RESOURCE PAPER

How Levels of Investment in Transportation Affect Economic Health

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Competing uses for limited government funding at all levels of government have forced government agencies to scrutinize public spending more closely. Government agencies responsible for public infrastructure investment increasingly are asked to justify their expenditures by showing the linkage between investments and economic performance. At the federal level, the Government Performance and Results Act of 1993 requires federal agencies to develop strategic plans and annual performance plans and to prepare program performance reports. Agencies must adopt "objective" indicators of performance and measures of both outputs and outcomes. In this context, the output of a highway system, for example, would pertain to the direct performance of the facility, such as number of vehicle miles or pavement conditions. Outcomes would include the consequence of this facility output, such as the increase in economic activity in the area served by the highway.

This requirement to assess infrastructure performance was further expanded under Executive Order 12983, signed by President Clinton in 1994. The order established "principles for federal infrastructure investment," which directed benefits and costs to be assessed for all major programs with annual budgetary resources exceeding $50 million. Thus, benefit-cost analysis was expanded from a project basis to a program basis. It required that benefits and costs be quantified and monetarized considering both market and nonmarket factors. This order prompted many agencies to consider how to carry out this formidable task. Several initiatives to explore methodology and data needs have taken place since then, most notably the Transportation Research Board (TRB) Conference on Information Needs to Support State and Local Transportation Decision Making in 1997 and the American Association of State Highway and Transportation Officials report on transportation and the economy.

This TRB conference offers another opportunity to revisit and extend the evaluation of infrastructure projects, specifically highway investments, and continue to explore ways to make the analysis more relevant to practitioners and policy makers. Particular attention will be given to the needs of state, metropolitan, and local government entities. The primary focus of the conference is to explore what information is needed to address the following topics:

- How levels of investment in transportation affect economic health;
- Economic evaluation for decision making on transportation projects, programs, and policies; and
- Estimation of revenues from use charges, taxes, and other sources of income.

This paper addresses the first topic: data and methodological needs for assessing the relation between transportation and economic health.

Three issues will be addressed in this paper:

- What key questions should policy makers be asking?
- How well do existing data and tools answer these questions?
- How do we improve the data to answer key questions?

Assessing Performance

There is no doubt that transportation systems are the backbone of a developed market economy. However, assessing the performance of transportation systems requires an understanding of a complex relation between transportation and economic health. Many of these relations are not well quantified or understood. To establish these linkages, policy makers need to take two dis- tinct steps: (*a*) assess the effect of the characteristics of the system or facility on its output, and (*b*) estimate the effect of the output of the facility on economic outcomes. The first step is basically internal to the system or facility itself. It relates the size, type, and condition of the facility to outputs that the facility produces. The second step relates the output of the facility to conditions and activities outside the facility.

Figure 1 illustrates the relation among the system characteristics, output, and outcomes. In general, policy makers are more familiar with the inventory or characteristics of the transportation facility than they are with outcomes and even outputs. Key highway characteristics are measured in lane miles, grade, tightness of curves, pavement condition, number of bridges, bridge load capacity, or volume capacity. Direct outputs of highway facilities are access, mobility, movement of goods, reliability of service, and safety.

The first step as outlined above is to relate lane miles, grade, tightness of curves, and so forth to the facility's ability to produce access, mobility, and traffic flow. The second step is to estimate the effect of these outputs on broader outcomes, such as economic productivity, job creation, income generation, improved public health and safety, environmental quality, residential and business location, and subsequent job opportunities and income inequality. In this way, the characteristics of the highway facility are related to economic outcomes, but with an appreciation for the intermediate step that the efficiency in which highway infrastructure produces highway services matters.

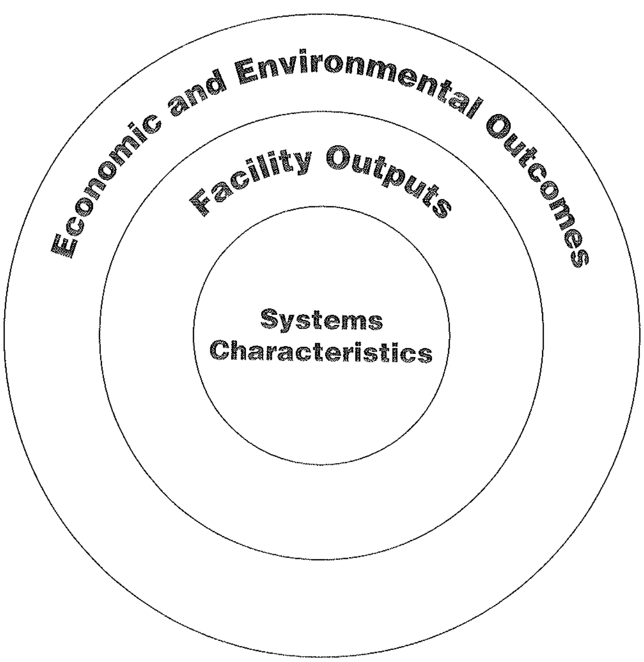

FIGURE 1 Relation among system characteristics, output, and outcomes.

In addition, these outcomes are geographically distributed, with the scope of possible effects radiating from the location of the facility. For example, job creation may occur at the interchange of two major highways, because of the increased access to transportation services, which increases reliability and reduces freight costs. Lower freight costs, in turn, make the area more attractive to businesses. An increase in business activity attracts other businesses that seek close proximity to suppliers or customers. The outcome of these activities spreads beyond the immediate vicinity of the highway interchange and the system. Increased vehicle usage of a highway system also may affect a broader geography, such as an increase in pollution affecting an area's air shed.

Obviously, facility outputs directly affect outcomes, whereas system characteristics have no direct effect on outcomes, except for perhaps construction costs. The distinction can be subtle for certain types of transportation infrastructure. However, the framework underscores two important points. First, decision makers must scrutinize the internal performance of the facility under their responsibility. Second, efficiency of the system (that is, that efficiency by which facilities yield output) is directly related to the capacity of the facility to generate outcomes valued by the decision makers. Succinctly, the ability of $1 million of investment in highway infrastructure to generate economic outcomes depends upon the efficiency in which the resulting facility produces output. Size, condition, and type of existing infrastructure will have a bearing on output. A $1 million investment to add a lane to a highly congested segment of highway will likely have a greater effect on improving traffic flow than a $1 million investment in adding a lane to a segment that is grossly underutilized. Furthermore, the same dollar amount of investment in improving pavement conditions may not improve traffic flow to the same extent as adding another lane. The subsequent increase in traffic flow then affects economic outcomes, such as job creation or income growth.

