gas are extremely capital-intensive industries. The manufacturing capital is more difficult to explain, since the shares of manufacturing capital allocated to Louisiana and Texas are almost twice their shares of national value added by manufacturing industries. The main explanation appears to be the high ratio of capital to value added for the specific manufacturing industries located in these states. For example, both Louisiana and Texas are dominated by the petroleum and coal and the rubber and plastics industries; in 1985, these industries had a ratio of capital to value added of 1.37. This number was almost twice the ratio of capital to value added for the average of all the nation's manufacturing industries (.76). To ensure that these high private wealth figures were not distorting the results, separate equations were estimated for the remaining 46 states and the results were virtually unchanged.

[b]These totals differ from those shown in Table 1 for two reasons. First, they do not include Alaska, Hawaii, and District of Columbia. Second, the totals are beginning of year values, whereas the data in Table 1 represent end of year values.

Source: Author's calculations. See Appendix A.

The results of this estimation procedure are presented in Table 3, which shows the per capita stocks of public and private capital by region for 1988 and the ratio of private to public wealth. Table 4 presents information about the growth in public and private capital for the periods 1970–80 and 1980–88. The most striking aspect of the data is that while all regions invested in both private enterprises and public infrastructure during the 1970s, only the South and West continued to add to public capital in the 1980s.

Table 4
Average Annual Rates of Growth in Public and Private Capital by Region, 1970–80, 1980–88
Percent

	Public Capital								Private Capital	
	1970–80				1980–88					
Region	Highways	Water & Sewer	Other	Total	Highways	Water & Sewer	Other	Total	1970–80	1980–88
Northeast	1.0	4.8	2.7	2.4	0	1.0	−.2	.1	2.8	2.7
New England	.5	5.2	3.3	2.3	−.2	1.2	0	.1	3.0	4.1
Mid Atlantic	1.2	4.7	2.6	2.4	.1	1.0	−.3	0	2.8	2.2
North Central	1.2	2.3	2.5	1.9	.2	1.3	−.2	.2	3.3	.9
East North Central	1.0	2.1	2.1	1.6	0	1.2	−.5	0	3.3	.8
West North Central	1.6	2.9	3.7	2.5	.6	1.3	.3	.6	3.5	1.1
South	2.2	3.8	3.8	3.1	1.1	2.9	2.0	1.8	3.9	2.8
South Atlantic	2.8	4.4	4.4	3.7	1.0	3.0	2.4	1.9	4.6	3.8
East South Central	1.9	3.3	2.6	2.3	.6	1.1	−.3	.3	4.3	1.8
West South Central	1.6	3.2	3.7	2.6	1.7	3.6	2.9	2.5	3.2	2.3
West	1.2	2.9	1.9	1.8	.5	2.3	1.7	1.4	4.1	3.9
Mountain	1.9	3.1	4.7	3.1	1.9	4.7	4.1	3.2	4.3	2.7
Pacific	.9	2.9	1.3	1.4	−.2	1.5	.9	.7	4.1	4.5
Continental United States	1.5	3.4	2.8	2.3	.6	1.9	.9	.9	3.6	2.5

Source: Author's calculations. See Appendix A.

This process of constructing state-by-state capital measures has produced 19 years of data for each of the 48 states in the continental United States; the question is whether it has produced any real information or whether, in effect, it has simply reproduced the relationships between aggregate inputs and outputs many times over. This is a particularly important question given that the procedure for constructing both private and public wealth involved apportioning national totals. Here the nature of the methodology is crucial; if the totals had been distributed to states, say, based on the national ratio of capital to labor, no new information would have been added.

This was not the approach; the share of public capital allocated to each state was based on actual state public investment data and the share of private capital was based on each state's involvement in specific types of economic activity. As a result, the data show significant variation; for example, the ratio of private to public capital, which

averaged 2.5 for the nation, ranged in the 1988 state data from a low of 1.5 for New York to a high of 5.1 for Louisiana. Moreover, the rate of growth of public capital varied enormously by state both in the 1970s and particularly in the 1980s. For example, California, the state that ranked twelfth in the ratio of public capital to labor in 1970, had dropped to thirty-fourth place by 1986, and West Virginia, which ranked thirty-fifth in 1970, had risen to seventh place at the end of the period. In short, the individual observations appear to contain real information.

The Role of Public Capital in the Production Process

Several studies have examined public capital as an input in the production process. Aschauer (1989) introduced the obvious, but heretofore neglected, notion that the stock of public infrastructure as well as the stock of private capital may be a key to explaining the level of national output in the private sector. His results showed a strong relationship between output per unit of private capital and the stock of public capital; he also found a statistically significant relationship between the level of multifactor productivity and the stock of public capital. Munnell (1990), examining the labor productivity slowdown in the 1970s, found a similarly strong, statistically significant, relationship between the nation's stock of public capital and the level of labor productivity.

Studies at the subnational level have generally been constrained by the lack of wealth data. Nevertheless, several researchers have attempted to relate proxies for public capital to output. For example, Garcia-Mila and McGuire (1987) analyzed the effect of the stock of highways and educational expenditures (representing publicly provided human capital) on statewide production functions, and found that both had a significant positive effect on output.

Eberts (1986) has done similar work on a metropolitan area level. He created annual values of the public capital stock for each of 38 metropolitan areas and introduced them into a translog production function, with value added as output, hours of production and nonproduction workers as labor input, and private manufacturing capital stock as private capital. Eberts found that the public capital stock made a positive and statistically significant contribution to manufacturing output, but that its output elasticity was quite small (0.03).

A few researchers have examined the relationship between the growth, as opposed to the level, of output and public infrastructure; the results have been mixed. For example, Hulten and Schwab (1984) explored whether the national productivity slowdown could be attributed to a decline in economic efficiency in the Snowbelt relative to the Sunbelt, due to aging infrastructure and a deteriorating capital stock.

They disaggregated the growth in manufacturing value added for the nine Census regions into its components, and found that regional variation in output growth was not due to differences in productivity growth but rather to variations in the rate of growth of capital and labor. This evidence appeared to leave no role for variations in public infrastructure in determining regional differences in output growth.[1]

On the other hand, Aschauer (1990) recently completed a paper examining the relationship between income growth and highway capacity using state data. He found that highway capacity and pavement quality had significant positive effects on income growth and that these effects were relatively stable across regions.

The following analysis builds on this earlier work and treats public capital as an input whose services enhance the productivity of both capital and labor. Hence, public capital becomes another input in the production function and the equation looks as follows:

$$Q = MFP * f(K,L,G), \tag{1}$$

where Q is output, MFP is the level of technology, K is the private capital stock, L is labor and G is the stock of public capital. Assuming a generalized Cobb-Douglas form of technology yields a more specific relationship between inputs and outputs:

$$Q = MFP * K^aL^bG^c. \tag{2}$$

Translating this equation into logarithms produces a linear function that can be estimated:[2]

$$\ln Q = \ln MFP + a\ln K + b\ln L + c\ln G. \tag{3}$$

[1] The problem with this interpretation is that no measure of infrastructure is included in the equation and total factor productivity is calculated as a residual. If public capital is a legitimate input, then omitting it from the equation produces a biased estimated of multifactor productivity. See Munnell (1990).

[2] The productivity component can also be specified in a fashion that yields a time trend when the equation is translated into logarithms. Specifically, if $Q = MFPe^{\lambda t}K^aL^bG^c$, then $\ln Q = \ln MFP + gt + a\ln K + b\ln L + c\ln G$. Since equations with the time trend differed little from the simpler version described in the text, the results were not generally reported. This is confirmed by comparing Equation 3 from Table 5 and the same equation including the time trend.

	lnMFP	+ λt +	alnK	+ blnL	+ clnG	+ dU%
Eq. 3	5.75		.31	.59	.15	− .007
	(39.7)		(30.1)	(43.2)	(9.0)	(4.7)
Eq. 3′	5.70	.002	.30	.59	.17	− .008
	(39.3)	(2.7)	(28.9)	(42.6)	(9.4)	(5.4)

The coefficients a, b, and c are the output elasticities of the factor inputs. In other words, the coefficients indicate the percentage change in output for a given percentage change in factor input. In production functions without public capital, making some further assumptions about factor markets and the nature of the production function allows the coefficients to be defined more precisely. Specifically, if factor markets are assumed to be perfectly competitive, so that factors are paid their marginal product, and if the production function exhibits constant returns to scale, so that a 10 percent increase in capital and labor leads to a 10 percent increase in output, then the coefficients equal the relative share of total income paid to capital and labor respectively. In the United States the relative shares of national income have been quite stable over many decades, with 35 percent of the total accruing to capital and 65 percent to labor.

While constant returns to scale over the private inputs has been the traditional assumption underlying most analysis of the Cobb-Douglas production function, the inclusion of public capital raises new questions about returns to scale. Given that increasing economies to scale play such an important role in determining the public provision of a good or service, one might be tempted to conclude that public capital in total may yield increasing returns to scale within the production function. Such a leap may be unwarranted, however. While a given highway may yield increasing returns to scale, the construction of an additional highway may not. Moreover, a doubling of the highway system would most certainly produce diminishing returns.

Given the uncertainty of the impact of public capital on returns to scale, several forms of the equation were estimated in addition to the original unconstrained equation. The first assumes that constant returns to scale holds only for the private inputs, but that the entire function shows increasing returns to scale. This assumption is captured by setting $a + b = 1$, so that the equation looks as follows:

$$\ln Q = \ln MFP + a(\ln K - \ln L) + \ln L + c \ln G. \qquad (4)$$

The alternative is that constant returns to scale applies to the entire production function, so that $a + b + c = 1$. Imposing the second constraint produces the third equation:

$$\ln Q = \ln MFP + a(\ln K - \ln L) + \ln L + c(\ln G - \ln L). \qquad (5)$$

The equations were estimated using pooled state output, capital and labor data for the period 1970 through 1986, the last year for which gross state product data were available. Labor is measured as total employment on nonagricultural payrolls from the Bureau of Labor

Table 5
Regression Results: Output as a Function of Private Capital (K), Labor (L), and Public Capital (G), 48 States, 1970–86

Equation for Output (lnQ)							$\bar{R}^2$	SE	DW
	Private Capital Only								
1) No Constraint:	lnMFP +	alnK	+ blnL	+	dU%		.992	.092	2.0
	6.75	.36	.69		.006				
	(69.2)	(38.0)	(82.4)		(4.0)				
2) a + b = 1:	lnMFP +	a(lnK − lnL)	+ lnL	+	dU%		.990	.103	2.1
	7.32	.30	1.0*		−.002				
	(74.2)	(31.9)			(1.0)				
	Including Public Capital								
3) No Constraint:	lnMFP +	alnK	+ blnL	+	clnG	+dU%	.993	.088	1.9
	5.75	.31	.59		.15	−.007			
	(39.7)	(30.1)	(43.2)		(9.0)	(4.7)			
4) a + b = 1:	lnMFP +	a(lnK − lnL)	+ lnL	+	clnG	+dU%	.992	.090	2.0
	6.33	.34	1.0*		.06	−.007			
	(59.6)	(39.6)			(15.9)	(4.6)			
5) a + b + c = 1:	lnMFP +	a(lnK − lnL)	+ lnL	+	c(lnG − lnL)	+dU%	.990	.102	2.0
	6.82	.27	1.0*		.08	−.002			
	(45.8)	(23.3)			(4.4)	(1.0)			

Note: Q = gross state product; MFP = the level of technology; K = private capital stock; L = employment on nonagricultural payrolls; G = stock of state and local public capital; and U% = state unemployment rate; t-statistics in parentheses.

*Constrained to equal 1.

Statistics. The public and private capital stocks are the data described in the first section. The unemployment rate is also included to reflect the cyclical nature of productivity. All dollar amounts used in the regressions are converted to 1982 dollars.

The regression results, which are summarized in Table 5, confirm, on the state level, that public capital has a significant positive impact on the level of output and does indeed belong in the production function. The first two equations show the estimated production functions without public capital; these equations look very sensible, with coefficients for capital and labor almost exactly in line with their shares of total income. When state and local public capital is added to the equation, it enters with a positive, statistically significant coefficient roughly half the size of that for private capital, and it reduces the standard error of the equation. The coefficient of 0.15 on public capital in equation 3 is noticeably smaller than the 0.35 estimated by Aschauer (1989) and Munnell (1990) in their analysis of national data. The number emerging

from the state data implies that a 1 percent increase in public capital would raise output by 0.15 percent.

The equations also provide some information about returns to scale. The coefficients of the factor inputs sum to 1.05 in the unconstrained equation, implying slightly increasing returns to scale. Constraining the equation either to have constant returns over the private inputs ($a + b = 1$) or over all inputs, both public and private, ($a + b + c = 1$) slightly increases the standard error.

Since public capital is an unpaid factor of production, the question arises as to how the benefits accruing from its contribution to output are distributed. It appears that capital and labor each receive a share roughly proportional to their output elasticities. In other words, the unconstrained elasticities for capital and labor in equation 3 are 0.31 and 0.59, respectively; if the 0.15 contribution from output from public capital is divided up proportionately, the result is very close to the traditional 35/65 division of income between capital and labor.

The coefficient of public capital is also sensible in that it implies a reasonable marginal productivity for public capital and equality between the productivity of public and private capital. That is, the elasticity of private sector output with respect to public capital is roughly half that with respect to private capital, and the state and local public capital stock is approximately one-half the size of the private capital stock. With these proportions, the coefficients imply that a 1 unit increase in either public or private capital will increase output by 0.35 units.[3] This result is important since the high values implied for the marginal productivity of public capital in Aschauer's results have been the target of criticism (Schultze 1990, p. 63).

Further support for the reasonableness of the results can be gleaned by examining the impact of various components of public capital on output. Table 6 summarizes the regression results with public capital broken into highways and streets, water and sewer systems, and other structures and equipment. Disaggregating in this fashion has almost no impact on the private labor and capital coefficients, yet yields coefficients for the components of public capital in line with expectations. Specifi-

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[3] In view of the importance of this number, it may be useful to report the calculation. The coefficient of each capital variable is the output elasticity, or the percentage change in output for a given percentage change in the input. In the case of public capital, this means that $0.15 = (\Delta Q/Q)/(\Delta G/G)$. Rewriting the equation in terms of marginal productivity produces $\Delta Q/\Delta G = 0.15(Q/G)$. In 1986, total gross state product (Q) was $3,680 billion and total state and local capital (G) was $1,595 billion. Substituting these values into the equation yields a marginal productivity of public capital of 0.35.

In the case of private capital, the relevant figures are 0.35 for the output elasticity and $3,670 billion for private capital. Introducing these figures into the equation yields $\Delta Q/\Delta K = 0.35 \times 3{,}680/3{,}670 = 0.35$.

Table 6
Regression Results: Output as a Function of Private Capital (K), Labor (L), and Disaggregated Public Capital (H, WS, O), 48 States, 1970–86

Equation for Output (lnQ)							$\bar{R}^2$	SE	DW
		State-Local Capital							
lnMFP +	alnK +	blnL +	clnH +	dlnWS +	elnO +	fU%			
5.72	.31	.55	.06	.12	.01	−.007	.993	.085	1.9
(42.0)	(28.1)	(35.4)	(3.8)	(9.6)	(.7)	(5.2)			

Note: Q = gross state product; MFP = the level of technology; K = private capital stock; L = employment on nonagricultural payrolls; H = stock of highways; WS = stock of water and sewer systems; O = other state and local public capital, primarily buildings; and U% = state unemployment rate; t-statistics in parentheses.

cally, the major impact on output from public capital comes from highways and water and sewer systems, while other public capital, which consists primarily of buildings such as schools and hospitals, has virtually no measurable impact on private production.

The lack of effect from schools and hospitals does not mean that government-provided educational and health services have no effect on productivity. One would expect a well-educated and healthy labor force to be more productive than one without such advantages. Rather, the results suggest that the stock of buildings devoted to, say, education may not be the best indicator of the quality of educational services; teachers' salaries, for example, might be a measure. Moreover, even if physical capital were a good measure of service quality, in a highly mobile society the state that provides the educational or health services may not be the one that reaps the benefits.

Finally, separate production functions were estimated for each of the four major regions of the country to see if the relationships were stable across the states (Table 7). The relationship between inputs and outputs appears to vary significantly from one region to another. The question is whether any story can be told that explains the regional variations in the coefficients on labor, private capital, and public capital.

One could argue that the large coefficient on labor for the Northeast, which indicates a high percentage change in output for a given percentage change in labor input, reflects the fact that the Northeast has a particularly well-educated, highly skilled labor force. At the same time, the relatively small coefficients on both the private and public capital in the Northeast may, in part, reflect the fact that this region has the lowest capital/labor ratio of any of the four; a relatively smaller amount of capital would imply a relatively smaller coefficient on capital in these equations, assuming the marginal productivity of capital is constant across the country. (These facts imply that the high wages earned by people in the Northeast are due to

Table 7
Regression Results: Output as a Function of Private Capital (K), Labor (L), and Public Capital (G), Four Regions, 1970–86

Equation for Output (lnQ)								$\bar{R}^2$	SE	DW
				Private Capital Only						
	lnMFP	+	alnK	+ blnL	+	dU%				
Northeast	9.31		.11	.95		−.01		.997	.068	1.5
	(28.2)		(3.3)	(28.9)		(3.2)				
North Central	6.90		.34	.72		−.003		.998	.048	2.0
	(27.9)		(14.2)	(41.2)		(1.8)				
South	6.03		.42	.62		−.01		.983	.098	1.7
	(31.1)		(22.4)	(30.3)		(4.7)				
West	4.92		.54	.58		−.02		.997	.058	1.7
	(31.6)		(36.9)	(51.4)		(7.9)				
				Including Public Capital						
	lnMFP	+	alnK	+ blnL	+	clnG	+ dU%			
Northeast	8.83		.09	.90		.07	−.01	.997	.067	1.5
	(22.7)		(2.7)	(22.2)		(2.3)	(3.7)			
North Central	5.68		.34	.62		.12	−.004	.998	.046	2.0
	(15.8)		(15.1)	(22.3)		(4.5)	(2.6)			
South	3.15		.38	.36		.36	−.02	.988	.082	1.7
	(10.1)		(22.8)	(12.0)		(10.8)	(6.8)			
West	4.53		.51	.53		.08	−.02	.997	.056	2.0
	(23.4)		(28.0)	(28.7)		(3.2)	(8.4)			

Note: Q = gross state product; MFP = the level of technology; K = private capital stock; L = employment on nonagricultural payrolls; G = stock of state and local public capital; and U% = state unemployment rate; t-statistics in parentheses.

their intrinsic human capital rather than the amount of physical capital with which they have to work.)

The other surprising result pertains to the production functions for the South. This is the only region where the introduction of public capital significantly alters the coefficients on the private inputs. Once public capital is included in the equation, the coefficient on labor falls from 0.62 to 0.36; moreover, the coefficient on public capital itself is also very large (0.36). No obvious explanation leaps out; the only point that may be worth noting is that the South had the highest rate of public investment during the 1970s, and was virtually the only region that continued to increase its public capital stock in the 1980s.

In summary, estimates of production functions based on pooled cross-section state data for the period 1970–86 indicate that public capital contributes to private output. The coefficient on public capital implies that its marginal productivity is the same as that for private capital. The benefits of the contribution from public capital seem to be divided

between private capital and labor in proportion to the elasticity of private sector output with respect to each input. Moreover, the components of public capital that one would expect to enhance private output—namely, highways and streets, and water and sewer systems—are the ones that have the statistically important relationship; public buildings, such as schools and hospitals, appear to have no direct measurable impact. Finally, the relationship between public capital and output holds up on a regional basis, although more work is needed to explain some of the variation in the coefficients.

Public Capital and Private Investment

Another aspect of the role of public capital in the production process is its impact on private investment. In other words, the discussion in this section shifts from documenting a steady-state relationship to exploring the adjustment process. In this process, two opposing forces may be at work. On the one hand, public capital appears to enhance the productivity of private capital, thereby raising the rate of return and encouraging more private sector investment. On the other hand, public capital may serve as a substitute for private capital; to the extent this occurs, more public capital will result in less private investment.

Eberts and Fogarty (1987), in an effort to determine the effectiveness of public infrastructure as a local investment policy, employed the Sims test of "Granger causality" for a sample of 40 metropolitan areas using investment data from 1904 to 1978. They found a statistically significant positive relationship between public outlays and private investment in all but seven of the 40 cases. In those cities where a relationship existed, public capital investment appeared to influence private investment the majority of the time, but in a substantial number of cases the opposite was true and private investment appeared to precede public investment.

This section explores what can be learned from the state-by-state public and private capital data to supplement the scant existing evidence on the relationship between private investment and public capital. The investigation consists of three parts: the first involves restating the production function estimated earlier to demonstrate the significant positive impact of public capital on the marginal product of private capital; the second involves the estimation of a translog production function where interaction terms can indicate the extent to which public and private capital are complements or substitutes; and the third consists of an effort to estimate an investment function that summarizes the key relationships.

The simple Cobb-Douglas production function used earlier can be

Table 8
Regression Results: Productivity of Private Capital as a Function of Private Capital (K), Labor (L), and Public Capital (G), 48 States, 1970–86

Equation for Private Capital Productivity (lnQ – lnK)					$\bar{R}^2$	SE	DW
lnMFP +	(a – 1) lnK +	blnL +	clnG +	dU%			
5.75	–.69	.59	.15	–.007	.91	.088	1.9
(39.7)	(67.2)	(43.2)	(9.0)	(4.7)			

Note: Q = gross state product; MFP = the level of technology; K = private capital stock; L = employment on nonagricultural payrolls; G = stock of state and local public capital; and U% = state unemployment rate; t-statistics in parentheses.

rewritten so that the productivity of private capital is the dependent variable. That is,

$$Q/K = MFP * K^{(a-1)}L^bG^c. \quad (6)$$

Again, translating this equation into logarithms produces a linear function that can be estimated.

$$lnQ - lnK = lnMFP + (a - 1)lnK + blnL + clnG. \quad (7)$$

The results of estimating this equation are shown in Table 8. Not surprisingly, given that it is simply a rearrangement of the general equation, the relationships are the same as those already described. For the current discussion, the usefulness of the equation in this form is that it highlights the positive, statistically significant relationship between the productivity of private capital and the stock of public capital. Through this mechanism, the stock of public capital would be expected to encourage private investment.

The next step is to determine the nature of the relationship between public and private capital. Are they substitutes or complements in the production process? One way of addressing this issue is to estimate a translog production function; this nonlinear relationship between output and factor inputs includes cross-product terms, which indicate the substitutability or complementarity of the inputs. Variables are entered in the translog function as deviations from their means.

The results of the estimation process are presented in Table 9. The first set of coefficients for private capital, labor, and public capital are similar to those estimated in the simple Cobb-Douglas production function; as before, public capital has a positive impact on private sector output. The coefficients of the quadratic terms provide an indication of economies of scale for each of the factor inputs. The coefficients indicate

Table 9
Regression Results: Translog Production Function, 48 States, 1970–86

Equations for Output (lnQ): Including Aggregate Public Capital	Coefficient (t-Statistic)	Disaggregating Public Capital	Coefficient (t-Statistic)
$\ln K - \ln \bar{K}$	.22 (18.9)	$\ln K - \ln \bar{K}$	.21 (16.1)
$\ln L - \ln \bar{L}$	.69 (37.5)	$\ln L - \ln \bar{L}$	.67 (35.7)
$\ln G - \ln \bar{G}$	.16 (9.1)	$\ln H - \ln \bar{H}$	.04 (2.7)
		$\ln WS - \ln \bar{WS}$	.15 (10.9)
		$\ln O - \ln \bar{O}$	−.02 (1.1)
$(\ln K - \ln \bar{K})^2$	.27 (11.7)	$(\ln K - \ln \bar{K})^2$	.27 (10.3)
$(\ln L - \ln \bar{L})^2$	.13 (3.2)	$(\ln L - \ln \bar{L})^2$	.17 (3.1)
$(\ln G - \ln \bar{G})^2$	.03 (0.5)	$(\ln H - \ln \bar{H})^2$	.02 (0.3)
		$(\ln WS - \ln \bar{WS})^2$	.01 (0.4)
		$(\ln O - \ln \bar{O})^2$	.09 (3.9)
$(\ln K - \ln \bar{K})(\ln L - \ln \bar{L})$	−.39 (9.8)	$(\ln K - \ln \bar{K})(\ln L - \ln \bar{L})$	−.35 (7.9)
$(\ln K - \ln \bar{K})(\ln G - \ln \bar{G})$	−.14 (2.1)	$(\ln K - \ln \bar{K})(\ln H - \ln \bar{H})$	−.10 (1.6)
$(\ln L - \ln \bar{L})(\ln G - \ln \bar{G})$	.12 (1.4)	$(\ln K - \ln \bar{K})(\ln WS - \ln WS)$	.08 (2.1)
		$(\ln K - \ln \bar{K})(\ln O - \ln \bar{O})$	−.20 (4.4)
		$(\ln L - \ln \bar{L})(\ln H - \ln \bar{H})$	.11 (2.0)
		$(\ln L - \ln \bar{L})(\ln WS - \ln WS)$	−.05 (0.6)
		$(\ln L - \ln \bar{L})(\ln O - \ln \bar{O})$	−.04 (0.8)
U%	−.006 (4.7)	U%	−.006 (5.2)
intercept	11.0 (1190.3)	intercept	11.0 (1168.1)
$\bar{R}^2$	.995	$\bar{R}^2$	.996
DW	1.7	DW	1.7

Note: Q = gross state product; K = private capital stock; L = employment on nonagricultural payrolls; G = stock of state and local public capital; H = stock of highways; WS = stock of water and sewer systems; O = other state and local capital, primarily buildings; and U% = state unemployment rate; t-statistics in parentheses.

slight increasing returns to scale for the private inputs, but constant returns to scale for public capital.

Information on substitutability or complementarity is provided by the coefficients of the cross-product terms. These estimates show a strong substitutability between private capital and labor, as expected, and a somewhat weaker degree of substitution between private capital and public capital. Labor and public capital appear to be complements, although the relationship is not statistically significant.

In an effort to gain more information about the nature of the substitutability between private and public capital, another translog production function was estimated with public capital disaggregated into highways and streets, water and sewer facilities, and other public capital. As before, the results indicate that most of the impact of public capital on private production comes from water and sewer systems and, to a lesser extent, from highways; other public capital has no measurable impact. As in the equation with aggregate public capital, the quadratic terms indicate that none of the components of public capital exhibit increasing or decreasing returns to scale.

The coefficients of the cross-product terms of private capital and the components of public capital are completely in line with one's intuition. Highways and streets appear to be substitutes for private capital; this seems quite reasonable in that smooth, well-maintained roads will reduce the wear and tear on commercial vehicles. Moreover, private employers or developers may sometimes be required to build their own access roads. Water and sewer facilities are strong complements to private capital; these inputs are generally publicly provided and clearly augment private production. On the other hand, other public capital is a direct substitute. As noted before, this residual consists primarily of hospitals and schools, both of which have private sector counterparts; it also consists of power plants, which are definitely part of the private sector in some states.

Thus, public capital, as hypothesized, has the potential for either encouraging or discouraging private sector investment. One attempt was made to combine these two influences into the simplest possible model of investment. Specifically, the production function indicates that the desired stock of capital ($\overline{K}$) is positively related to the level of output (Q), the supply of labor (L) and the stock of public capital (G). At the same time, the desired stock is positively related to the marginal productivity of capital (MPK) relative to the cost of capital. Assuming the cost of capital is constant, the desired stock can be expressed as

$$\overline{K} = f(Q, L, G, MPK). \tag{8}$$

The simple Cobb-Douglas production function suggests that the mar-

ginal product of capital can be expressed as a function of the logarithms of private capital, labor, and public capital:

$$MPK = lnMFP + (a - 1)lnK + blnL + clnG. \quad (9)$$

This means that

$$\overline{K} = lnMFP + (a - 1)lnK + blnL + clnG + dQ + eL + fG. \quad (10)$$

A stock adjustment approach was taken, whereby investment in a given year partially closes the gap between the desired and the existing stock of capital; that is,

$$K_t - K_{t-1} = \alpha(\overline{K} - K_{t-1}). \quad (11)$$

Introducing the described specification of the desired capital stock into the stock adjustment model yields

$$K_t - K_{t-1} = \alpha(lnMFP + (a - 1)lnK + blnL + clnG + dQ + eL + fG - K_{t-1}). \quad (12)$$

The results of estimating this equation are shown in Table 10.[4] (In addition to the traditional coefficients and t-statistics, Table 10 includes beta coefficients; these coefficients, which standardize for the magnitude of the individual variables, provide a better indication of the relative importance of the various factors in explaining private investment.) The signs of the coefficients on public capital are as predicted. As one of the variables that determine the marginal productivity of private capital, public capital enters the equation with a positive coefficient. (Unfortunately, the signs on the other variables representing the marginal productivity of capital are reversed; the logarithm of private capital should be negative and the log of labor, positive.) Thus, public capital appears to stimulate private investment through its influence on the productivity of private capital. On the other hand, the stock of public capital has a negative, statistically significant effect on private investment. Given that private and public capital are substitutes, an increase

[4] In estimating the equation, it is necessary to use lagged values of the determinants of marginal productivity of capital, since these determinants include this period's capital stock—the dependent variable.

Table 10
Regression Results: Investment as a Function of the Marginal Productivity of Capital (MPK), Output (Q), Private Capital (K), Labor (L) and Public Capital (G), 48 States, 1975–86

Equation for $K_t - K_{t-1}$	Coefficient (t-Statistic)	Beta
Marginal Productivity of Capital		
lnK	199.7	.05
	(0.4)	
lnL	−853.1	−.23
	(1.2)	
lnG	959.9	.24
	(1.0)	
G	−.11	−.81
	(3.8)	
L	−861.6	−.44
	(1.1)	
$\sum_{i=0}^{4} Q$	.09	1.97
	(3.7)	
K_{t-1}	−.02	−.30
	(2.1)	
intercept	−10,641.0	
	(1.4)	
$\bar{R}^2$	.46	
DW	2.2	

Note: Q = gross state product; MFP = the level of technology; K = private capital stock; L = employment on nonagricultural payrolls; G = stock of state and local public capital; t-statistics in parentheses.

in the stock of public capital, all else equal, will reduce the required level of private capital and private investment.

It may be pushing these results too far, but it is hard to resist estimating the net effect of public capital on private investment. On the one hand, a 0.1 increase in the log of public capital implies a $96 billion increase in private investment. In dollar terms, 0.1 increase in the log is roughly equivalent to a 10 percent increase in the public capital stock, or $172 billion. From these numbers, $1 of additional public capital appears to increase private investment by 56 cents. On the other hand, the coefficient on last period's capital stock indicates that an additional $1 of public capital reduces private investment by 11 cents in that year (more in subsequent years). On balance, the equation suggests that each additional dollar of public capital appears to increase private investment by 45 cents.

The simple investment equation, however, can certainly be improved, so the results should be interpreted only as an invitation for future researchers to pursue this topic. The more robust results in the investment area are: 1) public capital positively affects the marginal productivity of private capital, and 2) public capital and private capital in the aggregate are substitutes. A careful estimation of the net effect of these two forces remains to be done.

Infrastructure and Firm Location

The third strand in the literature pertaining to infrastructure and economic activity focuses on the relationship between public capital and new business formation or employment growth. For, after all, to demonstrate a systematic relationship between public capital, output, and investment is only the first step; the challenge is to describe the mechanism through which public capital enters into the process.

Infrastructure could influence the location decisions of both firms and households. For example, high-quality roads, sewer systems, schools, and hospitals would be expected to encourage people to move to a given area; similarly, firms requiring large amounts of water in their production process, such as fabric dyeing, would be attracted, all else equal, to areas with water supply facilities that can meet their needs.

Although an enormous literature explores the factors entering the firm location decision, relatively little work has been done focusing on the role of infrastructure in that process.[5] A notable exception is a recent study by Eberts (1989), who examined the relationship between changes in metropolitan area capital stock and firm openings. He found statistically significant positive effects in the case of small businesses, with lesser impact on large firms. He also looked at changes in the public capital stock, but did not find a significant relationship between public investment and openings.

This section uses the state-by-state public capital data to see whether public infrastructure is important in explaining state variations in private economic development. At the state level, the best indicators of economic development and growth are employment trends; hence,

[5] Several studies have attempted to examine the impact of publicly provided services on firm location decision. Investigators commonly include a measure of spending on welfare, which may be perceived by firms as an "unwanted" public expenditure, as well as measures of spending on "wanted" public expenditures, such as education or police and fire protection. See Wasylenko and McGuire (1985), Plaut and Pluta (1983), Bartik (1989) and Helms (1985).

the empirical work examines the relationship between employment growth and public capital within the context of a firm location model.

The theoretical literature and empirical studies of firm location are heavily oriented toward the locational decisions of individual manufacturing firms. The theory assumes that firms want to maximize their after-tax profit, so the location decision is driven by the firm's profitability at alternative locations. Profits depend on the difference between sales and the costs of production. Sales, in turn, depend on the nature of the market. For a company making intermediate products, useful data include the number and size of potential purchasers of the intermediate product and the number and size of competitors. If the firm produces for the consumer market, then the number and income of potential customers at each location would be relevant. On the cost side, the most important factors are probably wages and the skill of the labor force, although land and energy costs are also relevant.

The equations estimated here include variables to capture both revenue and cost components of profitability. The specific form of the equation is based on the disequilibrium adjustment model, which is commonly used in cross-sectional studies of regional economic growth. In this model, the change in the dependent variable, in this case private nonagricultural employment, is related to levels of the explanatory variables at the beginning of the period. For example, the growth in employment between 1980 and 1988 will be related to revenue and cost measures in 1980.

Three explanatory variables are included in the equations to represent the labor market: the average hourly wage in manufacturing (WAGE), the state unemployment rate (U%), and the percent of the state's population with at least four years of college (COLL). Two additional variables are designed to measure energy costs: the cost per million BTUs of purchased fuels and electricity (ENERGY) and the normal daily maximum temperature in July (TEMP). Finally, population density (POP DENSITY) is included to capture the cost of land. On the sales side, the percent of the population residing in metropolitan areas (URBAN) was introduced to reflect the potential market. Since both firms and individuals are interested in after-tax income, a variable was included measuring total state and local taxes as a percent of state personal income (TAXES). Finally, the stock of public infrastructure (PUBLIC CAPITAL) was introduced to determine whether it had an independent direct effect, once these other economic determinants were taken into account. The regional values for most of these variables are summarized in Table 11, and the public capital data are shown in Table 3.

The regression results, which are shown in Table 12, are quite interesting and suggest that infrastructure does contribute towards a

state's employment growth. Some general comments are required, however, before exploring the results in more detail. First, unlike the production function equations reported earlier, where the variables to be included are fairly well defined, the list of potential variables to explain state-by-state employment growth is limitless. For example, to estimate the effect of taxes on the growth in employment, one study employed five separate tax measures (Plaut and Pluta 1983). The goal of the exercise described below was to include only those independent variables whose presence would be viewed as essential by most observers.

Second, no matter how disciplined an investigator attempts to be, the temptation to try a number of different combinations or alternative measures is sometimes overwhelming. Since this part of the study involved some "fishing," the most useful way to proceed is to make all results available to the interested reader, report those that seem most persuasive, and then indicate what was learned from the process. One source of comfort is the fact that, while its statistical significance varies, the magnitude of the coefficient for public infrastructure remains virtually unchanged regardless of what modifications are made to the rest of the equation.

The first three equations in Table 12 are similar in approach; they vary only in the period spanned or the initial conditions. That is, the first equation explains employment growth over the 1970–88 period using 1970 values for wages, state unemployment rates, and so on; the second shortens the period of employment growth to 1970–80 but maintains the 1970 level for the independent variables; the third equation looks at employment growth over the 1980–88 period using 1980 levels of the independent variables. The fourth equation takes a somewhat different approach in that it attempts to explain employment growth for the 1980–88 period on the basis of what happened to the independent variables during the period 1970–80. For example, the independent variable becomes the change in the state's hourly wage level from 1970 to 1980 instead of the level of the wage in 1980.

The results are generally in line with what one would expect. The cost, availability, and quality of labor in a given state appear to play a central role in that state's employment growth; the lower the wage level, the greater the level of unemployment, and the more highly educated the work force in the base period, the greater the growth in employment during the subsequent period. Similarly, to the extent that population density serves as an indication of the cost of land, the results show that states with relatively plentiful, inexpensive land in the initial periods experienced the higher rates of growth in the subsequent periods.

The results for energy costs are somewhat less consistent. The original notion was that higher energy costs, all else equal, would

Table 11
Regional Data on Employment Growth (1970–80 and 1980–88) and Its Potential Determinants, 1970 and 1980

Region	Average Annual Rate of Private Employment Growth		Unemployment Rate		College Graduates		Urban Population		Tax Burden		Population Density[a]		Hourly Wage (Manufacturing)		Cost of Energy[b] (Per Million BTUs)	
	1970–80	1980–88	1970	1980	1970	1980	1970	1980	1970	1980	1970	1980	1970	1980	1970	1980
	Percent												1982 Dollars			
Northeast	.8	1.9	4.6	7.1	11.2	17.3	89.2	88.1	11.3	11.5	301	302	8.38	8.33	3.05	4.30
New England	1.9	2.6	4.9	5.9	12.2	19.3	82.9	81.2	10.5	10.4	189	196	7.92	7.61	3.81	4.52
Mid Atlantic	.5	1.7	4.5	7.5	10.9	16.6	91.2	90.5	11.6	11.8	372	369	8.53	8.60	2.91	4.26
North Central	1.7	1.3	4.7	8.2	9.6	14.8	71.5	70.5	10.3	9.6	75	78	9.20	9.66	2.96	3.91
East North Central	1.3	1.2	5.1	9.2	9.5	14.5	78.7	77.2	10.3	9.6	165	171	9.45	9.99	2.85	3.91
West North Central	2.7	1.5	3.8	5.7	9.9	15.4	53.8	54.0	10.5	9.7	32	34	8.51	8.85	3.35	3.93
South	3.7	2.6	4.5	6.4	9.7	15.0	66.8	67.8	9.3	8.7	71	86	7.26	7.65	1.86	4.20
South Atlantic	3.4	3.7	4.2	6.3	10.3	15.5	71.1	71.7	9.4	8.9	113	136	7.03	7.21	2.65	3.47
East South Central	2.9	2.1	4.8	7.9	7.7	12.1	53.5	53.4	9.4	8.7	72	82	7.08	7.48	2.08	3.76
West South Central	4.8	1.0	4.8	5.6	10.1	15.7	68.9	70.8	9.1	8.5	45	56	7.77	8.39	1.44	4.67
West	4.4	2.7	6.8	6.8	13.2	19.3	83.9	83.1	11.4	10.0	29	36	9.28	9.16	2.10	4.07
Mountain	5.9	2.6	5.1	6.2	12.9	18.9	60.7	62.4	10.8	10.1	10	13	8.42	8.60	2.22	3.32
Pacific	4.0	2.8	7.3	7.0	13.2	19.4	91.5	90.8	11.5	9.9	80	95	9.53	9.36	2.05	4.51

Note: See Appendix B for details on sources of data.

