Investigation of the Relationship Between Highway Infrastructure and Economic Development in Indiana

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A study was undertaken to investigate the relationship between highways and economic development in Indiana, using cross-sectional multiple regression analysis of data from 1980 through 1988. Seven highway variables in the broad categories of road conditions, highway mileage, and highway expenditures were used in conjunction with several other variables that were hypothesized to be significantly related to economic growth. Results indicated that highway mileage had a significant association with economic development in most cases. A sectoral model was used to investigate the impact of highways associated with 43 different standard industrial classification groups. Several forecasting models were developed for estimating the economic impact of the construction of two-lane highways, the upgrading of two-lane highways to four-lane highways, and the construction of new multilane highways in Indiana.

An issue that has received much attention in recent years is to what extent highways affect the economy, especially at the state and regional levels. This question becomes important in light of the declining condition of highway infrastructure and where funds for constructing new highways and for the maintenance of existing systems become more limited. Decision makers are increasingly aware of the potential economic development benefits of new or upgraded highways.

Many factors affect the economic development of a region, of which the available highway infrastructure is only one. The extent to which highways actually affect the economic development of a region is a highly debated issue. The literature on this subject uses many methodologies to model this relationship, and results vary, depending on the model, the period, and the unit of analysis.

The purpose of this paper is to investigate how economic development in Indiana between 1980 and 1988, as measured by employment growth, correlated with county-level highway infrastructure in 1980. Such a study does not establish that highways caused growth; it is, however, structured to demonstrate one element of causality: temporal precedence.

LITERATURE REVIEW

Input-output models appear to be the most commonly used methodology to determine the impact of highways on economic development. In most of these models, a distinction is made between the direct, indirect, and sometimes also the induced effects of highway construction (*1,2*). Detailed estimation of various economic sector responses to an external impact can be derived from these models. In general, the models are complicated and require detailed data as input, and they can be costly and time-consuming to calibrate and implement. Other limitations include problems with the timeliness of the data and difficulties modeling lagged effects. Several input-output models are in use today at various levels of analysis, such as the Regional Input-Output Model System (RIMS) or its updated successor (RIMS II) (*3*) and the Regional Economic Impact Model for Highway Systems (REIHMS) (*4*).

Regression analysis, using either time-series or cross-sectional data, or pooled time-series/cross-sectioned data, also has been used extensively to estimate the relationship between highways and economic development. An advantage of econometrics is its ability to analyze the simultaneous effect of a large number of variables, lags, and functional forms. Several other methods also have been used. Regression and input-output analysis appear, however, to be the most commonly used methods.

Several studies of the relationship between highways and economic development have been undertaken in recent years. At the national level, the relationship between the highway capacity level and the growth rate of per capita output for the 48 contiguous states between 1960 and 1985 was investigated (*5*). Regression analysis was used, and the results showed that, in general, states with a better highway infrastructure with regard to highway capacity and quality showed a higher per capita income growth over the period.

At the state level, several relevant studies were also performed. An ongoing study in North Carolina investigated the 100 counties in that state and indicated that the strongest growth was situated in urban counties (*6*). In the next part of the study, factor and cluster analysis were used to group counties together according to various factors (*7*). Regression analysis, using cross-section data and lagged variables, was employed to investigate the association between developmental highways and economic development in Georgia (*8*). Two studies were done in Iowa as part of the Revitalize Iowa's Sound Economy (RISE) program. One study (*9*) focused on developing a method to evaluate road projects to attract specific industries to an area. In the second study (*10*), a methodology was developed to determine priorities for primary road corridor development by using a regional analysis meth-

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odology involving the 954 incorporated cities and 99 counties in the state. A study undertaken in Minnesota used regression analysis pooling time-series and cross-sectional data from 1957 to 1982 for the 87 counties in the state (*11*). Granger-Sims causality tests were used to distinguish between the cause and effect of the relationship between highway expenditures and employment.

The four statewide studies mentioned above were typical of economic impact studies. The following are some of the common elements that can be identified. In urban areas, highways seem to have a significant impact on development. Because there are typically better and more extensive highway facilities in these areas, industries and jobs are concentrated in urban areas, thereby providing a bigger tax base and justification for better highway infrastructure. The effect of highway facilities on economic development in rural areas is not clear. There appears to be a significant amount of commuting to urban areas from counties close to urban areas.

The studies also indicated that because of a general decline in manufacturing employment in the United States in the past decade and an increase in service employment, both of these types must be considered in any study of the impact of highways on economic development. Specific service industries can be expected to play an increasing role in economic development in the future. In studies at the disaggregate level, such as within states or regions, counties appear to receive the minimum level of analysis because of data availability.

STUDY DESCRIPTION

In this paper, a study is described that dealt quantitatively with the relationship between highways and economic development in Indiana between 1980 and 1988. Regression analysis was used on cross-sectional data for 92 Indiana counties. The period was determined by the availability of highway data.