As we will see in the next section, most studies do not distinguish between the type of investment nor do they include a measure of the output of the facility. The major problem is the lack of adequate measures of highway characteristics and outputs that readily can be used to analyze economic outcomes. Highway capital stock typically is measured by adding expenditures on highways over a sufficiently long time period and subtracting depreciation. Because of the lack of adequate data, no attempt has been made to construct measures of different types of highway capital stock. Consequently, a state that spends $1 million on adding a lane may generate greater levels of economic activity than another state that spends the same amount improving pavement conditions, assuming everything else is the same. As discussed in later sections, this distinction becomes important in trying to estimate the effect of transportation infrastructure on the economic health of regions such as states or metropolitan areas. Estimates of the effects of highways on economic outcomes depend upon the efficiency in which highways are built and meet the needs of local users. At best, analysts linking highway characteristics to economic outcomes can only assume that the optimal configuration of highway infrastructure has been put into place.

The Relation Between Benefit-Cost Analysis and Assessing Economic Health

Benefit-cost analysis has been the traditional means of estimating the relation between transportation and economic benefits. The Office of Management and Budget has endorsed it as the basic tool to use in evaluating government programs and projects. Benefit-cost analyses typically include, for example, the number of jobs created, the amount of income generated, and the increase in land as measures of economic activity. However, there is an underlying concern that benefit-cost analysis may not capture all the benefits associated with large infrastructure projects, such as the interstate highway system or an intermodal freight facility. Many of these projects generate significant indirect benefits, which are difficult to measure with sufficient precision. Without an accurate accounting of both direct and indirect benefits, benefit-cost analyses may reject projects that are economically viable. [Hulten (*1*) discusses the differences between the benefit-cost methodology and the production function methodology in capturing these additional benefits that may accrue from transportation infrastructure.]

The suspicion that benefit-cost analysis may undercount economic benefits was heightened about a decade ago when several macroeconomic studies of the overall effect of public infrastructure on the economy were conducted. These studies correlated aggregate output with various measures of privately provided inputs and public capital, including transportation infrastructure. Estimates have been derived at the national, state, and metropolitan levels. Some of these studies suggested that the total effect of public capital on output growth is far stronger than indicated by benefit-cost analysis. The research gained particular notoriety around 1990 when one study implied a payoff of nearly $2 in output for each additional $1 of core infrastructure investment (*2*).

The staggering returns to infrastructure investment gained immediate attention among policy makers who saw these returns as justification for additional infrastructure investment and as a way to grow the economy out of the mild recession during the early 1990s. On the other, the high returns raised immediate skepticism among many economists and launched a subspecialty of investigation within the economics profession to see whether these results would hold up under closer scrutiny. Proponents of these high returns defended the results by arguing that the macroeconomic approach to estimating returns to public investment accounted for additional benefits, such as externalities, increasing returns to scale, and network effects, that conventional benefit-cost analyses may miss.

Since then, researchers have devoted considerable time and effort exploring whether the macroeconomic approach using production/cost functions could detect the additional economic benefits that may accrue from investment in transportation. Several reports provide a summary and critique of this literature, most notably Bell and McGuire (*3*), Nadiri and Mamuneas (*4*), and McGuire (*5*). Table 1 displays the results of previous production function and cost function studies, compiled by Nadiri and Mamuneas. These studies typically include all infrastructure in the estimation, whereas only a few have estimated the results of highway infrastructure separately. I am not aware of studies that have related other forms of transportation, such as mass transit or air transit, to output. Output in most studies is measured as manufacturing output, because it is the most easily quantifiable and readily available. A few studies have used gross state product or gross domestic product.

The basic approach is to estimate a production function in which output is related to private inputs—capital and labor—and public capital. The relation is shown in the following equation:

$$\ln Q = a_o + a_H \ln H + a_K \ln K + a_G \ln G + \varepsilon$$

where

Q = output (measured as value added),
H = hours worked by production employees,
K = private manufacturing capital, and
G = highway capital stock.

In this example and in most studies, highway stock is measured by summing highway expenditures over a sufficiently long time period, typically 30 years or longer. Depreciation, usually assumed to be the same for all types of highways and their components, is subtracted

TABLE 1 **Selected Production Function Studies**

Author	*Equation*	*Data*	*Elasticity**	*Comments*
Aschauer (*2*)	Cobb-Douglas production function and TFP regressions	Time series, 1949–85; Private business; economy	0.39–0.36, 0.37–0.41: significant	Constant returns to scale (CRS) in all inputs, including public capital input
Munnell (*6*)	Cobb-Douglas production function reproduces Aschauer	Time series, 1948–1987; private nonfarm sector	0.34–0.41: significant	CRS in all inputs; also private and public capital coefficient equal
Munnell (*6*)	Cobb-Douglas production function	Cross-section time series; 48 states, 1970–1986	0.15	See Munnell (*7*) and other references
Munnell (*7*)	Cobb-Douglas production function	Cross-section average, 1970–1986; states values: 12 high endowment, 26 mid-endowment, 10 low endowment	0.14, 0.11, 0.22: significant	Returns to scale: 1.01, 1.03, 1.04
Garcia-Mila and McGuire (*8*)	Cobb-Douglas production function	Cross-section time series; 14 annual observations of 48 states' gross state production, labor, and capital expenditures on education and highways	Highways: 0.045–0.044; education: 0.16–0.072—significant	Returns to scale: 1.04; cannot reject increasing returns to scale
Eberts (*9*)	Translog production function	Cross-section, manufacturing, 1958– 1978 ; 38 metropolitan areas	0.04: significant	CRS; public and private capital; substitutes public and labor complements
Hulten and Schwab (*10*)	Cobb-Douglas production function with first differences	Time series, 1949– 1985 (same as Aschauer)	0.42: significant; 0.028 insignificant	Negative coefficient for labor
Tatom (*11*)	Cobb-Douglas production function, including energy price, with first differences	Time series, 1974–1987; business sector	0.146: insignificant	CRS
Mera (*12*)	Cobb-Douglas production function	Japan: pooled data of regions and time; three sectors; four classifications of social overhead capital	0.22. 0.20 (.50), 0.12–0.18: significant	
Ford and Poret (*13*)	TFP regressions	USA and 11 OECD countries: time series and country cross-sections	Half of countries significant effect after 1960; mixed support of Aschauer results	
Hulten and Schwab (*10*)	TFP regressions	Cross-section time series; regional study of Snow-Sun Belt; 1970–1986; gross output value added	Public capital insignificant in all regressions; private capital insignificant in gross output regressions; significance in value-added implying scale, .88	

* Coefficient of infrastructure capital in logarithmic equation.

from the expenditures. The result is a generic measure of highway capital stock. It is generic in that it does not take into consideration differences in the efficiency of highway facilities and differences in construction costs across states and regions due to material and labor costs, financing costs, and terrain. Thus, there is an implicit assumption that one dollar's worth of net highway capital stock in the generally flat state of Kansas is the same as in the mountainous state of West Virginia, or that one dollar's worth of net capital stock is the same in the higher-wage state of Massachusetts as it is in the lower-wage state of Mississippi.

