Measuring Economic Impacts of Transpor

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May 1990

INTRODUCTIONS AND DEFINITIONS

This paper deals with the measurement of infrastructure investment, especially highway improvements. Infrastructure influences the quality of life directly by improving the access to certain basic necessities and comforts such as mobility, water, sanitation, health care, education, and social interaction, and indirectly by improving access to economic opportunity, increasing the productivity of labor, private capital and human capital, and by strengthening the tax base upon which public service provision is dependent. The perspective of the paper will be that of an analyst who must predict the net economic benefits of alternative highway programs. Therefore, issues related to the estimation of economic impacts of highway investments will be reviewed including major strengths and weaknesses of alternative approaches, obstacles to the accurate measurement of economic impacts, data sources, data limitations, and promising research directions.

Impacts are either distributional (shifts in benefits and costs among individuals, sectors, or locations) and/or net (changes in the total levels of costs and benefits). In most cases, a majority of impacts are distributional because public expenditures for the construction of the highway would have been made in another location, or on another type of project or service altogether, if the project under consideration were not undertaken. Included in this category

of impact are the so-called ripple or multiplier effects of an economic stimulation. Since the impacts are approximately the same as they would have been for alternative projects. Net impacts (net benefits) are more fundamental changes in the structure of the economy, in the economic base, and the size and composition of the economic multiplier. A wise investment in highways will increase the productivity of private capital, human capital, and other public infrastructure (better roads and bridges will make fire, rescue, police, and public education services more efficient, for example). Net benefits stem from the change in efficiency of consumption, as well as production, due to lower unit costs and/or higher valued services.

Another useful distinction is between short-run and long-run impacts. Short-run impacts include the distributional and net impacts discussed above which occur as an immediate and direct consequences of the highway. Long-run impacts occur as the highway stimulates the rate of economic growth and development. This economic growth is in response to the increases in productivity and the improved consumption possibilities discussed above but which occurs only when firms and households choose new locations, as employers invest in new plants and equipment, and as new markets are developed for the now lower cost products. These long-run impacts can also be either distributional or net since new economic growth and development will be stimulated (the net effect) but other growth and development will be attracted to the areas with new highways from other areas (the distributional effect).

In practice, net effects, whether short-run or long-run, are much more difficult to measure. As we will see, we know far less about the process which generates these net effects than we do about the distributional process. As a

result, there are fewer dependable methods developed to predict the net effects particularly those in the long-run.

One more comment about distributional impacts is in order. Many distributional impacts at the state or national level are net benefits or costs from the perspective of a region. If an investment in highways leads to the concentration of economic benefits in a particular area (county, city, or town) but not the costs, then the project is beneficial from the view of that region. In any event, both the distributional and the net consequences of highway investments are of interest to decision makers.

REVIEW OF LITERATURE

The literature on the economic effects of transportation and other physical infrastructure development may be categorized in a number of ways. On the basis of the discussion above, we may wish to distinguish those empirical approaches which are short-run from those which are long-run, and those which measure distributional effects only, from those which also measure net effects. A very useful basis for classification is the *ex ante* versus *ex post* distinction. *Ex ante* studies are those which attempt to predict the outcome of a process before it occurs. *Ex post* studies measure the outcome of a process after it has occurred. The purpose of *ex post* studies is to generate information and parameter estimates to permit, or to improve the accuracy of, *ex ante* studies. Still other bases for classification include the treatment of dynamic elements, whether the method deals with producer, consumers, or both, and whether it is a low, medium, or high user of data. Table 1 classifies several empirical approaches based on these characteristics.