[a]Measured as number of persons per square mile of land area.

[b]Measured as the ratio of expenditures on fuel and purchased electricity to consumption of fuel and purchased electricity, for the industrial sector.

Table 12
Regression Results: The Role of Public Capital in Private Employment Growth, 1970–88, 1970–80, and 1980–88

	Employment Growth							
	1970–88 (1970 Levels)		1970–80 (1970 Levels)		1980–88 (1980 Levels)		1980–88 Growth (Based on 1970–80 Changes)	
Explanatory Variable	Coefficient (t-Statistic)	Beta	Coefficient (t-Statistic)	Beta	Coefficient (t-Statistic)	Beta	Coefficient (t-Statistic)	Beta
Cost of Labor								
WAGE	−1.4	−.52	−.8	−.20	−1.0	−.70	−.1	−.44
	(4.1)		(1.6)		(4.4)		(3.6)	
U%	.4	.39	.4	.28	.3	.36	.2	.20
	(3.3)		(2.3)		(2.2)		(1.4)	
COLL	.3	.46	.3	.33	.2	.39	.1	.09
	(3.8)		(2.7)		(2.5)		(.7)	
Cost of Land								
POP DENSITY	−.003	−.64	−.003	−.41	−.002	−.24	.06	.41
	(5.0)		(3.2)		(1.3)		(3.2)	
Cost of Energy								
ENERGY	2.8	.56	1.8	.24	−.1	−.05	−.003	−.10
	(4.2)		(1.7)		(.3)		(.7)	
TEMP	.08	.34	.1	.38	−.008	−.03		
	(3.0)		(3.4)		(.2)			
Potential Sales								
URBAN	.01	.31	−.006	−.09	.03	.50	−.01	−.01
	(2.0)		(.6)		(2.9)		(.1)	
TAXES	−.3	−.32	−.3	−.24	−.4	−.30	−.4	−.22
	(2.6)		(1.9)		(2.0)		(1.7)	
PUBLIC CAPITAL	.0001	.35	.0002	.45	.0002	.18	.03	.24
	(2.7)		(3.4)		(1.0)		(1.7)	
INTERCEPT	−5.0		−10.1		5.3		−.02	
	(1.7)		(2.2)		(1.1)		(.01)	
$\bar{R}^2$	.63		.62		.41		.45	
DW	1.9		2.1		1.9		1.8	

Note: For description of variables, see Appendix B.

reduce profitability and therefore discourage the establishment of new firms and inhibit employment growth. The data support this hypothesis in two respects. First, all else equal, states with warmer climates tend to have greater employment growth. Second, energy costs have a negative effect on employment growth in the 1980–88 period.

The inconsistency arises in that energy costs [illegible]

One might wonder how much weight to put on these results. As indicated above, several regressions were run, adding and deleting variables for unionization and personal income and substituting heating degree days for the maximum temperature variable. No matter which variables were included in the regression equation, the coefficient for public capital never fell below 0.0001 or rose above 0.0003 for any of the time periods. In terms of the statistical significance, the t-statistics never fell below 1.2 for the subperiods or rose above 4.1. The reader must come to her or his own conclusion, but the author is convinced that public infrastructure matters in firm locational decisions and thereby affects employment growth.

Before leaving this topic, one further equation was estimated. It may be a little unorthodox, but it is based on the notion that investment and employment decisions are less related to the initial levels of the relevant variables than to how these variables have been changing in the recent past. The results of testing this hunch empirically are summarized in the last equation of Table 12. As noted earlier, this equation relates the growth in employment for the period 1980–88 to the changes in the variables over the period 1970–80. The $\overline{R}^2$ indicates that this approach explains more of the variation in state employment growth than including the initial levels. Almost all the variables have the expected sign and magnitude (except for population density[6]), and the growth of public capital appears to be considerably more important in this equation than its initial level was in the earlier equations. This should be interpreted as nothing more than one additional bit of evidence that public capital affects state-by-state levels of economic activity.

Conclusion

This paper consisted of three exercises exploring the relationship between public capital and economic activity. The first looked at the role of public capital in the production process and found that public capital had a positive, statistically significant impact on private sector output.

[6] The change in population density appears to be playing the role of population growth rather than change in land cost in this equation. One would expect a close relationship between state population growth and the growth of nonmanufacturing employment, as local merchants expand to provide a wide array of services for the enlarged pool of consumers. Indeed, in an equation with manufacturing employment, rather than private nonagricultural employment, as the dependent variable, the change in population density is no longer statistically significant. This seems to confirm a strong positive relationship between the change in population density and the growth of nonmanufacturing employment.

These results were robust. The coefficient on public capital implied the same marginal productivity as for private capital. The benefits from public capital, an unpaid factor of production, seem to be divided between private capital and labor in proportion to the elasticity of private sector output with respect to each input. When public capital was disaggregated into highways and streets, water and sewer systems, and other structures and equipment, the coefficient of each component was in line with expectations. Finally, the relationship between public capital and output held up on a regional basis, although more work is needed to understand the variation in the coefficients.

The second exercise involved investigating the role of public capital in private sector investment. Here two opposing forces were at work. On the one hand, the evidence clearly indicated that public capital enhances the productivity of private capital; through this mechanism public capital would be expected to stimulate private sector investment. On the other hand, the results of a translog production function indicated the bulk of state and local public capital is a substitute for private capital; this substitutability indicates that, for any given level of output, the more public capital on hand the less private investment required. A simple investment equation suggested that both these effects were evident, but these results were not robust and much more work should be done.

The third exercise explored the relationship between public capital and employment growth in order to see whether the stock of a state's physical infrastructure influenced firm location and subsequent growth. Although the specific model into which public capital should be introduced is much less precise than that specified by a production function, the empirical work provided convincing evidence, at least to the author, that a state's investment in public capital had a significant positive impact on that state's private employment growth.

The evidence seems overwhelming that public capital has a positive impact on private sector output, investment, and employment. But public capital is not just another form of private capital. These physical resources were produced by the public sector because they contribute additional benefits that cannot be captured by a private sector investor; the presumption is that inadequate quantities would have been produced if left to private sector initiatives. The fact that public capital has these externalities and that the marginal productivities of public and private capital appear to be the same in the private production process suggest that the United States has underinvested in public capital. But one does not really need equations to arrive at that conclusion.

The conclusion that this country has underinvested in public capital and that public capital has a positive impact on economic activity does not mean that the United States should blindly double the amount of

money it spends on public capital; nor does it mean that careful cost-benefit analyses are no longer needed for individual projects. Rather the results indicate that more spending on public investment, which is clearly needed to remedy serious safety hazards and to improve the quality of life, may also produce greater productivity and growth.

Appendix A—Creation of State Estimates of Capital Stocks

No state-by-state data are available on the stock of public or private capital. Hence, it was necessary to devise ways of dividing up the national totals published by the U.S. Bureau of Economic Analysis (BEA). The capital stock series selected were the constant-cost or "physical-volume" estimates, where assets are valued at a base-year price. In the case of public capital, the approach taken was to create for each year, 1969 to 1988, a state capital stock series based on annual state investment data and BEA discard and depreciation schedules, and use the state-by-state distribution of these series to apportion the BEA public capital totals for the nation. In the case of private capital, state investment data (other than for manufacturing) were not available, so the approach followed was to apportion the BEA national total for private capital on the basis of various measures of each state's activity in the agricultural sector, the manufacturing sector, and the nonfarm, nonmanufacturing sector. These calculations are described below.

Public Capital Stocks

An estimate of public capital stock was made for each state, and each state's share of the sum of these estimates was used to apportion the BEA national estimate of state and local public capital. The capital outlay data used as a basis for the state estimates of stock were taken from *Governmental Finances*, a U.S. Bureau of the Census publication, for the years 1958 to 1988. Capital outlay was defined as direct expenditure for the construction of buildings, roads, and other improvements, including additions, replacements, and major alterations to fixed works and structures, whether contracted privately or built directly by the government. Purchases of equipment, land, and existing structures were also classified as capital outlays. (Repair expenditures, classified under current operations expenditure, were not included here.)

Governmental Finances lists, state by state, the capital outlays for certain functions as well as total capital outlays. Some functions were not reported separately for the full time period, so it was not possible to estimate stock measures for all types of capital. Consistent series were available for highways, sewerage, and water supply facilities. (Data on capital outlays on water supply facilities were not available separately from 1958 to 1960, but as this is only a brief period and because water supply facilities are an important piece of "core" infrastructure, the stocks were estimated based on data from 1961 to 1988.)

The BEA procedure outlined in *Fixed Reproducible Tangible Wealth, 1929–1985* was followed in order to calculate public capital stock estimates for 1969 to 1988. The first step in this process was to deflate annual data on nominal dollar investment in each state into constant dollar investment, with the same deflators used by the BEA in its calculations of national public capital stocks. Obtaining an estimate for the gross capital stock required calculating the value of each year's investment that would have been discarded over the years. Assets are not always discarded at the end of the average service life, but rather some assets are discarded earlier and others remain in service longer. The retirement pattern used by the BEA to calculate gross stocks is a modified Winfrey S-3, with retirements starting at 45 percent of the average service life and ending at 155 percent of average life. The service lives used here were again taken from the BEA. Highways, sewer systems, and water supply facilities were assumed to last 60 years, thus this figure was used in the discard and depreciation calculations for these assets. The average service life for total public capital had to be estimated and was calculated as a weighted average of the service lives of its components, with the weights representing the component's percent of total constant dollar investment over the full period, according to the following formula:

$$\left(15 \text{ yrs.} * \frac{\sum \text{State \& local equipment investment}}{\sum \text{Total state \& local investment}}\right)$$

$$+ \left(50 \text{ yrs.} * \frac{\sum \text{State \& local investment in buildings, "other" structures}}{\sum \text{Total state \& local investment}}\right)$$

$$+ \left(60 \text{ yrs.} * \frac{\sum \text{State \& local investment in highways, water supply facilities, sewer systems, and conservation and development structures}}{\sum \text{Total state \& local investment}}\right) = 50.68 \text{ years.}$$

This calculation was based on BEA investment data. The value of discards was then subtracted from the annual real investments. Summing these investment figures over time gave the gross value of the capital stock. These estimates were then summed across states, with each state's share of this sum used to apportion the BEA national estimate of state and local gross public capital stock.

A similar procedure was used to derive net capital stock estimates. The value in the end year (that is, the year for which the stock is being estimated) of total depreciation on each year's original investment was calculated. The BEA assumption of straight-line depreciation over the average service life of the asset was used. (Service life estimates were the same as above.) Subtracting depreciation from the original annual investments left the net value in the end year of each year's investment. These values were summed to obtain the net value of the capital stock in that year. The stock estimates were then summed across states. Each state's share of this total stock was then used to apportion the BEA national total amount of state and local public capital stock for that year. Net capital stock estimates were used in estimating the production function; they better reflect the productive capacity of the stock because they are adjusted for wear and tear, accidental damage, and obsolescence.

The sum of estimates across states equaled approximately 75 percent of the BEA total state and local net stock measure in 1970. By 1980 the state stock estimates created here summed to 97 percent of the BEA total. The sum of state estimates in 1986 was 108 percent of the BEA total. This number exceeds the BEA total because of coverage and timing differences between Census expenditure data and the NIPA data on state and local expenditures used by the BEA.

Because public assets have long lives and investment data begin only in 1958, the stock estimates in the earlier years have the potential to underestimate stocks in the older parts of the country, where much investment may have occurred prior to 1958. Similarly, it may overestimate capital stocks in the newer areas of the country. Looking at the results of the procedure, the bias does not seem too pronounced, since older industrial states like New York, Illinois, Pennsylvania, Ohio and Michigan are all ranked in the top ten in terms of total public capital stock in 1969. While these estimates could undoubtedly be improved by collecting data over a longer time period, given the complete dearth of information on public capital stocks at the state level, and the limitations of consistent, currently available data, they represent a reasonable first attempt.

Private Capital Stocks

Private capital stocks were calculated by apportioning BEA national stock estimates of various sectors among the states, using a procedure similar to the one outlined in Costa, Ellson, and Martin (1987). This approach was adopted because investment data by state

are available only for the manufacturing sector, while the production function is to be estimated for the state economy as a whole. Thus data limitations prevented using the perpetual inventory method to calculate private capital stocks. The private capital stock in a state is given by the following formula:

$$K_i = (AGK_i / \sum AGK_i)AGK + (MFGK_i / \sum MFGK_i)MFGK$$

$$+ (NFNMFGK_i / \sum NFNMFGK_i)NFNMFGK$$

where: AGK = BEA constant-cost value of capital stock in the agricultural sector
MFGK = BEA constant-cost value of capital stock in the manufacturing sector
NFNMFGK = BEA constant-cost value of capital stock in the nonfarm, nonmanufacturing sector
AGK_i = proxy for capital stock in agriculture in state i
$MFGK_i$ = proxy for capital stock in manufacturing in state i
$NFNMFGK_i$ = proxy for capital stock in the nonfarm, nonmanufacturing sector in state i.

Much of the data used as proxies was taken from the economic censuses, which occur every fifth year: agriculture, manufacturing, and several nonfarm, nonmanufacturing sectors: construction, mining, services, and retail and wholesale trade. Several nonfarm, nonmanufacturing sectors were apportioned using data from sources other than the economic censuses: rail, air and water transportation, trucking, electric and gas services, telephone, and banking. A state's share of the proxy in the census year was used to distribute BEA assets for that year, preceding years and following years. Thus, data from the 1972 Census were used to apportion among the states the BEA national stock estimates for 1969 to 1974; 1977 shares were used for the 1975 to 1979 stock estimates; 1982 shares were the basis for the estimates from 1980 to 1984; and 1987 data were used to apportion national asset totals for 1985 and 1986. (In cases where data were not available for the census year, data for the closest year were used or another estimating procedure was employed. These exceptions are described below.)

The BEA estimate of capital in agriculture was distributed among states based on the value of land, buildings, and equipment in agriculture. The value of land, buildings, and equipment taken from the *1987 Census of Agriculture* was used as a proxy to calculate the stock for 1985 and 1986. Data from the 1982 *Census* were used to calculate shares for 1980 to 1984. Stocks for 1976 to 1979 were based on data from the 1978 *Census*. Data from the 1974 *Census* were used in estimating stocks for 1972 to 1975, while stocks for 1969 to 1971 were estimated using 1969 *Census* data.

The BEA estimate of capital in manufacturing was distributed among states based on their shares of the gross book value of depreciable assets in manufacturing. Asset data were taken from the 1977 and 1982 *Census of Manufactures*. State asset data were not yet available from the 1987 *Census* so the 1985 *Annual Survey of Manufactures* was used to estimate 1985 and 1986 stocks. The 1972 *Census* did not report asset data by state so the 1971 *Survey* was used as a proxy for stocks for 1970 to 1974, while the 1969 *Survey* was used to apportion the 1969 stock.

The BEA estimate of capital in the nonfarm, nonmanufacturing sector was divided among the states according to the sum of estimates for many subsectors: construction, mining, retail and wholesale trade, banking, railroad transportation, trucking and warehousing, water transportation, air transportation, electric services, gas services, telephone and telegraph, and services. The sum of asset estimates for all states, for all subsectors, represented nearly three-quarters of the BEA national total of nonfarm, nonmanufacturing assets. The following equation describes this estimating procedure:

$$NFNMFGK_i = (shCONSTR_i * CONSTRK) + (shMI_i * MIK) + (shR_i * RK)$$

$$+ (shW_i * WK) + (shBK_i * BK) + (shRAIL_i * RAILK) + (shTRUCK_i * TRUCKK)$$

$$+ (shBOAT_i * BOATK) + (shAIR_i * AIRK) + (shELEC_i * ELECK)$$

$$+ (shGAS_i * GASK) + (shTEL_i * TELK) + (shSVCS_i * SVCSK)$$

where sh = share.

The BEA estimate of assets in construction (CONSTRK) was distributed among states based on their share of the gross book value of depreciable assets taken from the *Census of Construction* for 1972, 1977 and 1982. No state data were yet available from the 1987 Census so 1982 shares were used to estimate stocks from 1980 to 1986.

Assets in mineral industries (MIK) were apportioned in two parts: assets in oil and gas extraction, and assets in all other mineral industries. The BEA figure for assets in oil and gas extraction was apportioned among the states based on their shares of oil production in 1972, 1977, 1982 and 1986. Production values for 1972 and 1977 were taken from the *Minerals Yearbook* while values for 1982 and 1986 were taken from the Energy Information Administration's *Petroleum Supply Annual*. (Since 1982, when the Department of Energy was created, it has been responsible for publishing data on fuel production. Prior to that time these data were tracked in the Bureau of Mines' *Minerals Yearbook*.) Assets in all other mineral industries were distributed according to the following methodology. The *Census of Mineral Industries* for 1977 and for 1982 listed end of year gross book value of depreciable assets, by state. These same data were not calculated in 1972, and the 1987 data were not available yet. The proxy for 1986 shares (used to distribute total asset values for 1985 and 1986) was calculated by increasing each state's 1982 asset value by the ratio of each state's value of nonfuel mineral production in 1986 to the value of its nonfuel mineral production in 1982:

$$\text{assets}_{i86} = \text{assets}_{i82} * \frac{\text{Value of non-fuel mineral production}_{i86}}{\text{Value of non-fuel mineral production}_{i82}}.$$

The 1972 proxy was calculated in a similar manner, with the 1977 asset value multiplied by the ratio of the value of 1972 production to the value of 1977 production. State asset values were summed, and then each state's share of this total value was calculated and used to apportion the BEA's total national value of assets in mineral industries (excluding oil and gas extraction).

The values of retail and wholesale trade assets (RK and WK) were apportioned according to each state's share of sales, taken from the *Census of Wholesale Trade* (1972, 1977, 1982, and 1987) and the *Census of Retail Trade* (1972, 1977, 1982, and 1987). According to Costa, Ellson and Martin (1987), the differing structure of retail and wholesale trade across states does not significantly affect the asset/sales ratio.

Assets in banking (BK) were distributed in a manner similar to wholesale and retail trade, using each state's share of deposits in 1972, 1977, 1982, and 1986. The source for deposit information was the *Statistical Abstract of the United States*, and the data reflect deposits of insured commercial banks.

The national estimate of assets in rail transportation (RAILK) was divided among states based on their proportion of track mileage in 1972, 1977, 1982, and 1986. Data on miles of track by state were taken from *Railroad Facts*.

Trucking and warehousing assets (TRUCKK) were distributed to states using the number of trucks in each state. Data on number of trucks by state were available from the *Census of Transportation* for 1972, 1977 and 1982, and from the *1987 Census of Transportation* for a limited number of states. The average growth rate in the number of trucks for states that had both 1982 and 1987 data points was used to extrapolate the number of trucks in 1987 for states without 1987 data.

The BEA national estimate of assets in water transportation (BOATK) was apportioned among states based on data from *Waterborne Commerce of the United States* (1972, 1977, 1982, and 1986) on the value of commerce in ports.

Each state's share of total civil aircraft was used to distribute the national value of assets in air transportation (AIRK). The Federal Aviation Administration's *Census of U.S. Civil Aircraft* (1972, 1977, 1982 and 1986) provided the data on the number of aircraft.

The proxy used to distribute assets in electric services (ELECK) was the generating capacity installed in each state, taken from the *Statistical Abstract* for 1972 and 1977, and the *Inventory of Power Plants in the United States* for 1982 and 1986.

The national estimate of gas services assets (GASK) was divided among states based

on their share of miles of pipeline and main. *Gas Facts*, a publication of the American Gas Association, was the source for these data.

Assets in telephone and telegraph (TELK) were divided among states using their share of miles of wire in cable. These data came from the Federal Communication Commission's *Statistics of Communications Common Carriers* for 1972, 1977, 1982, and 1986.

The final categories of assets to be distributed among states are those in the services sector (SVCSK). BEA national asset estimates in six service categories were apportioned using each state's share of sales in that category. These six estimates were summed for each state to approximate assets in services. The six categories were hotels, personal services, business services, auto repair services, amusement services, and legal services. Sales data were taken from the *Census of Service Industries* for 1972, 1977, 1982 and 1987.

The next step was to sum the asset estimates of all these nonfarm, nonmanufacturing subsectors for each state to arrive at a proxy for nonfarm, nonmanufacturing assets. These values were then summed across all states and each state's share of this sum was used to apportion the BEA national estimate of capital stock in the nonfarm, nonmanufacturing sector.

Appendix A: Sources

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Appendix B
Variables Used in the Firm Location Model of Employment Growth

Variable Name	Definition	Source
Dependent:		
CHPE	Average annual percent change in private nonagricultural employment	U.S. Bureau of Labor Statistics, *Handbook of Labor Statistics,* 1989
Independent:		
Cost of Labor		
WAGE	Hourly wage in manufacturing	U.S. Bureau of Labor Statistics, *Handbook of Labor Statistics,* 1989 and 1976
U%	Unemployment rate	U. S. Bureau of Labor Statistics, *Employment and Wages, Annual Averages 1980* and U.S. Department of Labor, *Employment and Training Report of the President, 1976*
COLL	Percent of the population aged 25 years or older that has completed at least four years of college	U.S. Bureau of the Census, *Census of Population, General Social and Economic Characteristics,* 1970 and 1980
Cost of Land		
POP DENSITY	Population density calculated as the ratio of total population to land area	U.S. Bureau of the Census, *Statistical Abstract of the United States,* 1979 and 1989
Cost of Energy		
ENERGY	Cost per million BTUs of purchased fuels and electricity in the industrial sector	U.S. Bureau of the Census, *Statistical Abstract of the United States,* 1983 and 1984 and U.S. Department of Energy, Energy Information Administration, *State Energy Price and Expenditure Report, 1987, State Energy Data Book, 1960–1979*
TEMP	Normal daily maximum temperature in July	U.S. Bureau of the Census, *Statistical Abstract of the United States,* 1979 and 1989
Potential Sales		
URBAN	Percent of the population living in metropolitan areas	U.S. Bureau of the Census, *Statistical Abstract of the United States,* 1984
TAXES	Total state and local taxes as a percent of personal income	U.S. Bureau of the Census, *Governmental Finances,* 1969–70 and 1979–80, and U.S. Bureau of Economic Analysis, *Survey of Current Business,* August 1987
PUBLIC CAPITAL	Per capita public capital stock	See Appendix A for a discussion of the creation of public capital stocks. Population data from U.S. Bureau of the Census, *Statistical Abstract of the United States,* 1979 and 1989

Note: All dollar values for equations employing 1970 levels were expressed in 1970 dollars, while dollar values for equations using 1980 levels were expressed in 1980 dollars. The variables in the equation employing changes in independent variables from 1970 to 1980 were calculated as the percent change in constant (1982) dollars for variables measured in dollars or the absolute change for those variables measured as percentages.

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Discussion

*Charles R. Hulten**

It was almost ten years ago that the Boston Fed held a conference on the causes of the post-1973 productivity slowdown. That conference came just after the second oil-price shock of 1979, and much of the discussion focused on the role of energy. It was hard to resist the intuitive idea that the OPEC oil price shocks had precipitated the slowdown, and this intuition was buttressed by econometric studies that seemed to show that energy explained almost all the decline in labor productivity.

Now, ten years later, few growth analysts would argue that the energy crisis was the sole explanation of the productivity slowdown. However, a new candidate for "Cause of the Slowdown" has appeared: Aschauer and others have noted a strong relationship between public infrastructure and economic growth and have argued that the slowdown could be largely attributed to a decline in public investment spending. (Aschauer also implies that international differences in productivity growth rates can be largely explained by differences in public investment spending.) This explanation was missed by previous studies, it is said, because they did not take into account the trend in the stock of public capital.

As with the earlier energy explanation, the basic issue is to sort out the relative importance of the many factors that influence economic growth, including public capital and energy. The study by Alicia Munnell provides a valuable step in this direction by using estimates of gross state product and of private inputs of capital to develop estimates

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of public capital stocks for forty-eight states over the period 1970 to 1986. These data are then used to estimate Cobb-Douglas and translog production functions. The analysis is then supplemented with a discussion of the factors influencing regional employment growth in the private sector. Munnell concludes that "The evidence seems overwhelming that public capital has a positive impact on private output, investment, and employment."

The production function approach has generally provided support for the hypothesis that infrastructure matters a lot, so this conclusion comes as no great surprise. What is surprising is the relatively small magnitude of the effect: the output elasticities associated with public capital are much smaller than the output elasticity associated with private capital (6 percent to 15 percent versus 27 percent to 34 percent). This result is consistent with the results reported in studies by Eberts and by Garcia-Mila and McGuire, which also analyzed state-level data, but differs sharply from some of the results obtained in studies based on times series. The latter typically find much larger output elasticities with respect to public capital (often exceeding the corresponding private capital elasticity).

The smaller estimates are much more plausible. Infrastructure capital typically is in the form of networks of interacting investments, and the completion of a network, where none had previously existed, can have a major impact on economic growth. For example, the growth of the United States was greatly stimulated by the building of the intercontinental railroads, and the establishment of electricity, road, and irrigation networks in developing economies can have a huge payoff. However, *adding* to an existing network will rarely have the same return: at some point, the increasing returns to scale aspects of infrastructure are exhausted and, other things equal, marginal additions bring increasingly smaller benefits. Since the primary U.S. infrastructure networks were well established by 1970, a regression analysis based on post-1970 data should not be expected to show a large infrastructure effect, and even the smaller estimates of this paper may overstate the benefits of *additional* investment in public capital.

It is also important to recognize that the positive association between infrastructure and output growth does not necessarily mean that too little public capital existed during the time period studied. An efficient allocation of resources requires that the ratio of marginal social product to input cost be the same for all inputs. The paper does not address this second issue directly, but a comment is informative: "The coefficient of public capital is also sensible in that it implies a reasonable marginal productivity for public capital and equality between the productivity of public and private capital." If the corresponding resource costs of both types of capital are roughly the same—that is,

opportunity cost plus depreciation and maintenance—the results of this paper would imply an *efficient* allocation of capital, and not an underinvestment in public capital. Since resource costs are not presented, it is not appropriate to conclude that the allocation of capital is efficient, but neither is it appropriate to draw the opposite conclusion.

The results of this paper should also be interpreted in light of several potential biases. First, the measure of public capital that enters the state production function is the own-public capital stock of each state. This implies that an additional road in Ohio affects output in Ohio alone, and ignores the productivity benefits of Ohio's roads that accrue to other states. A 1 percent increase in roads in every state may thus have productivity effects greater than the sum of the direct state benefits, if the spillovers are important. Although this does not necessarily lead to a problem (for example, if spillovers are perfectly symmetric and public capital increases at a uniform rate everywhere), the estimates will, in general, exhibit a bias that depends on the extent and nature of the spillovers.

Second, no adjustment is made for congestion or intensity of use. The capital services obtained from a highly congested road could be less, per unit of capital stock, than the services associated with an uncongested road. The direction of any bias is unclear, however, since congestion can be high both in new, rapidly growing areas where investment has not kept up with growing demand and in older, declining areas where a declining fiscal situation has led to underinvestment. My own research suggests that a crude correction for utilization in an aggregate time series analysis considerably weakens the correlation between private output and public capital. This is, in my view, a crucial area for further research.

Third, it is reasonable to expect a lagged response in private sector output to a change in the quantity of schools, roads, and the like. A new subway system may, for example, have a sizable impact on private output, but only after businesses have had a chance to adjust to the new patterns of demand and supply. The finding of a high contemporaneous correlation between public capital and private output is thus somewhat implausible.

Finally, and most important, it should be recognized that the production function is but one structural equation in a system of simultaneous equations, and that the correlation between public capital and private output might come from other parts of the economic system. Specifically, rising incomes in rapidly growing areas may cause voters to demand more infrastructure. If this is the case, then the direction of causality is ambiguous: more public capital may help produce more output, but more output leads to an increase in the amount of public capital. To associate this joint relation with the first effect alone is to

generally overstate the impact that an exogenous increase in public capital would have on output growth.

These problems are hardly unique to Munnell's paper, and pose interesting and difficult challenges that must be confronted by future research. This paper is, indeed, to be applauded for the progress it makes on a tough problem, particularly in the area of data development. Considerable effort went into the development of public capital stocks by states, and such an effort is not always appreciated by nonspecialists. This data set will be a valuable input to future infrastructure research.

Discussion

*Ann F. Friedlaender**

In her interesting and exhaustive paper, Alicia Munnell argues convincingly that public infrastructure investment has a positive impact upon regional output and growth. I, for one, do not have to be convinced of this; on a purely intuitive and anecdotal level in both developed and less developed countries, one senses that regions with an extensive base of public infrastructure have stronger economic performance than those with a weak or decaying base. It would have been surprising if Munnell had failed to find positive relationships between infrastructure and output and growth.

While Munnell's empirical findings are convincing, I am somewhat uncomfortable with the analytical structure that she utilized. In what follows, I would like to sketch out an alternative approach, one that I believe is not only on a somewhat firmer analytical footing, but also subject to empirical estimation. In doing so, I hope to stimulate work on this important and as yet relatively unresearched topic.

Cost versus Production Functions: An Alternative Approach

While a long tradition is associated with using production functions to estimate technology and technical change, economists have also recognized that the econometric estimation of production functions

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suffers from an important problem of misspecification. In particular, since input prices affect factor utilization and thus where firms are positioned on their transformation function, omitting them in an econometric analysis of technology could lead to substantial biases in the estimated technological coefficients. Of course, if relative input prices are constant over the sample, this is not a problem. A substantial variation in input prices over the sample probably would be a legitimate cause for concern, however.

While I am not an expert in this area, casual empiricism suggests that the omission of input prices could create bias in Munnell's analysis. Not only did real interest rates rise significantly while real wages fell somewhat during the sample period, but it is also likely that one would observe significant regional differences in relative input prices in view of regional differences in the composition of output, the work force, and capital. Indeed, the rather striking differences in the estimated production functions by region may well reflect these differences, rather than differences in technology per se.

This suggests that it might make sense to estimate a cost function rather than a production function. Not only would this incorporate input price effects into the analysis, but it would also enable one to determine the extent to which public infrastructure is under- (or over-) capitalized, providing some boundaries for those who believe a major shortfall in public infrastructure exists.

To see the basic framework, assume that labor and private capital are adjustable over a year and thus are in equilibrium, but that public capital is not. (Note that we could assume that private capital is also in disequilibrium and adjust the analysis accordingly.) We would consequently estimate a short-run variable cost function of the following form:

$$C^v = C^v (Q, w, r, G, t) \qquad (1)$$

where Q = output, w = the wage rate, r = the cost of private capital, G = the amount of public infrastructure, and t represents a time trend to capture technical change. If we assume a Cobb-Douglas production function, omit the time trend, and substitute a technological factor instead, this equation can be thought of as the dual of Munnell's production function. It is inherently more general, however, since it permits technical change (the time trend (t) can be introduced to represent neutral and non-neutral technical change) as well as the explicit role of input prices in the equilibrating process.

Although this approach presents significant data problems, they are probably not insurmountable. Munnell's analysis shows that it is possible to construct reasonable data on regional output (Q), labor (L),

private capital (K), and public infrastructure (G). Since short-run variable costs are simply the sum of the costs of the variable inputs,

$$C = wL + rK. \tag{2}$$

To estimate a regional cost function, we therefore need additional data on regional wage rates (w) and the cost of private capital (r).

Data on regional wage rates should be relatively straightforward to obtain from the U.S. Bureau of Labor Statistics or similar sources. Estimating regional data on the cost of capital is considerably more difficult, however. As a first approximation, one could assume that regional capital markets are spatially perfect, but that the cost of capital differs by broad industry groups (to reflect differences in inherent risk as well as debt structures). By utilizing data on the regional composition of output, one could then construct Divisia indices of the private cost of capital by states. While admittedly difficult, it does not appear to be impossible to obtain the requisite information to estimate this regional cost function.

Using this short-run cost function, it is possible to estimate elasticities of substitution among the various inputs, the nature of technical change (neutral, labor-augmenting, and so forth), and returns to scale, as well as the relative marginal products of the various inputs.

In addition, by utilizing Shephard's lemma (admittedly one may have to make a leap of faith about cost minimization and perfect input markets), one could use the input demand functions to estimate the direct investment and employment effects associated with public infrastructure. Equally important, it should also be possible to determine whether the amount of public capital is in equilibrium, by considering the relationship between short-run and long-run costs. In particular, total costs are given by

$$C = C^v (Q, w, r, G) + \gamma G \tag{3}$$

where γ represents the opportunity cost of public infrastructure and $C^v(\cdot)$ represents the variable cost function.

The shadow value of public infrastructure represents the savings that would accrue to variable costs if the stock of public capital were raised by one unit. Thus we define:

$$\rho = \frac{\partial C^v(\cdot)}{\partial G}.$$

It is straightforward to show that the equilibrium amount of public

infrastructure obtains when the opportunity cost of public capital equals its shadow value. Thus in equilibrium

$$-\frac{\partial C^{v}(\cdot)}{\partial G^{*}} = \gamma \tag{4}$$

where the asterisk indicates the cost-minimizing level of G. If the shadow value of capital is greater than its opportunity cost, this indicates insufficient public infrastructure (and the reverse is true if the shadow value of capital is less than the opportunity cost). More importantly, by solving this equation for the equilibrium level of infrastructure (G^*), one can determine the amount of under- (or over-) capitalization that exists with respect to public capital.

Of course, the validity of this analysis depends on our ability to estimate the opportunity cost of public capital, admittedly not an easy task. Nevertheless, to the extent that state bonds are issued for infrastructure investments rather than for operating costs, state bond yields could be used to construct regional series on the cost of public capital. Thus by utilizing this framework it should be possible to estimate the extent to which particular states and/or regions are underinvested or overinvested in public capital.

While it may be pushing things a bit, it should also be possible to incorporate demand effects into this framework and extend the analysis in a fashion that is somewhat analogous to that followed by Munnell in her analysis of the relationship between employment and public infrastructure. Instead of utilizing a reduced-form analysis, however, this approach explicitly models the demand effects of infrastructure.

Assume that a regional or state authority is interested in maximizing the net benefits of public infrastructure. The cost function is given in equation (3), above, while the benefit function depends on regional activity or output (Q), prices (P), and infrastructure (G). Gross benefits can be expressed as

$$B = B\,(Q, P, G), \tag{5}$$

while net benefits can be expressed as

$$NB = B\,(Q, P, G) - C^{v}\,(Q, w, r, G) - \gamma G. \tag{6}$$

If the regional authority seeks the welfare-maximizing level of

infrastructure, it is straightforward to show that this is given when

$$\frac{\partial B(\cdot)}{\partial G^*} - \frac{\partial C(\cdot)}{\partial G^*} = \gamma. \tag{7}$$

This indicates, of course, that to the extent that public infrastructure enters regional demand as well as regional production functions, the equilibrium level of infrastructure rises. Thus, if one were to observe undercapitalization with respect to the amount of public infrastructure based on an analysis of costs alone, it is likely that the true extent of undercapitalization is even greater than indicated. Conversely, if one observed overcapitalization on the basis of a cost analysis alone, to the extent that infrastructure affected regional demand, one would have to discount the extent of overcapitalization.

I have to admit that I have not fully formulated a gross benefit function suitable for estimation. Presumably, the benefit function represents the consumer surplus accruing to the population, that is, the area under the appropriate demand function. This suggests that it might be possible to estimate a marginal benefit function that depends on prices and infrastructure. Alternatively, following the literature on the benefits associated with air pollution, it might be possible to estimate a marginal benefit function for infrastructure directly. This, however, is obviously a difficult activity, because of problems posed by spatial aggregation, omitted variables, and the like. Nevertheless, intuition tells me that such an analysis is probably feasible and that it also could yield interesting results.

Conclusion

Let me close by stressing again the valuable insights and contributions provided by Munnell's paper. She has, I believe, convincingly shown that public infrastructure has a positive effect upon regional output, investment, and employment. Equally important, she has created a significant data set that could be utilized to explore interesting questions for future research.

While not directly addressing the details of Munnell's paper, these comments have attempted to sketch out an alternative framework that could yield not only the insights contained in Munnell's analysis but also further insights into efficiency aspects of the provision of public capital. This is clearly one area that could produce important dividends for future research. We owe Munnell our thanks for a stimulating and provocative paper.

Is Public Infrastructure Undersupplied?

*George E. Peterson**

Over the past decade, infrastructure issues intermittently have moved toward the forefront of the domestic policy agenda. The coming year promises to intensify debate. By September 1991, Congress must re-authorize the federal highway program. Unlike past re-authorizations, this time Congress almost certainly will have to set new priorities and incorporate new principles of cost sharing for highways, since the original mission of the federal highway program will have been accomplished. Sometime in 1991–92, workers will complete the last segments of the interstate highway network, bringing to an end an era of road-building that began with Dwight D. Eisenhower in 1956 and has dominated infrastructure spending since that time. Any consensus that Congress reaches regarding the definition of a new federal role in the highway program, or the appropriate use of price incentives in grant programs, is likely to spill over to the financing of other infrastructure functions.