Compared with other states in the region and the United States in both 1980 and 1988, Indiana had a relatively strong manufacturing base, although this sector showed a slight decline over the period. The primary metal manufacturing industry in particular showed a large decline. In the service sector, defined as all industries with standard industrial classification (SIC) codes between 40 and 99, the state showed increases in employment and wage-income, similar to those of the East-North Central region and the United States. Almost all service industry groups experienced growth, with the largest actual increase in health services. Because of the larger share of the service sector in the state's economy, the net effect was an increase of over 10 percent in both total employment and wage-income.

For the purposes of this study, multiple cross-sectional analysis was used. A review of the economic development literature identified factors other than highway infrastructure hypothesized to affect economic development:

- Resource costs (*12*);
- Airport accessibility (*13*);
- Facilities that enhance the quality of life (*14*);
- Proximity to metropolitan areas (*15*);
- Relative wage rates and the presence of similar industries in a region (*16*);
- Tax rates; (*17*) and
- Education levels (*18*).

MODEL DEFINITIONS, ANALYSES, AND RESULTS

For the purposes of this study it was assumed that economic development can be modeled as either the change in employment or the change in wage-income over the period. Seven highway infrastructure variables in the broad categories of pavement condition, extent of highway facilities, and highway expenditures were defined. In the analysis, a series of increasingly disaggregate models was defined.

THE LIMITED MODEL

The first model, the limited model, was defined as follows:

$$Y = X'B + e$$

where

Y = The change in a county's employment or wage income in all economic sectors, in the manufacturing sector, or in the service sector between 1980 and 1988;
X = vector of independent variables;
B = vector of estimated parameters; and
e = vector of errors.

The independent variables included the following:

- COND is the road condition variable, defined alternatively as the average weighted road condition of the state highway system in a county (PSR), the percentage of roads with a PSR of 25 or less in a county (POOR), and the percentage of the total highway system that was paved in a county (PAVED);
- MILES is the highway facility variable, defined alternatively as the total mileage per square mile (ROAD80), the multilane mileage per square mile (G2LN80), and the highway facility rating in 1980 (HFR); and
- EXP is the total highway expenditures per square mile in a county from 1980 to 1988 in 1988 dollars (EXP).

The HFR variable was developed to approximate the extent of highway facilities in terms of highway capacity by using the two-lane and four-lane mileages weighed by their respective unconstrained capacities. Highway variables were used individually and in various combinations in separate regressions.

The limited model appeared to explain fairly well the variance in economic development in Indiana from 1980 to 1988 in the total industry and service sectors. It did not explain well the changes in manufacturing employment or wage-income. Road condition appeared to have a significant and positive association with economic development in only a few cases, and highway expenditures were significant with a negative relationship in some regressions. The extent of highway facilities was, however, significant in all instances, with a positive association in the total industry and service sectors. Multilane mileage density (G2LN80) were also associated with higher changes in economic development than were the total mileage density (ROAD80).

THE COMPREHENSIVE MODEL

A more comprehensive model was then defined with the same response variables as those in the limited model. The highway infrastructure variables were included in the same way as those in the limited model, namely each individually and in combination. However, other variables hypothesized to affect economic development were added to the model as explanatory variables. The independent variables in this model included the highway-related variables mentioned in the limited model and the following additional variables:

- ELEC is the industrial or commercial electric rate in a county in 1980, as applicable, in dollars per kW-hour;
- WATER is the availability of water in a county measured on a scale of 2 to 7;
- APT is the straight-line distance in miles from a county to the nearest large airport;
- COLL is the percentage of college graduates in a county in 1980;
- MSA is the distance in miles for a county to the nearest metropolitan statistical area;
- RECR is the acreage of federal, state, and local public recreational facilities in a county in 1988;
- TAXRT is the net property tax rate in a county in 1980;
- WAGE is the average wage rate for the total industry, manufacturing, or service sectors in a county in 1980, as applicable; and
- AGGL is the agglomeration variable, measured as the manufacturing or service sector employment, or both, in a county in 1980, as applicable.

Results from these regressions were as follows:

- Overall, road condition was not a significant variable, except in some instances in the service sector. PSR was positively related to growth, whereas the percentage of poor roads (POOR) was negatively related to growth, as hypothesized. The percentage of paved roads (PAVED) was not significant in any instance.
- Highway mileage was positively related to growth and statistically significant in most cases in the total industry and service sectors. In was not significant in the manufacturing sector, probably because of influences outside Indiana that affected this sector during the period. Parameter values showed consistent behavior in all three models, and, in particular, multilane mileage density had much higher parameter values than the total road mileage density within a fixed configuration of highway variables and agglomeration variables.
- Except for the wage-income manufacturing sector model, highway expenditures were significant in many cases, with a negative association. Expenditures over this period were aimed at localized construction and improvements that may have had only marginal economic impact. In addition, highway expenditures may have been deliberately undertaken in counties with low economic growth because of declining highway conditions.
- The percentage of college graduates and the property tax rate in a county were highly significant, with, respectively, positive and negative associations in most cases, as postulated.
- The adjusted coefficient of determination (R^2) for the comprehensive model increased considerably over that of the limited model. The highest value of this parameter in the total employment sector, manufacturing sector, and service sector, respectively, were 0.75, 0.51, and 0.99. Also, within each specific sector, the employment model attained a higher adjusted R^2 in general than with the same regression in the wage-income model.