To illustrate the relations that are typically found among these variables, consider estimates obtained from a pooled data set of state observations from 1988 through 1992. The variables are entered in log form, so that the coefficients (denoted by the *a*'s) are output elasticities, which are interpreted as the percentage effect on output of a 1 percent increase in each of the inputs. Plugging the results back into the equation shows the relative contribution of each input to output:

$$\ln Q = 0.56 \ln H + 0.38 \ln K + 0.15 \ln G$$

All coefficients are statistically significant. We see that a 1 percent increase in highway capital stock is associated with a 0.15 percent increase in output. However, while highway infrastructure has a positive effect on output, its effect is much smaller than the other two key inputs. Labor contributes the most to output, with an output elasticity of 0.56, and private capital is a relatively close second with an output elasticity of 0.38. In this case, each input contributes at least twice as much to output as highway capital.

Many (but not all) of the econometric studies have found a positive relation between net public capital stock investment and private-sector economic performance. However, results vary widely across studies, and the results of some studies, particularly those using a fixed-effect methodology, have been negative and statistically insignificant. For those production function estimates that are statistically significant, the magnitudes range from a low of 0.04 percent to a high of 0.41 percent.

The magnitudes vary by time period, technique, and level of aggregation. As shown in Table 2, estimates differ significantly by time period. Using national-level production function estimates, similar to the technique used by Aschauer (2), estimates are large, positive, and statistically significant for the period between 1949 and 1967. However, during the 1968 to 1985 period, the estimates turn negative and are statistically insignificant. The same decline in returns over time is found for highway investment. Nadiri and Mamuneas (4), using a cost function approach at the national level, find that the output elasticity of highway capital is 0.084 between 1950 and 1991 and half that amount (0.039) between 1981 and 1991. Fernald (*14*), using the same output and private input data as Nadiri and Mamuneas but estimating a production function, also finds that the productivity effects of highways decline over time. He concludes that "roads had an above-normal return before 1973, but probably do not have an above-normal return today" (*14*, p. 632).

TABLE 2 Public Capital Elasticities

I. Split Time Periods	
1949–1985	0.42
1949–1967	2.32
1968–1985	–0.08
II. Time Series	
Differenced	Statistically insignificant
Cointegration	Statistically insignificant
III. State-Level Equation	
Pooled	0.15
State dummies included	–0.02
State and time dummies	–0.03
Year dummies	0.16
Regional dummies	0.09

One problem with time-series estimation is the possibility of spurious correlation. Variables dominated by long trends produce strong correlations that offer a false sense of explanatory power. Studies, such as Tatom (*11*), that correct for the spurious correlation by first differencing or using other methods of correcting for nonstationarity in the data find much smaller and even negative and statistically insignificant effects of infrastructure on output.

Production functions using cross-section data and cross-section time-series (panel) data for states or metropolitan areas typically yield estimates that are much smaller than national-level estimates. For instance, Munnell (*6*) finds that the output elasticity of public capital is less than half as large as her time-series estimates using aggregated state data. Garcia-Mila and McGuire (*8*), using gross state product as the measure of output, find that highway capital per square mile has a positive and statistically significant effect with an elasticity of 0.04. Holtz-Eakin (*15*) argues that estimates based on cross-section time-series data are biased because they do not account for differences across states in factors that could affect output. Using methods to correct for these differences, Holtz-Eakin finds that infrastructure does not contribute to output. He interprets these results to suggest that some critical threshold level of infrastructure is essential to economic performance, but expansion in infrastructure beyond this level does not increase output.

Estimates also appear to vary somewhat systematically across different levels of aggregation. The general tendency is for national-level estimates to register the largest magnitudes, followed by state-level, and then by metropolitan-level. Munnell and others have argued that this ranking may reflect that narrower levels of aggregation do not capture the indirect effects of infrastructure as well as broader levels. For instance, according to this argument, metropolitan-level estimates would not include the network and other spillover effects that may be captured in national-level estimates. Of course, this relation between the size of estimates and level of aggregation may change depending upon specifications and the controls for nonstationarity that are included in the estimation, which may undermine this argument.

It is difficult to reconcile the different results obtained from different data, methodologies, time periods, and levels of aggregation. Garcia-Mila et al. (*16*) attempted to find a preferred production function specification based on various econometric tests. However, their preferred model, which controlled for nonstationarity and state-fixed effects, yielded results that suggest that public capital, both in aggregate and separated by type, has no significant effect on output.

The conclusion most supported by the literature is that there is no definitive estimate of the effect of infrastructure in general and transportation infrastructure more specifically on output. Different studies yield different estimates. Therefore, policy makers must understand the sensitivity of results to a host of factors, not least important of which is the effect of transportation within various economic circumstances, such as the robustness of the local economy and the availability of other economic factors that affect economic growth. The next section of this paper provides a framework for understanding the possible linkage between transportation and economic health.

What Key Questions Should Policy Makers Be Asking?

The primary focus of this paper and conference is on state and metropolitan decision makers. Therefore, when considering the relation between transportation infrastructure and the economy, the emphasis is within specific state and metropolitan economies. For these decision makers, the health of the local economy takes on several dimensions including the need to create more jobs and generate income, to enhance the livability of the region, and to reduce urban sprawl. Policy makers and stakeholders may have different opinions about the appropriate outcomes to include in their analysis. Some areas will decide that the creation of new jobs takes precedence; others may focus on environment quality to enhance the livability of a region; whereas a third may emphasize mass transit as a means to aid low-wage individuals in gaining access to jobs. Although stakeholders and policy makers can place a higher priority on one outcome over another, most attributes are inextricably linked by a regional growth process. Therefore, some actions by decision makers may yield unintended results, whereas others may be difficult to obtain, particularly if they run counter to market forces inherent in the regional growth process.

Infrastructure Investment as a Stimulus of Growth

Many policy makers see infrastructure investment as a possible stimulus of growth.[1] For instance, state policy makers may be interested in the effect of additional highway spending on economic development within their borders. Local metropolitan planning organizations or other regional metropolitan governments may want to know how a proposed intermodal freight facility or the expansion of a regional airport might boost their local economy. The questions might be even more specific and concentrate on segments of highways and types of improvements. Policy makers may ask how adding another two lanes to an existing interstate segment between two major cities can stimulate the creation of jobs within that region. Policy makers also may want to know if a new interchange on an existing interstate may stimulate growth in and around that area.

As suggested by the questions, the queries regarding the economic benefits of highway and other types of transportation investment may focus on specific types of transportation within narrowly defined geographical areas. Understanding the economic development process provides a framework for judging the possibility of adequately answering these questions, given the current research methodologies and data available to address the questions.