This paper sets out to provide an introductory perspective on the current infrastructure policy debate. It begins by considering the record of public capital spending. Most of the studies claiming extreme erosion of infrastructure investment start their story with the 1960s, which turned out to have been the peak period for infrastructure spending. A somewhat longer perspective better captures the wave pattern that has characterized infrastructure investment, but the impression of a secular decline in gross investment is weakened. In this perspective, the late

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1970s and early 1980s still stand out as a period when the net public capital stock (after depreciation) almost ceased to grow.

It is one thing to demonstrate that capital spending has declined. It is another to prove it is also too low. Is public capital undersupplied? Recent approaches to this question have emphasized the role of infrastructure as an intermediate good contributing to private production. In a series of studies, Aschauer has argued that public capital enters strongly into the private sector's production function, raising the productivity of both private capital and labor. His findings imply rates of return to infrastructure investment as high as 50 to 60 percent. Insofar as these returns vastly exceed those available to private investment, they imply that, yes, public infrastructure capital is undersupplied.

Infrastructure also yields final consumption services for households. In many states, households still vote directly on the bond issues used to finance capital projects, or on the tax and fee revenues raised to recover initial investment costs. As a result, direct evidence is often available regarding household demand for infrastructure spending. The evidence of undersupply, using consumer willingness to pay as expressed in bond referenda, is almost as strong as the evidence derived from production function studies. Over the past six years, 80 percent by value of all state and local infrastructure bond proposals have passed. The average margin of voter approval exceeded 66 percent, a substantially higher approval rate than found in any other kind of expenditure referendum. These results imply that, at least in recent years, taxpayer-consumers have been willing to buy more infrastructure capital than was actually provided by public authorities.

This paradox merits more attention than it has received. How can one account for the apparent undersupply of infrastructure? Aschauer's results imply that private producers can benefit more in terms of private output from a dollar of public investment than they can from a dollar of their own investment in private plant and equipment. Since the costs of public investment are shared with households, it would seem that, out of self-interest, business groups should be lobbying violently for tax hikes to finance an expanded public capital budget; and, if this fails, they should volunteer to pay the costs of additional public capital investment entirely on their own. Furthermore, the recent rates of voter approval of infrastructure projects at referendum imply that, with even modest leadership from the business community, it should be possible to stitch together a politically persuasive constituency for greater infrastructure spending. Either the empirical results are exaggerated, or the political system has failed to undertake high-payoff investments that also have broad political support.

The possibility that recent studies have overstated infrastructure benefits will be explored throughout the conference. This paper consid-

ers various explanations that could account for undersupply in the face of genuine demand. The argument offered is that political leaders have overreacted to what might be called the "fear of rejection at referendum." Since the taxpayer revolt of the 1970s, the very act of referendum voting—and the possibility it brings of public repudiation—appears to intimidate officials. Rather than designing capital proposals that satisfy the median voter, they seem to aim higher (or with more risk aversion) to win support from as large a majority of the electorate as possible in order to minimize the chance of rejection. This tendency has been exacerbated in some states by formal changes in the laws, which now require super-majority approval for capital financing issues. Infrastructure spending at the state and local level has become misaligned with taxpayer-voter preferences, in part because officials are reluctant to put forward capital proposals that go as far as the majority of voters want.

The paper concludes by considering how this political bottleneck on infrastructure spending can be broken. Traditional decision-making mechanisms are badly equipped to handle joint consumer and producer demand for publicly provided goods. Referenda and other voting proxies incorporate the principle of "one man, one vote." No device is available for weighting votes by willingness to pay or by economic stake in the outcome. Business, for its part, is accustomed to expressing its expenditure demands largely through lobbying. As a result, a good deal of political ingenuity in recent years has gone into inventing institutions that can legally invest in infrastructure without submitting to the referendum process. This strategy seems to be a mistake. The most striking cases of turnaround in state or local infrastructure spending have occurred precisely where new business-consumer alliances have taken their case to the public and asked for voter support. Typically, these proposals have included a redesigned tax or fee package that has targeted a greater share of costs to business and users, thereby relieving the cost burden on the general taxpayer who must approve the new spending.

Trends in Public Capital Investment and Capital Stock

The first warnings of an impending infrastructure crisis were issued more than a decade ago by authors who called attention to the sharp decline in public capital investment. This decline has been measured in several ways. For example, the National Council on Public Works Improvement (1988) reported a drop in public works capital outlays by all levels of government from 2.5 percent of GNP in 1963 to about 1.2 percent of GNP in 1978 and 1.0 percent in 1984. Growth in the public

capital stock, net of depreciation, fell to less than 1 percent per annum between the late 1970s and mid 1980s.

It is true that maintenance and operations costs associated with infrastructure facilities rose substantially over the same period. This makes interpretation of the capital spending data alone somewhat problematic. As large capital programs, such as the construction of the interstate highway system, are completed and the first generation of facilities built under the program matures, it is natural that the infrastructure spending mix should shift toward maintenance. Indeed, until legislative modifications in federal highway financing were made in 1982, one of the principal criticisms of federal highway aid was that it was inefficiently directed almost exclusively to new construction. Now, some 40 percent of federal highway funding goes for repairs and rehabilitation of existing roads and bridges.

More active maintenance throws into question some of the assumptions about depreciation that are built into estimates of the public capital stock. In principle, depreciation rates should be treated as endogenous. Better maintenance and repair can stretch the useful life of infrastructure facilities, and even keep them in as "good as new" condition for a significant period.[1] The assumption, used by the Bureau of Economic Analysis and others in estimating capital stocks by the perpetual inventory method, is that depreciation schedules are fixed exogenously and not affected by maintenance practice. This assumption may exaggerate the rate of slowdown in capital stock accumulation that occurs when, as recently, public works spending shifts toward maintenance away from capital construction.

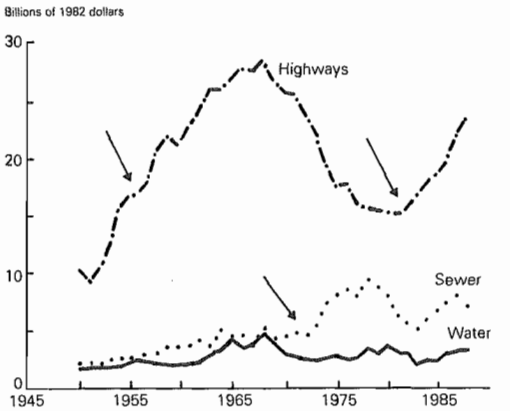
Figure 1 places gross investment in three of the core infrastructure functions in somewhat longer perspective. It shows that the 1968–71 level of capital spending for highways was the product of a decade's climb in gross capital investment. From a longer perspective, the decline in gross investment may seem to be more a cyclical receding from the initial impetus of the highway program than a secular trend. As Tarr (1984) has pointed out, broad cyclical swings have long characterized infrastructure investment in the United States, as one wave of building programs subsides and another begins to rise.

Figure 1 also illustrates the central role of federal legislation and federal aid in initiating the major waves of public capital formation. Critical legislative dates are highlighted in the figure. In 1956 Congress passed the federal highway program. In 1982 it boosted the federal gas

[1] In their examination of capital spending in 433 New Jersey communities, Holtz-Eakin and Rosen (1989) find that they cannot reject (at the 5 percent level) the hypothesis that depreciation *net of maintenance* is zero for local infrastructure

Figure 1

State-Local Gross Investment in Infrastructure by Function, 1949 to 1988



Source: U.S. Bureau of Economic Analysis.

tax to augment the highway trust fund. Both measures triggered strong growth in highway investment; ironically, the two pieces of legislation were adopted, twenty-six years apart, at almost the same level of real state and local gross investment in roads and highways. Wastewater investment began its upward swing shortly after passage of the 1972 Water Pollution Control Act, which first incorporated grants for municipal treatment facilities.

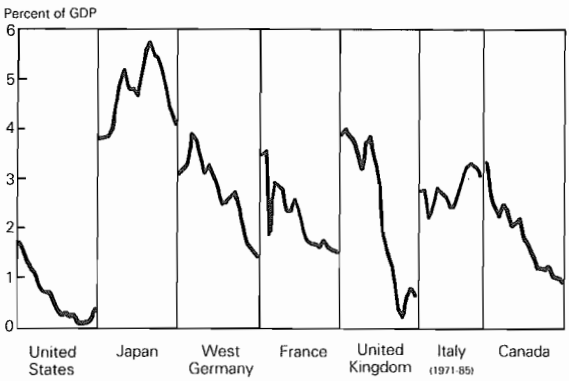
International comparisons also extend the frame of reference for capital spending. A comparison of net public investment as a share of gross domestic product in the Group-of-Seven countries, for example, seems to show investment trends for several European countries comparable to those in the United States (Figure 2).[2]

In fact, interpretation of these trends points to some important definitional issues that underlie current discussions. "Infrastructure" spending has been equated with public nonmilitary investment and, in the United States, with state and local investment. Many infrastructure functions, however, can be provided by either the public or the private

[2] See Reidenbach (1986) and Jackson (1988) for further detail of infrastructure issues in Germany and the United Kingdom, respectively.

Figure 2

Net Public Investment as a Share of Gross Domestic Product, 1967 to1985[a]



[a]Excludes military expenditures. Data for Italy begin in 1971.
Source: Aschauer (1989b) from OECD National Accounts.

sector. In fact, in response to budgetary pressures on government, a tendency has developed to shift previously public capital responsibilities into private hands. The most widely publicized privatization efforts are those that involve complete and sudden breaks with public supply—for example, the building of private toll roads or the United Kingdom's sale of regional water authorities to the private sector.

The precipitous decline in government infrastructure spending in the United Kingdom during the 1970s, however, stems in part from another kind of privatization. During this time government changed from a significant land developer and investor in land improvements to a net seller of improved land. The growth in the net sales of improved land, which enter into OECD's national income accounts as negative capital formation by government, alone accounts for more than one-half of the real decline in general government capital investment between the years 1975 and 1982. This substantially distorts any cross-national estimates attempting to relate productivity decline to measured decline in public capital formation.

Another example of the impact of public-private classification on the recorded growth of infrastructure capital occurs in Sweden. At first glance, Sweden appears to be an interesting exception to the pattern of decline in the growth rate of public capital stock—especially in the

transportation and communication sector. However, closer examination shows that total sectoral capital growth has been the product of two strikingly different trends (Sundberg and Carlen 1989). Telecommunications investment has been rising rapidly, while highway investment has been falling. The fact that in Sweden both are public responsibilities masks a shift in investment pattern that in other nations would reveal itself as a relative decline in the public capital stock. As privatization initiatives accelerate, it would seem important to begin measuring infrastructure capital in functional terms, summed across the public and private sectors, as well as according to ownership or source of financing. Government-produced infrastructure may be of special interest because of the way expenditure and financing decisions are made. If, largely for historical reasons, infrastructure networks serving fast-growing sectors of the economy have been assigned to the private sector while networks serving manufacturing and slower-growth sectors are in public hands, the shift toward lesser intensity of public capital in production may reflect not a failure of government supply but an orderly change in factor usage that would occur regardless of public or private provision.

Is Public Infrastructure Undersupplied?

The mere fact that infrastructure investment has suffered a steep or persistent decline does not mean that the country should invest more in public capital. In considering whether public infrastructure is undersupplied or oversupplied, analysts have pursued two quite different lines of study, reflecting the joint nature of infrastructure services. Public capital simultaneously provides inputs into private production and yields direct services to final consumers. When infrastructure is viewed as part of the private-sector production function, the desirability of further investment can be judged by the rate of return it generates in terms of private output. If the return to infrastructure investment exceeds that available from other investment opportunities, the public capital stock ought to be expanded.

How the optimal level of public capital for final consumption should be decided is perhaps less clear. Many infrastructure needs studies imply that public officials should first make an expert judgment regarding the quality of infrastructure services that is appropriate for the citizenry, as well as the condition of the underlying capital, and then find ways to pay for this desired level of output and maintenance. In many states, however, voters have substantial opportunity to vote directly on infrastructure programs and their financing. Under a taxpayer-voter model of state and local government, public officials ought to supply the level of final infrastructure services that consumers

are willing to pay for, either as expressed directly through their votes in bond and other referenda or indirectly in general elections.

Recent literature has devoted its principal attention to the payoff in private sector production from investment in public capital stock. This line of analysis was initiated by Aschauer (1988a, 1988b, 1989a, 1989b) and extended by Munnell (1990), among others. It represents public infrastructure—especially core infrastructure—as entering directly into private production functions. Therefore, increases in the public capital stock produce increases in private output, and increases in public capital usage relative to other factors of production increase the productivity of both private capital and labor.

The empirical findings have been striking. In his original studies, Aschauer reports results that imply rates of return to public investment as high as 50 to 60 percent per annum. The decline in the growth of the public capital stock since the 1960s is found to explain by far the largest part of the slowdown in private sector productivity growth over the same period. In some of the studies, a dollar of public investment yields more private output gain than does a dollar of direct, private investment. These results are so strong that skepticism has been expressed as to whether they simply reflect coincident trends in infrastructure investment and productivity growth since the 1960s rather than a causal linkage.[3] Taken at face value, however, the findings imply that public infrastructure capital is presently greatly undersupplied, *even if infrastructure facilities have no value in providing final services to consumers.*

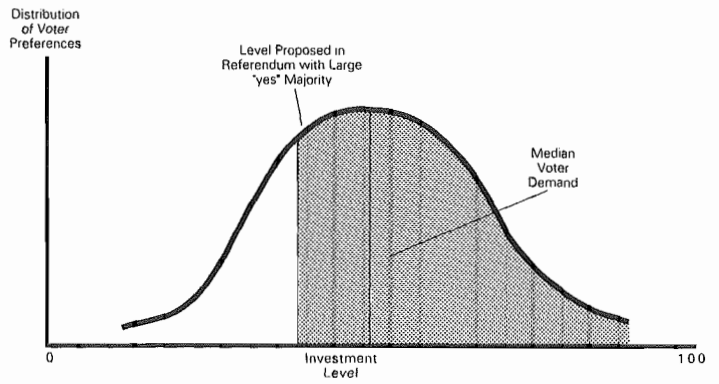
Taxpayer-Voter Demand

Whether infrastructure capital is undersupplied from the point of view of the taxpayer-voter has received less analytical attention. A partial answer to this question can be obtained from a closer look at voters' revealed preferences as expressed in bond elections and other referenda. The measure is admittedly imperfect, because only part of state and local infrastructure spending passes through the referendum process. (In 1988, $26 billion of new bond proposals for capital invest-

[3] For example, see Schultze (1990) and Hulten (1990). The risk of attributing too much significance to parallel trends can also be seen in international comparisons. As noted in the text, the steep decline in net infrastructure investment recorded in the United Kingdom (Figure 2) is to an important degree an accounting artifact created by government changeover from being a land developer to a net seller of developed land. Given Aschauer's cross-country analysis of productivity change (1989b), the disposition of government assets in the United Kingdom would by itself have been sufficient to depress the U.K. productivity growth rate by 1.2 percentage points. The coincidence of this (reported) slowdown in public capital formation with productivity decline also is likely to produce overestimates of the productivity impact of infrastructure capital.

Figure 3

Voter Demand for Infrastructure Investment



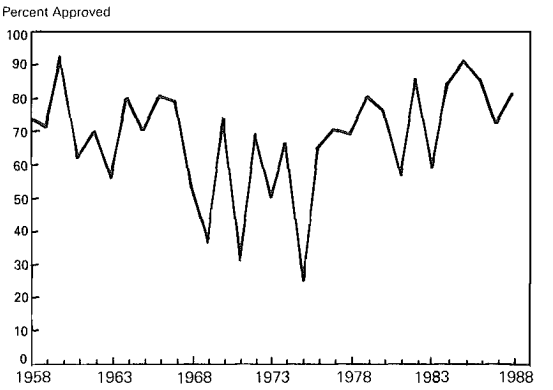
ment, excluding refinancing, were submitted to voters, of which $21 billion were approved. This compares with total state and local gross investment in 1987–88 of $104 billion.) However, referendum results may be taken as a general proxy for citizens' broader spending preferences.

If states and localities with referenda procedures truly tried to satisfy the median voter, they would submit frequent bond proposals for voter consideration in order to assess voter demand. Bond approval rates and margins of passage should hover near 50 percent. That is, if local officials attempt to design capital programs that match the median voter's preference, bond elections should be closely contested. High majorities voting "yes" in bond elections imply that even after a new project is built, infrastructure still will be undersupplied, relative to simple majority preferences.

The relation between bond referendum approval rates and desired spending is illustrated in Figure 3 under the assumption of a normal distribution of voter preferences. The percentage of voters in favor of an infrastructure bond proposal will be the cumulative percentage who desire at least this much investment spending (shown as the shaded area in the diagram). A high rate of voter approval implies that many voters who would vote against an infrastructure proposal that just

Figure 4

Approval Rate for Non-School Bond Referenda, 1958 to1988



Source: Sanders (1991).

matched median-voter demand nonetheless support the actual proposal, because it involves a lower level of investment.

The record of infrastructure bond referenda voting suggests that, since at least 1984, voters have been willing to support higher levels of public infrastructure investment (Figure 4). Between 1984 and 1989, on a value basis 80 percent of infrastructure bond proposals were approved at public ballot.[4] Even this figure understates the extent of public support, because the lowest approval rates were registered in states that require more-than-majority margins for bond approval. The margins by which spending proposals have passed have also been high. Since 1984, the average infrastructure bond proposition submitted to referendum has commanded more than 66 percent voter approval—a rate of support exceeding that recorded for any other type of referendum.

Voter support for infrastructure initiatives has not been a permanent feature of the fiscal landscape. During the early 1970s in particular, bond approval rates occasionally reached as low as 30 percent as public exasperation with state and local expenditure growth manifested itself

[4] Infrastructure bonds are defined to include the following functions: roads and highways; water and sewer; public buildings (including jails and general government facilities); and education. Education is the largest single category.

as opposition to all classes of public spending, including infrastructure financing.

Besides the broad cyclical swings in voter support visible in Figure 4, annual voting outcomes have a strong sawtooth pattern. The low points in voter approval come in odd-numbered years—the years without general elections, when voter turnout is much lower. The most ardent voters have been those opposed to new tax and spending proposals. General voters, who tend to vote on referendum propositions only during general elections, have been far more likely to vote in favor of new infrastructure projects.[5] The annual fluctuation in voting outcomes was most marked during the 1970s and early 1980s, when a core group of tax opponents regularly voted against and defeated bond and tax proposals during "off" years. Over the past few years, the passionate division of the electorate into opponents of spending and others seems to have subsided.

All in all, the record of taxpayer voting suggests a history of clearly expressed preferences that correlates well with actual state and local investment patterns. Bond rejection rates surged for the first time in 1968. That date also marks the high-water mark in state and local infrastructure investment, and the beginning of a long period of slowdown in public capital formation. Voter approval now has recovered and stabilized. The reasons for taxpayers' change of heart are not completely clear, but they seem to combine diminished opposition to government spending in general with special support for infrastructure proposals. Years of low state and local investment, coupled with more evidence on the consequences of cutbacks, appear to have convinced the electorate that, at the margin at least, it is now appropriate to increase infrastructure commitments.

Explaining the Undersupply of Infrastructure Capital

Arguments that affirm an undersupply of public infrastructure require a political explanation. With two powerful constituencies demanding more public investment—a business community that perhaps can gain as much from government-financed infrastructure investment as from its own capital spending, and an electorate that appears disposed to approve higher levels of public capital outlays—what political mechanisms could frustrate these demands? Why should public capital remain undersupplied?

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[5] This is consistent with the survey findings of Gramlich, Rubinfeld, and Swift (1982), who found that nonvoters generally opposed tax limits and were more likely to support public spending than those who voted.

Benefit Spillovers

One class of explanations for undersupply emphasizes the spillover benefits inherent in some types of infrastructure systems. As long as some of the benefits from public capital facilities spill over to users outside the local taxing district, local taxpayer-voters, looking only at their own benefit-cost trade-off, will choose to provide a suboptimal level of infrastructure capital.

Spillover benefits are dealt with most efficiently by the pricing system. A universal user charge system, in which all users, regardless of place of residence, pay a fee that covers the marginal costs they impose on a network, will automatically balance demand and supply. (An additional fixed subsidy may be necessary for networks that show declining marginal costs.) Where user fees are impractical, the same result can be approximated through intergovernmental matching grants. A higher level of government compensates the local jurisdiction for the share of system costs imposed by nonresidents. Faced with a lower tax price, local voters will demand the optimal level of infrastructure provision.

The system of matching grants used in the United States, however, has capped allocations. The matching provisions do not apply at the margin where expenditure decisions are made.[6] Under these circumstances, state or local governments will still undersupply infrastructure that generates spillover benefits.

The practical importance of the spillover argument to infrastructure supply decisions is unclear. Spillover benefits certainly are present in some networks, such as road systems used by out-of-state drivers. They are likely to be particularly important in the networks used by business, where greater national market orientation is to be found. The spillover argument therefore may help to explain why the business sector has not asserted more leadership in demanding higher levels of local infrastructure investment. Local firms are able to use capital networks paid for by other jurisdictions for part of their business; conversely, any infrastructure that local business helps pay for through local taxes will be used in part by outsiders who do not have to pay.

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[6] Seen from a local perspective, the "capping" of categorical matching grants may be exaggerated. Few of the federal grant programs operate by simply matching local spending up to a fixed amount. Many involve discretionary determinations of which local projects will be eligible for federal matching. Thus, the federal highway program has included discretionary bridge projects. Other highway funds and Environmental Protection Agency grants for municipal wastewater treatment have had fixed allocations at the state level, but competition by state criteria for individual project eligibility. Local jurisdictions thus face the possibility of stretching or shrinking federal matching dollars based on the projects they propose.

The spillover share of use for almost all infrastructure systems, however, is well under 50 percent. Even after discounting the reported aggregate private returns to exclude the share attributable to externalities, and therefore not captured locally, recent estimates of the private sector payoff to infrastructure investment imply that the local return should be enough to generate strong business support for infrastructure investment financed through local general taxes. Thus, the paradox remains. Why has business not been more active, and more successful, in demanding increased state and local capital outlays?

Spillovers, of course, do not help account for the paradox of apparently unmet infrastructure demand from household voters. Voting in bond elections reflects the pricing rules and grant system currently in use. A reform of user charges or the grant structure, so as to shift more of the incremental capital costs to outsiders, might well induce local voters in the future to support still higher levels of infrastructure spending, but current voting already takes into account any caps on federal or state grant aid.

Voting Requirements

When public officials are asked to identify the principal constraint on expanding infrastructure investment, their answer is the need to submit bond or tax proposals to the electorate for voting.[7] The tax revolt of the 1970s and early 1980s has left a strong residue of apprehension. Out of fear of rejection, officials have been reluctant even to *propose* expenditure and tax increases for voter consideration.

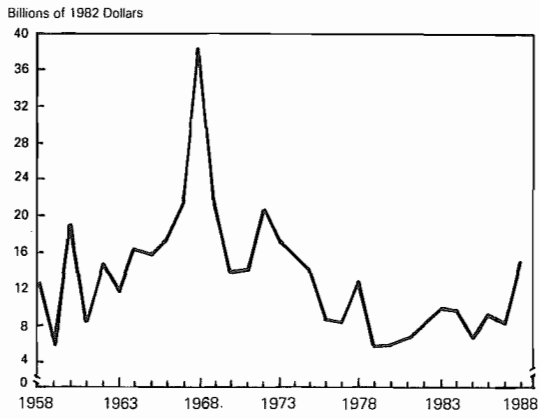
The intimidation effect can be seen by comparing Figures 4 and 5. In the early part of the period, bond approval rates were very high, and public officials appeared to ratchet upward capital spending proposals in response to these high rates of voter approval. By 1968, the volume of bond proposals submitted to the public in referendum exploded to $40 billion. However, that year also brought a steep decline in voter approval rates, which continued to fall in 1969 and in off-year elections thereafter.

In response, public officials began to back away from infrastructure bond proposals. The dollar volume of bond initiatives fell sharply (Figure 5). This process was accelerated by the imposition of new state tax and spending limitations, some of which required super-majority

[7] For example, in a survey conducted by the National League of Cities, 35.9 percent of all cities stated that the major obstacle to increased local infrastructure spending was the need to secure voter approval at referendum, a larger percentage of respondents than identified any other obstacle. Among cities that actually are required to seek voter approval, this was overwhelmingly cited as the principal obstacle.

Figure 5

Dollar Value of Non-School Bond Proposals, 1958 to1988



Source: Sanders (1991).

votes to override tax or borrowing ceilings. Only recently, after years of strong voter support for infrastructure proposals, has the volume of spending initiatives submitted to the electorate by state and local officials begun to rise again.

The potentially distorting effects of agenda setting on the referendum process have been pointed out by others (for example, Romer and Rosenthal 1978). A commonly expressed fear has been that local officials can manipulate expenditure outcomes upward by proposing excessive spending levels, to which the only alternative may seem continuation of the status quo or reversion to a lower level of spending if the proposal is defeated. The data presented here suggest a more realistic fear is that risk-averse local officials will be intimidated by the voting process into proposing less infrastructure spending than voters are willing to support.

A special case where local voting requirements clearly have imposed inefficiency and underspending on capital expenditure decisions occurs in states that have imposed super-majority voting rules for bond or tax approval. Local governments in California, Massachusetts, Missouri, Washington and other states have had to secure two-thirds or other extraordinary margins of voter approval to pass bond initiatives or tax overrides. Other states (for example, Michigan) have required voter

approval at referendum plus a super-majority legislative approval for state bond initiatives. The requirement that more than a majority of voters approve a new bond issue has been devastating to tax-supported bond financing and infrastructure investment. California, for example, has fallen from one of the leaders in per capita highway investment to last or next to last in the nation, as the result of bond-voting and tax restrictions.[8]

Public officials have sought to circumvent the limitations placed on tax-supported infrastructure by creating special districts and special authorities outside of the general government structure. These are typically empowered to raise project revenues and issue bonds for capital spending as long as they do not tap the general taxing authority. Authorities that are exempted from state bond limitations, such as the city redevelopment authorities in California, have had to take on a broad and otherwise inexplicable array of capital financing responsibilities.

We thus are presented with the curious juxtaposition of states and localities failing to respond in full to voters' apparent willingness to increase capital spending, while continuing to search for complicated institutional ways to avoid public referenda in the future. The picture can be reconciled only by visualizing governments that distrust the electorate, and therefore are reluctant to interpret their positive voting signals too literally.

Failure to Take Advantage of the Joint Products of Infrastructure

As emphasized earlier, the typical infrastructure facility delivers joint products—input services to private producers as well as final services to household consumers. The combined demands of these two groups should be able to sustain aggregate infrastructure demand that exceeds the levels supported by either source on its own. Business and consumer demands are not entirely separable, of course—households presumably value the same congestion savings in the journey to work as producers. Nonetheless, the areas of overlap are limited.

Unfortunately, the mechanisms normally used to express infrastructure demand at the local or state level are ill-suited for aggregating business and consumer preferences. Most referendum voting operates under the principle of "one man, one vote." Unless the tax costs of a

[8] Econometric studies of state capital spending have found debt ceilings to have significantly depressing effects on capital outlays (Bunch 1988; Burstein 1984). When these studies are reformulated to identify states that must submit tax-supported bonds for voter approval, either because of general constitutional provisions or because they are at a debt ceiling that requires voter approval to override, the depressing effect on capital spending is much stronger.

project can be allocated so that cost shares are matched with willingness to pay, voting results are likely to underrepresent efficient infrastructure provision levels, since each voter's opinion is counted equally rather than being weighted by willingness to pay.[9] As a result, business demand is likely to be underrepresented in traditional referenda. Business can be more effective in government through lobbying and logrolling arrangements, but this demand too has proved difficult to unite with the interests of final consumers. In states where ultimate voter approval is required for most infrastructure financing, business persuasion of the legislature in any event may be an insufficient condition for realizing greater infrastructure investment.

The jurisdictions that have achieved the most dramatic turnarounds in infrastructure investment are those that have managed to forge a business-taxpayer alliance to take the case for infrastructure spending to the public. Business typically has taken the lead in organizing and financing these alliances, and sometimes has accepted a mix of general taxes and fees that falls more heavily on the business community, in order to increase voter support. In effect, some of the producer surplus generated by higher levels of infrastructure spending is spent on the campaign to achieve that investment. For example, in Cleveland, Ohio, the business community took the lead in demanding higher levels of capital spending, in order that the region could restore its business cost competitiveness. Business leaders organized the voter campaign in support of an increase in the local income tax rate, once they were assured that one-half of the increased revenues would be earmarked exclusively for capital reinvestment and they were guaranteed a role in identifying specific project priorities for future investment. The recent campaign to increase California's gas tax and dedicate the proceeds to transportation investment was similarly a joint business-citizen effort organized by business. The constitutional proposal, which increases state capital spending on highways by an estimated $15.5 billion over ten years, passed with 52 percent of the vote. If subject to the super-majority voting standard of an ordinary local bond proposal, it would have failed.

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[9] Some voting systems have attempted to weight votes in a way that approximates willingness to pay. For example, it has been common in Texas and some other states to weight votes in municipal utility districts by the number of individual lots the owner possesses. That is, the decision whether to install utility networks is decided on a "one lot, one vote" basis. A developer may control 1,000 lots or more and therefore have his economic interest represented far more strongly in the referendums than an individual owner. This system has been shown to lead to much higher demand for infrastructure provision.

Conclusions

In the end, the undersupply of public infrastructure is as much a problem of political economy as pure economics. The view most commonly expressed by public officials is that they know more public investment is desirable, but their hands are tied by an electorate that does not share their opinion and makes the final determination about expenditure levels. The evidence reviewed here suggests that this explanation for undersupply of infrastructure is spurious. If anything, voters appear to be ahead of public officials in their willingness to support the costs of increasing public capital investment. Nevertheless, a great deal of political ingenuity during the past two decades has been devoted to circumventing the need for voter approval of infrastructure spending proposals. Over the long run, this effort is likely to be counterproductive. Proponents of stronger infrastructure investment seem to be better off taking their case directly to the public.

The debate over public capital's role in private productivity so far has been pitched at the national level, with the implication that if the claims of linkage are borne out, the appropriate response would be greater federal funding for infrastructure programs. Why this should be so is not explained. Ordinary state and local spending systems should be able to channel and accommodate any sustained increase in demand for infrastructure. If spillover benefits are a significant deterrent to local expenditure choice, the user fee and grant systems should be revamped so that at the margin local price signals induce efficiency. Otherwise, the major impediments to demand expression seem to be state and local officials' fear of the voting process and the uncertainty of the business sector about how best to combine its demands with those of final consumers. Public voting behavior with respect to infrastructure finance has stabilized a great deal over the past decade. Voters appear willing to support spending programs where cost-sharing arrangements have been tailored to reduce the burden on the general taxpayer. Therefore, it should ultimately be up to the business sector to resolve the current debate over the productivity impact of public capital, by deciding whether the infrastructure payoff justifies business shouldering a significant part of new investment costs at the state and local levels.

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Discussion

*Alan S. Blinder**

According to a popular view that has found its way into many newspapers and magazines, the sharp decline in the rate of spending on public infrastructure capital since the 1960s has left the United States with a serious shortfall of public capital. Awareness of this problem is not new. I can remember a business conference in the early 1980s at which Amitai Etzioni and I spoke. I was listening as Etzioni concluded his remarks with some advice given only half in jest: "If you come to a bridge on your way home, don't cross it." At that time, the Mianus River bridge was still standing.

Until recently, the evidence for a shortfall in public infrastructure was mainly anecdote and opinion. Lately, however, Aschauer (1989) and others have given this popular view more scholarly cachet by adducing econometric evidence that (1) the marginal productivity of public capital is extremely high compared to that of private capital and (2) the falloff in public investment accounts for much of the productivity slowdown in the United States.

All this has led many commentators, including me, to advocate more public spending on infrastructure (Blinder 1988, 1989). About a year ago, I testified at a Joint Economic Committee hearing on the subject. Congressman Lee Hamilton asked four of us whether we would favor an additional $15 billion in infrastructure spending, if that meant increasing the federal budget deficit by $15 billion. I believe he was surprised when three of the four said yes (U.S. Congress, Joint Economic Committee 1989).

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In his interesting paper for this conference, George Peterson does not really dispute this common view. He starts out as if he *might* by bringing up several measurement issues. First, he points out that highway spending spurted from 1950 to about 1968 and then declined until about 1982. (See Peterson's Figure 1.) Thus comparing the early 1980s (the cyclical trough) with the mid-1960s (the cyclical peak) exaggerates the decline. Second, he notes that most infrastructure can be provided either publicly or privately. Since the mix of public versus private infrastructure differs across countries, and on occasion changes dramatically within a single country, international comparisons of levels or trends are hazardous.

Peterson is correct on both counts. However, the second problem is irrelevant to time series studies of U.S. infrastructure, since our public/private mix has not changed. Regarding the first problem, Peterson's Figure 1 seems as exaggerated (in the opposite direction) as the numbers he criticizes. After all, it is hardly germane to compare *absolute levels* of spending in two years almost four decades apart. Peterson's graph shows that spending on highways was about two and one-half times higher in 1988 than in 1950. But the U.S. population was 62 percent larger and real GNP was three and one-third times as large. So highway spending declined as a share of GNP, just as everyone has been saying. Finally, I would have thought that the demand for public infrastructure capital has an income elasticity greater than one. (Compare, for example, the relative infrastructures of rich and poor countries.) If so, we should expect infrastructure to grow faster than GNP. Plainly, it has not.

In the end, Peterson accepts the evidence for undersupply of infrastructure. Two pieces of evidence persuade him.

The first is Aschauer's finding that public capital has a very high rate of return, perhaps as high as 50 to 60 percent. Here I would like to underscore an important point that Peterson makes, but does not emphasize. Many of the most important benefits from public infrastructure do not accrue to businesses and/or are not counted in the GNP. If I spend less time waiting at airports, I am happier; but the improvement in my well-being does not appear in GNP. If my car and my back absorb fewer shocks from potholes, I am surely better off; but GNP may even decline as a result of fewer car repairs and doctors' bills. The only benefits from public infrastructure that get into Aschauer's calculations are the ones that add to GNP. That these alone might account for a 50 to 60 percent return (or even half that much) is amazing to me.

Peterson's second type of evidence is a creative idea—creative, at least, to an economist. He points out that about 25 percent of infrastructure spending proposals are subject to direct approval or disapproval by voters and that, lately, such referenda have passed about 80 percent of the time—and by majorities averaging 66 percent. Such an overwhelm-

ing record of voter approval amid a taxpayer revolt suggests that Americans actually want more infrastructure than they are getting and are willing to pay for it.

I agree and would enter just two qualifying remarks. First, if (1) the median voter theory is correct, (2) politicians know voter preferences, and (3) politicians fear losing at the polls (as Peterson says), then all public bond issues should win approval. So an 80 percent victory record is hardly amazing. What *is* surprising is the two-to-one average margin of victory. It suggests either an extreme degree of risk aversion among politicians, or that something is wrong with either (1) or (2) above. The second remark is just a question for Peterson: Are the 25 percent of infrastructure projects that are submitted to referenda a random sample of the population? I simply do not know.

The most interesting parts of Peterson's paper come next. If you accept the case that infrastructure has been undersupplied, you come face to face with a question: Why? Peterson mentions three possibilities that I would like to discuss.

First, and foremost in his mind, is politicians' fear of rejection by the voters. I find this a plausible hypothesis, and not just because of the evidence Peterson offers. Anyone who lived in tax-revolting America in the 1980s must find it believable that politicians asked voters to tax themselves only with great trepidation. After all, Ronald Reagan was watching.

Peterson's analysis contains an implicit political model that might be missed: the number of bond proposals that politicians bring to the voters is a function of approval rates in the recent past. A reasonable idea. As a macroeconomist, however, I feel duty-bound to report that this is not a rational expectations model unless lagged approval rates are the best predictor of the current probability of approval. It may, however, be a good model despite potentially "irrational" expectations. How else, for example, can you explain the fact that the members of Congress display so little political courage even though their reelection rate approximates their body temperatures?

Of course, Peterson's tacit model is more substantial than this. Referendum approvals lead, with a distributed lag, to more construction and hence to a higher infrastructure stock. And more infrastructure, in turn, lowers the public's appetite for still more, hence reducing approval rates. If we put all of these pieces together formally, I suppose we would end up with a cobweb model of infrastructure spending. Before we conclude that everything is nicely regulated, let me remind everyone that cobwebs need not converge.

Peterson's second explanation for undersupply is a more conventional economic one: externalities. Since some of the benefits from an infrastructure project accrue to people outside the jurisdiction that pays

for it, underinvestment can be expected from a social point of view. I agree again. Peterson suggests user fees as the right way to deal with this problem, and I agree yet again. However, the problem is a bit trickier than Peterson indicates when an infrastructure project has public good aspects. In those cases, a free rider problem exists even *within* the jurisdiction, and user fees may not do the job. In fact, in some cases user fees can be positively harmful. For example, a toll booth can make an uncongested bridge congested.[1]

Peterson's third explanation is the only one with which I must take exception. He argues that the political process systematically underweights the benefits that infrastructure gives to businesses (as opposed to those it gives directly to consumers). I find this notion implausible on two grounds.

First, it presupposes a very thick form of corporate veil—almost an iron curtain. After all, each of us is both a consumer and a producer, and nothing says that we voice—or vote—only our interests as consumers. On the contrary, every stockholder, manager, and employee of every corporation that can benefit from more infrastructure spending is capable of making herself heard in our democracy. Many of them do. I always thought it was the consumers who were the silent majority.

Second, as one who grew up under the American system of government-by-lobbyist, I have a hard time believing that business interests do not get a fair hearing in state legislatures. In fact, it seems to me that business lobbyists are all too successful when it comes to regulatory issues, antitrust enforcement, trade protection, special tax favors, and the like. Why should I believe that these same interest groups suddenly become impotent when it comes to voicing their demands for infrastructure? In addition, we all know—or, rather, I *thought* we all knew—that large companies often extort favors from state and local governments by threatening to move their plants or offices to another jurisdiction. Why is it that they cannot clamor for more roads, bridges, and schools?