Table 1: A Comparison of Features of Alternative Approaches

	Ex Ante *Ex Post*	LR/ SR	NET BEN	Dynamics	RESID INDUST	GEN EQUIL	Data Needs
Input-Output	*Ex Ante*	LR	No	Poor	Indust	No	Low
Var I/O	*Ex Ante*	LR	No	Poor	Indust	Yes	Mod
Prod Benefits	*Ex Ante*	SR	Yes	Fair	Indust	No	Mod
Travel Time	*Ex Ante*	SR	Yes	Fair	Both	No	Mod
Will to Pay	*Ex Ante*	SR	Yes	Fair	Both	No	Low
Programming	*Ex Ante*	SR	Yes	Poor	Indust	No	Mod
CGE	*Ex Ante*	LR	No	Poor	Indust	Yes	Mod
Spatial Equil	*Ex Post*	LR	No	Poor	Indust	Yes	High
Indust Locat	*Ex Post*	LR	Yes	Good	Indust	Yes	Mod
Resid Locat	*Ex Post*	LR	Yes	Good	Resid	Yes	Mod
Hedonic	*Ex Post*	LR	Yes	Good	Both	Yes	Mo

SR - Measures the short-run impacts only.
LR - Measures the long-run as well as short-run impacts.
NET BEN - Measures Net Benefit as well as distributional impacts.
Dynamics - Treatment of dynamic elements is good, fair, or poor.
RESID - Measures the impacts of residential choices.
INDUST - Measures the impacts of industry decisions.
GEN EQUIL - Measures the general equilibrium impacts.

In this section the *ex ante* approaches will first be reviewed, followed by reviews of the *ex post* approaches. The final *ex post* approach, hedonic land pricing, will be developed in greater detail in the following section.

Input-Output Approach

Input-output models are the quintessential economic impact assessment tool. There are numerous examples of the use of I-O in the prediction of the economic consequences of highway investment (Polenske; Liew and Liew, 1980, 1984; Stevens, et al.; Madden). In most cases, the models assume fixed input-output coefficients, and therefore, no change in input costs. This, of course, limits their ability to measure the impacts of highway development.

In contrast, Liew and Liew introduce the multiregional variable input-output (MRVIO) model in which the regional technical coefficients change in response to transportation cost, wage rates, and price of capital. The data needs of this approach represent one of its greatest weaknesses. In order to implement this model, a series of data synthesizing procedures must be performed which seriously reduce ones confidence in the predictions.

All studies based on the input-output approach will inevitably find positive impacts from transportation development because this follows logically from the assumptions upon which the analysis is conducted. The magnitude of the benefits depends solely on the magnitude of the cost savings. This strictly *ex ante* approach then is not an appropriate mechanism for asking the *ex post* questions, "Do improved highways lead to economic development?", or even, "How much economic development do highways generate?"

Producer Benefit Measure Approach

In the "producer benefit measurement" approach (Diewert; Gruver; Harris; Kanemoto; Mohring and Williamson), the objective is to measure the change in profits among all users of an infrastructure service and to aggregate over users. The costs of providing the infrastructure service are then subtracted. Profits are estimated from a restricted profit function and infrastructure costs from a restricted cost function. The approach considers all the necessary adjustments in outputs and inputs as well as use of capital and other types of infrastructure services. The restricted profit function must be estimated using econometric means. Diewert discusses issues of functional form, measurement, data, and interpretation.

This approach ignores the economic dynamics involved in infrastructure development. Only the effects on existing firms and enterprises can be measured using this approach. More important, the impact on consumers is ignored. Furthermore, the method is strictly partial equilibrium in that it ignores price changes related to the infrastructure development. Adding a temporal dimension and general equilibrium features will help, but the shortcomings remain.

Lakshmanan briefly describes a similar approach used to estimate the contribution of infrastructure to the Indian economy. Normalized variable cost functions and costs of adjustment for physical infrastructure stocks were estimated econometrically. The model is explicitly dynamic, employing a flexible accelerator approach and endogenous adjustment of physical infrastructure stocks. Flexible functional forms were employed presumably to permit interrelationships between public and private capital and nonlinear responses.

Estimation of the impact of transportation improvements on travel time (Mohring and Williamson; Gruver) is similar to (and often an integral part of) producer benefits measurement.

Willingness to Pay Approach

Willingness to pay for infrastructure (Diewert) is similar to the producer benefit approach. In fact, they will lead to equivalent measures if estimated perfectly. In this approach measures of producers' willingness to pay for an infrastructure service before and after an investment are compared and the difference is an estimate of the gross benefit of the project. Costs of providing the infrastructure are then subtracted to get net benefits.