Economic development is typically defined as the process by which additional income is generated within a region. As shown in Figure 2, there are several channels through which transportation investment might stimulate regional growth. Consequently, the appropriate questions raised by decision makers depend upon the source of growth and the role that infrastructure plays in affecting growth. Resource growth can occur in three ways. One source is an increase in the economic use of resources already residing in a region. This source is referred to as internal growth and includes increases in a region's employment rate or labor force participation rate. The second source is an inflow of resources from other regions. Referred to as external growth, this source results from the movement of households and businesses from one region to another. The third source is more efficient use of resources already in place and employed in

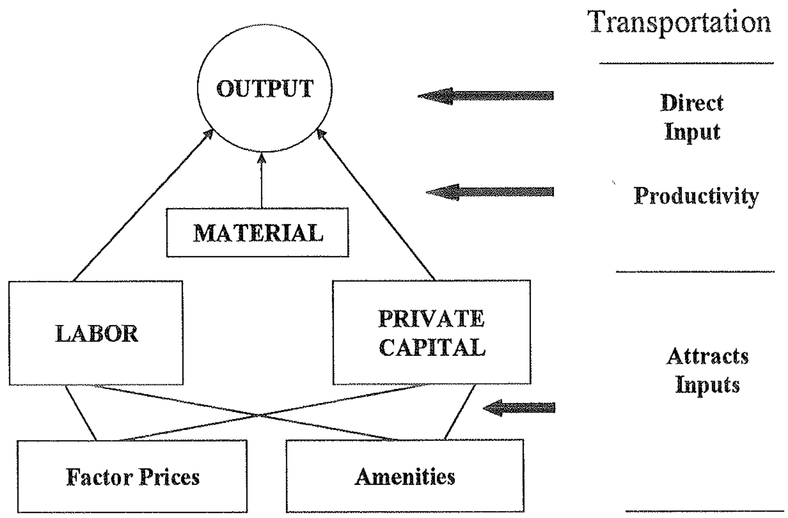

FIGURE 2 Regional growth process.

the area. More efficient use of resources leads to greater productivity gains.

The economic and social benefits of growth then depend upon the type of growth that takes place. For example, state policy makers may seek to promote growth within their own region by enticing businesses from outside the state to locate within their state. Obviously, any jobs created from the relocation of businesses in one state result in a loss of jobs (or foregone potential expansion of jobs) in another state. By pursuing this strategy, state policy makers may be able to meet their goal of stimulating growth in their own state in the short run. However, as other states pursue the same policy, a bidding war is likely to ensue, which typically results in economy-wide inefficiencies.[2]

Another important point to consider with respect to internal growth is that the creation of new jobs and income may not necessarily benefit the residents of the area. If the purpose of growth is to provide jobs for those unemployed in the region, Bartik (*18*) has shown that a large percentage of newly created jobs may not go to these people but to those who move into the region. Immigrants are typically more educated and otherwise better qualified for these jobs than unemployed residents.

State policy makers who pursue growth through the first channel of internal growth can do so without necessarily adversely affecting other states. In this case, unused or underutilized resources are used more fully and thus add to the resources of the state without detracting from the actual or potential resources of another state.

Several studies offer insights into which of the two sources of growth is more important to regional growth. With respect to labor, studies show that both sources of growth contribute equally to employment change. Population change, which can be considered a measure of external growth, accounted for half the labor supply response to employment change. Labor force participation and unemployment, a source of internal growth, together contributed to the other half (*19*).

Determinants of Increase in Resources

Both internal and external resource growth responds to price differentials and regional amenities. Higher wage rates and greater job opportunities offer better matches between job postings and an individual's work preferences. Nonworking residents in such areas will have more incentive to seek and obtain jobs. The same incentives increase local entrepreneurial activity, which leads to the formation of businesses. Factors such as relatively high entrepreneurial activity or business spin-offs from local research and development activities could account for the internal creation of capital. Also, lower wage rates in established jobs in the area may lead some individuals to pursue self-employment or to start up their own businesses.

External sources of input growth are related primarily to determinants of migration between regions. The traditional, neoclassical view of regional development is based on the notion of perfectly mobile inputs that flow to regions that offer the highest rate of return. Workers, for instance, migrate toward regions offering higher wages and away from regions offering lower wages, holding all other metropolitan characteristics the same. However, workers and their families are attracted to an area by more than higher wages. One important criterion in the household location decision is the level of amenities.

Amenities include a host of local attributes, including a comfortable climate, recreational opportunities, cultural attractions, good schools, public transportation, and an efficient highway system.

The flow of capital (that is, the location of plants and equipment) is determined in part by factor price differentials. Firms will locate in areas that provide the highest rate of return. Economic profits depend on the price and quality of the inputs that are used by businesses to produce their products. These inputs include labor, privately owned capital, materials, land, and transportation costs. Areas that offer these inputs at a lower cost to the firm typically are more attractive. However, the quality of inputs varies across regions, and the price of an input must be compared with its productivity. For instance, the quality of a region's labor force depends on the educational and training level of the workers, their work ethic, and whether or not there are institutional factors, such as trade unions, that may affect workplace arrangements. All of these attributes affect a worker's productivity. It may be the case that even though wages in one location are higher than another, the higher productivity of workers in the first area offsets their higher compensation. The business that locates in the high-wage *and* higher-productivity area would be more profitable, with all other factors the same.

The same holds for public inputs, such as government services and public infrastructure. Local government services typically are financed through some form of local taxes. Businesses typically seek low-tax areas. As with privately provided inputs, the price of government services should not be the only factor considered in business locations. Quality schools, responsive protective services, and adequate and dependable water distribution and treatment systems are important considerations. Transportation infrastructure also is important. In fact, recent surveys of chief executive officers place access to highways at the top of the list of factors important in location decisions. More will be said about transportation in the next section, but suffice it to say here that transportation infrastructure can enhance profitability either by increasing productivity or by reducing factor costs. One way the latter effect is achieved is by augmenting the efficiency of private inputs employed by firms. Another is by providing an attractive environment for households. Although government services, such as quality schools or plentiful open space, do not influence businesses directly, they do influence the type of worker who would be attracted to an area. Increasingly, businesses are concerned about attracting and retaining highly skilled workers. These workers are attracted to areas with governments services that improve their overall quality of life.

Several studies have examined the effect of infrastructure on the attraction of firms and households to an area. Fox and Murray (*20*) show that the presence of inter-state highways in a county is a significant determinant of where businesses locate. Eberts (*21*) finds that public infrastructure positively affects the number of firm openings in metropolitan areas, and Eberts and Stone (*22*) show that public capital stock positively affects employment growth through business start-ups and expansions. Fox et al. (*23*) examine the effect of local government public policies, of which infrastructure investment is presumably one such policy, on residential location. Although they do not include public infrastructure per se in their analysis, they do find that the level and quality of public services generally attract migrants, from which one can infer the positive link between infrastructure and household location. Obviously, given the large contribution of workers to output, as revealed in the production function estimates, more research needs to be conducted to look at the effect of transportation infrastructure on household location decisions.