I think they can. In fact, I would like to advance a different hypothesis: that business is not in fact pushing for more infrastructure (and for the taxes that go with it) even though it might be in its own interest to do so. That, some Chicago economist will object, would be irrational. But Peterson can hardly raise that objection after assuming irrational behavior by politicians and an iron corporate veil! More seriously, I think we are entitled to see some evidence before we accept Peterson's hypothesis that, on this one issue, corporations are political eunuchs. Are the potential users of infrastructure (not the road builders)

[1] Once I waited in a long line to pay a five-cent toll on a bridge near Philadelphia!

in fact lobbying hard for more spending, but failing? I'm from New Jersey: show me.

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Discussion

*Joel A. Tarr**

George Peterson advances the hypothesis that the decline in public infrastructure spending during the past decade or so is largely cyclical rather than reflective of a secular trend. After a period of stagnation, he now sees demand for infrastructure increasing on the part of both the public and business. For him the critical question is why public capital is undersupplied, in the face of demand from two powerful constituencies. As a historian, my interest is in examining his hypothesis about the cyclical nature of infrastructure provision as well as exploring the conditions in which upturns in infrastructure spending have occurred in the past. My remarks are primarily intended as an historical addendum to both Peterson's paper and the focus of the conference as a whole.

The Cyclical Nature of Infrastructure Investment

An examination of the history of the infrastructure in nineteenth and twentieth century America reveals a series of cycles or bursts of spending followed by periods of retrenchment and stability, not necessarily marked by any regularity. This characteristic relates to spending for capital infrastructure by both the private and public sectors. Private sector spending has been tied relatively closely to the general business cycle (with some notable exceptions, such as electric traction construction in the 1890s and telephone sales in the 1930s), while public sector expenditure is somewhat more complicated. The public sector has

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engaged in infrastructure formation in periods of rapid urbanization and economic development, but it has also undertaken infrastructure construction for countercyclical purposes. Federal government activity during the New Deal is the most famous example of such countercyclical spending, but both municipal and state governments also followed the practice in the nineteenth century. In fact, for municipal governments this pattern often created debt crises.

Infrastructure construction was marked not only by a cyclical funding pattern but also by occasional shifts in the level of government doing the spending. That is, while some infrastructure historically has been provided by all levels of government—city, county, state and federal—the role of major provider has often shifted from one governmental level to another. The major impetus for change was an inability to finance infrastructure spending because of constitutional limitations resulting from previous overspending. These shifts also increased the role of the private sector. A brief history of the major cycles of nineteenth and twentieth century infrastructure spending illustrates this generalization.

The concept of "the state" acting as a service provider rather than a regulator of the economy was a relatively new one in the nineteenth century. In the decades of the 1820s, '30s, and '40s, however, state governments were especially active in providing capital for transportation infrastructure. These projects were either under state control or were "mixed enterprises," combining public and private construction and operation. State interest in these projects included promotional goals, a desire for public profit, concern over the limitations of private corporations, and the provision of employment. These state public works projects reached a peak in the 1820s and '30s, but spending dropped sharply after the depressions of 1837 and 1857 due to overinvestment, high taxes, and corruption. In addition, state constitutional restrictions on borrowing, passed after the depressions, forced many states to follow a pay-as-you-go policy, which severely restricted new projects.

Municipalities and counties, convinced that their economic futures depended on access to transportation, often filled the infrastructure investment gap. State legislatures passed hundreds of laws permitting local aid grants for construction projects. During the middle of the century, city governments increasingly assumed the function of service providers, investing in streets, waterworks, and sewers, as well as other infrastructure elements. Some of these projects, such as street improvements, were financed by assessments on abutters or even general tax revenues, but increasingly cities came to depend on borrowing to finance infrastructure construction. As historian Eric Monkkonen notes,

during the period after 1850, the "issuance of debt changed from a rare expedient to the norm for cities" (1984, p. 129).

Cities invested heavily in infrastructure improvements in the years from 1866 to 1873, and per capita municipal debt increased from $6.36 in 1860 to $13.38 in 1870, at a time when state debt only increased from $8.17 to $9.15 (current dollars). A sharp economic downturn in the early 1870s, however, forced many municipalities to default on their obligations. State legislatures responded by establishing limitations on municipal debt based on a percentage of assessed valuation, inserting debt limitations in city charters, and requiring devices such as sinking funds and voter approval of bonds. By 1880, more than half the states had constitutional limitations on city debt, usually a set proportion of the tax base. In the 1890s, however, as urban population soared, state limitations were eased and instruments to bypass them, such as public authorities, were created. As a result, city borrowing for capital improvements resumed, continuing until World War I.

The 1920s witnessed a return to the earlier, nineteenth century pattern of heavy state involvement in transportation improvements, especially road construction and surfacing. The generative factor was the automobile, which became widely available as production costs dropped dramatically. The federal government also provided funds for road construction on a matching basis. The most important innovation, however, was the enactment of the gasoline tax, beginning with Oregon in 1919. By 1929, all states had approved the tax, which became the principal source of highway revenues. These user fees provided 60 percent of the funds for the increase in highway expenditures between 1913 and 1930.

In the 1930s, the federal government assumed its largest role in infrastructure investment to that time. Various federal agencies, especially the Public Works Administration, provided between 60 and 65 percent of all public construction from 1933 to 1938. This unprecedented intervention was aimed at four goals: relieving mass unemployment; developing the use of public works as a yardstick by which to measure the performance of private enterprise; "priming the pump"; and winning political support for the Democratic party. Heavy federal involvement in infrastructure spending continued during World War II, but primarily for the war effort rather than civilian needs. In the decades since the end of the war, federal involvement in infrastructure construction has gone through the familiar cycles of contraction, expansion, and then contraction, with the largest spending devoted to the interstate highway system, urban mass transit, and environmentally related technologies such as sewage treatment facilities.

The history of infrastructure provision, therefore, shows a cyclical pattern in terms of both levels of funding and governmental involve-

ment, rather than any consistent trend. And, these cycles did not necessarily follow any regular pattern. In addition, every period of limitation was not necessarily followed immediately by great expansion in investment, even though demand appeared to exist. Periods of large public investment required a combination of factors, not all demand-related. In short, the history does not necessarily guarantee that we are on the eve of a new burst of spending for infrastructure.

Public and Private Provision of Infrastructure

Although it is widely believed that today's movement towards privatization represents the first major shift from public to private supply of infrastructure, history provides many instances of shifts in both directions. A good example is water supply. Well into the nineteenth century, householders either obtained their own water supplies (from wells and cisterns) or relied upon private water companies. Increasingly during the century, however, the inability or unwillingness of private companies to meet the needs of growing cities to provide water for fire protection, household uses, and industrial purposes forced municipalities to assume this function. At the time of the Civil War, about 42 per cent of the 136 waterworks in the nation were publicly owned, including those of the nation's sixteen largest cities. The trend towards public ownership reversed during the decade after the depression of 1873 when municipal spending was capped, but resumed once again by the 1890s. In 1914, about 70 per cent of the nation's waterworks were municipally owned and, by 1925, municipalities and public authorities owned about 82 percent of the nation's waterworks, servicing between 85 and 90 percent of the population. Data are sparse for the intervening years, but by 1989, 58 percent of the nation's 59,621 water systems were privately owned, serving about 20 per cent of the population. Private, investor-owned companies have increased in number and share of the population serviced, but most large city systems remain publicly owned.

The provision of other elements of the infrastructure has also shifted from the private to the public sector. Bridges, for instance, made a transition from being largely privately owned (with tolls) in the nineteenth century to largely public ownership in the twentieth. Municipal transit was mainly private until World War II, although various forms of public ownership or mixed public/private construction and operation existed in some large cities such as New York. In the 1950s, as private transit companies experienced heavy losses, many were acquired by city governments and by public authorities created for that purpose. With the creation of the Urban Mass Transportation Admin-

istration in 1964, the federal government became a major player in the provision of transit services. Other urban services, such as waste collection, have over the past two centuries shifted back and forth between private and public provision because of dissatisfaction with the quality of service, a failure to fulfill contract provisions, and political change. In contrast, citywide sewerage systems have been almost entirely publicly constructed and operated from the time of their first appearance in American cities in the 1850s.

Why Periods of Rapid Infrastructure Construction Occur

One of Peterson's major arguments is that although public demand for infrastructure spending exists, the various anti-tax campaigns of the 1980s have made public officials excessively timid about advancing infrastructure spending programs. McDonald and Ward (1984) have recently suggested, however, that this type of behavior is the norm for local public officials, not the exception. That is, because of restrictive fiscal ideologies, vested bureaucratic interests, and failure to achieve consensus on fiscal expansion, "local politicians" have usually been "timid, seemingly inert, and always incremental" in regard to spending (p. 32). One might ask, then, under what past conditions has rapid infrastructure investment occurred?

An examination of past periods of rapid infrastructure formation, such as the mid-1890s through 1914 and again 1921 to 1929, suggests a combination of factors on the demand and supply sides. First, these were periods of great city growth and therefore of increased city building, which created a large demand for services in order to create a more viable and operative environment. Some of these demands required infrastructure that would facilitate production, while others were more oriented toward providing an infrastructure for consumption, although the two have often overlapped. Since urban commercial elites usually believed that infrastructure was linked to economic development, they often supported public spending for infrastructure, especially for downtown improvements.

A second important factor in generating investment was the appearance and adoption of new technological innovations. New technologies have played critical roles in driving infrastructure cycles because they often require additional infrastructure for their implementation and lead to an expansion of urbanized areas that require other forms of services. This process has been most identified with the automobile, but it was also true of other transport technologies such as the steam locomotive, the street railway, and the airplane. Some of these technol-

ogies, such as the steam railroad or the automobile, increase mobility; the automobile also provides flexible mobility. Yet, they often require inflexible infrastructures, such as roads, highways, viaducts, railroad stations, and garages, that can become barriers to change.

Large expenditures for infrastructure have often been undertaken because policymakers believed that the technologies involved would help solve major problems facing society. In the nineteenth century, for instance, municipalities often invested in systems of piped-in water because they had experienced disastrous epidemics and/or fires and wanted to avoid them in the future. A further incentive for the adoption of waterworks was the lower fire insurance rates that would result. Investments in sewers resulted from the realization that they would substantially reduce mortality and morbidity, as well as from a desire to eliminate the nuisances created by overflowing cesspools and flooding. In the early twentieth century, municipalities made large expenditures for water treatment technologies because of a concern over the disastrous health effects of drinking sewage-polluted water. The technology itself evolved because of advances in bacterial science. Closer to our own time, huge federal investments in sewage treatment technologies have taken place since 1972 because of a concern over environmental deterioration and the health effects resulting from pollution. Here a rise in leisure time and leisure activities appears to have changed public values, making voters willing to pay for environmental quality.

Conclusion

This brief history of infrastructure investment and construction affirms the essential cyclical nature of investment patterns, the shifting proportions of public and private ownership, and changes in the level of government providing the service. It also suggests that bursts of infrastructure spending do not necessarily result from concerns over infrastructure deterioration and inadequacy of service. Rather, such periods of rapid increase in investment occur because of a combination of factors on the demand and supply sides. On the demand side, population changes, especially rapid city growth, concern over social problems susceptible to a technological solution, and political developments appear most important. On the supply side, capital availability and technological innovation loom the largest.

The contrast between our own time and periods of rapid infrastructure investment in the past is informative because it highlights the extent to which today's conditions differ from past periods of expansion. Those earlier periods were marked by major urbanization and critical technological change, as well as by new funding mechanisms and

sources of capital. While the United States has experienced the emergence of a new urban form—the decentralized "outer" city—in the past 25 years, this new "city" has primarily generated extension and retrofitting of old technologies rather than technological innovations. The major exceptions in regard to technology have been communications advances. These developments, however, have essentially been involved with increasing the efficiency of existing systems rather than replacing them. Real interest rates are relatively high, and while some new funding mechanisms have appeared, no major innovations, such as creation of an infrastructure bank, have occurred. What the history appears to say is that we are in a period unlike any past period of infrastructure "growth" in regard to its configuration of social, political, fiscal, and technological forces. This suggests that those interested in expanding infrastructure investment should avoid strategies that emphasize massive needs at enormous cost and should opt instead for a variety of flexible approaches.

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Little historical writing is available on municipal spending patterns, although the literature on the history of urban infrastructure is expanding as a general topic. Unless otherwise noted, all material used in this comment has been derived from three of my previously published articles. Full citations can be found in:

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What Are the Prospects for Privatizing Infrastructure? Lessons from U.S. Roads and Solid Waste

*Jose A. Gomez-Ibanez, John R. Meyer, and David E. Luberoff**

Interest in the private provision of infrastructure has been increasing in recent years. The Bush Administration's proposed fiscal year 1991 budget document, for example, touted a proposed private toll road in Virginia as an example of the kind of creative public/private partnership needed to address the nation's transportation problems. The Environmental Protection Agency (EPA) has launched a major initiative designed to foster public/private partnerships in environmental infrastructure, such as water and wastewater treatment plants. Proposals to sell airports to the private sector have been seriously discussed in Los Angeles, Albany, and Peoria.

The increased interest in privatization is driven by a number of factors. A primary motivation is the belief that the private sector is inherently more efficient than the public sector and can therefore build and operate facilities at less cost than the public sector. Also, the public sector, facing increased taxpayer resistance, may simply be unable to finance facilities that the private sector would be willing and able to undertake for a profit. Privatization proponents contend that federal tax laws have often distorted decision-making to favor the public sector in the provision of infrastructure.

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This paper explores the prospects for the privatization of infrastructure by examining two categories of infrastructure: toll roads and solid waste disposal facilities. Both are capital intensive, but in the United States they historically have had different levels of private sector involvement. Roads, although normally built by private contractors, are typically planned, owned, and operated by state transportation departments or state authorities. By contrast, the private sector has historically been a major owner and operator of solid waste disposal facilities such as landfills and, more recently, resource recovery plants. Furthermore, in solid waste the structure and role of private industry has substantially changed in the last two decades.

Missing Dimensions in the Privatization Debate

The current debate over the potential cost advantages of the private sector and the concurrent attempts to modify the federal tax code to encourage privatization (or at least level the playing field for the private sector), while certainly relevant, may also divert attention from other major dimensions of the privatization decision. First, while the private sector may be able to build facilities faster and operate them at lower cost, particularly when competition is present or potentially available, cost is neither the only important barrier to infrastructure provision nor the only consideration in the choice between public and private providers. Local neighborhood and environmental opposition to the siting of new roads or solid waste facilities, for example, is often as much of a bar to infrastructure investment as cost. Although the presence of a private operator can change the dynamics of such siting processes, it is unclear whether the private sector offers any major advantages in siting. Additionally, siting, equity, and other considerations may lead to direct or indirect public regulation of the prices charged by private operators, particularly in situations where private operators do not face much competition. The regulation, as well as the regulatory process itself, could conceivably undermine many of the advantages of private involvement in infrastructure provision. At any rate, the *total* advantages of the two options, public or private, must be weighed, rather than simply construction, operating, or financial costs.

The debate over the cost advantages of privatization also often fails to distinguish between those savings that are net efficiency gains to society as a whole and those that represent transfers from one sector of society to another. The debate over the federal tax code and financing costs commonly focuses only on the net return that must be paid investors, for example, without considering the extent to which federal taxpayers win or lose under either public or private financing or the cost

to state or local taxpayers of the equity they often contribute to public projects.

To investigate these issues, this paper first reviews the evolution of private sector involvement in the provision of highways and solid waste disposal facilities in the United States. The advantages of the public and private sectors are then compared, not only for the conventional concerns of costs and financing but also for the often neglected dimensions of siting, pricing, and government regulation. In this discussion, an attempt is also made to distinguish the net efficiency savings of privatization from the transfers. Finally, an overall assessment is offered of who wins and who loses from privatization as well as the circumstances under which privatization might prove an attractive public policy.

Trends in the Privatization of Roads and Solid Waste

Interest in privately owned and operated toll roads has undergone a revival recently in the United States, after being a rare phenomenon for 100 years or more. By contrast, private toll roads have been comparatively common in Europe for the last two decades. The best known example is the cross-channel tunnel (using auto on rail) now being built by a private Anglo-French consortium. Nine-tenths of the expressways in Italy are privately owned and operated, as are a significant portion of the expressways in Spain and France.[1] In most cases these private roads are based on a "build-operate-transfer" model under which the private firm builds the facility, operates it for twenty-five to forty years, and then transfers title and control back to the public.

Although private toll roads are not without historical precedent in the United States, virtually all of the U.S. highway system is publicly owned and operated today. The few exceptions include approximately a dozen bridges over major rivers in rural areas; these are either special development promotions of local business groups or historical remnants of the more extensive private toll road system of the eighteenth and early nineteenth centuries. Other exceptions include private toll roads inside major resorts built by a single developer, such as "Seventeen Mile Drive" in the Carmel, California development owned by Del Monte Properties or the road through the Avery Island Resort in Louisiana (U.S. Federal Highway Administration 1987).

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[1] See Poole (1988, p. 509). Many of these European private toll roads, it should be noted, receive some public assistance in the form of equity investments, low-interest loans, or tax benefits; see European Conference of Ministers of Transport (1990, pp. 16–21).

Publicly owned and operated toll-road initiatives are also relatively rare in the United States, although this also was not always the case. The Northeastern states embarked on an extensive program of building publicly owned toll expressways in the late 1930s. This lasted, except for wartime interruption, into the early 1950s. By 1956, toll-road enthusiasts could boast that one could drive from New York to Chicago without stopping for a single traffic light: but, of course, one did have to stop for several toll booths (Rae 1971, pp. 171–183). The construction of tolled public highways fell off sharply after 1954 when Congress authorized construction of the 42,000-mile Interstate and Defense Highway System on which tolls were largely forbidden. The only major exceptions, undertaken as a compromise to capture Northeastern political support, were 2,447 miles of pre-Interstate toll expressways incorporated into the Interstate System. The remaining 40,000 miles or so of Interstate highways were 90 percent financed by grants from the federal government (raised, in turn, by increased federal excise taxes on motor fuels and vehicles) and 10 percent by the states (raised largely from state fuel taxes).

The Revival of Private Toll Roads

The recent revival of interest in both tolls and private highway provision was stimulated in large part by government budgetary pressures. While the Interstate System is largely complete, federal funds can still be used to widen existing Interstate routes. Congress has not agreed to expand the eligible Interstate route network, however, which hurts the unserved areas that have experienced growth in the thirty-six years since the Interstate System was designed. Federal aid remains available for some non-Interstate roads, as are the states' own tax revenues. But in many fast-growth areas, such as the South, the West, and the outlying suburbs of major metropolitan areas, the growth in traffic has been so rapid that available public funds seem inadequate.

Of the 902 miles of new toll road projects that are now being planned in seventeen states, most would be publicly owned and operated.[2] In 1987 Congress relaxed its ban on the use of federal aid for publicly owned toll highways and authorized seven demonstration toll road projects (two more were added in 1988) on which up to 35 percent federal funding could be used to match toll receipts.[3] The State of Texas

[2] Estimates from the International Bridge, Tunnel and Turnpike Association cited in U.S. Office of Management and Budget (1989, p. 172).

[3] Prior to this Congress had authorized some specific exceptions to the prohibition on collecting tolls on highways built with federal aid. Only seventeen facilities had been

completed one of the first of the new crop of public toll roads without federal aid in 1987, an expressway on the outskirts of Houston, and is scheduled to open a second in 1990. The State of Colorado has established a public authority to build a new fifty-mile toll road on the eastern fringe of Denver. California created a similar authority to build three toll roads in Orange County, and Pennsylvania, Delaware, and Georgia are participating in the federal demonstration project. In several of these cases private landowners or developers along the route are donating rights-of-way to help make the projects financially feasible, but the facilities will remain under the control of state and local governments.

Of the several serious proposals for private toll roads that have emerged in the last few years, the most advanced is the Toll Road Corporation of Virginia (TRCV) proposal to build a fifteen-mile private toll road connecting Dulles Airport with Leesburg, Virginia.[4] The private road would be a western extension of the present state-owned Dulles Toll Road, which connects the airport and nearby communities with one of Washington's circumferential beltways. The State of Virginia and Loudoun County have already approved the extension's alignment, although they still must review the detailed roadway and structure designs and the State Corporation Commission has not yet approved the financial plan and the proposed toll rates. If the financial plan and rates are approved in the summer of 1990, the TRCV hopes to begin construction soon after and open the road by March 1993.

In 1989, the California legislature passed a law allowing private companies to build up to four privately funded, for-profit toll roads, bridges, and tunnels in the state over the next ten years. Ten consortia of private construction and finance companies have been qualified to propose projects. The state's present schedule calls for conceptual proposals to be submitted by August 1, 1990 and for the state to select the four best and sign exclusive development agreements by the end of the year. Among the schemes being discussed are a new San Francisco Bay bridge and the double-decking of a thirty-mile stretch of an existing Los Angeles freeway.

Proposals have emerged in other states as well, although they are either less advanced than Virginia's or on a less ambitious schedule than California's. In Colorado, the private Front Range Toll Road Company

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exempted, however, mainly toll bridges, tunnels, and approach roads to the Interstate System. See Sandlin (1989, pp. 49–50).

[4] In addition to the private toll road proposals, one private toll bridge has already been constructed. The $2 million bridge, which opened in June 1988, connects Fargo, North Dakota with Moorehead, Minnesota and was developed after voters had rejected a special assessment to finance a publicly owned and untolled bridge.

has proposed to build and operate a 210-mile toll highway between Pueblo and Fort Collins. The States of Illinois and Missouri are in the preliminary stages of evaluating the feasibility of a 400-mile private toll road between Chicago and Kansas City.

The Evolution of Private Solid Waste Disposal

Solid waste disposal was mainly the responsibility of private citizens and scavengers until the mid-1800s, when the emergence of large industrial cities greatly increased urban waste problems.[5] Many cities responded by assuming the responsibility for the collection and disposal of waste. A 1913 survey of 25 major cities conducted by the Civil Service Commission of Chicago found a variety of waste disposal practices and a variety of public/private relationships for waste collection and disposal (Hering and Greeley 1921, p. 106). At that time, labor was the largest disposal cost because cheap land was available near the city and waste disposal systems were relatively simple.

Disposal practices changed little through most of the first half of the twentieth century. However, many cities stopped contracting out for waste collection and disposal just before and after World War I, an outgrowth of the Progressive movement which believed that providing services publicly would reduce opportunities for graft and mismanagement. After World War II a number of cities began contracting out again, in part because they wanted to avoid the high costs of collection equipment and the political difficulties of siting waste disposal facilities.[6] Both public and private operators generally disposed of garbage in open dumps or burned it at incinerators.

The rise of the environmental movement in the late 1960s dramatically changed waste disposal practices and, in the process, transformed private waste disposal from a labor-intensive industry made up of many small firms into a capital-intensive industry, dominated by a handful of giants. Emissions limits from the 1970 Clean Air Act forced many communities to close their incinerators. The Resource Conservation and Recovery Act (RCRA), passed in 1976, established strict controls over the design and operation of landfills, required separate hazardous waste disposal facilities, and encouraged the development of resource recovery facilities. Drafters of the bill believed that by increasing the cost of landfills, they would make resource recovery a more viable option,

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[5] For an excellent history of solid waste disposal in the United States, see Melosi (1981).

[6] Telephone interview with Rita Knorr, Director of Research, American Public Works Association, May 14, 1990.

particularly if energy prices continued to rise (Clunie 1987, pp. 2–4). The Public Utilities and Regulatory Policy Act (PURPA) of 1978 made prospects for waste-to-energy plants even more attractive by requiring utilities to buy energy from the plants if their costs are lower than the long-run marginal costs of providing power from new utility facilities.

As a result of stricter standards in RCRA, more than 70 percent of the approximately 14,000 landfills operating in 1978 were closed by 1988 (National Solid Wastes Management Association 1990, p. 7). In 1988, EPA estimated that about 40 percent of the remaining 6,000 or so landfills then operating would have to close by the mid-1990s (National Solid Wastes Management Association 1989a, p. 3). Concerns about groundwater pollution, odors, and increased traffic stymie the siting of new landfills. Resource recovery plants, which burn waste for energy, sometimes after sorting the incoming stream for recyclables, raise similar fears plus additional concerns about toxic air emissions and the disposal of the potentially toxic ash the facilities generate. As a result, the nation is closing landfills at a faster rate than the added capacity through new landfills and resource recovery plants. At the same time,

in even fewer hands with two firms, Ogden Martin Systems and Wheelabrator, accounting for close to 45 percent of the business (Cook 1988, p. 102). For both hazardous and solid waste, these companies are estimated to have annual revenues in excess of $8 billion (Wingerter 1990, p. 282).

The private firms operate under a variety of scenarios. At the risk of some simplification, private waste disposal is done on either a contract or a merchant basis. In the first case, a private firm agrees to design, build, and operate a plant for one or several municipal governments. The contract fixes the tipping fee per ton (often with provisions for inflation) and guarantees a minimum volume of waste to be delivered. The public sector often assists or takes responsibility for siting. Actual ownership, private or public, is usually dictated by advantages offered by the tax laws in effect when the plant is built. Under the usual contractual scheme, the private company absorbs the risk that the plant will work correctly and can be built and operated within budget, while the public sector absorbs the risk that open-market tipping fees might decline or local trash volumes fall below contract minimums. Many communities choose the contract route because they are not prepared to build or operate today's technologically sophisticated disposal technologies and they do not want to be exposed to the risk of ever-increasing tipping fees.[7]

The merchant plant, by contrast, is generally built and operated without prearranged public or private clients and without siting assistance. These facilities, however, are free to charge whatever the market will bear for waste disposal. In terms of risks, merchant plants are closer to toll roads than contract plants, since the merchant plant operator assumes not only the risks of whether the technology will work and can be brought in under budget, but also the risks of fluctuations in market demand or prices.

Some communities remain wary of relying on private solid waste firms, whether on a contract or merchant basis. Many have instead banded together to form special districts to build and operate their own public waste disposal facilities. These districts can give communities some of the economies of scale exploited by the large firms emerging in the private sector.

On the whole, considerations of cost, risk, and expertise seem to be making the private sector an increasingly major player in solid waste disposal. More than half the cities surveyed in a recent American Public Works Research Foundation study rely on private waste disposal (1990).

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[7] Another risk communities often seek to avoid is the fluctuation in the prices utilities will pay for the electric energy produced by resource recovery plants.

Although private landfills represent only 14 percent of the total number in the country, they contain about half of the nation's existing disposal space. In addition, almost half of the nation's resource recovery plants are privately owned.[8] Whether these trends continue will, in large part, be driven not only by issues of efficiency and cost, but also by siting ability and regulation.

The Conventional Concerns: Cost and Financing

A common argument in favor of privatization is that private involvement will help alleviate the infrastructure crisis by increasing the total investment in infrastructure and the quality of the projects selected. Privatization might increase infrastructure investment above the levels possible with limited public budgets by tapping a new source of funds: the private capital markets. And as Robert Poole (1989), one of the leading proponents of privatization, argues, "When projects must meet [private] investors' rate of return expectations, only economically sound, high-priority projects are likely to get selected."

Aggregate Investment and Project Selection

While private involvement might increase total infrastructure spending, privatization does nothing (at least directly) to increase the pool of private savings from which private capital markets must draw; therefore privately financed infrastructure is likely to displace some other investment. Publicly provided infrastructure, by contrast, at least has some possibility of increasing total investments made by society (in infrastructure and all else), to the extent that the public programs are funded by current user charges[9] or taxes rather than by debt, and these charges or taxes are borne (at least in part) by a reduction of private consumption rather than private saving. Privatization would offer an advantage, then, only if there were little chance of increasing public funding and if the additional infrastructure investment were more worthwhile than the investments it displaced.

Private investment is also no guarantee against economically unsound infrastructure projects, since private investors may be perfectly willing to invest in unsound projects if the construction of those projects

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[8] Government Advisory Associates, *Resource Recovery Yearbook* (New York: 1986–1987), p. 72 as cited in NSWMA 1989b, p. 5.

[9] In other words, if user charges are employed to pay capital expenses on a current or "pay-as-you-go" basis rather than to pay the interest and principal on debt.

is linked with implicit or explicit public subsidies or guarantees. Some governments have attempted to reduce this risk by specifying that privatization receive no government subsidies. California's Department of Transportation has announced, for example, that no public subsidies will be granted to private highway projects; presumably in California these projects must depend entirely on toll proceeds or revenues from other private ancillary activities, such as the development of adjacent land owned by the private road company or its financial backers.[10]

State and local governments may believe that some infrastructure projects warrant public subsidies because they generate important social and economic benefits that are not easily captured by private (or public) operators. A private toll road might reduce congestion on parallel untolled roads, for example, and rural expressways might provide important social benefits by stimulating the development of promising but otherwise undeveloped areas (much as the western railroads were thought to have done in the previous century) or areas with laggard economies and high unemployment rates. A recent financial analysis of the proposed Kansas City to Chicago private toll road commissioned by the States of Illinois and Missouri, for example, concluded that toll proceeds would be inadequate to fund the road and recommended that the two states purchase the rights-of-way for the private operator with proceeds from special tax assessments on neighboring land, in the expectation that the road will stimulate development (Price Waterhouse 1990).

Subsidies to private companies might receive closer scrutiny, of course, simply because the companies are private and not public. Nevertheless, as long as public officials believe, for better or worse, that the social benefits of some infrastructure projects are real or warrant public subsidy, that enhances the possibility that some unwise or unsound projects might be built, whether publicly or privately. In a sense, that risk is the unfortunate reverse of the possibility of the subsidies enabling some worthwhile projects that might otherwise be ignored.

Cost or Technical Efficiency

The most commonly cited advantage of private operators is that they can build and operate infrastructure facilities at lower cost than their public sector counterparts. Numerous studies of the relative costs

[10] If these ancillary revenues are more readily captured by private but not public projects, then private projects may have an advantage. This advantage is not likely to stem from a real saving in resources to society, however, as we shall explain later.

of public and private services suggest that private operations do cost less, as long as competition is present to ensure that the private operators remain efficient.[11] Most of these studies deal with labor-intensive services, such as garbage collection or building maintenance, however, with few careful studies of capital-intensive services.[12] As a result, any comparison of private and public infrastructure costs must rest to a considerable extent on a subjective assessment of the claims of various supporters and detractors, with only limited empirical evidence for guidance.

Some of the cost advantages claimed by proponents of privatization are also clearly transfers from one group to another rather than real savings in resources for the economy as a whole. Private companies may be able to pay lower wage rates than public authorities, for example, although this will not always be allowed. (California has specified that private toll road builders must pay the same prevailing union wages as public authorities are required to pay.) Lower wage rates would reduce the budgetary costs of the project, but (absent productivity differentials) would not reduce the amount of labor resources required. Of course, to the extent that the lower factor prices paid by private vendors were closer to "true" free market prices, as presumably they often would be, then a more efficient combination of factors should be achieved by the private than by the public sector. In short, working with "better" factor price signals, the private supplier should be more productive than a public sector counterpart, all else equal.

Similarly, landowners and developers may be more likely to donate rights-of-way to private than to public road projects. Most of the land for the Dulles Toll Road Extension, for example, would be donated by neighboring landowners who stand to benefit. Landowners often donate land to public projects as well, where donations might encourage public highway authorities to give the road project higher priority. Nevertheless, the threat that the project might not survive without donations may be more credible where a private rather than a public operator is involved. But whether the project is public or private, donations of land represent a transfer from landowners to road users or investors, and generally do not reduce the total land required for the

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[11] John D. Donahue, in reviewing these comparative cost studies, concludes that the critical factor is not the form of ownership but the presence of competitive markets. "Public versus private matters, but competitive versus non-competitive usually matters more," he writes (1989, p. 76).

[12] One exception is the literature on the comparative costs of publicly and privately owned electric, gas, and water utilities. There is no consensus in these studies as to which form of ownership has lower costs. The privately owned utilities are usually publicly regulated, however, and public regulation can reduce the potential efficiency advantages of private ownership. (See Donahue 1989, pp. 73–76.)

project. Furthermore, if the land input is fixed, then no productivity gain would be expected even if the private sector faced more realistic market prices for land.

While many private sector "savings" may simply be transfers, private firms do appear to have a number of real cost advantages. These are created in part by the incentives provided by the profit motive, in part by avoidance of some cumbersome public sector bidding and contracting requirements, and in part by achieving efficiencies of scale, scope, and experience that might elude public operators. Private operators, for example, may have a stronger incentive and more flexibility to use resources, such as labor, productively. Comparisons of labor-intensive public and private services, such as garbage collection, often show that private firms have higher labor productivity than public agencies because they have more freedom to structure compensation, promotion, and other incentives to encourage worker productivity and are less constrained by cumbersome workrules.[13] While no comparative studies of productivity are available for waste disposal or roads, these industries probably offer similar opportunities. Some private landfill operators, for example, reportedly use their sites and labor more efficiently by giving managers and employees strong incentives to compact trash more thoroughly and to grade and cover it more carefully.[14]

Private firms may also achieve real cost savings by building facilities more quickly. The public sector generally plans, designs, bids, and builds major facilities such as roads in a sequential process, completing each stage before starting the next. Private firms may have more flexibility to use design-build or fast-track parallel processes, in which design engineers and private contractors are selected simultaneously and the planning, designing, bidding, and construction phases overlap. By using such an approach, for example, proponents of the private Dulles Toll Road Extension assert that they can plan, receive approval for, finance, and build a road several years faster than the Virginia Department of Transportation.[15] The use of such procedures need not be

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[13] In a comparison of public and private provision of eight different labor-intensive services, for example, Barbara Stevens found that the cost savings stemmed in large measure from higher labor productivity and not just from lower wage rates in seven out of the eight cases (1984, pp. 395–406).

[14] Interview with Ronald Jensen, Director of Public Works, City of Phoenix, Arizona, April 19, 1990, at Cambridge, Mass.

[15] Lauren Walters, chief operating officer of the Toll Road Corporation of Virginia, claims that their company can plan and build a road in four to five years while the public sector would take at least six to eight years to build a similar facility. The history of the Dulles Toll Road Extension, however, so far has been marked by delays from the corporation's original schedules. In April 1988, the toll road backers estimated that the

limited to the private sector, of course, but faster construction would save on the capital required for a project by bringing the investment into service more quickly.[16]

Most intriguing is the possibility that the private sector may be better able to exploit economies of scale, scope, and experience than the public sector. For example, building or operating plants in a variety of locations, private firms may be able to achieve greater specialization of labor by hiring experts in specialized technical or managerial areas while smaller public agencies often must hire generalists who will oversee a number of such areas. Multiple plant operation may also allow the private operator to achieve economies in administrative or overhead functions and to offer staff more opportunities and incentives for career advancement (thereby enabling the recruitment of a better work force at less cost, all else equal). Private operators may also be better positioned to exploit their experience, or the learning curve, because by building larger plants or building plants more often, they do not have to learn about the practical and technological problems anew each time.

Many of these advantages appear to have contributed to the rapid growth in the last two decades of large waste disposal firms. Increasing technological complexity has undoubtedly made economies of scope and experience more important in waste disposal. But some of these same advantages appear to be present in road construction as well, which is also dominated by large firms, particularly for major road projects with sophisticated design or engineering problems. If private toll roads became more common, large companies might emerge that managed as well as built roads, much as is the case in solid waste disposal.

The public sector may encounter difficulties in achieving these economies of scope and experience on its own (or, more precisely, without contracting with the private sector). Even banding together on a regional basis, for example, local communities are unlikely to build or operate more than one large waste recovery plant or landfill every ten or twenty years. The public sector's appreciation of these potential economies is reflected in the near universal practice of contracting with private firms to construct complex infrastructure facilities (even when they are

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road would be open in the fall of 1991, but that schedule has been extended several times and the latest forecast (as of May 1990) is for the road to open in March of 1993. These delays are due in part to public regulatory oversight, however, which will be discussed later in this paper. Testimony of Lauren Walters of the Toll Road Corporation of Virginia, "Supplemental Testimony and Exhibits in Response to State Corporation Commission," May 2, 1990, pp. 10–13 and exhibits.

[16] The public sector could of course use similar procedures. For example, many states use design-build procedures to speed the construction of prisons.

publicly owned) and the growing practice of contracting for private management as well, particularly in the case of solid waste.

The Financing Issue

In the early 1980s, private firms providing infrastructure could issue debt through both government and industrial revenue bonds, whose interest payments were exempt from federal individual income taxes. The 1981 federal tax bill also gave generous depreciation allowances and investment tax credits to investors in privately owned infrastructure. In a sharp reversal of policy, however, the federal tax bill of 1986 restricted the use of tax-exempt bonds to finance privately owned projects and eliminated many of the accelerated depreciation allowances and investment tax credits.[17]

Privatization proponents contend that private firms are now unable to compete fairly with the public sector because public entities have access to tax-exempt debt while private firms do not. As a result, some privatization proponents have argued for changes in the tax code to make the private sector more competitive with the public sector, either by giving the private sector access to tax-exempt debt for public purpose projects or by giving the private sector generous depreciation allowances.

The debate over the tax treatment of public and private financing seemingly has little to do with efficiency as economists conventionally define it. Efficiency would be involved only if the choice between public and private financing affected either the total amount of capital required or the degree or nature of the risks involved in the infrastructure project. Neither of these factors is likely to be affected substantially by the choice of public or private financing *per se*. However, public or private financing may affect the nominal financing costs to the investors by transferring some of the financing costs to other parties, such as federal or state taxpayers.[18]

Privatization proponents may be wrong, moreover, in arguing that

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[17] Exceptions were limited to some energy-producing facilities, including resource recovery plants and a few other very special circumstances.