The willingness to pay approach suffers from a number of problems, the most serious of which is the difficulty in getting respondents to indicate their true willingness to pay. Strategic behavior may lead them to give answers unrelated to their true willingness to pay. The respondents may not know accurately what the change in infrastructure will mean to them, or they may not understand how the infrastructure will change. In addition, like other approaches, the survey of current firms and households ignores the willingness to pay of those who will move to the areas because of the infrastructure project.

Programming Approach

A popular way of estimating highway and other infrastructure impacts is to use programming models to simulate the effects of the investment. The models are based on assumed average practice or best practice relationships for each of the users or types of user-expected use of the infrastructure service. This approach usually requires an enormous amount of work and number of assumptions. In the end the estimates may be of limited value. For one thing it begs the question, "What are the development effects of infrastructure?", since this must be assumed in order to incorporate the activities into the programming model.

Computable General Equilibrium Modeling Approach

Computable General Equilibrium (CGE) Models can be used to measure the impacts of transportation investments if they are designed with this use in mind (Shoven and Whalley). CGE models overcome some of the problems of other methods but they generate considerably more information than necessary. This in itself is not a failing but the effort and cost needed to develop, calibrate, and use the model is a serious drawback. Because of the complicated nature of CGE models

and the costs involved in using them, they are usually replete with simplifying assumptions not necessary in other approaches. Like other approaches, the demand for the highway must be estimated accurately if the model is to make reasonable estimates of impact.

Spatial Equilibrium Approach

Harris describes a model of spatial production in which output in each sector is a function of location rent, the value of land, demand, supply, input supply, and gross equipment purchases. Location rent is calculated from differences in an average variable cost and transportation costs between each location and the marginal location for each good.

Migration (by age and race) is also estimated as a function of wage rates, changes in employment, and labor supply.

The estimated equations are then used with an input-output model (INFORUM) to predict other variables such as total output, employment and income. These variables are then used to estimate next year's output and a recursive system is developed.

The model is estimated with cross-sectional and time-series (panel) data at the county level. A more disaggregated approach is suggested which would essentially piggy-back on the county level model in a top-down approach.

The model is pseudo-dynamic in that static solutions are arranged sequentially with arbitrary lags of one year. The model predicts, in some instances, negative impacts of transportation investment. This occurs when (1) transportation cost reductions lead industries to be attracted, by other factors, to alternative locations, and (2) as rural consumers are able to travel greater distances to purchase retail goods in neighboring areas.

As Liew and Liew point out, the approach embodied in the MRMI model of Harris and others predicts the regional output share but not the regional expansion or contraction--that is, it is distributional in nature. It is unable, therefore, to predict any change in aggregate economic activity related to the highway.

Other spatial equilibrium approaches employ optimization to minimize costs of production. This optimization is frequently the major disadvantage of this approach since it tends to predict very little interregional trade. In reality, a great deal of cross-hauling is observed between regions, at least if sectors are aggregated to any degree. Aggregation makes sectors heterogeneous which assures cross-hauling.

Industry/Residential Location Approach

A relatively popular approach to the estimation of infrastructure impacts is to directly measure the relationship between industrial and/or household location decisions and the level of infrastructure. The Tiebout Hypothesis is frequently cited as the basis for this approach, especially when household residential choice is analyzed. This approach explicitly considers the longer-term issue of development while it considers the efficiency and profit issues, at best implicitly as a factor in the location choice.

Kuehn, Braschler,and Shonkwiler found that adequate transportation, educational, water, sewer, and sanitation facilities attracted firms. Carlino and Mills used a somewhat more sophisticated approach to measure the determinants of population and employment growth at the county level. A simultaneous equations model was estimated for 3,000 counties using two-stage-least-squares. Their study indicated that an interstate highway increased population density and manufacturing employment. Dorf and Emerson estimated the relationship between

transportation and plant location and found that access to interstate highway or water transportation affected larger firms but had little effect on small to medium-sized firms. Kriesel found that access to interstate highway increased the probability of attracting manufacturing firms with 10 or more employees. Finally, Goode and Hastings, in their Northeast Economic Development System (NEEDS) included a number of infrastructure variables including access to rail service, airlines, interstate and primary highways, size of hospital, proportion of homes with water, sewer, and telephone. Each of these had an influence on some of the manufacturing industries included in the study. Roche et al. propose to use a geographic information system (GIS) as the basis for estimating industrial and residential locations due to transportation and other infrastructure.