Productivity Growth

Another source of regional growth is productivity growth. In this case, a region can expand output, even though the stock of inputs remains constant because of an increase in the ability of inputs to produce. This enhanced ability can be a result of new technological advances embodied in the capital stock and higher skill levels of workers. It also can come about because of increases in the size of plants and even in the size of the metropolitan area. In some industries, larger plants can produce goods at a lower unit cost, and if these so-called economies of scale increase in the region, then productivity also increases. The size of the metropolitan area also affects productivity by achieving a critical mass in which a variety of goods and services become readily available. [Eberts and McMillen (*24*) provide a review of the literature on the effect of metropolitan size on productivity.] Consequently, firms save transportation cost and time by being able to purchase locally instead of importing these inputs from outside the region.

Infrastructure Investment as a Tool to Manage Growth

In some high-growth regions of the country, the concern may not be how to stimulate growth but rather how to manage it more effectively. Policy makers in these areas may face issues of urban sprawl and the contribution of highway construction to the future outward growth of the metropolitan area. Or they may be figuring how an improvement in mass transit within the core city may encourage residents to move back to the center of the metro area, thus reducing sprawl. To analyze this issue, it would be important to examine factors that contribute to urban sprawl. For instance, it would be advantageous to understand the effect of transportation systems on commuter patterns, residential patterns, and business location behavior for specific areas. By understanding these components of regional growth, we can better understand the effect of transportation on regional growth. Yet, looking at regional growth in the aggregate would not give sufficient insight to policy makers as to which components of growth they might be able to influence through various policy instruments. How important is highway access for business location decisions relative to household decisions? These questions relate most directly to the internal sources of regional growth enumerated in a previous section. However, insights into these issues go beyond the typical treatment of internal growth and include topics such as the role of transportation infrastructure in influencing commuting patterns and the location of businesses.

Effect of Transportation Infrastructure on Regional Growth

With all these cases, the questions go beyond the direct economic benefits and costs of a specific project, as would typically be addressed by a benefit-cost analysis. Rather, the issue is the effect of transportation investment on various dimensions of a regional economy. The focus is not necessarily on a specific project but instead on a generic type of project, such as mass transit or rail freight transport, or simply the effect of an additional lane of interstate highway. Policy makers may or may not have a specific project in mind when asking these questions, but they want to know the effect of a type of project, such as mass transit. It is the broader scope of the questions with respect to the economy that separates this topic from the second of the three topics—economic evaluation for decision making on transportation projects, programs, and policies—addressed at this conference.

As shown in Figure 2, transportation investment can affect economic development in several ways. These effects can be divided into supply-side and demand-side influences. The supply-side effects refer to factors that can increase the amount of resources in an area or make existing resources more productive. In this role, transportation infrastructure can (*a*) contribute directly to output as an input in the production process; (*b*) augment other factors of production to allow them to operate more efficiently; and (*c*) attract mobile resources, such as business capital or households, from other areas.

The demand-side effects refer to factors that can increase the demand for a region's products primarily through expanding its market area. Access to efficient transportation can (*a*) lower the costs of a region's output, making it more competitive with the products of other regions; and as a result, (*b*) provide the stimulus for additional resources to enter the region. It is important to recognize that transportation infrastructure alone cannot stimulate growth or help to manage growth. An efficient transportation system, that is, one with minimal bottlenecks and congestion, is a necessary but not a sufficient condition for regional growth. Unless other factors are in place, a region will not grow, even though it may have an efficient transportation system. The previous description of the economic development process provides a basis for understanding the importance of the other determinants.

Other examples of public infrastructure as private but "unpaid" inputs include municipal water treatment facilities. If not provided publicly, firms would need to construct their own waste treatment plants, assuming firms would have an incentive to treat wastes, perhaps because of environmental protection standards set and enforced by government agencies.

Consequently, any firm entering a region that has constructed this infrastructure immediately benefits by initially earning profits or rents according to the value of the contribution of public capital to production. If local governments do not extract all the profits coming from public infrastructure through higher taxes, these profits will attract other firms into the area until the profits are dissipated as the infrastructure becomes used more fully.

Viewing public capital stock as another input into the production process raises an additional question about the effect of public investment on growth. So far, the discussion has concentrated on the effect of public capital stock (as an input) on the growth of output. But there is another dimension to considering public capital as an input, and that is how it relates to the other inputs. This relation is particularly important to regional growth, because growth is measured not only in output but also in terms of private investment and employment.

Two basic relations exist between inputs. First, inputs can be considered substitutes for each another. In this case, an increase in the amount of public capital may be considered by firms to provide the same services as private capital, so less of the private capital is demanded. An example would be water treatment facilities. If a local government provides the facilities, then private firms do not need to construct their own facilities. Consequently, less private investment would be observed in the area. The same relation could exist between public capital and labor.

The second possibility is that two inputs are complements. This means basically that one input cannot function without the other. The classic example is tires and automobiles. Automobiles cannot function properly without tires, and tires are not worth much unless they are attached to automobiles. In this case, an increase in one input would then induce an increase in the complementary input. One can extend this example to highways. Automobiles and highways are also complements in that automobiles are not as useful without an adequate highway system and a highway system would not be as valuable without automobiles.

How Well Do Existing Data and Tools Answer These Questions?

After the listing of possible questions that could be important to policy makers, the next issue is, how well do existing data and tools answer these questions? The short answer to this question is that analysis to date falls short of what generally can be used by state and local decision makers. There are several reasons for this shortcoming. One reason is that studies at the subnational level have not focused on specific regions when estimating the relation between transportation investment and the economy. Most studies have used specific state or metropolitan information as one of several observations to estimate the models. The result is an estimate of the effect of state- or metropolitan-level transportation investment in general on output, but these estimates per se do not provide insight into the effect of transportation investment within specific regions.

In order to derive estimates for a specific state or metropolitan area, we would have to approach the analysis in a different way. One way would be to collect observations on the specific state over a sufficiently long period of time. We would need enough observations or replications of a specific interaction between transportation investment and economic outcomes to derive precise estimates. A drawback of this approach is that the observations may extend back in time to a point in which the economy was sufficiently different or the transportation infrastructure was a different vintage. National-level analysis shows that the effect of highways on manufacturing productivity was considerably larger in the period from 1950 to 1970 than since 1970 (*4*).

Another approach would be to include in the production function or cost function estimation characteristics of transportation infrastructure and state economies. Characteristics such as the vintage and type of highway system within a state, the level of congestion, the pavement condition, and the type of vehicle usage may have an effect on the relation between highways and economic activity. Eberts (*25*), for example, included these measures and others to estimate production functions at the state level and found some significant effects.

Moreover, the characteristics of the state economy, such as its unemployment rate and other measures of resource utilization, its industrial composition, its degree of urbanization, and the stage of economic development (particularly for less developed regions), may influence how highways affect output. The effects of highways on the output of specific states then can be approximated by considering the characteristics of specific states and adjusting the estimates accordingly. Suppose that a state is characterized by high unemployment, low traffic congestion, poor pavement condition, and a low degree of urbanization. By including these characteristics, state decision makers can obtain estimates of the effect of transportation infrastructure on output that are more specific to their states.