[18] It is conceivable that private financing might typically require less capital because private ventures use a combination of debt and equity while some public ventures are financed entirely out of debt. The use of some equity might reduce total capital requirements if bondholders in 100 percent debt-financed projects required that more capital be tied up in the form of higher debt reserves or coverage ratios. It would be difficult to determine whether or not this was the case and, in any event, the advantages (if any) do not depend on tax laws or even public or private financing per se but only on the willingness of the investors (whether public or private) to use equity for a portion of the financing.

even the nominal financing costs to private investors are much higher than those to public investors under the current tax laws.[19] On the one hand, the public agency can issue debt whose interest is exempt from federal individual income taxes, which reduces the nominal interest rates the public agency must pay. On the other hand, interest payments on a private company's debt are a deductible business expense, which reduces corporate income taxes the company pays, presuming it is profitable. Even if the private company is not profitable (as is the case in the early years for many long-lived, capital-intensive projects), the company may be able to get another profitable company to build or buy the facility and then lease it back, thereby effectively capturing (in the lower lease payments) a portion of the tax advantages derived from the deductibility of interest. These tax advantages of public and private debt may be roughly equivalent, given that the present marginal rates for federal individual and corporate income taxes are approximately the same (28 and 34 percent, respectively). Indeed, for the past several years the yield on A-rated municipal tax exempt bonds has been higher than the after-tax cost of A-rated corporate bonds (Gurwitz 1989, p. M3). Nevertheless, it seems that if two projects, one private and one public, were otherwise identical (and in particular generated the same cash throw-off before interest, taxes, and all book charges such as depreciation), the chances of collecting income taxes from the private vendor's cash flow would be much greater; state and local government operating entities not only can issue tax-exempt debt but also are largely tax exempt on their own operating earnings, whether paid out or retained.

The nominal financing costs may also sometimes appear lower for public than private projects, either because the public sector is able to borrow a higher portion of the project costs or because it uses some public equity on which it requires little or no return. In the former case, while the average interest rates may be lower in the public than the private case, the total financing costs may not be, because revenue bondholders often will require larger coverage ratios or debt reserves for projects with little equity (which, in turn, increases the total amount of capital that must be financed). In the latter case, financing costs may also be comparable to those of the private sector if the public equity (which is sometimes provided, for example, by paying for project planning, design, and engineering costs out of general government budgets) is properly valued and is accorded a fair return on its opportunity cost.

To the extent that the nominal costs of public and private financing do differ, it is usually only because some transfers are effected between

[19] Many of the arguments in the following two paragraphs have been made by Gurwitz (1989, especially pp. M1-M6).

the facility's investors or users and other parties. If the nominal cost of public debt is lower than private debt under current tax laws and market conditions, then the use of public rather than private debt will simply transfer some burden to the federal taxpayer (and the state taxpayer as well, in an area with state corporate income taxes). In essence, tax realizations will be reduced to the extent that the total amount of tax shields has been increased in the economy. The tax loss commonly will be captured either by investors, in the form of higher returns, or by facility users, in the form of lower tolls or tipping fees. If nominal public financing costs are also lower because the public agency contributes equity which is undervalued or earns no return, then the state or local taxpayer loses (from not receiving a fair return on that equity) while the facility user usually benefits (in lower tolls or tipping fees).

All these issues are illustrated by the Dulles Toll Road Extension. At the time of its initial (1990) application to the Virginia State Corporation Commission, the private toll road corporation proposed to build the road for $199 million and then sell it to another private company that could take advantage of the tax benefits.[20] The other private company would lease the road back to the toll road company for payments with an equivalent cost of 10 percent interest. The toll road corporation would contribute $30 million in equity needed to cover losses in the early years (when lease payments plus operating expenses would exceed toll revenues because of the slow build-up of traffic). On its 15 percent equity stake the toll road corporation projects an average annual pre-tax return of 20 percent, so the total financing cost (lease plus equity) would average around 12 percent per year. The private toll road corporation plans to charge a toll of $1.50 per car for the first eighteen months of operation, with toll rates rising in two increments thereafter to reach $2 per car three and one-half years after opening.

The Virginia Department of Transportation's (VDOT) counterproposal is to build the toll road as a public facility for a cost of $236 million, with much of the higher cost apparently due to the public authority paying for some of the land that would be donated by landowners to the private corporation. VDOT proposes to finance the project by issuing $218 million in tax-exempt debt and $18 million in surplus toll revenues generated by the existing state-owned Dulles Toll Road. VDOT also believes the state would need a $70 million line of credit at 7.5 percent interest to cover early-year operating deficits and debt coverage require-

[20] The public proposal is as described in hearings before the Virginia State Corporation Commission and summarized in Commonwealth of Virginia, State Corporation Commission (1990).

ments. VDOT proposes to charge a toll of only $1 per car, which would not be raised over the life of the project.

Putting aside the issue of whether the private company's and VDOT's cost estimates and timetables are realistic (which both parties dispute), the possible substitution of 7 to 8 percent public debt for the 10 percent private debt implicit in the lease payments would represent a transfer from federal and state taxpayers (in lower individual and corporate income tax payments) to road users (in the form of lower tolls). The possible substitution of $30 million in private equity at 20 percent for $18 million in public equity (in the form of the excess revenues on the existing road) with no apparent return also represents a transfer from a combination of federal and state taxpayers (in the form of the forgone return on the state's equity and, to lesser extent, lower federal and state corporate income taxes) to road users (in lower tolls). Indeed, if VDOT charged the same tolls as the private company proposes, it would earn approximately the same return on its equity (20 percent) as the private company is projecting. Put another way, if VDOT acknowledged that the risks of its project were similar to those of the private proposal and therefore required a similar return on its equity, it would have to charge approximately the same tolls.

The Dulles Toll Road Extension raises other issues besides financing costs. The private company claims that VDOT cannot build the road as fast or as cheaply as it can, for example, while VDOT argues that the private cost estimates and construction timetable are unrealistic and that VDOT will enjoy some operating and toll collection economies from operating the extension as well as the existing toll road. The case illustrates, however, that the nominal costs of financing may not be so different if the private company uses leases and other devices to take full advantage of tax shelters and if the public equity is properly compensated. To the extent that nominal financing costs differ and all else is equal, moreover, the differential represents largely transfers rather than real cost savings to society.

Additional Considerations: Siting, Pricing, and Regulation

Some of the cost advantages of the private sector may be offset if extensive public oversight and regulation of private siting or pricing decisions are required. Siting infrastructure facilities is often at least as much of a problem as cost containment, especially in built-up areas.

The Siting Problem

In the case of highways, new facilities are sometimes welcomed as spurs to development, particularly in rural or outlying areas. But these cases may now be the exception rather than the rule, as each decade has added new sources of concern and opposition, and new government regulations controlling highway siting decisions. Land assembly for highways has always been difficult if only because a long continuous right-of-way is required, and governments have usually had to resort to condemnation proceedings, which are governed by constitutional and other safeguards.

By the 1960s, neighborhoods in the path of new highways learned to mobilize politically, and their opposition eventually led to the cancellation of some of the proposed inner-city extensions of the Interstate System in major metropolitan areas and to federal requirements that highway planners provide relocation assistance and consider "no build" and mass transit alternatives to federally aided highways. By the 1970s, concerns about the destruction of parks and sensitive environmental areas and automobile air pollution led the federal government and many states to require environmental reviews and public hearings on highway and other major project proposals. The 1980s brought a renewed concern that new highways would stimulate too much development, particularly in suburban areas where growing traffic congestion and development densities seemed to threaten the quality of life many residents had moved to the suburbs to enjoy. The highway extensions now being planned in most major metropolitan areas are located on the outermost periphery, where neighborhood and environmental opposition is generally less intense and development is more likely to be welcome.[21]

Opposition to the siting of solid waste facilities is based on similar concerns. A landfill or waste recovery plant does not require a continuous right-of-way, so condemnation may not be as necessary. But such facilities have long generated neighborhood opposition because of heavy truck traffic and, more recently, fears of groundwater contamination or air pollution. Local community dumps and municipal incinerators are increasingly being replaced by large regional facilities because environmental regulations have increased the technological complexity and minimum efficient scale of disposal facilities. These larger facilities intensify the feeling of nearby local groups that they are being unfairly singled out to bear regional costs and risks, and strengthen the now familiar "not in my back yard" (NIMBY) syndrome.

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[21] For a description of the evolution of public concerns and government regulations governing highway siting decisions, see Altshuler (1979).

Private ownership or operation does not eliminate the pressures or opportunities for government oversight or public involvement in siting decisions. Private facilities will typically require zoning or other local permits as well as state and federal environmental approvals and other related requirements. In the case of the Dulles Toll Road Extension, for example, Virginia's Commonwealth Transportation Board had to pass on the "public need" for the project and approve the alignment; both Loudoun County and the Virginia Department of Transportation must still approve the final roadway and interchange designs. The Dulles Toll Road may need Loudoun County to exercise eminent domain on its behalf as well since, although most of the right-of-way is being donated, the owners of a few parcels are still holding out. Such permits and approvals give affected governments and citizens a variety of opportunities and grounds to modify, delay, or conceivably stop private projects.

Private firms may have some advantages over public agencies in resolving these siting problems, however, such as the ability to avoid the public spotlight until relatively late in the siting process, after many of the concerns of local residents and government regulations have been resolved. For example, a private waste disposal firm in Phoenix was able to negotiate agreements with surrounding property owners and meet with state environmental regulators before the site of their proposed new landfill became public knowledge, so that by the time the required public hearings on environmental impacts were eventually held, many of those who initially might have been opposed were already supporters of the proposal.[22] In contrast, a public agency is more likely to have to conduct a search for a new site openly from the start, so that local opposition have more chance to become mobilized and intransigent before their concerns can be met.

Private firms also may have more flexibility than public agencies in the compensation they offer objectors, or they may be more skilled both in marketing the benefits and minimizing the risks of proposed projects. Private solid waste firms are increasingly seeking out poor and thinly populated counties as host communities for landfills, and compensating these communities with a share of the tipping fees, new deep wells and water supply systems for surrounding houses, and new neighborhood facilities such as parks, golf courses, and even a baseball stadium (Katz 1990). Public agencies can adopt the same practices, of course, and have in some cases. Some local public authorities have recognized that large profits may be made in opening their landfills to other communities, for example, especially in the Northeast where tipping fees are high. Still,

[22] Interview with Ronald Jensen. (See footnote 14.)

more parties will be involved in the negotiation and agreement may be more difficult if, instead of a single private firm, a consortium of neighboring communities must initiate and approve the compensation plan for the host community or a local city council must design the compensation scheme for its immediate neighbors.

These potential siting advantages of private firms, nevertheless, may be offset by disadvantages, such as public apprehensions that private firms will not take their environmental and other community responsibilities seriously. Mistrust is probably more of a problem for solid waste than for highways, both because the environmental risks are perceived to be greater and because the solid waste industry suffers, fairly or not, from past associations with organized crime, price fixing, and environmental neglect.[23] The degree of public mistrust has led one of the dominant private waste recovery firms, Ogden, to specialize in building and operating plants under contract to municipal authorities rather than merchant plants for the spot market. Ogden has managed to site more new plants than its nearest competitor, Wheelabrator, because, in acting as the agent for municipalities, Ogden is less vulnerable to attacks from environmentalists and those who simply do not want a plant nearby.[24]

In the case of highways, private involvement may intensify siting problems by increasing local concerns that the new highway will bring too much new development. Private toll road proposals are often motivated in part by the development prospects they offer and, as with the Dulles Toll Road Extension, made financially possible by donations of rights-of-way by the landowners who stand to gain. In the case of the Dulles Toll Road, Loudoun County welcomes development, in part because it still has not experienced either the benefits or the problems of rapid growth of counties closer to Washington, D.C. But developer interest and support of private road projects may only heighten fears of development opponents in communities where too much development has become an issue.

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[23] Whether the apprehension is warranted or not is difficult to say. On the one hand, even one of the largest and most reputable private landfill operators, Browning-Ferris, has been convicted of price fixing and fined for serious environmental violations. See Novack (1988); Cook (1985). On the other hand, the private landfills are much more likely to be equipped with liners, leachate collection systems and groundwater monitoring equipment than their older public counterparts they may be replacing. The equipment may be better in part because the average private landfill is newer than the average city or county landfill and in part because state environmental inspectors may be tougher on private than public operators. See Hamilton and Wasserstrom (n.d., especially p. 5).

[24] Wheelabrator is gambling that the profit at the spot market rates will be higher on the plants that it can site (Cook 1990, p. 49).

Finally, public agencies may have an advantage simply because they have more established institutions and proceedings for dealing with the types of equity issues involved in siting. The private sector, almost by definition, has to rely on bargaining to reconcile conflicting interests. Where the parties involved are very numerous or the conflict is so polarized that mutual agreement seems difficult if not impossible, public institutions, with their established procedures and authority, may be quicker or their involvement unavoidable.

It would be difficult, therefore, to assess whether the involvement of a private firm, on balance, reduces or increases the problems of siting. Such a judgment probably varies according to the particular circumstances, such as the type of facility involved, the reputation of the private firm and its skills at negotiation and compromise, and the strength and nature of the local opposition. If private firms have an advantage it is probably a modest one, however, and private ownership per se probably will do little to overcome the serious obstacles to siting new infrastructure facilities that exist in many communities. In those cases where the siting disputes are so intolerable or complex that government agencies must become deeply involved, moreover, some of the private sector's potential advantages in faster construction are likely to be offset.

Pricing and Rate Regulation

A related issue in the privatization debate is whether private firms are more likely to charge users of their facilities the socially appropriate or desirable prices and, if not, whether public oversight or regulation of their rates is required and what the consequences of that regulation might be. Of course, user charges or prices, such as tolls or tipping fees, are not the only potential revenue source to finance infrastructure facilities. Revenues from ancillary activities are often used as well, such as the sale of energy or recyclables from waste recovery plants or the profit from the development of neighboring land parcels that a private toll road company or its backers might own. Government revenues also may be made available, including the proceeds from broad-based taxes (for example property, income, or sales) or special taxes such as gasoline excises or assessments on neighboring landowners.

A large literature is available on the circumstances in which user charges, supplemented perhaps with ancillary revenues, are more appropriate than general government revenues as the means for paying for infrastructure or other public services. Most economists agree that user charges are more appropriate when the users are the primary beneficiary of the services provided by the facility; when the level of use affects the costs of building and operating the facility; when the prices

charged affect the level of use; and when the administrative costs of collecting the user charges are not too high.

All these conditions favorable to user charges seem to apply to solid waste disposal and, with two important exceptions, to expressways as well. One of these exceptions is that collecting tolls may be costly and pose safety problems on some high-density urban expressways. The other is what transport economists call the "two road problem": when two parallel roadways are, from the motorist's perspective, relatively close substitutes for one another, the imposition of tolls on one road but not the other can seriously distort the distribution of traffic between the two facilities and cause undesirably high levels of congestion on the untolled facility.[25]

Of course no theoretical or practical reason requires that the choice of a private firm dictate the use of user charges or preclude government tax revenues or subsidies. Private firms can build or operate facilities under government contracts that provide for some or all of the costs to be paid out of tax proceeds rather than user charges or ancillary revenues (as the proposed Kansas City–Chicago toll road illustrates). The interesting question is whether a private firm or a public agency is the more likely to charge the appropriate or socially desirable prices in a situation where both would rely on user charges and ancillary revenues to the same degree.

One argument in favor of the private firm is that it may be more likely to price its services at marginal cost rather than at average or historic costs. If the capacity of the existing facilities is limited, and new facilities will cost more than the old ones, marginal costs may exceed average or historic costs. Pricing at marginal cost sends signals to users about the true cost of adding more capacity, and users, in turn, may choose to change their behavior, for example, by recycling, using mass transit, or carpooling. A potential political problem with marginal cost pricing in such cases is that it will produce revenues in excess of the costs of existing facilities. Public operators may be less willing or able to produce such "windfall" profits for equity or legal reasons, despite the fact that the pricing signals would, in the long run, produce more efficient behavior on the part of users. Of course, public authorities may also be reluctant to let private operators reap such windfalls and may regulate rates to prevent their realization.

The private firm may have more incentive to apply marginal cost pricing atomistically, moreover, so that fees for different types of users

[25] For a discussion of the "two road problem" theory see Meyer and Straszheim (1971, pp. 44–59). For a discussion of the practical impact of this problem in Britain see Button (1987).

are more closely aligned with the different costs they impose. A private toll road operator might be more willing than his public counterpart to charge peak-hour motorists more than off-peak motorists, for example, much as private airlines charge travellers to Europe more during the peak summer season than during the winter. Higher peak period charges might be socially desirable because the peak-hour traveller may be responsible for more of the capacity costs in the long run and (in the absence of a surcharge) imposes socially undesirable congestion on other roadway users in the short run. Similarly, a private waste disposal firm might be motivated to charge tipping fees that varied with the density or the combustibility of the refuse, if the disposal costs so varied. In contrast, public authorities might be more inclined to charge different users the same price because equal charges seem fairer at first glance (ignoring the fact that different users may impose different costs) and because a public agency may have less incentive than a for-profit firm to distinguish between cheap and costly users.

The key potential disadvantage of a private firm is that it may be more tempted than a public agency to exploit any monopoly or market power it might enjoy by pricing its services well above costs. As long as a market is competitive, of course, private firms cannot price above their marginal costs in the long run; they may be able to do so in the short run if demand temporarily outstrips supply, but only for as long as it takes the industry to build additional capacity. If the market is not competitive, however, a firm may be able to sustain prices in excess of marginal costs even in the long run. As a consequence, some users could be discouraged from using the facility even though they valued its use at least as much as it would have cost to serve them.

A few states have decided to regulate the tipping fees or tolls charged by private operators out of concern about such potential abuses of market power. New Jersey is the only state that systematically regulates the tipping fees of private waste disposal firms so far, although other states have considered doing so. New Jersey imposed regulations because of allegations that private waste carting companies were colluding to fix prices, and tipping as well as transport fees were regulated because some of the private companies owned disposal sites as well as carting companies. The state is reportedly considering abandoning regulation of transport fees because state price controls are perceived to have been so stringent that they reduced the availability of carting services. New Jersey's regulation of tipping fees is likely to be maintained, however, because the number of disposal sites in the state is so limited.[26]

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[26] Interview with Allen Blakey and Edward W. Repa, Director of Public Affairs and Director of Technical and Research Programs, respectively, of the National Solid Waste

Private expressway tolls are perhaps more likely to be regulated, although the experience to date is limited. Virginia's 1988 law authorizing the construction of private toll roads specifies that the State Corporation Commission, which regulates public utility rates, will regulate the tolls and rates of return on private roads as well, including those on the proposed Dulles Toll Road Extension. California's 1989 law authorizing the construction of up to four private toll roads does not require that the state regulate tolls. The California Department of Transportation plans to approve only those projects where motorists have alternative routes, however, and to review whether the rate of return generated by the proposed toll is fair.[27]

As to whether concerns over market power are justified and warrant public regulation of rates, the situation appears to vary slightly between solid waste and toll roads. In the case of solid waste, more reason exists to fear that private firms might enjoy and abuse market power in the short run than the long run, but even in the short run, regulation may be unwise. In the short run, the closing of many old landfills and incinerators because of more stringent environmental regulations and the difficulties in siting new facilities have greatly constrained waste disposal capacity, particularly in the Northeast and around major metropolitan areas. The tipping fees of $75 to $100 per ton now charged in some areas are probably several times the cost of operating a modern and environmentally responsible landfill and perhaps as much as twice the cost of a new waste recovery plant (presuming a new landfill or plant could be sited). In some areas, such as New Jersey, Chicago, and Philadelphia, private waste disposal firms are alleged to be using the shortage of disposal capacity not only to raise tipping fees well above long-run disposal costs, but also to squeeze out rival firms that are engaged in carting but do not own their own disposal sites (Cook 1985, p. 130).

The ability of private waste disposal firms to maintain charges above costs is probably very limited, however, especially in the long run. Even in the short run, tipping fees are somewhat constrained by the possibility of transporting wastes to more distant facilities. Transport costs (of roughly one dollar per ton mile) are now comparatively small relative to tipping fees in the Northeast, for example, which increases the distance it is worthwhile to transport waste to enjoy a lower tipping

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Management Association, Washington, D.C., April 20, 1990. Also see Hamilton and Wasserstrom (n.d., pp. 11–12).

[27] See "Private Roads Get Go-Ahead From California Government," *Public Works Financing*, August 1989, pp 5–7.

fee.[28] In the long run, high tipping fees will be further constrained by the strong incentives they create to organize more effective waste recycling programs and to overcome the opposition to the siting of new landfills and waste recovery plants. Such considerations led the state of Minnesota to conclude that regulation of tipping fees was probably unnecessary, despite the fact that Browning-Ferris and Waste Management together had a near monopoly on local private waste disposal facilities.[29]

Regulation of tipping fees may be unwise even in the short run, moreover, simply because it might reduce the incentives to increase long-run disposal capacity. It is hard to imagine that public or private operators would ever overcome the present capacity constraints and siting problems without the stimulus of the high profits some disposal firms are now earning. Regulation of these profits might reduce the incentives of private firms to find new sites, for example, or the compensation they could offer to host communities.

The case for regulation of private toll roads is more complex because of a possible trade-off between achieving financial feasibility and avoiding excessive congestion on any parallel untolled facilities. The proposed private Dulles Toll Road Extension will compete for traffic with Virginia's Route 7, a parallel highway that is untolled but not built to expressway standards. Similarly, motorists could avoid the tolls on the proposed Kansas City to Chicago private toll road by using one of two slightly more circuitous and untolled routes: Interstates 70 and 53 (to the south of the toll road) or Interstates 35 and 80 (to the north). Too many parallel untolled or lightly tolled facilities can make toll operations both financially infeasible and socially undesirable. On the one hand, it may be difficult or impossible to collect tolls sufficient to finance a new road, while on the other hand, high tolls might aggravate the "two road problem" by keeping the level of congestion on the competing untolled roadway too high.

The case for government control of private toll rates is therefore strongest at either competitive extreme. In the case of too little competition, it might take the form of conventional public utility rate regulation such as is applied to local electric, gas or telephone rates. In the case of too much competition, government regulation might take the form of the imposition of tolls on the parallel public facility, with the public tolls set at levels that make it possible for the private operator to charge rates

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[28] In the Northeast, however, long-distance transport usually means that garbage is crossing state lines, which creates some difficult political problems.

[29] Interview with Allen Blakey and Edward W. Repa. See also Hamilton and Wasserstrom (n.d.).

sufficient to earn a fair return and balance the allocation of traffic and congestion between the two roads.

The decision as to whether government regulation of toll rates is necessary will probably vary according to the particular circumstances. In many cases it is possible that parallel roadways will provide just enough competition to limit the market power of a private operator, but not so much as to make toll operation unworkable. State governments will probably feel obliged at least to review the competitive circumstances of each private toll road proposal before granting a franchise, as California proposes, even if they do not require continuing public regulation of rates during the operation of the facility, as Virginia has done.

Government regulation of rates and returns to investors may reduce the advantages of private ownership and operation by increasing delays and other risks that investors face. Government review of the proposed rates and returns during the initial franchise application may slow the procurement process considerably and offset some of the potential advantages that private operators may have in faster construction. Virginia's State Corporation Commission did not approve the initial application of the backers of the Dulles Toll Road Extension, for example, and has asked them to supply additional information about their costs and proposed toll rates. Continuing regulatory review of rates after the initial franchise is approved will provide an additional element of risk for investors, moreover, for which they may require higher rates of return as compensation.[30]

Government regulation may also create incentives that reduce the technical or cost efficiency of the firm. Regulatory economists have long worried about regulatory authorities' ability to set the appropriate rate of return on investments when approving rates: too high a return can lead to wasteful overinvestment or gold-plating of the facility, while too low a return may lead to underinvestment. Setting the appropriate rate of return involves difficult and controversial assessments of the nature and degree of risks to which the investors are exposed.[31]

An Overall Assessment

Any overall public policy assessment of infrastructure privatization must deal not only with efficiency issues but also with the questions of

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[30] Such a possibility is suggested, for example, by Kolbe and Tye (1990).

[31] See Averch and Johnson (1962) and the reviews of the literature in Kahn (1988, vol. 2, pp. 49–59) and Baumol and Klevovick (1970).

transfers and who wins and loses from privatization. The transfers of costs from one party to another, which may not be too important from the perspective of society as a whole, are obviously of great concern to the parties involved. And knowing who captures any net efficiency gains of privatization is obviously also important to the parties involved. The actual incidence of gains and losses from privatization depends to a considerable extent on the particulars of the individual cases. Only some broad tendencies can be identified, and these only very tentatively.

Winners and Losers

The most likely losers from the privatization of a proposed facility would seem to be organized labor and, to a lesser degree, landowners. Labor will lose to the extent that private sector operation results in lower wage rates or less protective workrules than public sector operation. Landowners surrounding a private road may also lose if a private operator is more successful than the public sector in extracting land donations or other contributions to advance the enterprise. In both cases, the losses come from the private sector's greater incentives to seek out and capture economic rents.[32]

The clearest winners from privatization would usually be federal, state, and, in some cases, local taxpayers. Taxpayers potentially gain in several ways. First, federal and state taxpayers usually would gain from higher individual and corporate income tax payments made by the private facility owners and bondholders, using taxable rather than tax-free financing. If a state-owned facility were as efficient as a private operation and set rates at the same level, for example, privatization would transfer income from the state to the federal government because the state-owned operation (and its surpluses) would have been tax-exempt. Second, to the extent that private equity or debt replaces public equity that received little or no return, the state or local taxpayers who would have contributed that equity would gain from not having to make that uncompensated contribution, while federal and state taxpayers would gain from higher income tax payments on returns realized by the private equity. Finally, state or local taxpayers might capture some of the efficiency gains of private sector operation or the transfers of economic rent from labor or landowners (particularly if the facility, though privately owned or operated, could not be supported from user charges

[32] Economic rents are payments or other benefits that owners of land, labor, or capital receive that are in excess of those that would be required to induce them to supply those services or factors.

alone and the efficiency gains or transfers were used in part to reduce the required government subsidies).

Investors might also gain from privatization of a proposed facility if they were able to hold on to any of the economic rents (captured from labor or landowners) or the efficiency gains from privatization, instead of passing these on to facility users in the form of lower user charges or better services. The prospects for doing so would depend on how competitive the markets for the facility's services were or, failing that, how closely public regulators were able to monitor the private operator's costs and force them to price closely to their costs. In a competitive market or under perfect regulation (a perhaps unattainable ideal), the facility owners would be forced to pass these savings on to facility users and earn only a normal return on their investment. With a less competitive market and lenient regulation, the facility investors might be able to earn above-market returns. (With excessively stringent regulation the investors could lose by earning a below-market return in the short run, but would eventually withdraw their capital by underinvesting or not maintaining the facility.)

Whether facility users would gain or lose depends on the particular circumstances. Facility users might lose in two ways. First, if the nominal costs of private sector financing were greater than the nominal costs of public sector financing, the users are likely to bear the costs in higher user charges. In effect, the users are likely to pay in higher tolls or tipping fees for any gains taxpayers receive in higher income tax payments or in avoiding uncompensated contributions of public equity. Second, the users might lose if the private owners were more willing and able to exploit any monopoly or market power by charging users fees that exceeded the costs of building and operating the facilities. Facility users stand to gain, however, to the extent they realize, in lower fees, any transfers (from labor and landowners) or efficiency gains generated by privatization. If the private owners are forced to pass these savings on to facility users (by either competitive market or regulatory pressures), these savings might offset the users' other possible losses and leave them, on net, better off.

The Importance of Efficiency Gains and Competition

This discussion of winners and losers strongly suggests that privatization is a more attractive public policy where the potential efficiency gains are great and the private operator faces effective competition. The larger the efficiency gains from privatization, the greater the prospects that most parties will gain from privatization and few will lose. The prospect of greater efficiency gains may also mean less pressure to extract any economic rents from either labor or landowners. More

importantly, the larger the efficiency gains, the more likely that users will be net beneficiaries. Competition is important, both because it might help stimulate efficiency gains and because it will force investors to pass any savings on to facility users rather than retaining them in the form of above-normal returns.

Any assessment of the efficiency advantages of private provision of infrastructure must balance a variety of conflicting considerations and arguments. On the one hand, private firms probably have real cost advantages in many cases in the form of economies of scale, scope, and experience, in the incentives they can offer their employees and managers to be more productive, and in faster procurement. Private firms may also be better able to arrange the compensation needed to resolve siting problems, as long as the disputes are not too complex, and are more likely to tailor their prices to match the costs of different users. On the other hand, government involvement in siting may be quicker or even unavoidable where problems are complex and opponents intransigent. The fear that private operators might abuse their monopoly power also may be real enough to compel some form of public rate regulation, particularly in the case of roads. Either type of government involvement may undermine some of the normal cost advantages of the private firm, particularly in speedier procurement, or add significantly to other private sector costs by increasing investor risks or distorting investment decisions.

In this light, the potential advantages of privatization are probably greater in solid waste disposal than toll roads. In the case of solid waste, the technological sophistication and complexity of modern disposal facilities make the potential efficiency gains from both private construction and management large. Solid waste also raises fewer market power or anti-competitive problems, especially in the long run. The emerging practice of relying on the private sector to both build and operate disposal facilities, either on a contract or merchant plant basis, reflects these potential advantages.

In the case of roads, the largest or most obvious efficiency gains would seem to lie in private construction rather than private operation of the facility; however, the public sector probably already captures many, or even most, of these construction economies through the near universal practice of contracting with large and specialized private road building companies for the construction of major public roads (although they might do more, for example, by more closely emulating private sector "fast-track" procurement practices). Private sector operation of roads probably offers efficiency gains in some cases, but it may raise troubling competitive issues as well. A lack of competition may make private operation both less efficient (by constraining demand or reducing efficiency incentives) and politically less attractive (since users are

more likely to be made worse off), while corrective government regulation of rates may cause efficiency problems of its own.

Privatization and the "Infrastructure Crisis"

Finally, privatization, although often advantageous in other respects, will probably do relatively little to alleviate the real or perceived shortfall in infrastructure spending that has come to be known as the "infrastructure crisis." Privatization alone will not increase the pool of available capital for infrastructure spending as long as the public sector also is willing to tap private capital markets, by issuing revenue or general obligation bonds for similar facilities. The tapping of private capital markets (whether by the private or public sector) is likely to come at the cost of displacing other investments. By contrast, public funding of infrastructure out of taxes (although politically more difficult) might have a slightly greater chance of increasing aggregate investment (in both infrastructure and other facilities) to the extent these taxes were borne by consumption rather than savings.

Privatization also offers only moderate potential advantages in siting facilities, which is probably as much of a constraint on infrastructure spending as the availability of capital. The private sector may be able to arrange compensation more easily in some cases to overcome siting opposition, but, rightly or wrongly, it may heighten fears in others.

In sum, the limited experience thus far with privatization of waste disposal and highways in the United States suggests that privatization may be generally helpful but is no panacea. Some shortfalls in public investment may be well suited to a privatization solution while others may not be, with that suitability being very dependent on both the competitiveness of the markets served and the realizable extent of any efficiency gains.

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Discussion

*Sir Alan A. Walters**

It is difficult to disagree with the main conclusions of Jose Gomez-Ibanez, John Meyer, and David Luberoff. First, they conclude that privatization is most attractive when the potential efficiency gains are greatest and the private operator faces effective competition. Second, they conclude that privatization, however advantageous, will do little to alleviate the real or perceived shortfall in spending known as the "infrastructure crisis."

Gomez-Ibanez, Meyer, and Luberoff do not present an explicit "model" of the infrastructure supply and demand process, or, more pertinently, the privatization process and the public choice analysis. Yet an implicit framework is developed within which the evaluation takes place. They contend that private provision will be better than public provision if

(1) Rapid technological progress takes place in the industry (and their judgment is that more of such change is taking place in solid waste disposal than in highways).
(2) Privately owned competitive firms are feasible as an alternative to public sector provision (and again solid waste scores).
(3) "Depoliticization" of production activities is most likely under private ownership.

A fourth possible addition would suggest that a powerful case for privatization can be made if it were an effective way of reducing the

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overweening power of trades unions (and if that were the only way to escape from the provisions of the Davis-Bacon condition).

New versus Existing Facilities

Of course, most privatization in the West as well as in the Third World has been concerned with turning over existing state-owned assets and liabilities to the private sector. Gomez-Ibanez, Meyer, and Luberoff, however, are primarily concerned with the creation of *new* assets, and whether they are best financed, created, and owned by the private rather than the public sector. For example, they do not consider, even tangentially, the possibility of a complete privatization of the Interstate Highway System. And although selling existing roads or bridges to the private sector is discussed, this is clearly a marginal consideration.

Gomez-Ibanez, Meyer, and Luberoff are probably being quite realistic in eschewing the radical privatization solution. Political economy, like politics, is the art of the possible. (The contrast with Clifford Winston's paper is notable; Winston considers a radical rebuilding of highways, but he does not discuss a feasible program and its costs and benefits.) Nevertheless, it would have been interesting to have seen their view on the efficacy of a completely privatized road system. Would the standards of construction have been more efficient, would it have been possible to avoid the vast waste of overbuilt roads in rural America (the Ann Friedlaender thesis), would it have produced more urban highways, would the operation be more efficient, would pricing be more appropriate? —and so on.

Contractual Systems and Regulatory Systems

Gomez-Ibanez, Meyer, and Luberoff refer obliquely to various contractual arrangements but they do not discuss the vast variety of contractual systems that may be generated under private ownership. In solid waste disposal, one would expect to find many hedging arrangements—forward markets, futures, and options would be developed, operating (except for forward markets) with standardized contracts. Why cannot solid waste disposal markets develop like the traditional ones in commodities?

It is more difficult to see this developing in tolled facilities, yet the development of pricing and supply contracts in electricity (Britain has had a crash course in these matters) gives one pause before ruling it out. The modern methods of electronic pricing provide a wealth of opportunities for auctions in road-use rights. In many circumstances, compet-

itive supply, given the capital stock, is possible (such as on the four or five roads between Washington and Baltimore).

In the absence of competition, Gomez-Ibanez, Meyer, and Luberoff suggest that, while fully recognizing the criticisms, the traditional rate of return regulation be introduced. However, other methods are available which are likely to be introduced in the United Kingdom. Misleadingly called "price-cap" systems, they avoid at least some of the inefficiencies of rate of return regulatory systems. (Note it is a cap on *average revenues per unit of output* and it applies *only* over the part of the revenue with some monopoly power.)

Macroeconomics

Gomez-Ibanez, Meyer, and Luberoff make the curious claim that while privately financed infrastructure is likely to displace some other forms of private investment, publicly provided infrastructure, when funded by user charges or taxes rather than debt, is likely to generate additional savings. Thus a consequence of the increase in tax revenue would be some reduction of private consumption, rather than a reduction of private (non-road) investment.[1] I find it difficult to follow this argument. The authors are holding real income fixed in this comparison. Then, increasing taxes on a pay-as-you-go basis to finance the investment will be considered by the private sector as an expenditure occurring today which, other things equal, will increase future disposable income, compared with the alternative of paying the future interest on debt incurred today. The form of finance will affect the timing of savings, as people finance their chosen and unchanging consumption stream. Total investment should not be affected.

Wages and Transfers

The authors are too dismissive of the effects of privatization (and, one may add, deregulation and competition) in eliciting lower wage levels, partly in lower wage costs per unit of output but also in lower real wages per hour. They claim that these effects are simply transfers from

[1] This, of course, denies the validity of the Ricardo equivalence theorem, where debt finance, in contrast with current tax finance, would induce additional savings by consumers to meet their future higher tax liabilities. No net effect on investment or capital stock would occur. It must be noted, however, that because of the discrete generation effect and the absence of perfect bequest motives, among other things, the Ricardo proposition has not been supported by empirical enquiries.

one group (labor) to another (owners and customers). But if the excess wage rate is due to monopoly power, whether formally or sanctioned by government, a reduction of those rates to competitive levels is, at least, an elimination of a *distortion* in the system and so will generate efficiency gains as well as transfers. It will result in an increase in employment and possibly a reduction in unemployment. Moreover, the process of privatization will also reduce more serious distortions generally associated with high unionized wage rates, such as issues of manning, seniority rules, work practices, and so forth.

Conclusion

On balance, one can find more achievable gains from privatization of the highways than Gomez-Ibanez, Meyer, and Luberoff offer. The only evidence as support, however, is anecdotal—such as the construction of Alliance Airport, the experience of the Channel Tunnel (compared with, for example, the Thames Barrage), and the management and maintenance of toll-ways. Clearly, more work needs to be done—and the authors have provided a most useful initial framework.

Discussion

*Gail D. Fosler**

Jose Gomez-Ibanez, John Meyer, and David Luberoff approach a sometimes passionate topic with a remarkably dispassionate view. Their paper provides a broad and extremely useful discussion of the advantages and limitations of privatization, and it adds important perspectives to the work of those who would advocate privatization as the solution to America's infrastructure problems.

Several important points in the paper should be emphasized. First, the privatization discussion has more to do with efficiency, pricing, technology, and shifting burdens among users, taxpayers, and wage earners and among economic and financial sectors, than with the total quantity of infrastructure. Privatization of some infrastructure services, such as solid waste disposal, has increased over the past decade. Yet infrastructure investment relative to GNP has shown little change or has even declined. Given the requirements of technology and systems management, the private sector can be an equal or even superior partner in the provision of infrastructure. Nonetheless, Gomez-Ibanez, Meyer, and Luberoff do an excellent job of identifying both the practical and the theoretical limitations to the privatization of infrastructure investment.

The second point, implicit in the selection of toll roads and solid waste disposal facilities as examples of privatization, is that privatization of infrastructure investment and of public services generally has not progressed very far. The paper cites the extensive privatization of solid waste disposal capacity. However, this is more the exception than the rule. The 4,128 miles of highly visible toll road projects represent only

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Table 1
Private Fixed Reproducible Tangible Wealth in the United States, 1982 and 1988
Billions of 1982 Dollars

	1982	1988	Percent Change 1982–88
Constant Dollar Gross Stock			
Local & Interurban Passenger Transit	9.6	8.5	−11.5
Transportation by Air	73.0	69.2	−5.2
Transportation Services	34.5	35.4	2.6
Sanitary Services	18.2	25.1	37.9
Total	135.3	138.2	2.1
Constant Dollar Net Stock			
Local & Interurban Passenger Transit	4.1	4.0	−2.4
Transportation by Air	39.8	34.0	−14.6
Transportation Services	18.1	16.8	−7.2
Sanitary Services	10.5	14.6	39.0
Total	72.5	69.4	−4.3

Source: U.S. Bureau of Economic Analysis, *Fixed Reproducible Tangible Wealth in the United States, 1925–85* (June 1987), and the Bureau.