Land Value Capitalization (Hedonic Prices) Approach

The most direct approach suggested for estimating the benefits of spatially fixed infrastructure, public services, and amenities is that of hedonic land prices. This approach asserts that the benefits of changes in spatially fixed amenities, services, and infrastructure are capitalized into the value of land and can, therefore, be estimated by measuring the contribution of these variables to differences in land values. The validity of the approach has been the topic of considerable conceptual and empirical debate. The validity of the approach depends on whether all benefits are capitalized into land values (locational rent) or if some are left as quasi-rent (profits and consumer surplus). The critical factors are whether there are enough buyers in the land market to ensure ideal prices, whether consumers are relatively homogenous, and whether the general equilibrium effects lead to significant changes in prices and wages.

Arnott concludes, on the basis of conceptual arguments, that only part of benefits of such spatial investments will be capitalized into land values and that this approach will underestimate the benefits. Arnott argues that the following conditions limit the value of this approach. First, if the economy is not sufficiently open, new residents and firms will not bid up the land prices sufficiently to capitalize all benefit. Secondly, if similar improvements occur widely, then the demand will again be insufficient to fully capitalize benefits. Finally, Arnott argues that if the land buyers are not identical, then some changes in consumer (and presumably producer) surplus will occur which are not reflected in the marginal valuation of land. This latter point is rather inconsequential when reasonably small changes are taking place. The first two conditions essentially require that the market operate reasonably well.

Kanemoto (9188) develops a rigorous general equilibrium treatment of the issue. He assumes a competitive market and considers the *ex ante* measurement of benefits and costs using hedonic land prices. He concludes that:

1. hedonic prices will in general over-estimate benefits;
2. hedonic price estimates of benefits will be accurate if prices and wages do not change because of the investment or if production and utility functions do not permit substitution among commodities;
3. the hedonic price approach does include the consumers' surplus;
4. heterogeneity in consumers tends to reinforce the paper's conclusions;
5. hedonic pricing is preferable to direct measures of infrastructure price because the latter ignores consumers' surplus;
6. benefits received by producers are measured equally well by hedonic prices if long-run, free entry competition is assumed;

7. the results are unchanged if we assume that labor supply is endogenous, that is, if workers determine the number of hours they work based on wages and prices;
8. the results are unchanged if wage rates are dependent on infrastructure, if land is demanded by both consumers and producers since any wage rate differences due to infrastructure and amenities will be reflected in the bid price for commercial and industrial land; and
9. "the hedonic measure can be used as an upper bound estimate...If mobility is imperfect, capitalization tends to be less than perfect, which creates a counteracting tendency for under-estimation and the net result is uncertain" (p. 989).

McHone reports on an empirical test of a theory developed by Fishel and later by Fox (1978). This theory relates location rent, local tax rates, and industrial development. McHone empirically estimate a simultaneous model in which tax payments per employee and manufacturing employees per capita are price and quantity variables respectively in supply and demand functions for industrial locations. The price of land is a significant variable in the demand function. The study indicates that manufacturing firms pay for some locational value through taxes and capitalize the rest into land value. This is consistent with the conceptual predicts of Kanemoto and suggests that total benefits should be increased by the change in tax revenues collected due to the infrastructure investment.

A COMPARISON OF ALTERNATIVE METHODS

A review of Table 1 shows the degree of diversity among the approaches identified. Depending on one's objectives, different approaches may offer more advantages than others. If one is primarily interested in an estimate of the industry relationed distributional impacts of a highway project, then input-output analysis used alone would be most appropriate. An example of this type of application might be the case where the decision has already been made to invest in a given infrastructure project and the only question is the local sectoral impacts, excluding the development which was induced by the change.

If, on the other hand, one needs to know the level of all benefits and costs in order to prioritize a series of alternative investments, then the hedonic land value model is most appropriate. For the latter purpose, few alternatives exist. At a minimum, one must measure the long run net benefit impacts for industries and residents. The only other approaches which simultaneously meets these conditions are residential and industrial location models. These two models would have to be used together if estimates of the full value of the investment was desired. The separate estimates would have to be carefully added together.