Some researchers have argued that confining the estimation of production or cost functions to observations based on small geographical areas, such as counties or metropolitan areas, may reduce the ability of these estimation methods to capture the indirect benefits of transportation investment. Munnell (*6*), for one, has argued that the fact that state-level estimates of the effect of highways on productivity are smaller than national-level estimates is evidence that the state-level estimates are not capturing the externalities of networks and spillover effects of highways. Munnell's position is debatable. Furthermore, it may be possible to capture indirect effects by using measures of highways and other transportation systems that more directly measure the network effects.

Most production function and cost function estimates include measures of highways based upon the perpetual inventory method. This measure basically adds real expenditures on highways and subtracts off assumed depreciation rates. By accumulating expenditures over a sufficiently long period of time, one can measure the size of the capital stock. However, this approach has its shortcomings.[3] The measure does not include specific characteristics of that capital stock, such as functional type or condition. One possibility is to find alternative measures of highway capital stocks that measure network effects more directly. A measure explored by Eberts et al. (*27*) is to compare the number of miles between origin and destination that goods are actually transported with the shortest possible distance between the two points (i.e., as the crow flies). According to this metric, a highway network would be considered more efficient as the gap between the actual distance and the shortest possible distance narrows.

Factors such as highway speed and congestion also could be incorporated into the perpetual inventory method. Fernald (*14*) measures congestion as the ratio of miles driven by trucks, automobiles, and other motor vehicles to road stock (constructed using the perpetual inventory method). He shows that congestion measured in this way reduces productivity after 1973. Potentially better measures of congestion and service flow of highways are available from the Highway Performance Monitoring System (HPMS) data. Dalenberg and Eberts (*28*) have proposed a hybrid method of constructing highway capital stock that integrates highway characteristics into the perpetual inventory method.

Spatial Correspondence

Another level of criticism against current research practices is the lack of spatial correspondence between the location of transportation infrastructure and the establishments using the infrastructure. Transportation in-frastructure—roads, highways, rail—is location specific. Businesses benefit from their proximity to highways, which provide access to local suppliers and customers and to the wider national network of highways. National-level, and even state-level, estimates do not provide precise geographical linkages between infrastructure facilities and business activities. For national-level estimates, it is typically assumed that the entire highway system affects national productivity. This assumption may be defensible at this broad level of aggregation in which all economic activity in the country is related to all the stock of public capital. One also can argue that the national-level measure of highways captures the system or network effect of the highway system. However, even if estimates based on national-level studies were credible, they are not very informative from a policy perspective.[4] Highway investment takes place on a project-by-project basis. State decision makers want to know how their investment will affect the economic health of their state.

The lack of spatial correspondence between highways and businesses within national-level studies becomes more problematic when individual industries are considered. The problem is that some industries are concentrated in specific parts of the country, such as primary metal production or transportation equipment in the Great Lakes states. Therefore, national-level studies implicitly assume that highways in large states such as California and New York are as important to establishments located in Indiana or Rhode Island as they are to establishments located in those two states. Fernald (*14*) suggests that estimation bias due to differences in the location of manufacturing firms vis-à-vis highways could be substantial.

State-level estimates typically have the opposite problem. Most studies regress a state's productivity measure against its level of highway capital stock. Consequently, only the highway stock within the state is assumed to affect the state's output, which ignores the effect of the entire highway network, comprised of the highway stock in neighboring states and along major corridors, on business activity. Therefore, it is important to establish the spatial linkage between the business and the highway system it uses. Unfortunately, few studies have been able to make this correspondence. Eberts (*25*) finds that including capital stock from other states, which firms within a given state ship to, changes the estimates of the effect of highway capital stock on output.

Measures of Highway Utilization

Another issue that has not been satisfactorily treated in the literature is the utilization of highways. Since capital stock is fixed, at least in the short run, businesses do not have the capability of adjusting the quantity of capital in response to short-run changes in demand for highway services. Therefore, while the quantity of highway capital may remain unchanged, businesses may use their fixed stock with different levels of intensity. To account for the variation in private capital utilization over time and across plants, researchers typically include a variable in the production function that proxies the utilization rate. Yet, researchers have not typically included a variable that accounts for the difference in utilization of highways. Fernald (*14*) uses the share of vehicles owned by industry to account for utilization. However, this approach appears to be incomplete because most shipments by manufacturing firms are by trucks for hire.

Highway utilization takes two forms. The first is similar to the utilization of private capital. As product demand fluctuates in the short run, the firm's use of highway capital may fluctuate along with its use of private capital. In this case, the same variable used to adjust private capital stock for differences in use could be used to adjust highway capital stock. The second form of highway utilization is different, and it is not captured by the variable measuring fluctuations in product demand. Businesses in different industries and in different parts of the country use highways with different intensity. For example, in Illinois, businesses in the food and kindred products industry ship 64 percent of their output by trucks, whereas establishments in the chemical industry ship 83 percent of their products by truck. Similar differences in the use of trucks are found regionally. For example, 60 percent of the commodities originating within Illinois are shipped by trucks, while 77 percent of the commodities originating within Michigan are shipped by trucks. Therefore, since businesses within industries and states use highways with different levels of intensity, treating highway capital stock the same across industries and states would misrepresent its contribution to economic activity.

How Do We Improve the Data to Answer Key Questions?

The final issue is how to improve the data to answer key questions, keeping in mind the possible development of new and improved tools and methodologies.

Better Measures of Transportation Systems and Outputs

Most studies of the effects of transportation infrastructure on the economic health of a region use a blunt instrument when it comes to measuring transportation capital stock. As previously mentioned, the perpetual inventory approach has been the primary measure of transportation capital stock. This measure is inadequate for the more detailed questions that policy makers seek to answer. As suggested in the previous section, better measures would include more specific and detailed information about the transportation system. For highways, we would benefit from measures such as those that are included in the Highway Performance Monitoring System (HPMS). These measures include many of the system characteristics and facility outputs that were listed in the previous section on performance assessment. In order to use data such as appear in the HPMS, they must be recorded for several years and not simply updated as is the current practice. Thus, production and cost functions could be estimated using both cross-section variation in these data as they relate to regional output and time-series variation.

Another data need is to find better measures of the network effects of highway infrastructure. As mentioned several times, one of the basic differences between the production/cost function approach and the benefit/cost methodology for measuring benefits is the possibility that the former includes indirect benefits, which may be significant for transportation systems. Direct measures of network effects could include the ratio of actual to shortest distance traveled, as previously described. Another possibility is simply to consider the number of lane miles per square mile.