0.2 percent of total highway miles in America. In the states of Virginia and California, toll roads account for less than 100 miles of highway. The American Association of State Highway and Transportation Officials estimates that only 200 miles of toll roads will be built in the 1990s. Similarly, privatization does not appear to be a major factor in water, sewers, urban transportation, or education.

To be sure, it is difficult to get a good measure of private infrastructure investment or of the private investment share by type of infrastructure service. The U.S. Bureau of Economic Analysis series on fixed reproducible tangible wealth provides a hint of the limited private involvement. The gross capital stock in local and interurban transportation, air transportation, sanitary services, and other transportation services is virtually unchanged since 1982 at $135 billion to $138 billion in constant dollars, and on a net stock basis it has declined. True, investment in private sanitary services is up almost 40 percent in real terms since 1982, but other types of private infrastructure investment are down (Table 1).

These trends raise the question of why the United States is not undertaking more of this investment if it is such a good idea, which raises a third point in the paper. The incentives required for private involvement in infrastructure activities appear from all indications to be extremely high. To the extent the private sector requires incentives or various forms of monopoly power, the efficiency gains from privatization are limited.

As the paper points out, the tax code before the 1986 reform provided substantial incentives for privatization of water, sewer, and solid waste disposal services. These incentives were justified on the basis that private companies should enjoy the same financial advantages that state and local governments have in the tax-exempt market. While the total federal tax expenditures dedicated to this purpose were not substantial, local bonds used for private purposes rose dramatically in the mid-1980s. From 1975 to 1980, bond issuance for pollution control averaged $2 billion to $3 billion. By 1984, with the explosion of private purpose tax-exempt finance for pollution control, total issuance jumped to over $8 billion. By 1986, the spread between tax-exempt bonds and taxable Treasuries was less than 100 basis points.

In 1986, tax reform eliminated or substantially curtailed private purpose tax-exempt financing. Last year, tax-exempt financing for sewage disposal, solid waste, and non-nuclear hazardous waste was only $1.9 billion, not very different from the amounts in the 1970s. The former incentives were important primarily for pollution control, and often served as a subsidy for private spending. Once these incentives were removed, privatization of other services simply has not progressed very far, even with the remaining incentives.

The experience (and incentives) in privatizing solid waste may provide a key to "why." The publicly traded solid waste companies are highly successful and highly profitable. The price-earnings ratios for many of these companies are 50 percent above the market, because of their spectacular profitability. The operating margin for the environmental industry is well over 20 percent, with a 12.5 percent return on capital. Indeed, the companies with the highest price-earnings ratios are those with near monopolies in waste handling and disposal.

In short, public infrastructure activities become private when they are profitable. And, they are often profitable where they enjoy noncompetitive market advantages, either in terms of market area or landfill capacity. Thus, while it is undoubtedly true that private services are more efficient in terms of cost "as long as there is competition to make sure that private operators remain efficient," as Gomez-Ibanez, Meyer, and Luberoff state, some evidence suggests that the private companies are successful precisely because they face limited competition and are unregulated.

I would like to make one final point on the paper itself and then conclude with some observations about the role of privatization in public infrastructure. The paper does a very good job of introducing the political problems associated with infrastructure spending. Problems associated with siting are a key limitation, as are decisions regarding who bears the cost burden. Local developers continue to press for development rights in advance of adequate public facilities; waste

disposal sites are huge local political issues; and local jurisdictions and states often battle over who should bear the cost of schools, roads, and other infrastructure. Indeed, a key question arises out of the siting discussion: If we had all of the funding necessary to build infrastructure, would the local politics of development and the environment permit it to be spent? In many instances, the answer is undoubtedly no.

Observations on the Role of the Private Sector in the Provision of Infrastructure

Along with the rapid growth in government in recent years comes the increasingly popular notion that the private provision of public services will substitute for the public provision of infrastructure and at lower cost while, at the same time, creation of a private market for public goods will somehow substitute for the political process. In a few remarkable instances the privatization of infrastructure has met both of these objectives; solid waste and toll roads are good examples. It is also true that the debate over the privatization of infrastructure has spilled over into human services, prisons, and more recently into education.

Nonetheless, the task of government is to determine which public goods should be provided and then to determine what can be done publicly and what can be done privately. With this said, it is equally clear that whatever the outcome on the debate on its rate of return, infrastructure spending, probably both for new construction and for maintenance, will have to rise substantially; and it will have to rise in areas in which neither the economics nor the political process will favor private solutions.

A key private role, beyond the provision of the service, must therefore be to help shape the political process in such ways that the required levels of taxes and spending are forthcoming from the public sector with the least distortions to the economy. This is proposed in other papers at this conference. Moreover, whatever favor infrastructure may find in the public process, it is also clear that the private sector—both individual and business—will bear higher direct costs through taxes and higher indirect costs through increased product prices for the infrastructure needs, especially environmental needs, as a consequence of public policies and regulations.

How Efficient Is Current Infrastructure Spending and Pricing?

*Clifford M. Winston**

Congested highways and airports, collapsing bridges, deteriorating roads, periodic water shortages, and suspect waste disposal facilities bear silent witness that the infrastructure of our nation, currently valued at close to $1 trillion, is inadequate. To shore up America's foundations, many economists and policy analysts have urged the federal government to increase spending substantially. The urgency of the problem, however, does not preclude the need to ask whether the current use of facilities is efficient, whether choices about how current facilities are used are possible, and how current use will affect the efficiency of new facilities. In fact, surprisingly large benefits are to be gained from making efficient use of our current infrastructure by pricing it and investing in it efficiently. Efficient pricing and investment will reduce the need for massive public investment and will prevent the recurrence of infrastructure problems. The primary reason why the current facilities are gravely deficient is that they are priced in ways that do not reflect economic costs and designed in ways that result in higher life-cycle costs of use.

In their anxiety to address the infrastructure problem, policymakers are pushing policies that, if adopted, would indefinitely foreclose consideration of efficient pricing and investment. Congressional renewal of the gas tax in 1991, for example, would perpetuate a method of

*Senior Fellow, The Brookings Institution. This paper draws heavily upon and extends my paper "Efficient Transportation Infrastructure Policy," *Journal of Economic Perspectives* (Winter 1991). I am grateful to C. Evans, S. Morrison, and K. Small for helpful comments and collaboration on much of the research reported here. I also received useful suggestions from A. Downs and D. Lashar.

charging trucks for interstate highway use that could foreclose consideration of the far more efficient cost-based, axle-weight charge for nearly a decade. It is therefore crucial for policymakers to consider more efficient infrastructure policy before the window of opportunity is closed.

The Theory of Efficient Infrastructure Policy

The nation's infrastructure assets consist primarily of highways, airports, transit stock, water resources, and water supply and waste disposal facilities. At a valuation of nearly half a trillion dollars, highways account for more than half of these assets. Infrastructure supports a community's basic activities and any expansion of them. Putting it slightly more technically and in a transportation context, infrastructure provides *capacity*, in the form of traffic lanes and runways, as well as *durability*, in the form of thick pavement. Users of the infrastructure impose costs on themselves and others by contributing to congestion, which increases travel time, and by wearing out the infrastructure, which necessitates maintenance expenditures to repair pavement and vehicles. Efficient infrastructure policy maximizes the difference between social benefits and the costs of use, including the costs that users impose on others, by specifying pricing guidelines to regulate demand and investment guidelines that will specify design. A mathematical derivation of these guidelines is contained in Winston (1985); a nontechnical discussion is presented here.

Although the theory of efficient pricing and investment was originally developed to analyze transportation problems, and indeed much of the following discussion will draw upon transportation infrastructure, it can be applied to any infrastructure problem.[1] The efficient pricing rule calls for infrastructure use to be priced at short-run marginal cost. Because the user will take only his average cost into account when making travel decisions and ignore his contribution to congestion and infrastructure wear, short-run marginal costs to the public will exceed private average cost. The infrastructure authority must therefore set congestion tolls and charges for infrastructure wear to close this gap. The efficient investment rule calls for capacity and durability to be

[1] Although the literature on optimal pricing and investment has a long and distinguished history that dates back to the writings of Pigou and Knight among others (see Winston (1985) for a survey), Mohring and Harwitz (1962) were the first to rigorously determine optimal pricing and investment policies in a long-run framework. Recent work has extended Mohring and Harwitz's model to account for demand uncertainty, lumpy investment and so on. But the basic insights and usefulness of this model are still intact.

produced to the point where the marginal benefit from increasing investment in each dimension equals its marginal cost. Optimal investment is commonly viewed as being achieved in the long run. The pricing and investment rules jointly constitute an efficient long-run policy, in which a user's marginal cost is determined at the optimal level of capacity and durability.

Mohring and Harwitz (1962) applied existing theoretical results to transportation and showed that the financial viability of a public infrastructure facility under optimal pricing and investment depends upon the technological properties of its cost function. If capacity and durability costs are jointly characterized by constant returns to scale, then the facility's revenue from marginal cost pricing will fully cover its capital and operating costs. If costs are characterized by increasing returns to scale, then the facility's revenues from marginal cost pricing will fall short of its operating and capital costs and it will require a subsidy; if costs are characterized by decreasing returns to scale, then the facility's revenues from marginal cost pricing will exceed its operating and capital costs.

The following discussion summarizes in some detail the economic effects of optimal pricing of, and investment in, highways and airports. The discussion is then extended to other infrastructure facilities.

Efficient Highway Pricing and Investment

A country laced with nearly four million miles of roads, as is the United States, would not appear to have a serious highway infrastructure problem. Road mileage, however, is not the issue. Roughly half of America's nonlocal roads are currently in fair or poor condition, and traffic during commuter rush hours approaches capacity on one-half of the urban interstates and on one-third of the other main arterial highways (Small, Winston and Evans 1989). Most proposed solutions to these problems call for substantial increases in annual highway spending. But efficient highway pricing and investment could dramatically improve the condition and performance of our roads and require only a small increase in capital spending.

Historically, gasoline taxes have been used to charge vehicles for their use of roads and to finance expenditures. Tolls are levied on some roads, and eleven states have adopted taxes that assess trucks according to their total weight and distance traveled, but such charges account for a small share of highway revenues.[2] Although the gasoline tax was

[2] Wyoming, Colorado, and Nevada have recently repealed their weight-distance taxes.

probably a reasonable way to raise revenue as long as roads were uncongested and in good condition, of late, revenue shortfalls have made it increasingly necessary to supplement the gas tax with state and local revenues. The reason for the shortfalls is that fuel tax receipts fluctuate with economic conditions and fuel prices, and the recent trend in fuel tax revenues has been downward in real terms (because of improved fuel economy and increased use of untaxed gasohol).[3] These shortfalls are one reason to move away from the fuel tax as a source of highway revenue. A more important reason is that the fuel tax does not reflect the pavement damage and congestion caused by vehicles.

Charges for Pavement Wear

Pavements do not last forever. They become worn as vehicles pass over them and they eventually require resurfacing in the form of an overlay. Trucks and buses cause most of the damage, cars very little. Pavement damage itself depends on *vehicle weight per axle,* not total vehicle weight. The damage caused by an axle is defined in terms of the number of "equivalent standard axle loads" (esals) causing the same damage; the standard is a single axle of 18,000 pounds. This damaging power rises very steeply with its load.[4] For example, the rear axle of a typical thirteen-ton van causes over 1,000 times as much damage as that of a car.

A marginal-cost pavement wear charge can be assessed by multiplying a vehicle's esal-miles by the marginal cost of an esal-mile. For example, Small, Winston and Evans (1989, p. 42) estimated the marginal cost of an esal-mile on rural interstate highways to be 1.5 cents. Thus a truck equivalent to two standard axles traveling 100 miles on a rural interstate would accrue 200 esal-miles and a charge of $3.00.

Such a pavement wear charge would accurately reflect the damage caused by vehicles using the road. It would also give truckers an incentive to reduce axle weights by shifting to trucks with more axles, thereby reducing highway damage and maintenance expenditures and extending pavement life. The fuel tax currently in use provides truckers with the opposite incentive: the tax *rises* with a vehicle's axles, since trucks with more axles require larger engines and get lower fuel economy. Similarly, many state turnpikes charge more for a given weight if it is carried on a vehicle with many axles.

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[3] This downward trend appears to have reversed in just the past few years.

[4] It was previously thought to rise to the fourth power, but Small and Winston (1988) find that it rises closer to the third power.

Optimal Durability of Pavement

The damage that a truck does to a pavement depends not only on its axle weight but also on the durability (thickness) of the pavement.[5] Historically, pavement thickness has been strongly influenced by design guidelines issued by the American Association of State Highway and Transportation Officials (AASHTO). Recently, Small and Winston (1988) reexamined the recommendations issued by AASHTO with a model that determined optimal thickness by minimizing the sum of capital and maintenance costs. They found that optimal thicknesses were significantly higher than current thicknesses, especially for heavily traveled interstates.[6] Greater road thicknesses would substantially reduce annual maintenance expenditures and, because they would lower the marginal cost of an esal-mile, would also soften the impact of taxes promoting efficient pavement wear.

The economic effects of building roads to optimal durability and of charging truckers marginal-cost pavement wear taxes are shown in Table 1. Optimal durability and the marginal cost of an esal-mile are determined by the Small-Winston model along with extensive Federal Highway Administration data on the inventory of highway types and traffic levels; truckers' vehicle shifts in response to the marginal-cost tax and associated welfare effects are predicted by a truck-type choice model, where truck types are defined by trailer and axle configuration; and freight shifts to or from railroads are predicted by a shipper modal-choice model. The effects of the (first) best policy are shown in the first column of Table 1; columns 2 and 3 show the results of partial implementation. Gains in net welfare from the (first) best policy total $7.75 billion annually (1982 dollars). The source of these benefits is a huge annual reduction in maintenance costs of $9.4 billion, which is achieved with only a $1.3 billion annualized increase in capital costs. This policy is also attractive from a political viewpoint because it entails little redistribution. In fact, all major highway interests gain. Truckers and their customers gain because increased durability *lowers* the efficient road-wear charges from today's levels. The public sector gains because trucking firms distribute their loads over more axles (change vehicle types), reducing standard loadings (esals) by 38 percent, reducing highway maintenance expenditures. Railroads gain slightly from an

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[5] Besides making a pavement thicker, durability can also be improved by improving drainage, using better construction materials and so on. Aging and weathering leave a pavement more vulnerable to heavy loads.

[6] Small and Winston argue that their recommendations differ from AASHTO's because AASHTO failed to incorporate economic optimization into the design procedure and relied on a relationship between pavement life and pavement thickness that was statistically flawed.

Table 1.
Annual Economic Effects of Efficient Infrastructure Policy for Roads
Billions of 1982 Dollars

Item	Change,[a] Relative to Current Practice		
	Efficient Pricing and Investment (1)	Efficient Pricing with Current Investment (2)	Efficient Investment with Current Pricing (3)
Investment costs			
Maintenance savings	$ 9.428	$ 6.441	$ 8.536
Annualized capital savings	−1.276	—	−2.236
Total savings	8.152	6.441	6.300
Trucking firms' and shippers' welfare[b]	0.134	−5.586	—
Government revenues	−0.574	3.884	—
Modal shifting[c]			
Modal surplus	0.029	0.204	—
Rail profits	0.011	0.411	—
Total welfare	$ 7.752	$ 5.354	$ 6.300
Change in standard loadings[d] (Percent)	−38.12%	−48.38%	0.0%

[a] Positive dollar values indicate an improvement.

[b] These estimates do not include changes in user costs (vehicle damage and slower speeds due to damaged pavement). Small, Winston, and Evans (1989) point out there are difficulties in obtaining reliable estimates of this effect. Their rough estimates indicate that under optimal pricing and investment user costs are reduced by $3.03 billion when they are optimized along with maintenance and capital costs. User costs still fall by $1.8 billion under optimal pricing and investment when they are not explicitly optimized.

[c] Modal surplus measures the benefits to shippers who shift freight to or from railroads in response to the change in truck taxes.

[d] The reduction in standard loadings is accomplished with only a small change in ton-miles that results from modal shifting; most of the reduction is from truck-type shifts.

Source: Small, Winston and Evans (1989).

increase in traffic,[7] and the budget balance of the federal government is improved because the reductions in maintenance expenses greatly offset the loss in highway revenues and the increase in capital expenses.

The economic and political importance of combining optimal pricing and investment is also shown in Table 1. Setting efficient pavement wear taxes at current highway durability (column 2) produces a smaller welfare gain and generates substantial redistribution from the trucking industry to the public treasury. This finding confirms that truckers are

[7] Railroads gain because truck charges tend to rise on intercity traffic shipped long distances in large quantities; hence their business grows despite a small overall decrease in truck charges.

currently being undercharged for their use of the roads, but it also reveals how inadequate infrastructure investment can penalize an industry. Building roads to optimal durability while maintaining current pricing (column 3) also produces a smaller welfare gain and requires greater capital outlays. Because optimal investment is a long-run policy and the benefits from reduced maintenance expenses will be seen only several years after initial capital outlays, extra capital expenses could arouse short-term budgetary concerns. Nonetheless, the annualized benefit-cost ratio from optimal investment approaches 4:1, which is a healthy return.

Congestion Charges

Traffic congestion appears to be one of the most intractable infrastructure problems of the nation. Regardless of what policies are implemented—from high-occupancy vehicle lanes to subsidies for public transit—delays become longer and drivers and passengers become angrier. A conclusion being reached more and more frequently is that we have no choice but to build more roads. At first sight, increasing highway capacity appears as sensible as increasing highway durability, but capacity and durability inadequacies have different effects on road users. Few vehicles are discouraged from using a road because of its durability problems. Therefore, optimal durability produces benefits without significantly increasing use. On the other hand, because a lot of motorists are discouraged from using a road when it is congested, traffic will be attracted to it if capacity is expanded to relieve congestion. Benefits may be accrued, but congestion will persist in the long run.[8] The only way to reduce congestion permanently is to set an explicit price for capacity.

Congestion pricing has been advocated by economists for many years. But it has either been ignored by policymakers or been dismissed on political and practical grounds.[9] Small (1982), however, shows that objections by those who protest that lower-income drivers would be unfairly penalized are unfounded if revenues are used properly. If toll revenues are explicitly used to lower property taxes, invest in public transit, replace registration fees or fuel taxes, or invest in central cities,

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[8] This is known as Downs's law (1962, p. 393): on urban commuter expressways, peak-hour traffic congestion rises to meet maximum capacity because commuters shift from less preferred modes and times of day.

[9] For example, congestion pricing is not mentioned in an eight-page cover story on gridlock in *Time* (1988). It is dismissed by Ross Sandler, New York City Commissioner of Transportation, in a 1989 *New York Times* article where he is quoted as saying, "What would you do—put tolls on all the highways?"

congestion pricing can actually work to the benefit of all income classes.[10]

Objections that tolls are impractical are also overstated. Congestion pricing can be implemented without disrupting a traveler's journey. An automated vehicle identification (AVI) system, in which an electronic number plate is mounted underneath each vehicle, can be used to transmit a numbered identification to a control center each time a vehicle passes over a power loop embedded beneath a toll site. The vehicle owner is then sent a monthly bill similar to a phone bill. The technological side of such a system has been tested in Hong Kong and found to perform exceptionally well (Catling and Harbord 1985; Hau 1989).[11] In the United States, an AVI system is currently operating on the North Dallas Tollway.

Because the effects of congestion pricing vary widely by locale, most studies of its effects have been site-specific. But a study by Lee (1982) made a rough estimate of the effect of adopting congestion pricing nationwide and found that it would generate nearly $6 billion (1981 dollars) in annual net benefits, mostly in the form of travel delay savings. If congestion pricing were accompanied by optimal investments in road capacity, annual net benefits would be even higher and the initial redistribution from road users to the road authorities would probably be less.

Highway Finance

Although efficient road pricing and investment would generate substantial benefits, one must estimate the degree of scale economies in highway production to determine whether this policy would enable highways to be financially self-sufficient. Because highways produce two "products," traffic volume requiring capacity (for example, number of lanes) and standard loadings requiring durability (such as thickness), multiproduct scale economies must be estimated. These economies are a function of product-specific economies and economies of joint production, commonly referred to as economies of scope. Small, Winston and Evans (1989) find strong product-specific economies associated with producing heavy vehicle loadings because the ability of a pavement to withstand traffic increases far more than proportionally with its thickness. They conclude from the literature that mild product-specific

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[10] Virginia Secretary of Transportation John G. Milliken recently signalled his state's willingness to use Dulles Toll Road profits for express mass transit service.

[11] Hau also discusses a solution for overcoming some of the objections in Hong Kong to implementing congestion pricing.

economies result from producing traffic volume. They also find diseconomies of scope from jointly producing volume and standard loadings: as the road is made wider to accommodate more traffic, the cost of any additional thickness required to handle heavy vehicles rises because all lanes must normally be built to the same thickness. Multiproduct scale economies are estimated by combining these components.[12] The result is that the product-specific economies are virtually offset by the diseconomies of scope, which leads to approximately constant returns to scale in highway production and a budget for urban roads that approaches long-run balance.[13] For uncongested rural roads, durability economies would lead to a budget deficit, and additional fees would be required to attain a balanced highway budget.

This finding reveals an important additional benefit from congestion pricing. If efficient road-wear pricing is undertaken alone, the road authority would face a deficit for urban roads because of the economies of pavement durability.[14] But when efficient road-wear pricing is combined with efficient congestion pricing, the (marginal) cost of building the pavement itself is effectively charged twice: once from trucks because they require a thicker pavement and once from cars because they require a wider pavement. The result is that losses from pavement durability economies are eliminated.

As a further benefit, congestion pricing could substantially reduce the public transit operating deficit, which, according to the Urban Mass Transportation Administration, approached $9 billion in 1985. The higher congestion tolls will cause some motorists to shift to public transit.[15] This increased ridership will cause an increase in transit

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[12] The mathematical expression for these multiproduct scale economies is:

$$S_m = \frac{wS_V + (1 - w)S_Q}{1 - S_C}$$

where S_V is product-specific returns to traffic volume, S_Q is product-specific returns to durability, w is the proportion of user charges accounted for by congestion charges, and S_C is economies of scope.

[13] Small, Winston and Evans (1989) discuss the possible efficiency gain from a road system that separates truck and auto traffic, which is motivated by their finding of diseconomies of scope.

[14] Small, Winston and Evans (1989) find that the "pavement deficit" is reduced by optimal pavement wear pricing and investment from its current level of $16.16 billion (1982) dollars) to $9.84 billion (1982 dollars). The pavement deficit is defined for the optimal and current policy as the difference between tax revenues and the annualized value of resurfacing expenditures and the cost of the paving material itself.

[15] For example, Viton (1983) finds that congestion pricing in the San Francisco Bay Area would raise mass transit's share of downtown commuters by 10 to 20 percentage points.

capacity, which is usually achieved by running buses or trains more frequently. The increased frequency will lower expected wait times and generate even more ridership. The result is that congestion pricing in combination with appropriate pricing and service responses by transit agencies could raise transit revenues and reduce the need for federal, state, and local operating subsidies.[16]

Efficient Airport Pricing and Investment

Airport congestion and flight delays are increasingly receiving public attention. Many observers argue that the problem stems from a lack of airport capacity, citing the fact that no major airports have been built since 1974. Federal support of the proposed new Denver airport, estimated to cost $2.5 billion, is seen as a constructive step in alleviating air delays.

Congestion has probably not affected air travel choices to the same degree it has affected automobile travel choices, and additional airport capacity is not likely to attract as much traffic as additional highway capacity. But the tremendous growth in air travel during the past decade, partly spurred by deregulation, and the high cost and long lead times associated with building new airports suggest that society will be faced with a difficult and expensive catch-up task if it commits itself to reducing air congestion simply by building more airports. A less costly and more effective long-run solution is to price and invest more efficiently in existing airports.

Efficient Runway Pricing and Capacity

The most common method of assessing landing fees at airports is by aircraft weight. Thus during a given hour a jumbo jet pays considerably more to land than a small private plane. Weight-based landing fees were probably a reasonable way to allocate airport costs and raise revenue when airports were uncongested, but today the principal cost that an aircraft imposes when it takes off or lands is that it delays other aircraft from these activities. Morrison and Winston (1989) found such a delay to be substantial. For example, the elasticity of average departure delay with respect to commercial carrier departures is 2.9; the elasticity with respect to general aviation departures is 2.5. Current landing fees

[16] Winston (1991) discusses how efficient highway pricing and investment will provide additional benefits by improving performance in the deregulated motor carrier industry.

Table 2
Annual Economic Effects of Efficient Infrastructure Policy for Airports
Billions of 1988 Dollars

Item	Change,[a/] Relative to Current Practice	
	Efficient Pricing and Runway Investment (1)	Efficient Pricing and Current Runway Investment (2)
Consumer surplus change from landing and takeoff fees[b]	$ 1.10	$−12.53
Reduced delay to travelers	7.91	3.62
Carriers' operating cost savings	2.77	1.23
Airport revenues less costs	−0.77	11.50
Total welfare change	$ 11.01	$ 3.82

[a/] Positive dollar values indicate an improvement.

[b/] The consumer surplus change measures the effect of changes in landing and takeoff fees on travelers who continue to fly and those who are driven from or attracted to airline travel.

Source: Morrison and Winston (1989, p. 93).

undercharge aircraft in inverse proportion to their weight, because they do not account for the congestion externality.

An airport's capacity is primarily determined by its number of runways.[17] If it already owns the land, an additional runway 10,000 feet long and 150 feet wide can be constructed for roughly $40 million (1987 dollars) (Morrison and Winston 1989). Optimal runway capacity is reached when the marginal cost of an additional runway is equated with the marginal benefit of reduced delay.

The effects of replacing weight-based landing fees with marginal-cost congestion fees and of building the optimal number of runways at airports are shown in Table 2. Marginal-cost fees include delay costs and marginal maintenance, operations, and administrative costs. Optimal runway capacity is determined under the assumption that no additional land is needed for runway expansion. Although this is an unreasonable assumption for some airports, other capacity-enhancing mechanisms are or will be available that could by themselves produce a similar effect or enable runways to be built closer together at airports with limited room for growth.[18] In any case, this assumption produces an upward bias in the estimate of net benefits. An airline carrier choice model is used to estimate travelers' value of the reduced delay and of the change

[17] Terminal facilities and gate space also determine capacity.

[18] These mechanisms include high-speed runway exits, microwave landing systems, phased array radar, and digital pilot-air traffic control communications.

in their surplus in response to the change in landing fees. The effects of efficient runway pricing and investment are shown in the first column of Table 2, and the effects of adopting efficient runway pricing at current runway investment are shown in the second column.

Optimal airport pricing and investment policy could generate roughly $11 billion (1988 dollars) in annual benefits. Travelers would reap $8 billion in reduced delays and face lower fares, because the expansion in runway capacity called for under optimal investment, combined with congestion pricing, would reduce congestion to such an extent that on average landing fees would fall.[19] The annualized cost of the runway investment is only about $1.5 billion. Carriers benefit from lower operating costs, which result from reduced delay. Airports' net revenues would fall slightly, but, as argued below, they would become financially self-sufficient.[20]

The combination of efficient pricing and efficient investment policies is again economically and politically important. If airports adopted efficient congestion fees alone, net welfare would improve by only one-third as much, and considerable redistribution would occur to airports from travelers, who would primarily absorb the higher takeoff and landing fees through higher fares.

Combining efficient pricing and investment would also postpone the need to build expensive new airports. The FAA estimates that the new Denver airport will reduce current delays at the Denver Stapleton airport by 35 to 50 percent. Optimal pricing and investment at Stapleton airport would lower delays by at least that much at lower cost (Morrison and Winston 1989). Continued growth in air travel will eventually necessitate the construction of new airports, but these decisions will be made efficiently only if our current airport capacity is used optimally.

Airport Finance

As a simplification, airports produce two outputs, commercial carrier operations and general aviation operations. Although general aviation usually requires less terminal capacity and shorter runways than commercial aircraft, Morrison (1983) finds that airports are characterized by (overall) constant returns to scale and would therefore be financially self-sufficient under optimal pricing and investment. Their self-sufficiency would help lower the federal government deficit because

[19] General aviation travelers will face higher landing fees. But the Morrison-Winston model does not account for the greater flexibility that general aviation travelers have in their choice of airport and in arrival and departure time, thus their losses are overstated.

[20] Winston (1991) discusses how efficient airport pricing and investment will provide additional benefits by improving performance in the deregulated airline industry.

airports would no longer need funds from the government to finance improvements.

Efficient Pricing and Investment of Other Facilities

Less empirical work is available on the economic effects of efficient infrastructure policy on bridges, water supply, and water resources, but the information that is available suggests that significant benefits could also be derived from more efficient use of these facilities by pricing them and investing in them more efficiently.[21]

In contrast with pavement wear, bridge wear depends solely on *vehicle weight*, roughly in proportion to its third power (Moses, Schilling and Raju 1987). Thus, a fully efficient highway tax would account for a vehicle's contribution to damage from bridge stress by including a charge related to weight. Catastrophic bridge failure is caused by simultaneous passage of heavy vehicles over a given bridge section. Simultaneous passage and thus the likelihood of catastrophic failure could be reduced by congestion pricing, which would spread the traffic flow. Current bridge design could also be economically suboptimal. Design guidelines are not explicitly based on optimization and include arbitrary margins of safety. Efficient bridge investment and design could result in significant cost savings.

Reisner's *Cadillac Desert* (1986) focused popular attention on the nation's inefficient policy toward water use: water is priced below marginal cost, far below for agricultural uses, and laws regarding water ownership provide farmers with a disincentive to conserve water. The current infrastructure stock for water (dams and aqueducts) is inefficiently used, while the price distortions and the absence of a market for water in most states have spurred proposals by some Western locales to build expensive new dams. Benefits would clearly be derived from efficient pricing of and investment in water supply.

Use of the nation's waterways could also be improved through more efficient pricing. Until October 1980, no charges were imposed on users of inland waterways. Some believe that this policy was justified because the rights-of-way are a pure public good. But Boger (1985) has shown positive social marginal costs of waterway use, chiefly caused by congestion at locks. Efficiency could be improved if the current nominal charges were replaced by a marginal-cost congestion fee.

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[21] For an overview of the inefficiencies in waste disposal see National Council on Public Works Improvement (1988).

Summary of Benefits

The potential clearly exists to realize substantial benefits from an efficient infrastructure policy. The annual welfare gain from efficient pricing of and investment in highways and airports alone exceeds $25 billion (1988 dollars). It can be obtained for only about $3 billion (1988 dollars) in annualized capital expenditures to increase road thicknesses and to build more runways. Benefits would actually be higher than these estimates suggest, because performance in the deregulated airline and trucking industries would improve. Optimal pricing of and investment in other infrastructure facilities would add even more to the benefits tally.

Alternatives to Efficient Infrastructure Policy

Many people in public and private life question whether the benefits from efficient infrastructure policy would be achieved in practice and whether they would be worth the cost of politically undesirable redistribution. These fundamental concerns will be addressed in the process of evaluating alternatives to efficient infrastructure policy, focusing on highways and airports. The alternatives include traditional approaches, privatizing infrastructure facilities, and significantly increasing infrastructure spending.

Traditional Approaches

Most policymakers fall back on traditional approaches such as the gas tax or moderate increases in spending to solve current problems. My analysis of efficient pricing showed how current road and airport pricing, which chiefly relies on the gas tax and weight-based landing fees, is highly inefficient.[22] To simply increase spending, especially without charging efficient prices, could also be inefficient. But policymakers find current approaches appealing because they are practical and appear politically safe. Thus they must be convinced that efficient pricing and investment *can* be implemented and will not inevitably be faced with political opposition by stakeholders.

Technological feasibility. Efficient infrastructure pricing and investment can be implemented with proven technologies. The axle-weight

[22] The Bush Administration has recently proposed consideration of passenger facility charges at airports. These charges are not based on the aircraft's contribution to congestion; they are in fact weight-based landing fees under a different name.

truck tax is currently being implemented in Oregon. A 1988 U.S. Department of Transportation study concluded that the administrative and compliance costs of this tax at the national level would be little more per vehicle than the current federal heavy-vehicle use tax. Although the theoretically ideal road-wear charge would vary by road type to reflect the much greater vulnerability of thin roads to damage, Small, Winston and Evans (1989) found that simplified charges, which would be easier to administer, would retain a surprisingly large proportion of the benefits. For example, a two-part axle-weight tax, with one rate applied to freeways and another to nonfreeways, would provide more than 99 percent of the welfare gain possible from the axle-weight tax applied to all road types.

As noted earlier, road congestion pricing could be implemented without disrupting a traveler's journey, using an automated vehicle identification system. This system could permit officials to set a detailed pricing schedule with charges varying by time and locale. Although it would be costly to install, it would represent a far more efficient investment for reducing traffic congestion than the "smart cars–smart streets" technology, which is starting to capture the imagination of the public and the federal government despite having an estimated cost of $18 billion to build and $4 billion a year to operate and maintain.[23] Efficient airport pricing would be easy to implement. Because hourly takeoff and landing activity is recorded by control towers, the current weight-based fees simply could be replaced by a schedule of hourly takeoff and landing congestion charges.

Efficient infrastructure investment would use current construction technology to add thickness to roads and more runways at airports. The best way to upgrade existing highways would be to increase thickness—beyond what would normally be added to restore its original strength—each time a pavement is resurfaced. Small, Winston and Evans (1989) found that the benefits from increased thickness do not depend on unrealistic precision in building design. Even large errors in forecasts of traffic loadings do not affect the benefits by more than 10 percent. New runways should be efficiently added to congested airports that have available land.[24] New landing aids and better technology for air traffic

[23] The smart cars–smart streets technology amounts to computerized displays in automobiles that receive instantaneous traffic updates and detour instructions from a traffic management center. See John Cushman, "Smart Cars and Highways to Help Unsnarl Gridlock," *The New York Times*, April 12, 1990, p. A16.

[24] At least 50 percent of the congested airports have available land for additional runways. Environmental concerns would have to be met. One could argue that noise pollution would be reduced by efficient airport policy because use would be less concentrated during particular hours of the day.

controllers could enable runways to be spaced more closely together. The benefits from efficient airport investment do not have to depend on great precision in airport design. Morrison and Winston (1989) find significant benefits would result at many airports from just one additional runway.

Political considerations. It is widely believed that the radical revision of infrastructure pricing called for under efficient pricing is impractical because it would generate politically unfavorable redistribution.[25] Current approaches to pricing, however, are held hostage so relentlessly by political forces that policymakers are effectively prevented from taking any substantial steps to improve the infrastructure.

The federal government's decade-long aversion to new taxes complicates raising the federal gasoline tax. Individual states face strong voter opposition to proposed gasoline tax increases. Just recently California voters narrowly supported a doubling of their state gasoline tax, but the tax, which had not been raised for years and is now roughly equal to the national average, was part of a widely lobbied proposition to relax stringent limits on state expenditures. Airports are currently limited by law on the amount of revenue they can raise from pricing. Because of budgetary concerns, all levels of government are reluctant to increase—or in some cases even maintain—current spending on infrastructure without a committed source of additional revenue. The impact of politics has become clear: current calls for action have largely triggered finger-pointing.

By comparison, the political difficulties of efficient infrastructure pricing are manageable. The key to overcoming political objections to efficient infrastructure pricing is combining it with efficient investment and publicizing the expected outcome for beneficiaries. In the long run, no major highway interests will be harmed by efficient road wear pricing and investment. In the short run, the trucking industry would be hurt if charges were immediately set to marginal cost at current levels of durability. Political tensions could be minimized if road wear charges were initially set midway between current and ideal marginal-cost charges, with a definite schedule for reducing the charges to reflect planned improvements to road durability. Congestion pricing need not raise political objections if toll revenues are used in part to compensate lower-income drivers, in which case congestion pricing would work to the benefit of all income classes.

In the long run, efficient pricing and investment for airports will

[25] I interpret politically unfavorable redistribution as occurring when a well-defined economic interest, such as the trucking industry, or a social stratum, especially a disadvantaged one such as the poor, is made worse off.

lead to higher user fees only for general aviation. Compensation could be provided by using some of the toll revenues to upgrade navigational aids at general aviation (reliever) airports. This would make these airports far more attractive to fliers driven from commercial airports by higher tolls. In the short run all aircraft would face higher user fees. Thus landing and takeoff fees should be initially set midway between current and ideal marginal cost charges, with a definite schedule for reducing the charges as additional runways are built or as technological aids are implemented. The losses to commercial travelers could also be softened by reductions in the 8 percent ticket tax used primarily to support air traffic control.

Current strains on federal and state budgets have put a damper on proposals that call for an increase in infrastructure spending. But the findings presented earlier indicate that efficient infrastructure investment, coupled with efficient pricing, will generally improve federal and state budget balances in the long run and will lead to an approximately balanced budget for those facilities where some congestion is optimal. Budgetary demands will be fairly minor in the short run because efficient pricing will reduce initial capital outlays and because these outlays will be made efficiently.

Privatization of Infrastructure Facilities

The objective of efficient infrastructure policy is to maximize the welfare of the public. Can this goal be accomplished in the public sector? Some analysts believe it cannot because policymakers typically pursue their own interests, which are frequently in conflict with the efficiency aspects of welfare maximization. Privatization of public infrastructure is therefore advocated on the grounds that policymakers will never implement efficient pricing and investment; efficient pricing and investment would be pursued only by privately run enterprises subject to competitive market forces.

In practice, of course, most parts of the country do not have alternative roads and airports that could facilitate competition. Thus privatization would typically amount to franchised monopolies with regulatory oversight.[26] It is not clear, however, that this type of market organization would improve on publicly provided and priced infrastructure. The argument is that substantial welfare gains would result from legislation requiring the public sector to implement efficient pricing and investment guidelines. Policymakers would not have to implement

[26] For a discussion of privatization of highways see Poole (1988); for a discussion of privatization of airports see Poole (1990).

these guidelines precisely in order to realize most of the benefits, nor would they have much latitude to adjust pricing and investment levels to pursue other objectives.