The producer benefits approach would be useful if the impacts of a transportation project on a specific industry, or at most, a series of industries. To estimate the impact on more than a few industries would be an enormous task. The models also vary widely in data needs, and ease of use.

Input-output analysis is always relatively easy to use once the model has been developed and tested. The producer benefits, and programming approaches, require the most data if we want to measure the total economy-wide benefits. This is especially true if we want to estimate the developmental as well as distributional impacts. CGE models also require enormous amounts of data and a

difficult to use and interpret once they are complete. CGE models are probably not appropriate for anything but very large study areas. They must necessarily be highly aggregated and will not, therefore, provide very good estimates of the local effects.

The willingness-to-pay approach is useful when data does not exist, or is too expensive to collect in a less direct approach. Willingness-to-pay studies must be undertaken very carefully so that bias is not introduced to the results. An advantage of the hedonic approach is that it can and must be very specific with respect to space. On the other hand, it gives almost no detail at all about the sectoral impacts. If the sector by sector impacts are important, then an input-output model should be used in conjunction with the hedonic model.

Many of the industrial and residential location approaches explicitly generate estimates of the probability that various types of development will occur. The hedonic approach cannot generate such probabilities although it implicitly incorporates the buyer's perceptions about probabilities.

A MODEL OF TRANSPORTATION DEVELOPMENT

Since highways are locationally specific, it follows from economic theory that their benefits and costs (along with the benefits and costs of other local services and amenities) will be capitalized into the value of real property when spatial equilibrium is established. (Prior to the establishment of this equilibrium quasi-rent or short-run profits will be earned by someone.) Some of these values will be highly location specific (for example, within a mile of an interstate ramp, or within the service area of a water system), while others will be much more widespread (within a county that provides solid and hazardous waste services).

When economic disequilibrium is introduced through some economic change, the impacts will first be reflected in price changes. However, these price changes will lead to changes in quasi-rent and to changes in the level and/or location of production. Through this location process one would expect that spatial equilibrium would be re-established with new levels of land rent. Note that since land is used to some extent by many sectors, including residential housing, this spatial equilibrium will involve the relocation of other types of production and households. Furthermore, since local governments provide local public services based on their revenues, and the demand for the services, some further changes will occur in response to the changes.

We hypothesize the following relationships:

A hedonic land value equation,

LANDVALUES = f(TRANSPi, INFRASi, PUBLICSERVEi, MARKETSi, INPUTSi, COSTSi, PLACEi)

where the variables are defined as follows:

TRANSP

This group of variables includes indices of access to various modes of transportation, including interstate, primary road, air service, and shipping.

INFRAS

This will include measures of other important infrastructure services including water, sewer, industrial sites, communications, and colleges.

PUBLICSERVE

This group will include measures of the important noninfrastructural public services such as police, education, fire protection, jails, etc.

MARKETS

These variables will measure the size and purchasing power of each area's markets. This will include population, income, and demographics weighted by effective distance.

INPUTS

These variables will include the costs and availability of inputs to the area's producers and the cost and availability of consumer goods and services.

COSTS

This category of variables will include costs not included above, to firms and households, notably taxes, utilities, etc.

PLACE

This group includes place-specific amenities and variations in productivity.

The approach will involve the statistical estimation of these relationships from panel data (cross-section and time-series). This approach is a hedonic land value model. The method makes a number of critical assumptions. These include:

1. The land market is perfect.

   A perfect land market will assure that values reflect the Ricardian location rent possible from the land.

2. Perfect information.

   Information about future uses and returns will lead to more accurate land values. On the other hand, if there are genuine risks (with objective probabilities), then land values should reflect them. Still, better information will improve the accuracy of this method.

3. No transactions costs.

   One view is that high transactions costs prevent land from gravitating to its highest and best use. Land values then reflect lower than ideal levels. On the other hand, one can argue that transactions costs are a cost of transition and thus correctly reduce land values. A corollary argument is that land values, and thus development, can be enhanced by reducing transactions costs.