More emphasis should be placed on measuring the outputs of highway facilities. As presented in an earlier section, such measures include the service flow and reliability of highways. Considering this intermediate step between highway facilities and economic health helps to appreciate the characteristics and efficiency of the highway system and their effects on output. For instance, many businesses depend upon just-in-time delivery. For this type of operation to work, shipments must arrive consistently within a narrow window of time so that the material is at the plant when it is needed in the production process. There is no advantage in the product arriving early, but a great cost if it arrives late. Therefore, businesses are more concerned that shipments are not delayed due to bottlenecks on the highways than they are about the speed of delivery. Measures such as the variance of travel time should be included as a characteristic of the highway facility.[5]

A key factor missing in all production functions and most cost functions is a measure of the cost of providing transportation infrastructure. As previously mentioned, one benefit of infrastructure is as an unpaid factor of production. However, highway infrastructure is directly financed by a user tax (fuel tax) that is fairly closely related to the use of highways. In this way, it approximates the cost of using highways. Production functions typically contain no cost or price information, except in special cases in which factor demand equations are included as a second stage of estimation [see Eberts et al. (27), for example]. Cost functions include prices or inputs, but not the tax rates or other measures of financing infrastructure. If one is only considering the technical relationships between transportation infrastructure and output and other inputs, then a production function is appropriate and other prices are not important, except to address econometric issues of endogeneity. However, if one is considering the rate of return of highway infrastructure using a cost function, then omitting the cost of infrastructure may bias the estimates.

Another untapped source of information about highway facilities is geographic information systems (GIS). As these systems become more fully developed and maintained, they offer a wealth of information about the location, size, and condition of highway systems. Moreover, they also can provide information about the proximity of existing economic entities and other outcome measures to highways. This spatial correspondence would help address the issues regarding the current lack of this information and the omission of such variables in production function frameworks, except for some recent work.

More Comprehensive Measures of Outcomes

The relatively crude measures of highway capital stock, and other transportation systems, used in much of the recent literature is not the only problem with estimating the effect of transportation on economic health. It was not possible to deal with many of these issues until recently with the availability of the 1992 Commodity Flow Survey (CFS) (the first published survey since 1978) and access to individual manufacturing establishment data through the Census Bureau's Longitudinal Research Datafile (LRD). An ongoing project by Eberts et al. (27) uses both data sources. Furthermore, access to establishment-level data from both the LRD and the CFS offers the unique opportunity to combine the CFS with the individual establishment data. This matched data set provides the ability to track where and by what mode each establishment ships its products. This new data source opens the possibility of systematically addressing issues pertaining to spatial correspondence, the level of aggregation, the use of highways, causation, and the sufficient number of "natural experiments."

Another source of information on individual establishments is the state ES202 data. These data are compiled by state employment security offices to aid in administering the unemployment insurance program. They include information about employment for each establishment within the state that is included in the unemployment insurance system. These data are collected on a quarterly basis, which offers a large number of observations on individual establishments over a relatively short time period. The files also include total payroll expenditures for each establishment. Unfortunately, the files do not contain information on output or inputs other than labor. Nonetheless, by compiling the quarterly data into a longitudinal data set, we can track the employment dynamics by establishment.

Considerable emphasis has been placed on measures of economic outcomes of transportation systems, such as production output, employment change, and per-capita income. As mentioned previously, stakeholders also are concerned about other types of outcomes, such as land use patterns, environmental quality, and overall quality of life. However, little research has been devoted to the linkage between transportation and these outcomes, particularly exploring how they fit into a broader view of regional growth. Some work has been done on the environmental effects, such as noise pollution, of airports. More spatially specific data on environmental quality needs to be collected so that a closer relation can be drawn between the location of particular transportation systems and the quality of the local environment. Furthermore, regional models must be expanded to include the broader scope of outcomes.

Regional Growth Models

In addition to finding sources of better data, we also can improve our analytical capabilities by developing more complete models of regional growth. Production and cost functions typically do not include variables other than those that are related to technical and allocative relationships between inputs and outputs. The starting point for these studies is the firm, and states and metropolitan areas are considered simply as firms aggregated to those levels. Other characteristics of these areas seldom are included, except to adjust for capacity utilization or in the form of fixed effects estimation. Duffy-Deno and Eberts (*29*) extended the production function approach in a simple way by including in a two-stage regression determinants of public infrastructure investment, since it is unclear whether infrastructure determines output (and thus income) or income determines infrastructure investment. Including this additional equation reduced the estimate of the effect of infrastructure on output. Mehta et al. (*30*) construct a more comprehensive model of regional growth that includes explicit equations for growth rates of input and population. Within this framework, they find that investment in highways and streets is positively associated with per-capita income growth. Most other types of public infrastructure are found not to be statistically significantly related to output.

More work needs to be devoted to developing regional growth models and to incorporating more detailed measures of transportation infrastructure into the models. One suggestion has been to use large regional econometric models to estimate the effects. However, these models do not estimate relationship but only use estimated relations from other studies. Without reliable estimates of the relation, econometric models are not useful. It would be beneficial if research could be conducted to establish reliable estimates of key relations between different types of transportation systems and various outcomes that could be included in econometric models. This would be an ambitious project, and one of the keys to success would be whether these models would pertain to infrastructure investment within different economic environments.

Data Collection

Maintaining high-quality, quantifiable measures of transportation systems, their output, and outcomes requires the continuing commitment of appropriate agencies. Commitment to data collection and commitment to performance assessment are inextricable. One cannot exist without the other. Nevertheless, going beyond simply recording facility outputs and beginning to understand the broader outcomes of infrastructure investment require close cooperation among several agencies at different levels. Transportation infrastructure is a system with extensive networks of facilities, both within specific modes and across modes. The labyrinth of highways is useful only because the many segments are connected. Yet, for an efficient system, vehicular, rail, water, and air transportation systems must interconnect. Therefore, in order to undertake performance within this system and to collect relevant and useful information, agencies at the local, state, and federal levels need to coordinate their efforts in collecting data and in performing assessments. (It is apparent from this conference and other initiatives that the Bureau of Transportation Statistics is one entity that is assuming this role.)

The necessary collaboration goes beyond transportation agencies. Although many of the decision makers in the transportation arena are associated with transportation departments, the stakeholders in the outcomes of transportation investment extend beyond their offices. Stakeholders include economic development entities at the state and local levels, environmental protection agencies, land-use planning departments, to include a few. Some of these entities collect data that can be helpful in piecing together the linkages between transportation systems and outcomes. Greater effort needs to spent on finding ways to bring these groups together to share resources and to share the motivation to properly assess the performance of transportation systems. Broad initiatives are underway in other areas of government to collaborate in the sharing of information. The devolution of government services to state and local governments, particularly in the welfare and employment service areas, has prompted government agencies in some states to coordinate their data collection efforts. The same collaborative efforts could be pursued for transportation-related agencies.

Summary and Proposed Research Statements

Research on the linkage between transportation systems and economic health leads to the conclusion that transportation systems in general have a positive and statistically significant but small effect on several economic outcomes. The glaring deficiencies in the research are the lack of a deeper understanding of the avenues by which these linkages occur and a more comprehensive investigation of the effect of transportation on a broader scope of outcomes. As highways become more mature and the economy more developed, stakeholders who value and advocate outcomes, such as smart management of growth, job creation, quality of life, or environment quality, will demand that these outcomes be closely scrutinized and promoted when investing in new infrastructure projects. Knowledge of these linkages will be more than a way to justify new expansion. Proper and accurate assessment may be crucial for stakeholders to permit future investment to take place.