Shapiro and Willig (1990) have shown that privatization will not improve upon public enterprise unless the political system compelling public officials to pursue public interest objectives fails to reach a given threshold. In contrast, public enterprise could be superior to privatization if public officials have private information regarding the public impact of the enterprise activity.

A fundamental problem with privatization that could lead to serious inefficiencies is that it gives the owners and managers informational autonomy from the regulator of the enterprise. For example, the staff of Virginia's State Corporation Commission recently cited "a number of unknowns and uncertainties" as justification for holding up the progress of a private firm's plan to extend a toll road from Washington, D.C. to suburban Dulles Airport. Another problem is that to the extent that regulators have a final say over pricing and investment, they may not approve efficient levels. However, a privatized facility, such as a toll road, could be used as a demonstration project to show policymakers the effects of an efficient policy.

Privatization is starting to gain the attention of policymakers. But it faces obvious political obstacles and could be inferior to public enterprise. Nonetheless, the privatization movement has helped focus attention on the need to pursue more efficient pricing and investment policies. There is justification for believing, however, that these policies could be implemented effectively in the public sector.

Significantly Increasing Infrastructure Spending

A consensus has developed among many economists, some policymakers, and a large part of the public that capital investment in roads and airports must be increased substantially. The belief of most economists that public infrastructure spending should be substantially increased has been shaped largely by the work of Aschauer (1989), who finds that the decline in public works capital spending has been a major factor in the recent productivity slowdown. His findings suggest that large capital investments in public infrastructure produce enormous benefits.

My 1991 paper questions the accuracy of Aschauer's findings. His estimates imply that a one-time $60 billion increase in public works capital spending would achieve a benefit-cost ratio that exceeds 10:1 and would pay for itself in just one year. This return is implausible. Charles Schultze (1990) argues that Aschauer's findings simply demonstrate that the time patterns of productivity and public investment growth are

similar, and that this correlation generates grossly inflated estimates of the return to public infrastructure investment.

A fundamental flaw also exists in efforts to solve infrastructure problems by making substantial capital investments in new facilities or technologies, as can be illustrated by the following example. Pick any pothole-laden, congested, two-lane road in an urban area. Suppose public funds are used to widen the road to four lanes and repave it. Benefits will immediately flow from this investment in the form of faster travel time and less vehicle damage. But many travelers who previously avoided the road during peak travel periods will now find the road attractive to use. The short-term improvements will also induce irreversible decisions on land use and vehicle purchase. Before long the road will again fill to capacity and will steadily deteriorate. The corresponding social costs of congestion and road wear will be even higher than before the investment because more travelers use the road.[27] To generalize from this example, the money spent on new facilities or technologies would result in expanded transportation capacity that eventually faces the same problems as before but now requires even more money to "fix."

Although the empirical and conceptual basis for making large public infrastructure investments is highly suspect, this approach has generated interest in the social payoff from increased infrastructure spending. I found that the benefit-cost ratio for efficient investment in roads and airports is roughly 4:1,[28] and it can be obtained with only a small increase in annualized capital expenditures. Most importantly, efficient investment and efficient pricing will provide a long-run solution to infrastructure problems, a goal that cannot be met by just increasing spending.

Are Policymakers Interested in Efficient Infrastructure Policy?

My goal in this paper is to proselytize. I realize, however, that many will remain skeptical about the practicability of efficient pricing and investment until it is clear that some policymakers have been convinced.

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[27] The social costs on this road will be partly offset if congestion and road wear are reduced on alternative roads.

[28] Although the benefits from efficient investment represent Pareto improvements and Aschauer's represent productivity gains, this cannot account for Aschauer's benefit-cost ratio (10:1) exceeding the ratio for optimal investment by such a large amount.

To this point, a few have stepped forward and many are thinking seriously about it.[29]

The Bush administration has admittedly set back the cause of efficient policy. The National Transportation Plan (*Moving America: New Directions, New Opportunities*) mentions efficient pricing and investment in only a vague way, if at all, and usually refers to it in connection with inefficient policies.[30]

Although the Administration appears reluctant to take a clear position, it could pressure the states to implement efficient infrastructure policy. In fact, some signs indicate that the Administration would be willing to play this role. Secretary of Transportation Samuel Skinner has argued that if the states are forced to contribute a greater share of highway expenditures, then they will pay more attention to how the money is spent. The government has also proposed a plan that would enable airports to impose new fees to raise money, with the money to be spent only on projects that would increase capacity.

These proposals suggest ways the federal government could encourage highway and airport authorities to make more efficient investments. The authorities and the federal government would be better off if the federal government also encouraged efficient pricing. Many of the authorities would become financially self-sufficient, and the federal government's deficit would be reduced. The debate over each level of government's share of capital expenditures would become irrelevant. The challenge still remains to convince both parties that their interests would be served by efficient infrastructure policy.

Greater interest in efficient infrastructure policy is developing in Congress. A group of representatives, the "House Wednesday Group," has identified the Small, Winston and Evans (1989) proposal for efficient highway pricing and investment as a policy option in addressing highway needs.[31] Because Congress will be debating the Highway Reauthorization Act during 1991, this proposal could receive serious consideration. Legislation has also been proposed in the House that includes consideration of efficient pricing to reduce congestion in airport

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[29] In a highly misleading discussion of this paper at the conference, Alan Altshuler characterized the paper as claiming that efficient infrastructure policy would be implemented in this country. This claim is never made. In this section I do point out encouraging developments that would probably have been unimaginable when many economists began to advocate efficient infrastructure policies in the 1960s.

[30] For example, on page 5 it is stated, "For example, local passenger facility charges at airports and tolls on highways offer significant potential as financing mechanisms where there is heavy travel demand." I pointed out previously that passenger facility charges are inefficient; I cannot tell whether the highway tolls that are referred to would be based on efficiency principles.

[31] See its report *Highway Policy at a Crossroads* (1990).

system planning.[32] Congressional debate over newly proposed passenger facility charges might also provide an opening for efficient airport pricing to be considered.

The greatest encouragement thus far has come from individual states and transportation authorities. On January 1, 1990 Oregon implemented a system in which operators of heavy trucks pay a tax based on axle weight. The new taxes apply only to vehicles operated at gross weights above 80,000 pounds, but the Oregon Department of Transportation is very likely to recommend to the 1991 legislative assembly that this system be extended to lower gross weights.

Congestion pricing is beginning to receive support and interest from various government organizations in California. California Department of Transportation (Caltrans) Director Robert Best favors it, although the official position of the department is that it is still studying the possibility.[33] To this end, Caltrans and the Urban Mass Transportation Administration jointly sponsored a University of California conference on the effects of congestion pricing. In addition, the Southern California Association of Governments instituted a task force on market incentives for land use and transportation that recommended congestion pricing. It is now soliciting proposals for demonstration programs as called for in its latest regional mobility plan.

Various airports have also revealed interest in using the price mechanism to alleviate congestion. Some congested airports have implemented minimum landing charges for general aviation that exceed the inefficiently low weight-based fees. Logan Airport in Boston has gone a step further by significantly raising general aviation landing fees. This policy attracted attention because it was effective in reducing congestion, but it was found to be discriminatory and therefore illegal.[34] The final step is for airports to recognize that adoption of congestion pricing will legally meet the objective of reducing delay.[35]

The interest in and experimentation with efficient infrastructure policy has significant implications for its future. If axle-weight pricing is

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[32] See the legislation proposed by Representative Packard.

[33] See William Trombley, "Caltrans Embarks Upon the Road to Tomorrow," *Los Angeles Times*, July 24, 1989, p. 3.

[34] The revised fees at Logan Airport have been interpreted by some as an example of the political and legal failures of congestion pricing. But these fees were not congestion prices because they were not differentiated by time of day and because they were applied only to general aviation. Fees were actually lowered for larger planes to keep the plan revenue neutral; this added force to general aviation's charge that they were being discriminated against.

[35] Congestion pricing would not face the legal problems that arose at Logan Airport because the prices would be based on costs. Legislation would have to be passed to allow airports to increase the revenue they can raise from landing fees.

successful in Oregon, it could spur adoption by other states and the federal government. Similarly, if a few California cities and some airports adopt congestion pricing, other locales are more likely to adopt it. Given the absence of any other effective long-term solutions, this chain of events could be responsible for nationwide adoption of efficient infrastructure policy.[36]

Finally, the press is starting to become a source of support. In response to the National Transportation Plan, a *New York Times* editorial criticized Secretary Skinner for not advocating congestion pricing of airports and axle-weight taxes for highways.[37] California has also received editorial support for congestion pricing.[38] Favorable media attention would probably have been unthinkable a few years ago. This supportive publicity could bring efficient infrastructure policy closer to the center of the public debate and possibly persuade policymakers that there would be a political payoff from endorsement.

Taken collectively, these are encouraging signs that policymakers and the public will give efficient infrastructure policy serious consideration. But, as in the case of all policies, whether this consideration translates into adoption depends on the momentum generated. Thus far isolated instances of support are found, which could possibly grow into wider acceptance. But waiting for a gradual buildup of support among local, state, and federal policymakers almost surely means at least another decade of waste. It is time to seize the opportunity to improve the nation's infrastructure and at the same time husband scarce federal funds. Efficient infrastructure policy is an issue crying out for a leader.

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[36] Evidence from intrastate airline fares in California and from unregulated produce rates in trucking helped to convince policymakers that nationwide deregulation of airlines and motor carriers would lead to lower prices.

[37] See *New York Times* editorial, "Mr. Bush's Squeeze on Cities," March 11, 1990.

[38] See the editorials cited in Small, Winston and Evans (1989) p. 92.

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Discussion

*Alan A. Altshuler**

Clifford Winston has summarized well the case for economic "efficiency" in infrastructure pricing and investment, and nicely fleshed it out with some highway and air transport examples. Though I might quibble about a few supporting arguments,[1] I have no real disagreement with Winston on the merits.

Fortunately, though—since I might otherwise have been reduced to silence—Winston refuses to be contained by his discipline. He knows full well that for an economist to argue on behalf of marginal cost pricing and investment is scarcely big news. So he proceeds beyond the merits, to explain why he believes the political world may be on the verge of readiness to follow sound economic advice. In so venturing he captured my rapt attention. This *would* be newsworthy! But I remain unpersuaded.

Permit me to explain why, but then also to differentiate among the measures Winston recommends. It strikes me that they vary widely in potential feasibility, even if the political system continues to function about as it has for years.

The main points of evidence that Winston adduces in support of his political optimism are as follows:

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[1] For example, Winston suggests that congestion pricing would, by inducing some motorists to utilize transit, reduce transit deficits. In practice, transit patronage and deficits tend to rise in tandem, because rising demand tends to be accompanied by increased service and every service unit tends to lose money.

- When economists first began to argue for airline and truck deregulation in the 1960s, these ideas seemed as implausible politically as congestion pricing and the other key elements of "efficient" infrastructure policy seem today.
- The specific idea of an axle-weight truck tax has recently been adopted in Oregon, though only for vehicles operated at gross weights in excess of 80,000 pounds.
- Road congestion charges can now be levied by an automatic vehicle identification (AVI) system and periodic billing, like cellular telephone charges. Toll booths, with all the delay and inconvenience they entail, would no longer be required except for occasional users whose vehicles lacked AVI system capability.
- Toll systems need not be regressive. Lower-income drivers could be compensated directly, or the revenues could be used to support programs of primary benefit to lower-income people. Vested interests that are well-heeled might be won over in the same way. For example, general aviation interests would be first-order victims of a congestion fee system at major airports, but they could be compensated by use of some congestion fee revenue to upgrade general aviation airports.
- A few Congressmen and state and local officials, most notably in California, have recently expressed interest in the principles of "efficient" transportation policy. Several congested airports have actually raised their minimum landing fees for small aircraft, though only Boston's Logan Airport sought to implement "significant" increases and these were struck down judicially. Finally, *The New York Times* has editorialized in favor of airport congestion pricing and truck axle-weight taxation.

Two features of this argument stand out. First, the evidence cited is at most weakly suggestive. Second, it is one-sided. Winston, who states openly that his "goal in this paper is to proselytize," makes no pretense of weighing contrary evidence in the balance. Permit me to comment, then, on his points and to suggest a few others that seem pertinent.

The deregulation case is indeed a suggestive precedent, in that economists' arguments for efficiency eventually prevailed over some very entrenched interests. Reference to this episode can too easily become a mantra, however, like the phrase: "If we were able to send a man to the moon . . . ." With respect to the instant case, note that deregulation did not require politicians to take responsibility for any tax, price, or public expenditure increases. Its great political attraction was as an anti-inflation measure that required government simply to do less. Indeed, as John Kingdon notes, a key contextual element was Jimmy Carter's campaign theme of "getting government off your back" (King-

don 1984; and compare, more generally, Altshuler and Teal 1979; Derthick and Quirk 1985; Robyn 1987).

Oregon's adoption of an axle-weight truck tax may prove a harbinger of things to come. A couple of cautionary notes, however. Winston notes that the tax will apply only to vehicles with gross weight in excess of 80,000 pounds. This happens to be the federal Interstate Gross Weight Limit, and few states authorize higher loads at all without special permits. (Compare National Cooperative Highway Research Program 1988, Table B-l.) The Oregon tax will therefore affect a tiny proportion of commercial shipments. Large truckers have long been accustomed to paying higher taxes, fees, and tolls than the owners of lighter vehicles. They have also been egregiously undercharged relative to their impact on road wear, of course, but Winston does not provide any information on the magnitude of the new Oregon fees, or their relation to other motor vehicle taxes. Thus it is impossible to determine whether even this one state, with respect to this one trucking category, has taken a major step toward requiring heavy vehicles to pay their own way.

The technical barriers to congestion pricing have never been central. Singapore, after all, introduced its downtown area licensing scheme in 1975, and local planners recommended a similar scheme for Central London in 1974 (Altshuler 1979, p. 360). It is true that sophisticated systems, varying by time of day and route and extending far beyond downtown, were not feasible until recently. What I find most striking, however, is that only Singapore, a one-party quasi-dictatorship, has been able to implement any form of congestion pricing for a sustained period. I believe the only other city that has even ventured a pilot is Hong Kong. As for recent U.S. experience, New York City Transportation Commissioner Ross Sandler vigorously sought support during the late 1980s for a downtown area license/toll system. He made his argument not simply on grounds of efficiency, but also on grounds of public health and federal air pollution requirements. Technically, he had two major advantages. The Manhattan central business district is the most congested area in the nation, and the main vehicular approaches to downtown are already tolled. Sandler published a fine report, explained it in as many forums as possible, and persuaded Mayor Koch to chair the first set of hearings on this proposal. All to no avail. Business, labor, and nearly all civic groups were intensely hostile, and virtually no support appeared except from environmental organizations and a few academics. The idea quietly died.

We have another recent experience with recommendations to shape motorist behavior by price. The Clean Air Act of 1970 set precise ambient air quality standards to be achieved by the mid-seventies. Industrial processes and new cars were to be made to pollute less, and where these

measures did not suffice, others were to be called into play. Of these, the most promising by far were high gasoline taxes and parking surcharges. As the Environmental Protection Agency moved in 1973 toward imposing such charges, however, Congress voted to prohibit them. President Nixon vetoed the bill in question on unrelated grounds, but the EPA Administrator took the message to heart. All surcharges previously included in regional transportation control plans were immediately suspended. The prohibition on surcharges became law in 1974, nonetheless (Altshuler 1979, p. 195).

The energy crises of the seventies also generated widespread calls for the utilization of price incentives. Winston calls for a national leader to take up the cause. He might have been quite pleased in 1977 when a new President, Jimmy Carter, made reduced oil import dependency his single highest priority. Carter, who cited national security and prosperity as his justifications rather than mere congestion delays, sought an 11 percent reduction in national gasoline consumption between 1981 and 1985, to be achieved by the utilization of price signals. He recommended a tax on domestically produced oil, another on "gas-guzzling" cars, and a standby gasoline tax to be imposed if consumption exceeded the national target. The last was potentially the strongest measure. The standby tax was to rise five cents for every 1 percent that consumption exceeded the prior year's target. It never made it through a single congressional committee. In the end, the only Carter recommendation adopted was a watered-down version of the gas-guzzler tax, expected to apply at most to a few super-luxury European models (Altshuler 1979, pp. 136–40). Carter never recovered from the political backlash he stirred up with these proposals, and the idea of fuel taxation to conserve energy has never again been a serious item on the national agenda.

Winston calls for ingenuity in the structuring of efficient user fee and tax systems, to ensure that lower-income people are shielded from significant harm and that vested interests can be suitably compensated. Numerous advocates of fuel taxation to conserve energy have come up with such schemes, however, to no apparent effect. The public and media seem fiercely protective of existing arrangements. Even the advocates of high-occupancy vehicle lanes have learned from bitter experience to implement them only when new or contra-flow lanes are available, because the public reacts so negatively to having existing peak-direction lanes taken out of service.

While congestion pricing might in theory benefit everyone, one must recall that utility is a subjective matter. Many people fear that they would be driven from the roads during peak periods, others would pay but hate it, and still others would distrust any politician promising that new revenue will be used wisely. The media can be counted on to fan these flames when serious proposals are put forward. Those who would

be happy to pay for reduced congestion are few and too weakly motivated to become politically active. To my knowledge, they never have done so. As I have written elsewhere on this topic, I shall say no more here (Altshuler 1979, pp. 342–52, 355–69).

With reference to Winston's final point, that one can point to a few public officials and editorial writers who support efficient infrastructure pricing, who can doubt it? But how do their numbers and their levels of commitment compare to those who since 1973 have favored higher fuel taxes to conserve energy and reduce air pollution?

During the federal budget battles of recent years, various commentators have remarked that while tax cuts and spending programs have constituencies, there is no significant constituency for a balanced budget. Within most program areas, certainly including infrastructure, one can say the same about "efficiency."

Institutions are organized around key values. And the values around which the American political system is organized routinely conflict with efficiency. These include broad democratic responsiveness, the preservation of individual liberty, the protection of minority groups from majority tyranny, and avoidance of concentrated executive power.

The system's myriad checks and balances channel decision-making toward pluralistic compromise and logrolling. Its openness to popular sentiment, combined with its internal fragmentation and lack of control over the media, tends to preclude effective efforts to challenge ingrained public attitudes. (The courts can do so at times, particularly when constitutional values are at stake, but this need not concern us here.) Its direct democratic elements, which have been greatly strengthened over the course of the present century—nomination by direct primary, legislation by referendum, the decline of political parties, sunshine and citizen participation requirements, vastly increased mobilization of special interest groups—tend to sap both the will and capacity of elected officials to "educate" rather than "respond to" their constituents. On the whole, American politicians are more scared, more dependent on special interest support, more isolated from one another (in the absence of meaningful parties), and less confident of their ability to overcome gridlock on controversial issues than at any time in our recent history.

These are quite conventional points. They represent basic first steps, however, toward understanding why American infrastructure policy has been far more responsive to group pressures and broad popular attitudes than to efficiency arguments, and why it is likely to remain so.

This is not to say that progress toward efficiency in infrastructure policy is inconceivable. It is to suggest, however, that efficiency reforms are likely to fare very differently in the political arena, depending on the types of benefits they confer, which shibboleths they challenge, and

whose oxen they gore. There are not many guides to this estimation problem in which I have confidence, but here are a few simple ones. Reforms with narrow direct impact will be more feasible than those of wider scope. Reforms that call for business regulation and/or taxation will be more feasible than those that would be salient for large numbers of voters. The least feasible reforms will be those that would require politicians to take direct responsibility for imposing significant new charges and regulations on the mass public. The most feasible will be those that would extend familiar arrangements for easily understood purposes (for example, gas tax increases to finance new highways), and those that would confer large, easily understood benefits on well-mobilized groups without requiring politicians to antagonize many constituents.

What are the implications with respect to Winston's proposed reforms? First and foremost, I conclude that road congestion charges remain a political loser. The time to reconsider this judgment will be when some public toll-road authorities have eliminated commuter (read: peak period) discounts in favor of peak period surcharges.

Second, I judge that a shift in the basis of truck taxation from gross weight to axle weight, as Winston and colleagues have proposed, is quite plausible. This would amount to a modest revision of a long-standing arrangement. The more difficult question is whether trucking taxes will increase sufficiently under this scheme to bring about a major reduction in the implicit subsidy heavy trucks have long received. Here I have severe doubts, since the general nature of this subsidy has been well understood for decades. The problem is that commercial truckers are very strongly motivated to preserve this subsidy, while automobile owners and renters, who pay it, are very weakly motivated to oppose it.

Third, I believe that pricing strategies to alleviate airport congestion are forthcoming. Air traffic delays are of interest to large numbers of voters as well as to commercial airlines. It seems unlikely that runway and terminal expansion, or air traffic control improvement, will be sufficient to alleviate airport congestion in the face of rapid traffic growth in the decades ahead. The great question is whether the problem will become so severe that politicians are willing to challenge the general aviation lobby.

I doubt that Winston's proposed compensation scheme will discernibly mitigate general aviation opposition. It is not new. It has never worked before; why should it work now? Three easier paths to airport congestion pricing remain, however. One is simply to conduct periodic auctions of peak-period landing slots at congested airports, while reserving a percentage for general aviation. A second path would be to raise all landing fees proportionately in peak periods at congested airports, without requiring airlines to endure the risk of auctions. The

issue here would be to find an acceptable means of distributing the revenue—rebating it in the form of reduced fees during off-peak periods, using it to reduce other taxes, or using it to finance airport improvements. A third strategy would be for the federal government to deregulate in this area, giving state and local airport authorities wide discretion to manage congestion. This reform would be in tune with deregulation of the private aviation industry and with the Reagan-Bush New Federalism ideology. Within a decentralized framework, authorities in several of the nation's largest metropolitan areas would probably move quickly to adopt runway congestion pricing.

Finally, what about "optimal investment?" Winston's paper makes clear that this is a many-faceted topic. One can easily imagine the argument for thicker pavement that Winston and colleagues have developed triumphing fairly quickly. Pavement thickness is generally considered to be a matter for professional determination. Greater pavement thickness would not inconvenience anyone. And, if Winston is correct, this policy would enable government officials to take prompt credit for monetary savings as well as road quality improvements. Politicians will still be tempted to spread highway paving funds around more widely, but they are likely to accept clear engineering standards if these are forthcoming.

Optimal investment more broadly considered is another matter, however. In the absence of efficient road pricing, it does not make a great deal of sense to talk about optimal highway investment. And even if it did, Winston has not suggested any benefits that would be likely to induce politicians to give up pluralistic bargaining as the main basis for determining highway budget limits and distributing funds within them. Nor are airport authorities likely to build new runways as "rationally" as Winston suggests. Even where airports have land available, new runways generally stir major community and environmental conflict. Winston writes that noise pollution concerns might be met by arguing that additional runways would lead to reduced traffic concentration. The opponents would reply, of course, that increased runway capacity facilitates the accommodation of increased total volume. And they would be correct.

In short, there seems little reason to believe that economic efficiency is about to triumph in the infrastructure policy arena. But the political system is considerably more amenable to some reforms than others. Considerable waste motion may be avoided if one keeps hope in check while striving to discern which are which.

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Discussion

*Michael E. Bell**

These comments will highlight some of the important innovations in the Clifford Winston approach to how to think about infrastructure problems, some areas of possible extension of the author's arguments, and some concerns about how his approach might be applied to other categories of infrastructure (especially those categories relating to environmental protection) and about how the Winston solution might be implemented. In order to put my comments and reactions into perspective, however, I want to first give some background on the National Council on Public Works Improvement.

In the early 1980s, a number of studies raised serious questions about the condition of the nation's infrastructure and its ability to support continued economic development and promote international competitiveness (Choate and Walter 1981; Associated General Contractors 1983; Congressional Budget Office 1983; National Infrastructure Advisory Committee 1984). In response to the concerns expressed in those studies, Congress created the National Council on Public Works Improvement (NCPWI) to report on the state of the nation's infrastructure and to develop a strategy to ensure that this infrastructure will be adequate to support future economic growth and promote continued international competitiveness.

Throughout its two years of activity, the Council kept coming back to one fundamental question: If we as a nation had an extra dollar to spend, should we spend it on infrastructure rather than on health care, education, or the homeless? and, if we spend it on infrastructure,

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should we spend it on operations and maintenance or on new construction, and on what category of infrastructure? The Council recognized that increased investment in infrastructure is just one of many critical claims on the nation's resources. To respond to this and other claims requires coming to grips with the growing imbalance between consumption on the one hand and investment and saving on the other. This imbalance, reflected in the federal budget deficit and in other forms of borrowing against the future, affects all federal spending decisions (NCPWI 1988). Until this imbalance is addressed, the practical question remains how to ensure the maximum level and quality of infrastructure services given available resources, irrespective of whether or to what degree those resources might be considered inadequate. In other words, how can the nation spend limited resources on public infrastructure and avoid past mistakes of building canals or industrial parks that are not used?[1]

In pursuing this line of inquiry, the Council ran into a couple of major roadblocks. First, traditional needs studies provide no information on how specific physical infrastructure facilities are actually used. Rather, if a bridge is determined to be structurally deficient by the federal government it should be renovated to meet agreed-upon engineering standards, whether it handles 1,000 cars or ten cars per day. No useful information was readily accessible on the economic benefits provided by such facilities or, more importantly, the demand for infrastructure services.

Second, no analysis or data provided a link between actual dollar expenditures on new investment and/or operations and maintenance and the level and quality of infrastructure services resulting from such expenditures. For example, real per capita investment in public works decreased from 1965 to 1984 in absolute terms and relative to GNP, but real per capita spending on operations and maintenance increased over the same period at about the same rate as GNP. However, we cannot say how either trend affected the overall level and quality of infrastructure services being provided (NCPWI 1986). The lack of such a linkage is still a major impediment to extracting meaningful policy recommendations from analytical work that relates aggregate dollar flows of infrastructure spending to national productivity, gross state products, regional employment, or other measures of economic activity. Such macro studies can help make the general point that as a nation we need to spend more on infrastructure, but these studies provide little guidance as to how those expenditures should be allocated to obtain the highest level and quality of infrastructure services.

In my view, the Winston approach to analyzing infrastructure

[1] Examples provided by Joel Tarr during his oral presentation at this conference.

issues makes some significant contributions toward filling the informational gaps faced by the Council.

Major Contributions

One of the themes that runs throughout the work of the National Council on Public Works Improvement is the fact that physical infrastructure facilities, the focus of traditional needs studies, are not ends in themselves, but rather are important for the services they provide. Thus

> . . . from a public policy standpoint, it may be equally, if not more, important to consider the adequacy or inadequacy of a community's infrastructure based on the output, or level of service provided, as opposed to its physical condition alone. (1986, p. 12.)

This perspective on the infrastructure problem is a radical departure from the logic of traditional needs studies, but it is critical for developing meaningful policy initiatives because it opens the door to consideration of alternative, low-capital-intensive, means of providing infrastructure services. The Winston approach to the infrastructure issue is consistent with this perspective. For example, Winston states that ". . . efficient highway pricing and investment could dramatically improve the condition *and performance* of our roads and require only a small increase in capital spending." (Winston, this volume, emphasis added.)

Second, the Council found little evidence directly linking dollar expenditures on infrastructure investment, operation, and maintenance and the level and quality of service provided. The Winston paper explicitly links spending on capital investments and operations and maintenance requirements for highways and airports. Thus, Winston is able to discuss an efficient investment strategy and the implications it has for future maintenance requirements. This represents an innovative effort to systematically apply a life-cycle cost approach to questions of investment in and maintenance of the national highway network.

Third, recognizing that infrastructure services and performance are important and depend on how facilities are used, Winston makes efficient pricing of those services a central theme of his proposal. He differentiates components of demand and considers efficient pricing for both system capacity and durability. He extends the discussion of pricing to consider the implications of such an efficient pricing strategy for the demand for transportation services, how the delivery of those services might shift between modes of transportation as a result of changes in relative prices, and how the delivery of services might change in response to such price incentives by more efficiently combining private capital (multi-axle trucks instead of single-axle trucks) with public capital (highways). In essence, the approach moves toward a general equilibrium analysis of infrastructure issues.

Finally, the author raises legitimate questions about the benefits to be derived from privatization. The types of infrastructure categories discussed in the Winston paper, and by the National Council on Public Works Improvement, do have private good characteristics: for example, identifiable users who can be charged a price and excluded from using the facility or service if they do not pay that price. However, this does not create a competitive market for those services. Rather, as Winston points out, it creates a situation for a regulated monopoly that may or may not be efficient, depending on the extent of contestable markets, the incentive structure created by the regulators, and so on. He correctly argues that privatization is no panacea.

In my view, the analysis presented in the paper makes important contributions to the methods by which we should define, describe, and analyze infrastructure problems. Applying this approach to other categories of infrastructure, with a focus on services, how those services are priced, and the implications of that pricing strategy for how the services are provided, would indeed move the nation toward an efficient infrastructure policy. However, it is possible to extend this analytic approach beyond the discussion in Winston's paper.

Extensions of Winston's Analytic Approach

The first area for potential extension is the question of defining the output or product of expenditures on public infrastructure. For example, the author states that highways produce two "products": (1) traffic volume requiring capacity and (2) standard loadings requiring durability. Alternatively, he states that airports produce two "outputs": (1) commercial carrier operations and (2) general aviation operations. The highway definition focuses on physical characteristics of publicly provided capital, such as the number of lanes and pavement thickness. The airport definition focuses on services provided by the combination of public and private capital.

As mentioned above, physical infrastructure facilities are not ends in themselves, but rather they interact with private capital to produce a service. In the transportation area, public capital (roads, bridges or runways) interacts with private capital (cars, trucks or airplanes) to produce a service (mobility). That service, however, has a quantity and quality dimension. In the context of a Lancaster-type good, different characteristics of the service might be considered "products" to the extent that individual consumers value them differently. Durability, speed, and safety (for which pavement thickness and lane width might be possible proxies) are characteristics of transportation services that heterogeneous users might demand and be willing to pay for.

If one accepts the author's characterization that the products of

highways are capacity and durability, other attributes of the network might be considered equally important "products." For example, safety and reliability of the system are increasingly important as usage increases and the economy restructures itself to meet global economic challenges. In order to identify all such potential "products," it is necessary to understand fully the link between infrastructure and economic development. For example, if one accepts the argument, laid out above, that the service produced by the interaction of public and private capital is mobility, then public capital is seen to affect economic activity by complementing, rather than substituting for, private capital. In fact, empirical evidence consistent with this perspective is increasing (Eberts 1990; Duffy-Deno and Eberts 1989). Thus, public infrastructure can be considered an unpaid factor of production within a firm's production function (as an intermediate good) and the demand for infrastructure services is a derived demand that depends on the demand for the final product.

In this context, the elasticity of the derived demand curve is of interest. Assuming for the moment that factor inputs are used in fixed proportions, the derived demand curve will be more inelastic

(1) the more essential the factor input being considered;
(2) the more inelastic the demand curve for the final product;
(3) the smaller the fraction of total cost that goes to the factor in question; and
(4) the more inelastic the supply curve of the other factors (Friedman 1972, p. 153).

To develop an efficient infrastructure policy one must consider the impact of economic restructuring, both in the United States and globally, on the demand for and usage patterns of transportation infrastructure. This link between transportation and the economy is influenced by (1) changes in intra-firm production processes; (2) changes in the structure of the industrial sector, including both institutional structure and the types of products being produced; (3) shifts in the location of various economic activities; and (4) the increasing importance of the service sector in the economy (Bell and Feitelson 1989). For example, if one moves to a just-in-time production process, system reliability becomes important. One might invest in additional system capacity even if current capacity is not congested in terms of travel time.

In this context, the products of the transportation network (capacity, durability, safety, access to remote areas, and reliability) become important in identifying and measuring social benefits from transportation investment. Thus, when Winston argues that efficient infrastructure policy should equate marginal social benefits and marginal social costs, social benefits need to be interpreted broadly to include system and network effects as well as other attributes besides travel time and pavement thickness.

In addition to the definition of output, a second area for potential extension is the notion of efficient pricing. The author argues that users of infrastructure impose costs on themselves and others by contributing to congestion and by wearing out the infrastructure. Thus, his efficient pricing strategy contains a pavement wear charge to promote efficient investment and a congestion charge to regulate capacity. This characterization of the social costs associated with automobile usage ignores a major social cost, namely the environmental cost.

The automobile provides mobility and convenience that are particularly attuned to the American desire for personal freedom. As a result, the automobile dominates the nation's transportation network. Yet the automobile also threatens our quality of life by contaminating both urban air and the global atmosphere (Gray and Alson 1989). Transportation consumes more than 60 percent of all petroleum used in the United States and accounts for over one-half of all hazardous air toxins, including 40 percent of all hydrocarbon emissions and two-thirds of carbon monoxide emissions. As a result, automobile exhaust continues to come under fire from environmentalists (Wright 1990).

Gasoline prices in Europe and Japan are double or triple the U.S. price because of government levies that force consumers to internalize a greater share of the social cost of their behavior. Thus, to hold down oil consumption and the resulting hydrocarbon and carbon monoxide emissions, our pricing policies must be revised to reflect all energy-related costs (Gibbons, Blair and Gwin 1989). In this context, to be a truly efficient pricing strategy, Winston's pricing proposal should be extended to include a carbon or climate protection tax based on Btus generated from burning coal and oil (Ruckelshaus 1989). Such a tax could have a more profound impact on the demand and supply of transportation services than the road wear and congestion charges proposed by the author.

Implementation Concerns

I have two basic concerns about how the strategy outlined by Winston will be applied for both environmental protection categories of infrastructure and transportation. The first deals with the social acceptability of some of his suggestions. The second deals with the application of pricing schemes, common in transportation, to the environmental field where pricing is less common.

The computer industry is full of examples of technologically feasible activities that consumers have just not accepted, such as banking by telephone or personal computer. The congestion pricing scheme suggested by the author may encounter such public resistance. Some would argue that as a nation we have shown a willingness to make personal sacrifices for economic or other security. For example, some argue that our consti-

tutional rights have been compromised by unreasonable airport searches instituted to reduce the risk of hijackings. More recently, some argue that random drug testing in order to secure safer transportation services violates the same rights. However, it is not clear whether individuals will condone the government monitoring individual travel patterns, as suggested by Winston, in order to receive a more accurate bill for their use of the nation's highway network. Will such a monitoring scheme, although it may be technically feasible, be socially acceptable? While the jury is still out on that issue in the United States, it is my understanding that after an initial trial period, a plan to make such a pricing scheme permanent was voted down by residents in Hong Kong.

Assume for the moment that technically feasible means of pricing are accepted. An important implementation issue is how to adapt such fees to the environmental area. It is generally agreed that a pricing strategy similar to that outlined by Winston will improve economic efficiency. That awareness has contributed to the growing acceptance by politicians and others of the notion (or at least the rhetoric) of market incentives as one way to address emerging environmental problems—problems associated with a large number of relatively small, dispersed polluters in contrast to the traditional command and control approach of dealing with a single large identifiable polluter.

Attention is now shifting toward how such strategies might be implemented. One level of concern focuses on the winners and losers from these policy initiatives. Such distributional issues contribute to current difficulties in producing a clean air bill (Hager 1990; Levin 1990). Winston identifies and addresses some distributional implications of his pricing strategy and discusses some potential remedies. However, the issue is more troublesome in the environmental area. The objective of the "polluter pays" principle is to reduce the production, use, and discharge of substances that harm the environment, by equating price with marginal social costs (Winston, this volume). Thus, losers from such a policy could go out of business or incur significant cost increases. Compensation, based on such increased costs, could effectively mitigate the incentive effects of a more efficient pricing policy.

A second concern is the administrative and compliance costs of implementing such economic incentives. For example, for effluent fees to have a meaningful impact on polluting activity, detailed data are required on the industry's cost curves and total releases. My understanding is that no such analysis has been performed to analyze the impact of Super Fund taxes on the chemical industry, or to justify the levels of excise taxes on ozone-depleting chemicals.

More analysis along the lines of Winston's transportation work needs to be done in the environmental area. This will require that significant amounts of detailed data be provided by the private sector and analyzed by

regulators. In addition, the use of tradable pollution prevention permits will require monitoring and enforcement of individual permits, which may change hands a number of times (Feitelson 1990).

A final concern is with the overall effectiveness of economic tools as implemented through a political process. Recent studies provide evidence that some tradable permit schemes have not worked as anticipated and do not lead to more efficient outcomes (Hahn 1989; Malueg 1989). These failures may be related more to how the program was designed and implemented than to the effectiveness of economic instruments generally. However, it is important to consider whether such economic incentives would require fees that would be politically unpalatable if set high enough to affect the behavior of a firm or individual, when new materials represent only a small portion of the cost of most finished products (Levin 1990).

This raises a fundamental question about the political feasibility of implementing an efficient infrastructure policy as outlined by Winston. In his paper he addresses one narrow dimension of the distributional consequences of such a policy, namely how to allocate the revenues generated under an efficient pricing scheme to mitigate the cost to some of the losers, for example low-income highway users, those shifting to mass transit, and others who face a higher cost of obtaining transportation services. However, the paper does not address the larger, and politically more significant, distributional issue of compensating those who lose when expenditures in the transportation area fall from an estimated $20 billion to $25 billion annually to $5 billion or $10 billion as estimated by Winston.[2] It is not clear what motivation a politician will have to step forward and promote such economic efficiency.

Conclusion

In the final analysis, the approach toward infrastructure issues taken by Winston is fundamentally sound and should be extended to other categories of infrastructure. In order to develop the sustainable economic development strategy necessary to support the ten billion people who will inhabit the world in the next century, our consumption of goods and services, including infrastructure services, must reflect the total social costs associated with that behavior. Winston's efficient pricing proposal can play an important role in that strategy, but it must

[2] The presentation of the numbers in the Winston paper is somewhat confusing. For example, he talks about an increase in highway investment of $1.3 billion, but then he adds that to the estimated $1.5 billion total investment for airports. Similarly, Table 1 is misleading to the extent that it represents expenditures and savings in a future year without any discussion of the costs and savings that would be experienced before that year is reached.

be extended to cover total social costs, not just congestion, pavement thickness, or noise. Similarly, before specific policy recommendations can be made regarding future funding requirements, a broader concept of social benefits must be developed that will reflect the total benefits of an adequate transportation network in a changing global economy. Only then will the nation have a truly efficient infrastructure policy.