4. The land market is in equilibrium.

   Equilibrium, of course, is never achieved in the real world. Some quasi-rent (positive or negative) is always being earned. On the other hand, land speculators tend to adjust marginal land values quite rapidly--much more rapidly than land uses adjust. Thus, land prices established by recent sales should reflect, reasonably well, the future (equilibrium) land uses and value.

5. A marginal change in highways

   A large investment may lead to a violation of the perfect market assumption since it may require too many consumers and producers to move in order to capitalize benefits.

Summarizing this section then, it seems reasonable to hope that neither imperfect markets, imperfect information, transactions costs, or disequilibrium will reduce the ability of land values to indicate future economic development levels. Instead, each of these imperfections will tend to limit the rate of economic development--a matter which concerns us but not in terms of our ability to measure it.

This model will require a highly sophisticated temporal structure to capture the causality in the economic development process. This process includes the following characteristics:

1. The response of property values to economic stimuli will begin when investors anticipate the change rather than when it occurs. As investors become more certain that the change will occur, the response of property values will strengthen. Thus, some of the change in value, particularly that is unimproved land, will occur before the investment begins. Other increases in value will occur after the investment as investments in improvements occurs, and as the rate of development accelerates.
2. If infrastructure is a necessary and sufficient condition for economic development, then land values will always rise in response to (see 1. above) investments in infrastructure.
3. If infrastructure is a sufficient but not necessary condition for development, then the level of infrastructure will be related to at least some minimum level of economic development.
4. If infrastructure is a necessary but not sufficient condition for development, then the level of economic development will be related to at least some minimum level of infrastructure.
5. If economic development precedes, or enables the development of infrastructure (i.e., economic development is a necessary condition for infrastructure), then a situation similar to c. above will be expected.

These conditions are testable with the same data discussed above.

GEOGRAPHIC INFORMATION SYSTEMS

A geographic information system (GIS) would provide an ideal basis for storage and generation of the data needed above. A GIS organizes, stores and facilitates the analysis of data. Two types of base maps, and three types of data can be put on GIS systems. Figure 1 shows the types of base maps and data that would support a physical infrastructure impact system.

TABLE 2: Examples of Geographic Data on GIS

BASE MAPS	DATA
AREAS	AREAL DATA
county boundaries	population
city boundaries	income
town, townships, etc boundaries	demographics
	employment
minor civil divisions	land area
property boundaries	land value
sewer, water, telephone districts	land use
	utility rates
school districts	utility capacity
flood zones	
VECTORS	VECTOR DATA
road and highway centerlines	traffic levels
water course centerlines	accident statistics
bus routes	speed limits
	distances
	commuters
POINTS	POINT DATA
intersections	
bridges	weight restrictions
airports	flight frequencies
industrial parks	indus. park capac.
firm locations	firm employment
recreation sites	visitor days
traffic destinations and locations	traffic originat.
schools	enrollment
hospitals	hospital beds
fire & rescue stations	response time

GIS facilitates the generation of compound or derivative data. Some examples of compound data are:

- Air service indices: Which might include distance to airport, speed limits, traffic congestion, flight frequency, and layover time.
- Interstate access indices: travel time to interstate including bridge limits and speed limits.
- Input availability indices: As developed by Goode and Hastings.
- Market access indices: as developed by Goode and Hastings.

Once the data are collected, entered, and generated for a study area, GIS can create cross-sectional observations from the intersections of the various areas. For example if counties are overlaid by ranges of access to interstates, and ranges of access to airports, then each sub-area with unique values of access to interstates and access to airports and county will be an observation. For each observation other variables such as existence of a school, per capita income, distance to nearest railroad service, etc, will be assigned values. These data then can be analyzed with the GIS or exported to a statistical package. When the analysis is complete (or at appropriate intermediate stages) the estimated parameters can be imported and used for development of graphics, further analysis, validation, etc. More important, the GIS can now be used for simulations to predict the impact of changes in physical infrastructure.

CONCLUSION

Very little research is available to conclusively establish the nature of linkages between physical infrastructure and economic development. The need is particularly great to understand the role that infrastructure plays in creating new economic benefits as opposed to simply redistributing them among individuals, sectors, and regions. This requires an empirical analysis with very sophisticated temporal and spatial capabilities. The latter requirement seems best served by a GIS bases approach.

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