Expanded Measures of Transportation Systems

Description of Research Problem

Transportation systems have been constructed primarily using the perpetual inventory method and crude physical characteristics, such as lane miles of highways. These measures do not capture system utilization; output of transportation systems including traffic flow, reliability, safety, and volume; and characteristics of transportation systems including lane miles, grades, and functional types. Such measures are fundamental for estimating the relation between transportation systems and economic health that can be used by state and local decision makers. Omitting these characteristics from highway capital stock measures and from the analysis could lead to significant biases in the estimation of the effect of highways on economic activity. The lack of these measures also precludes state analysts from obtaining estimates specific to their states.

Work To Be Performed

This initiative proposes to improve the measures of transportation systems that typically are used in estimating the effect of transportation on economic outcomes. Highway stock estimates that incorporate these elements and that are consistent with the relationship among system characteristics, outputs, and outcomes will be pursued. This effort will be comprehensive in that it includes the several major types of transportation systems, including highways, rail, air, and water shipping. All efforts will be made to collect data so that they can identify facilities at specific locations (such as highway corridors) and so that they can be aggregated to various levels depending upon need. GIS will be explored as a means to organize this information. The primary product of this research is measures of highway capital stock at the state and local levels that incorporate the characteristics of that capital stock in those areas.

Cost Estimate: $750,000

Expanded Measures of Outcomes

Description of Research Problem

Most studies of the linkage between transportation and outcomes focus on a narrow range of economic outcomes, such as output or employment, and rarely include other types of outcomes, such as environmental quality and land-use configurations. A more complete list of outcomes is needed in order to offer greater insight into the various channels through which transportation systems affect economic health.

Work To Be Performed

This research initiative expands and improves the measures of outcomes from transportation systems. With respect to economic development, measures will include both the final outcomes such as per-capita income and the intermediate factors such as employment, private capital, and materials. Transportation costs also are included since one of the direct effects of transportation systems is the cost of shipping goods and of commuting by households. With respect to environmental quality and overall quality of life, measures such as air and noise pollution and land-use patterns are considered. Housing and land prices also are included since access to transportation systems affects land values. As with highway system characteristics data, these measures will be identified by location so that the two databases can be matched. Particular emphasis is placed on collecting establishment-level data that can be obtained from the Census Bureau's LRD and from state ES202 files. These data then are merged with the transportation systems data so that spatial correspondence between the users of transportation systems and the outcomes of businesses that use these systems can be established.

Cost Estimate: $600,000

Linking Commodity Flow Data to Establishment-Level Data To Measure Transportation System Utilization

Description of Research Problem

The primary purpose of transportation systems is to move goods and people. However, studies of the effect of transportation systems on economic activity have not taken into account the movement of goods. For example, with few exceptions, it is assumed that all highways are used with the same level of intensity, which is def-initely not the case. From a business perspective, the value of highways or rail depends upon the destination of shipments. The CFS shows that manufacturing establishments at the individual level and aggregated within broad industry classifications use highways with different levels of intensity. Thus, productivity estimates depend upon the extent to which businesses use highways.

Work To Be Performed

This project will build off of a study already begun at the Center for Economic Studies, Census Bureau, that has started to construct information that shows where and by what mode establishments ship goods. This is accomplished by merging the microfiles of the 1992 CFS with the establishment-level records of the Census Bureau's LRD files. In this way, information about commodity flows is linked to business outcomes (such as employment change, output growth, and productivity growth). The proposed research will extend this effort to more recent data as well as establish historical files so that estimates of the relation between systems and outcomes can be measured more precisely. To date, the focus of the project has been on highways. This effort also will be extended to other modes of transportation.

Cost Estimate: $700,000

Establishing Working Collaboration Among Agencies To Maintain and Improve Integrated Data Collection Efforts

Description of Research Problem

The ability to collect data on the characteristics and outputs of transportation systems and their related outcomes depends upon coordination among agencies to collect comprehensive and reliable data. It also depends upon the proper incentives and adequate resources to collect those data. Most transportation agencies collect information about the characteristics of the systems under their management. Most agencies also collect some information about the output of the systems, although in many cases more quantifiable measures would be desirable. However, more effort needs to be made to link the transportation agencies to organizations that represent the stakeholders of the outcomes of transportation systems. These organizations include economic development agencies, land-use planning departments, and environmental quality agencies.

Work To Be Performed

This initiative provides the motivation and some of the resources necessary to nurture the collaboration of agencies in collecting data that can link system characteristics with outcomes. Activities include forums to bring the various groups together to emphasize the benefits of such collaboration and training workshops to provide the hardware and software platforms that can combine the various data files. The activities will be patterned after similar efforts that have been started in other program areas such as welfare and employment services. This effort will provide for a more comprehensive assessment of the performance of transportation systems and thus help decision makers make investment decisions that take into account the broader outcomes of transportation systems.

Cost Estimate: $250,000

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NOTES

1. Forkenbrock et al. (*17*) present a comprehensive and accessible description of the various channels through which highway investments may affect economic development. This book is particularly geared toward state and local transportation practitioners and policy makers.

2. Bartik (*18*) points out that under certain conditions, competition among states (or other jurisdictions) can lead to economy-wide benefits, primarily if the reallocation of resources goes from low-unemployment to high-unemployment areas.

3. The shortcomings of the perpetual inventory method go beyond the problems listed here. The basic assumptions regarding depreciation and discard schedules and price indexes also are questionable. Fraumeni (*26*) recently critically reviewed these assumptions and offered improved estimates based on actual highway depreciation data. She noted that public capital stock estimates from the Bureau of Economic Analysis are designed to measure the nation's wealth and should not be used in productivity studies. It is more appropriate to measure capital stock in efficiency adjusted units to reflect the decline in the productive services of an asset as it ages. Several studies, particularly at the national level, have made the mistake of using the wealth method. Fernald (*14*) uses the wealth method but states that using highway stock based on the efficiency method did not alter his results significantly. For researchers using an efficiency factor of 0.9 to construct highway capital stock, Fraumeni offers some comfort to researchers who used this depreciation assumption. She found that this assumption was a reasonably good approximation of the depreciation function that she estimated. However, her study focused only on national-level estimates and did not offer any additional insights into how these depreciation functions might vary across states or how differences in construction costs across regions may affect the capital stock estimates.

4. Furthermore, in order for national-level estimates to yield precise estimates, they rely on historical data. Therefore, since the relation between investment and output changes over time, most national-level studies do not provide estimates of current relations.

5. The importance of the reliability of highways and the measure of the variance of travel time was suggested to me by David Forkenbrock.

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Additional Resources

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