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How Should Public Infrastructure Be Financed?

*Edward M. Gramlich**

Projections of large, even astounding, infrastructure "needs" are commonplace. According to these projections of what is known as the third deficit, the nation has undersaved in its public capital accounts as it has undersaved in its overall national income accounts, and major reinvestments are required to get back on track.

While the share of national output devoted to public capital investment has undoubtedly declined, it is another matter to argue that this investment share must be quickly recouped. Moreover, the notion of infrastructure "needs" is inherently uneconomic—who needs what, who is willing to pay what price? Hence this paper examines these needs from an economist's perspective, not so much to assess them as to ask who might pay for any added infrastructure investment and under what payment scheme. The paper is, in a word, about public sector payment schemes, not about quantitative amounts of investment.

It makes sense to confine attention to capital needs that are truly public: anything other would fall in the domain of the private sector and be the responsibility of private investors. The subject can be further narrowed to the public capital needs of state and local governments, for the simple reason that the federal government does not really make many direct domestic public capital investments in the United States. Apart from pork barrel dam projects, which are on no one's short list of national needs, the federal role is to give grants to state or local governments for capital purchases, and the main policy suggestions involve changes in the structure of these grants.

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The paper uncovers many instances where present laws provide incentives that seem deficient from a social point of view. For the most part, these deficiencies are simply identified and explained. No attempt is made to discuss why the incentives or disincentives were created in the first place. Such discussion would prove very valuable in making policy changes, but it is beyond the scope of this paper.

The paper goes through some normative considerations on how various types of public capital spending *ought* to be financed from the standpoint of orthodox canons of public finance. Each section then asks whether these normative considerations call for any major policy changes at either the federal or state and local level. The last section of the paper collects the main policy suggestions.

Types of Infrastructure Capital

The types of incentives that should be used for state and local public capital spending depend on why the public capital is desirable in the first place—whether this capital serves allocation or distribution purposes, whether spillovers occur, whether user fees can easily be assessed. Since different types of capital vary widely on these grounds, it makes sense to discuss the types separately. Broadly speaking, three types may be discussed:

- Local allocation: This type of public capital serves local needs where minimal interjurisdictional spillovers and minimal distributional implications are found.
- Local allocation with spillovers: Like local allocation except with benefit spillovers from one jurisdiction to another.
- Local allocation and distribution: Now public capital serves goals that importantly affect the distribution of income in the long run.

In distinguishing these types, two notions are particularly important. The first, interjurisdictional benefit spillovers, can be defined very simply. When community A builds a public facility, benefits spill over into community B, when some of its households are better off; examples include public roads or clean water and air treatment facilities.

The second, whether the public facility has long-term distributional implications, is trickier. By this, I do not mean that paying for the public facility has distributional implications: obviously any payment scheme will shift charges from one taxpayer to another and have short-term distributional implications. Rather it implies that the public facility promotes human investment and enables recipients to improve their long-run income prospects. The main examples of this occur in education, either local public schools or state university systems. Health

facilities would qualify as well; I will not discuss them because in the United States today the financing of health care facilities is by and large private, supported by massive federal insurance schemes that have their own special problems.

Local Allocation

When public capital satisfies only local needs with no particular distributional implications, orthodox microeconomic reasoning says it is efficient to provide the service with user fees. Were this not done, taxpayers would be taxed on a basis that is only coincidentally correlated with their own taste for the service. Economic inefficiency is minimized in switching to a regime where all consumers equate their marginal benefits with marginal costs, which then implies that the sum of marginal benefits equals the marginal physical costs of production. The classic example where such a scheme could prove workable is a public park system.

Even here, of course, the example might not be perfect. For one thing, while consumption of services from public parks cannot be said to be importantly related to future income prospects, some desire to make sure all consumers regardless of income get to consume some amount might warrant a general consumption subsidy. For another, the public service in question might be a so-called natural monopoly with falling average costs; again a fixed cost subsidy would be warranted. But these exceptions only moderate the degree to which user fees can pay for the cost of the facility; some user fees are still almost always an efficient financing device for this type of public service.

Another predominantly local service without distributional implications involves that new plague on most large cities—local landfills. Landfill costs are rising rapidly, and many localities are facing enormous capital expenditures simply to continue burying their trash. Many local politicians are toying with mandatory recycling schemes, and user fees would be a nice complement to recycling and a way of paying some or all of the landfill costs. Local governments could make households pay according to the volume of their own solid waste, by buying specially designated garbage bags if necessary. Confronted with this price, households will be more likely to voluntarily recycle newspapers, yard wastes, and the like. The city gains a source of revenue to pay for solid waste disposal, and the marginal benefits and marginal costs of landfill expansion can be brought into equality.

The main problem of moving to a regime where households actually pay for trash disposal is enforcement—what is to prevent households from just dumping their garbage? One thing that might prevent households from such dumping is a low disposal price, and if cities could start

assessing user fees now before the problem is serious and land becomes even scarcer, the enforcement problem would be less (it would have been less still, had user fees been in effect for the past thirty years). Beyond that, if communities have a serious enforcement problem, the best solution may be to pick up garbage without charge and pay for recycling. Such a scheme is costly, but it at least encourages conservation and recycling by maintaining the proper relative price structure.

Some types of local allocation goods have no feasible way to impose user fees—police cars, local streets, and perhaps the fixed-cost portion of natural monopoly public services. The American way is to pay for these costs by the local property tax. Without spillover benefits, calls for grants from higher levels of government are unwarranted. The services are local, the benefits are local, and the payments should be local.

Hence the major problem with present arrangements seems to be the public service areas such as landfills, where marginal costs are high and localities are facing large capital outlays. The obvious solution is to charge user fees. These fees might be fairly high, because of high marginal cost. While the high user fees may be unpopular, the culprit is not the idea of a user fee itself but the fact that many cities have allowed the problem to fester so long, charging households far too little to use landfills and encouraging "waste" and overuse, and now find themselves in a bind. The circumstances are regrettable, but for the solution, better late than never.

Local Allocation with Spillovers

The next step is to extend the analysis by assuming that benefits from the public service are partly internal and partly external, realized in other communities. Prime examples are national roads, wastewater treatment, or clean air facilities.

Again if feasible, the user fee solution is optimal, and this time it even solves the spillover problem. Suppose a road is being built from city A to city B. Assume either that fixed costs are minimal or that they can be amortized into the toll. This toll can be set to equal the marginal cost of use of the road, presumably more for heavy trucks, again with the property that every user equates marginal benefits to marginal costs. (Small, Winston and Evans 1989 discuss a set of such schemes.) Spillovers are dealt with automatically because if some driver desiring to use the road happens to be from out of state, that driver automatically pays. Out-of-state consumers of goods shipped by truck also pay.

But things are not so easy if user fees are costly to assess. Urban beltways might fall into this category because while toll gates can physically be constructed, the stop-and-go time loss can mount up (as any motorist skirting Chicago can attest). New technologies to deal with

this problem may be available, but until such technologies become widely feasible, various other schemes can achieve rough justice.

One scheme, following the classic prescription for the spillover problem, is for jurisdictions simply to join together to deal with spillovers, using regional special districts to conduct the same functions. Many large cities have such regional authorities for subways, ports, power, water, and public schools. The authority can plan and operate the service and assess fees that correspond to user benefits, and no higher government intervention is necessary.

Should these regional authorities not prove feasible, the higher government—hereafter the federal government—can step in and provide matching grants for the service. Ideally the federal matching rate should correspond to the percentage share of out-of-jurisdiction benefits, or approximately the share of out-of-jurisdiction use. Superficially many existing federal capital grant programs appear to be patterned after this rationale, but most of these existing federal matching grants have matching ratios that are 80 or 90 percent federal, 10 or 20 percent state. For the interstate highway system, for example, the federal matching rate is 90 percent and Department of Transportation (DOT) estimates of interstate travellers indicate that on the average interstate highway only 30 percent of the traffic is out of state. The typical state receiving a 90 percent subsidy when the external use ratio is only on the order of 30 percent will obviously expand use of the matching grants, with the consequence that the federal capital grant must be, as all now are, capped to limit use. But capping means no federal spending incentive at the margin, which in turn means that non-user-fee-financed federal roads are under-provided despite the generous initial federal matching.

The efficient solution is to return funds to states in the form of uncapped or open-ended 30 percent federal matching grants rather than capped 90 percent federal matching grants. The recent DOT report (1990) calls for part of this remedy—lower federal matching shares—but does not advocate removing the caps. I have previously estimated that were both changes made, total highway spending would be increased, economic efficiency would be improved, *and* the federal government would save money, all by noticeable amounts (Gramlich 1990). The key point is to alter federal grant incentives such that states have a price incentive to provide the right amount of highway spending, rather than to put a quantity limit on the grant.

Similar comments can be made about virtually all federal categorical capital grants. Inframarginal federal matching shares are higher than the likely out-of-state benefit spillover rate, the grants are capped, and capital is under-provided. The same is true of categorical grants in both Canada and Australia—the problem seems endemic in a federal struc-

ture. Exactly why the problem is endemic is unclear, perhaps because politicians realize greater gains in dispersing (and being lobbied for) a few large grants than many small ones. But whatever the cause, remedying this structure of matching rates would go a long way to providing proper subnational government spending incentives and cutting back on federal grant spending. To the extent that states would now have to pay more on average for facilities, they would have even more monetary incentive to find and levy efficient tolls, or user fees that are related to the true use of facilities.

A few topics require special comment. Airport capital spending is now financed by a federal ticket tax returned to localities in the form of capped 80 percent federal grants. Airport use studies are not as commonly cited, but surely 80 percent is again too high. If airports were given control of their own user fees, or if grants were made open-ended at a lower federal matching rate, airport spending could be encouraged and federal net spending could again be cut. To the extent airports need more funds to pay for their facilities, they could make stronger use of landing fees, especially at peak-load times. Landing fees would have the added advantage of cutting peak-load airport use *and* the need for airport expansions. Price signals can be a powerful force if used properly, and they really have not been for either highway or airport grants.

Efficient solutions are available for both highways and airports because it is possible to finance most capital needs with user fees. In other cases where the user fee approach is costly or difficult, financing questions become more difficult, but the same comments apply to federal capital grants. One such grant is for wastewater treatment, where it is costly to monitor the volume of household use. These facilities will presumably have to be financed by state or local general taxes, though federal matching rates should again be lowered and the grants uncapped. Clean air legislation is moving in the welcome direction of greater use of price incentives through resalable emission permits (Tietenberg 1988), but it would again make sense to finance some of the large capital costs by open-ended federal grants at low matching rates.

The bottom line is that while capital needs may be large, the real problem is that the country simply has not designed proper price incentive schemes. The preferred solution is to restructure, but not necessarily increase, federal grants in combination with much more vigorous use of user incentives at the state or local level.

Local Allocation and Distribution

Complicating matters again, now assume that whether or not benefit spillovers exist, the local capital stock in question also serves

long-run distributional needs. The standard examples are local public schools and state university systems.

The question of local public schools has always proved key in such discussions, partly because schooling does promote long-run economic opportunity for the recipients, partly because schooling is simply so large. In recent years, purchases for public schools have accounted for one-third of all state and local purchases in the United States.

Two basic democratic assumptions dictate the financing problems of public schools:

- Public schools are maintained and operated by local school boards, keeping the power of determining curriculum and so forth close to the people.
- As a matter of democratic right, public schools are free of charge. Since no form of user fee is possible, and since the main local tax in the United States is the property tax, public schools are essentially financed by local property taxes.

But they are not necessarily entirely financed by local property taxes. As is by now well-known, since communities vary widely by property wealth, a common-rate property tax applied across all communities will lead to widely varying levels of expenditure per pupil. Putting it differently, the tax price of a unit of educational services varies widely by community—higher in poor communities and lower in rich communities. Many state courts have argued that this varying tax price violates the "equal access to education" provision and have mandated states to come up with what are known as "district power equalization plans" to reduce the intercommunity variation in the tax price of public schooling.

It might first be noted that while the district power equalization problem has arisen for local public schools, in principle it could also arise for any of the non-user-fee local services discussed earlier. One difference is that public schooling is perceived to be the pathway to eliminating income differences in the long run, more so than, say, local streets or police cars.

A second matter arising is *how* states might correct unequal tax prices. The answer is once again by open-ended matching grants, where the state matching rate varies inversely with community taxable wealth. Feldstein (1975) worked out a simple model to show how this could be done: the state matching share is made inversely dependent on community wealth so that the full effect of wealth on education spending averages out to be zero across communities. Like the federal categorical matching grants discussed earlier, these state grants must be open-ended to influence tax prices at the margin. But now the matching rate is not related to benefit spillovers, as before, but to community wealth.

While public schooling is largely viewed as a matter between states and localities, the federal government enters in as well:

- The federal government has a limited amount of Chapter One grants for underprivileged school districts; as usual, they are capped, with high federal matching shares.
- The federal income tax permits deductibility of local property taxes, which works *against* power equalization since many more taxpayers itemize deductions in wealthy than in poor communities.

The appropriate policy toward education expenditures depends on one's goals. If the goal is simply to raise spending on public schooling, federal policies might be left unchanged and state schooling grants, matching and uncapped, should be provided to all schools. If, on the other hand, the goal is to improve poor schooling in underprivileged areas, a more complex set of remedies is called for:

- Federal tax deductibility should be abolished, as a fundamentally disequalizing measure. A large federal revenue gain would result from this change, and some of the funds might even be devoted to other education measures (Gramlich 1985).
- Federal Chapter One grants to poor schools should be reformed as suggested above, by removing the cap and lowering the federal matching rate.
- State power equalization plans must be substantially strengthened until they eliminate much of the variation in local tax prices.

The other important type of public spending with long-run distributional implications is higher education, operated mainly by state governments. Here the states can impose user fees, in the form of tuition charges, and no reason exists in principle why these user fees cannot cover the full cost of higher education. No state charges user fees nearly high enough to cover full costs, but some do assess full cost user fees on out-of-state students.

Whether user fees are full cost or not, higher education has become very expensive, and this just pushes the financing question down a rung. That question now becomes either how state legislatures can afford higher education (if user fees do not cover the full cost), or how families can afford it (if user fees cover a major share of the cost).

Families have basically two options—prepayment or postpayment. The tried and true prepayment scheme is for families to save up and pay for tuition. Since even many high-income families cannot manage to do that, some states are now experimenting with forced saving schemes, whereby a family would buy a contract when the prospective student is young and the money would accumulate. The price of the contract then

varies inversely with the interest rate and positively with the anticipated rate of growth of tuition. Any number of technical problems may emerge with such plans (Lehman 1990), and it remains to be seen whether they can resolve the financing problem satisfactorily.

The tried and true postpayment scheme is for student loans, though these have at least two problems:

- High default rates.
- The possibility that high payment obligations constrain the career choices of graduates.

Schemes that would make payback amounts income-related have also been discussed, but these too are still untested (Reischauer 1988). As earlier, present payment schemes operate on top of a small Pell grant federal program that provides grant assistance to very poor students, but Pell grants have not been, and are not likely to be, much help for students with incomes above the very lowest levels.

Of all the financing problems, then, those involving education seem clearly to be the most serious. At the elementary and secondary level, exactly how serious depends on whether the problem is felt to involve education spending in general, or just the education received by low-income children. Even if just the latter, state power equalization plans have to be significantly expanded, and the federal revenues that could be saved by eliminating local tax deductibility provide one possible revenue source. At the higher education level, the needs will be large too, and here new schemes might be required to help families pay their user fees.

Timing Issues

The discussion thus far has been timeless—concerned with which groups should pay how much for what facility. At this point timing questions need to be considered.

Whether the project involves local allocation goods, local allocation with spillovers, or distributional implications as well, the basic normative longitudinal principle is the same as the normative cross-sectional principle—those who benefit should pay. Under this principle, capital expenditures should be financed by long-term bonds with maturities close to the natural life of the structure. User fees or taxes should then pay annual depreciation expenses plus the interest and principal on the bonds. When the bonds are retired, new ones can be floated and the structures rebuilt.

Many states and localities have provisions in their constitutions that permit these kinds of arrangements for bond financing of capital

spending. By this standard, states and localities seem to follow fairly conservative spending practices; durable goods purchases and construction expenditures typically run about 15 percent of total state and local spending, while the overall general government surplus or deficit is typically close to zero (apart from the large, but independent, cash surpluses of employee trust funds).

One might carry the argument over to the federal level: if state and local capital spending should be bond-financed, why not federal capital grants? In principle, they should be. In practice, to do so would raise the ugly specter of federal capital budgeting, something that horrifies most Washington budgeteers. So many capital budgeting questions can be found at the federal level—what to do about depreciation on defense hardware or grants, on human investment programs, funded or unfunded social security liabilities, funded or unfunded saving and loan deposit liabilities, and so forth—that it would be impossible to raise the capital grant issue without getting into all the rest of the capital budgeting problems, many of which do not have clear solutions. Since federal capital grants to state and local governments are now only about 4 percent of federal spending, this would be a case of having the capital grant tail wag the federal budget dog. Moreover, federal policy-makers have assured that the federal budget deficit is *much* greater than federal capital grants—if it makes anybody feel better, these grants can easily be considered to be bond-financed right now.

To summarize these timing issues, no need or reason exists to change anything. One can make a strong normative argument for bond financing of capital spending at the state and local level, and generally present institutions are set up to accommodate the argument. One could make a theoretical argument for the same treatment at the national level, and while institutions are not set up to accommodate the argument, actual practice has more than provided the requisite bond financing.

Trust Funds

Both at the federal and at the state and local levels, much infrastructure investment is financed by dedicated trust funds. Governments often devote, say, gas tax revenues to a trust fund to finance highway construction. At the federal level, five such trust funds are in operation—for airports, highways, aquatic resources, harbors, and inland waterways.

These federal trust funds have been the focus of much discussion because all five are now running surpluses, amounting to about $2 billion a year. Lobbyists for the affected type of investment have made the predictable calls for taking the trust funds off budget, so that overall

Gramm-Rudman-Hollings-type spending limitations would not constrain spending. A set of deeper considerations also exists about why dedicated federal trust funds should have been established in the first place.

From a normative point of view, trust funds do seem to be a useful way to tie marginal benefits to marginal costs when dedicated taxes or user fees can be assessed and when no externalities are present. In this pure case, one budgeting sub-constraint is that the user fee revenue must cover spending over time, a sub-constraint that can be ensured by the trust fund arrangement. Even in this case, however, no good reason is evident for taking the trust fund off budget, at least if the federal budget is supposed to measure total federal spending.

But suppose externalities are present. On one side, it might be that the type of spending under consideration contains enough external benefits that a subsidy should be provided. The more relevant case for federal trust funds is on the other side. Say a tax, the federal gas tax for example, is assessed to pay for highways and devoted to the highway trust fund (as now). But in part this tax might also be assessed for general energy conservation purposes, or because it is viewed as an efficient way to finance overall federal non-highway spending. Then either the gas tax must be split between the highway trust fund and general revenues, or the highway trust fund should run at a substantial surplus. The debate inspired by Senator Daniel P. Moynihan suggests that it is so hard for the political world to understand why a trust fund should ever have a surplus (even when, as in the case of Social Security, a perfectly good reason exists), that the trust fund mode may become an impediment to sound fiscal policy.

That is not the only problem with the trust fund mode. For reasons that are not entirely clear, four of these trust funds—for airports, highways, inland waterways, and harbors—contain provisions whereby some of the spending is financed by general revenues (Congressional Budget Office 1989). In the case of highways, 15 percent of the spending is so financed, for airports one-half, for harbors two-thirds, and for inland waterways almost all spending. This arrangement seems to achieve the worst of both worlds: the subsidy encourages overspending, and the phony surplus energizes lobbyists who argue for still more spending. The proper remedy would be either to eliminate the trust fund (in cases where externalities are important), or to make sure that dedicated taxes or user fees finance all spending (in cases where externalities are not important).

Of the five federal trust funds, the fund for aquatic resources is now in balance; dedicated taxes or fees cover all spending, leaving a minimal overall surplus or deficit. The funds for airports, inland waterways, and harbors should be corrected by eliminating the general fund financing

and increasing user fees or dedicated taxes to cover all spending. Making these changes, and the further changes in matching provisions suggested above, would lower the overall federal deficit by about $5 billion a year. The Department of Transportation (1990) also suggested an expanded use of trust funds and dedicated user fees for the Coast Guard and railroads. Putting these operations in trust funds, with their own designated source of finance, could whittle the federal deficit by another $2 billion a year.

The case for the highway trust fund is the most interesting. The matching provisions should be changed as in the other trust funds. As for revenues, it would take an increase in the federal gas tax of about $.08 a gallon, for $8 billion, to cover all federal highway and transit spending. Were the trust fund mode preserved, this would be the minimum added revenue requirement. But, as mentioned above, one could easily argue for a higher federal gas tax increase on the basis of overall budget or conservation needs. In this case the easiest thing is probably just to get rid of the highway trust fund, or at a minimum redraw the treaty on how much of the gas tax is devoted to the trust fund.

Constraints

In addition to the matching provisions discussed above, federal grants often come with a number of other strings attached. For example, it has long been argued that federal capital grants suffer by being just that—grants for capital construction instead of grants for services provided (Schultze 1974). Various constraints also are placed on the types of user fees the recipient authority can assess. Although some of these constraints have been relaxed lately, it would seem to make sense to remove most of the constraints that force lower levels of government to use grants only for capital purchases or new construction, or to raise money in certain ways. Why not let states and localities decide for themselves how money is best raised and spent?

The highway trust fund contains an additional constraint—apart from bridges, highway grants cannot be used to finance construction of toll roads. In recent years, provisions added to the basic highway legislation have lifted this restriction in selected cases (ironically, with 35 percent federal matching in these cases), but why not just lift the provision universally? States have to finance their own share of highway expenses; why not simply let them decide whether to finance through a toll, a gas tax, or some other scheme?

Constraints could make sense when they achieve valid public purposes. As a general rule, that condition does not appear satisfied for most constraints on present-day federal grants.

Policy Changes

The previous discussion has compared the normative arrangements one might set up to deal with infrastructure financing with existing arrangements. Several important policy changes emerge from that comparison. Many of these suggestions are quite radical, compared with those usually made in Washington budget discussions. The justification for making radical suggestions is that even if they are not adopted, it is still helpful to know the directions in which changes should be made. Of course it should be understood that any steps in the right direction are just that—intermediate or piecemeal improvements are certainly to be welcomed.

Federal Level

Perhaps the most important suggestion at the federal level is that the trust funds that now finance many of the capital grants for infrastructure investment should be reorganized.

- All spending for the relevant function should be financed by user fees or designated taxes; the general revenue subsidies should be ended.
- Grants should be altered, with much lower federal matching rates (reflecting actual use shares) and with the caps eliminated, so that spending is subsidized appropriately at the margin and lower levels of government have more pressure to levy efficient user charges.
- Restrictions on how funds are raised or whether they are used for capital or maintenance expenses should generally be eliminated.
- In some cases, such as the highway trust fund, either the gas tax should be increased enough to generate a surplus in the fund, the gas tax should be shared between the fund and general revenues, or the trust fund arrangement should be abolished.

The next set of issues involves federal provisions that affect education:

- Again, those matching grants devoted to education and training should carry lower federal matching rates and be made open-ended.
- Depending on objectives, the federal tax deduction for state and

local taxes might be altered. This deduction might be left alone if one's goal is simply to raise spending on education, but if one's goal is to let poor districts consume public education on more equal terms with rich districts, the tax deduction should be curbed or eliminated.

State Level

The most important policy improvement at the state level is to enhance power equalization formulas so that rich and poor districts can in fact consume public education on more equal terms. Improvements in state power equalization schemes would satisfy both the goals of increasing and of equalizing spending on public education: mainly they should increase spending by poor school districts.

The policy choices for higher education are not so clear. One option is for states gradually to withdraw from public funding for higher education, letting state universities raise in-state tuition. Were this to be done, states would probably have to improve the capital market for higher education by enhanced prepayment or postpayment schemes. The other option is for states simply to continue present arrangements, recognizing that the growing relative cost of higher education will make such arrangements increasingly expensive.

Finally, states too have trust funds to finance capital spending, and the general comments would be the same as at the federal level. To the extent that user fee financing of the relevant type of spending falls short of efficient levels, it should be enhanced.

Even after such enhancements, it should be noted that the whole package of measures suggested here is likely to cause an increase in state government deficits. Certainly altering the federal grant matching rates in the way suggested and enhanced district power equalization schemes will work in this direction. This ultimately reflects the fact that compared to an efficient set of payment schemes, state governments now benefit. In part, states might restore their budget positions by pressing harder for user fees that reflect true wear and tear. Beyond that, were there a desire to hold states harmless, other fiscal adjustments would have to be made, such as changing the terms of finance for public assistance or Medicaid, or restoring some general revenue sharing.

Local Level

The main suggestion for local spending involves their new plague—landfill dumps. The large marginal costs have to be paid. Conservation and recycling at the household level should be encouraged, not by a set of mandates, but by a set of user fees that make households pay the true

cost of their own solid wastes. Such a scheme will both finance a major part of, and cut down on, the net landfill expenses faced by local governments.

Conclusion

All of these measures address the basic infrastructure investment problem now faced in the nation, the shortfall in public capital investment. But none of them do that by simply "throwing money" at the problem. The common theme is simply to get the incentives right. When that happens, aggregate government spending and/or budget deficits are as likely to go down as they are to go up. Ultimately, the shortfall is more a deficit in sensible payment schemes than in aggregate money spending.

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Discussion

*Rudolph G. Penner**

Having very much enjoyed Edward Gramlich's paper and finding little with which to disagree, my comments will elaborate on a problem that he mentioned only briefly—the problem of capped grants. They clearly illustrate how difficult it is to design an efficient grant system when decision-making is severely constrained by political considerations.

Why are federal grants and subsidies, whether for infrastructure or other purposes, often structured so differently than the ideal grants described in public finance textbooks? To an economist, the whole purpose of a grant or subsidy is to affect marginal decisions, but many federal programs do not do that and are very likely to provide large lump sum windfalls to someone who would have engaged in exactly the same activity in the absence of the grant or the subsidy.

The typical patterns alluded to by Gramlich can be described as follows. A law is passed that creates a large set of people or projects eligible for assistance. The assistance is described by a formula that provides a very generous per person or per project grant. The budget then created for the program is sufficient only to fund a small portion of the eligible population or projects, and the scarce funds are meted out by a rationing mechanism that is often controlled by the bureaucracy.

In theory, the project selection process might target scarce funds precisely on the marginal decision, such that the windfall component, which we economists know must exist in almost every subsidy system, is minimized. Frequently, quite the reverse occurs. In credit programs,

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which I know best, the rationing bureaucrat is often judged by the default rate within his or her programs and, therefore, the scarce funds are likely to be concentrated on the most creditworthy, eligible borrowers—the ones most likely to be able to borrow in private markets without government assistance. With regard to physical projects, the grants often go to the jurisdictions hiring the most able grantsmen or those mostly likely to perform well on the project—not those who, by some standard, need it most. During the height of the Great Society grant system, it was New Haven, Connecticut, that became famous for its ability to extract money from the federal government, while I never heard of particularly skillful grantsmen coming from, say, Biloxi, Mississippi, unless they happened to have moved to New Haven.

So the design of many grants makes little economic sense, the results are often perverse, and yet, as Gramlich points out, these perverse characteristics are pervasive. They exist in a wide range of U.S. programs from housing to highways, and they exist in the federal systems of most Western democracies.

If something so irrational by economic textbook standards is also so pervasive, something important must be going on. If the force that is at work could be identified, a paper might be written called "Why Gramlich's Sensible Suggestions Will Never Be Enacted." If a natural tendency exists for the design of grant systems to be fundamentally flawed, such a fact is of vital importance to the topic of this conference, because it severely limits the ability of higher level governments to induce lower level governments to exploit beneficial spillovers.

In discussing these issues with legislators, it becomes clear quickly that many results that seem wildly perverse to an economist often seem quite acceptable, indeed desirable, to legislators. Examples of this phenomenon will be described later, but first it should be noted that what Gramlich calls capped grants—I prefer to call them rationed grants—have an evil effect not noted by Gramlich. Many are very susceptible to corruption. Indeed, some beg to have money stolen from them. The recurring cycle of scandals in the Department of Housing and Urban Development (HUD) is, in my judgment, due in no small part to the rationed nature of grants under most HUD programs. The design of the subsidy has a two-pronged effect. First, the rationing mechanism often gives enormous discretionary power to bureaucrats and low-level political appointees who are susceptible both to bribery and to political influence from above. Second, the extreme generosity of the per project grant makes it worthwhile to try to steal from the program.

Why, then, are programs with such bad and inefficient results so popular with legislators? First, the programs can be very seductive because they often convey a great deal of discretionary power to the bureaucracy and to the legislators on the appropriate subcommittees.

People do like having power. But I am one who usually defends politicians and bureaucrats against the charge that they are power-hungry people. They are not completely crass. Most truly believe in public service.

Rationed grants are also politically appealing because they reduce the uncertainty facing politicians. If Gramlich's truly open-ended, low cost-sharing grants were used, the government would be uncertain as to total costs and the geographical distribution of the funds. Bureaucratic discretion in determining the latter is often constrained by formula, and when a generous subsidy is combined with a limited budget, the government knows with virtual certainty that no more or less than all of the spending authority will be spent.

The combination of rigid control that reduces uncertainty and discretionary power that varies from grant to grant is very seductive. When the advantages of rigid control are put up against the advantages of economic efficiency, the former generally wins. But perhaps this is largely because the noneconomist designers of grants are often unaware that they are inefficient. Since ignorance can be overcome, the situation most likely can be improved.

It is strongly believed by most that corruption is created by evil people and not by evil incentives. The media encourage this belief by focusing investigative reporting on the colorful individuals who become dishonest, and they seldom look at or understand the program characteristics that really caused the problem.

Noneconomists also have a strong propensity to believe that any project receiving a federal subsidy would not have been built if the subsidy program had not existed. The notion of a windfall is very hard to explain. It is not an intuitively obvious concept. The notion that a subsidy should be designed to affect decisions at the margin and minimize windfalls is even harder to explain. In fact, few people understand what an economist means by "a decision at the margin." The concept of "the margin" may be ingrained in the soul of economists but it is understood by few other species.

So, a lot of education is necessary before Gramlich's ideas have any hope of implementation and economists must find simpler language with which to explain these concepts. But this can be done.

One notion beloved by economists seems to have little appeal to politicians, even when clearly explained. That is the notion of horizontal equity. In discussions of rationed subsidies, I have often suggested that it would be fairer to give small per capita subsidies to 100 percent of the eligible population rather than subsidies ten times as high to 10 percent of the eligibles. This does not strike a responsive chord at all. The politician is likely to respond, "Why should I give a small, barely noticeable subsidy to a whole bunch of people when I can do a really big

favor for a few—one that might really change their lives?" One could concoct an economic model that rationalizes this intuition, but it would be pretty complicated.

Economists' discussions of user fees and earmarked taxes also pay too little attention to the difficulty of designing the right level of fee or tax in a political environment. Twenty years ago it used to be necessary to pledge to always oppose earmarked taxes in order to get a job at the Office of Management and Budget (OMB). The OMB model went like this: The special interest groups backing projects—the construction industry, unions, and users—would lobby for too high a tax or fee. They would claim property rights to the proceeds and OMB would be helpless to control the tied spending. This model developed because twenty years ago gas tax proceeds were flooding in; they mostly had to be used for new construction, and it appeared as though we would pave over America. Ultimately, the OMB model proved wrong. OPEC indirectly curbed the growth of gas tax revenues and the law was eventually changed to divert some portion of the proceeds to maintenance and mass transit. You can, again, talk about earmarking at OMB, but do not let the old-timers overhear you. They still do not believe that anyone can get it right.

If my remarks have a theme, it is to be careful out there. It is one thing to document the existence of public investment opportunities that promise a high social rate of return. It is quite another to design grant and political decision-making systems that effectively target resources on those opportunities. Most of us budgeteers thought that it was something of a triumph to reduce public civilian investment in the late seventies and early eighties. In one of his few successes, President Carter was able to control water projects, but at great political cost. God willing, we shall never build a Tombigbee Waterway again. Perhaps the budgeteers were too successful, but I remain skeptical. It does not take much encouragement for politicians to fund physical projects. They provide identifiable jobs; you can start them with a ceremonial shovel; and you can cut ribbons to open them—all on the nightly news. Again I say, be careful out there.

Discussion

*James M. Poterba**

This paper suggests several substantial reforms in the financing arrangements for public infrastructure spending. The general theme of Edward Gramlich's excellent and provocative paper is that greater reliance should be placed on the price mechanism in funding and allocating public goods, a position that is largely immune to attack from other economists. Nevertheless, some of the author's specific recommendations are at least subject to debate. My remarks first develop the general point that the financing mechanism used in providing public goods can significantly affect the level of such outlays. The question then is why closed-end matching grants are so popular despite their limited marginal incentive effects. The final section includes several brief comments on some of the particular reforms suggested here, notably those for pricing sanitation services, higher education, and highway utilization.

A central point to recognize in discussing reforms in infrastructure finance is that financing mechanisms are not simply accounting conventions. Rather, they directly affect the level of infrastructure spending. Two examples illustrate this proposition. First, transitions from general revenue financing to earmarked taxes affect the level of outlays. In a detailed study of urban mass transit systems, Cromwell (1989) found that transit workers in systems that adopted earmarked taxes received real wage increases totaling 20 percent over the next five years. This finding accords with claims that earmarking, by insulating the targeted activity from annual budgetary pressures, permits greater outlays.

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Whether such increases in outlays are consistent with an optimal fiscal program is unclear, but the results do suggest the power of earmarked taxes to raise expenditures.

A second example concerns the role of state capital budgeting techniques. Previous research by Bunch (1988) suggests that state debt limits constrain capital outlays; those states with such debt limits have lower levels of infrastructure spending. My own related research (Poterba 1990) on capital budgets suggests that states that distinguish capital from current outlays in their budget process ultimately spend approximately 15 percent more on capital than do states that combine capital and non-capital outlays in a single budget. These results underscore the role of fiscal institutions in affecting the outcome of public good provision, and suggest the potential importance of funding reforms in changing the level of such spending.

One of the major themes of Gramlich's paper is that closed-end matching grants, which provide matching rates well above plausible estimates of the marginal externalities from state and local infrastructure spending, should be replaced with open-end grants with lower matching rates. The pervasive nature of closed-end grants, however, suggests either that strong political factors incline politicians against such a change, or that some factors omitted from the standard efficiency analysis may be operating. Probably the most important political factor is the perceived need for equitable treatment of different jurisdictions. Open-end grants admit the possibility that rich states or localities will contribute several times as much as their poorer neighbors to the matching programs. The absolute transfer between the federal government and these jurisdictions will be larger than that to poorer jurisdictions, exacerbating pre-existing inequities. It may also be politically difficult for representatives of poorer jurisdictions to explain why much larger federal transfers were received by communities other than their own. These political considerations may be the principal reason for the prevalence of closed-end grants.

Closed-end grants may also be justified by efficiency considerations, a point widely recognized in various contexts in regulatory economics. With no uncertainty regarding the response of localities to subsidy programs, price and quantity schemes can be used interchangeably to encourage expenditures on particular activities. With uncertainty, however, good reasons may be found for choosing one program or the other. As Weitzman (1974) has argued, substantial uncertainty regarding the price sensitivity of the regulated agents may leave the regulator uncertain about the likely consequences of price-based schemes. For example, if federal grant-givers envision a minimally acceptable level of interstate highway in each jurisdiction, with relatively small marginal benefits to additional highways beyond this level,

then closed-end grants may be an optimal way to elicit desired local behavior. High subsidy rates on expenditures up to some level ensure that most jurisdictions will take advantage of programs to this point. The possibility that closed-end grants are an efficient way to achieve certain legislative objectives does not, of course, imply that these grants are well designed or that the "kink" in the matching rate is at the appropriate point. Nevertheless, the case for dismissing matching grants is weaker than the conventional analysis might suggest.

One of the most appealing features of Gramlich's paper is its blend of general theory with particular applications, many of which provide fertile opportunities for creative policy design. Each of these raises intriguing issues in policy design. First, consider the potential of user charges in ameliorating the growing solid-waste crisis in the United States. User fees undoubtedly can play an important role in encouraging recycling, particularly if they are levied on products at the time of purchase. User charges are more successful when levied on consumers buying a good than when they apply to consumer disposal of a bad. This is because fewer ways exist to avoid compliance with user charges for goods (How many people rent four-wheel drive vehicles so they can enter national parks without paying fees?) than with charges for disposing of bads. User charges for waste disposal are particularly problematic, since significant charges per can of trash may encourage illegal dumping. The net effect—trash in public parks and dumping in places where the environmental damages may significantly exceed those in traditional landfills—may be quite contrary to that of standard user charge models, which assume perfect compliance.

Another example of how user charges might be used concerns higher education. The rapid increase in the rate of return to higher education in the last decade suggests little need for direct state subsidies to those who wish to attend college. Arguments may be made for government assistance in relaxing liquidity constraints, coupled with strengthened enforcement to avoid significant revenue costs.

The final area is the user fee for highway use. One issue this paper does not address is the efficacy of imperfect user charges in targeting the ultimate activity that must be taxed. Gasoline taxes, the standard user charge for highways, illustrate these difficulties. Numerous studies have documented that different vehicles cause different amounts of damage on the interstate highway system, and that these marginal costs are not particularly tied to gasoline consumption. The policy options for raising user fees in this context therefore involve imperfections, a point that must be recognized in policy design. This is not an argument against user fees per se, but a call for further research on this intriguing aspect of the problem.

Gramlich's paper is a refreshing examination of how capital outlays should be financed. It raises a number of points that deserve central attention in the policy arena, and suggests several avenues for future research in public finance. In the austere budget environment of Washington and the state capitals in the early 1990s, this paper's proposals for more efficient infrastructure finance, often with a positive revenue yield, are sure to attract serious attention.

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