SECTORAL MODELS

Industries within the manufacturing and service sectors were identified and divided into 43 groups, according to SIC codes between 1 and 93. For each of these industry groups, the sectoral employment and wage-income data for 1980 and 1988 were obtained. The independent variables in this model were otherwise the same as those in the comprehensive model. The dependent variables varied, however, according to sector.

The results from the sectoral model varied across sectors. In the general industry group, consisting of the four SIC groups with SIC codes from 1 to 17, some conflicting results were obtained relative to highway mileage variables, although the overall models seemed to be fairly "good" in terms of the coefficient of determination. In the manufacturing sector, consisting of SIC groups with SIC codes from 20 to 39, results varied according to sector. Better models were obtained for some industries than had been obtained in the aggregate manufacturing sector model. Some unexpected results pertaining to highway variables were also obtained, with total highway mileage density being significant and positively related to economic development in some manufacturing sector groups, contrary to results from the aggregate model. These sectors were food products, chemical products, and metal industries. In the service industry sector, with 23 SIC groups containing SIC codes from 40 to 93, highway mileage was significant in a majority of sectors, with positive association in the majority of cases, which was consistent with the aggregate model. Also, the adjusted R^2s were high in most sectors.

FORECASTING MODELS

The final part of this study was aimed at the development of models that could be used to estimate the economic impact of highway improvement and expansion projects. Residual analysis was used to investigate the models, and Glejser's test for heteroscedasticity (*19*) was employed when indications of this phenomenon were found in residual plots.

After detecting heteroscedasticity in most models, several measures were attempted to correct for the phenomenon. Deletion of outliers, normalization of dependent variables by county area and population, and weighted least-squares analysis using county population as weights were undertaken. In the total and service industry sectors, several models were

MODEL 1

TEMP = -4,968** + 1,220 ROAD80** - 18,336 ELEC80 + 202 WATER* -17 APT
+ 24,765 PCOLL*** + 26 MSA* -0.00206 RECR + 88 TAX+ 0.0156 TOTWAG80

ADJ. R**2=0.18 SSR=0.09478 SSE=0.27401

MODEL 2

TEMP = 1571 + 7,174 G2LN80** - 71,227 ELEC80*** + 208 WATER*** +9.75 APT
+ 12,883 PCOLL** + 37 MSA*** -0.00537 RECR - 179 TAX - 0.0602 TOTWAG80

ADJ. R**2=0.16 SSR=9.979E-11 SSE=3.153E-10

MODEL 3

TWAGINC = -103** + 26 ROAD80** - 358 ELEC80 + 3.97 WATER* - 0.4075 APT
+ 519 PCOLL*** + 0.5918 MSA* - 3.204E-5 RECR + 1.4237 TAX

ADJ. R**2=0.17 SSR=4.025E-5 SSE=1.28E-4

MODEL 4

TWAGINC = -21 + 164 G2LN80** - 982 ELEC80 + 4.97 WATER** - 0.541 APT
+ 498 PCOLL*** + 0.709 MSA** -0.00013 RECR + 0.7068 TAX

ADJ. R**2=0.14 SSR=3.67E-5 SSE=1.32E-4

MODEL 5

SEMP = 69 + 566 ROAD80** - 12,490 ELEC80 + 106 WATER -14 APT + 30,075 PCOLL***
+ 29 MSA** -0.00422 RECR - 96 TAX - 0.06636 SVCWAG80

ADJ. R**2=0.54 SSR=0.04339 SSE=0.03039

MODEL 6

SEMP = 2234 + 5,003 G2LN80** - 34,539 ELEC80 + 111 WATER - 9.1 APT
+ 29,293 PCOLL*** + 27 MSA** -0.00609 RECR - 89TAX - 0.06731 SVCWAG80

ADJ. R**2=0.54 SSR=0.0431 SSE=0.0304

MODEL 7

SWAGINC = -27 + 15 ROAD80*** - 733 ELEC80 + 2.79 WATER - 0.21961 APT
+ 696 PCOLL*** + 0.72154 MSA*** -0.00007 RECR - 2.4960 TAX

ADJ. R**2=0.65 SSR=2.591E-5 SSE=1.238E-5

MODEL 8

SWAGINC = 44*** + 81 G2LN80*** - 1,459 ELEC80*** + 2.086 WATER***
+ 0.2699 APT***+ 161 PCOLL*** + 0.3697 MSA*** - 0.00002 RECR - 1.616 TAX

ADJ. R**2=0.38 SSR=3.31E-14 SSE=4.26E-14

NOTE : * = VARIABLE DIFFERENT FROM ZERO AT A 10% SIGNIFICANCE LEVEL
** = VARIABLE DIFFERENT FROM ZERO AT A 5% SIGNIFICANCE LEVEL
*** = VARIABLE DIFFERENT FROM ZERO AT A 1% SIGNIFICANCE LEVEL
VARIABLES AS DEFINED EARLIER.

TEMP = TOTAL EMPLOYMENT CHANGE BETWEEN 1980 AND 1988
TWAGINC = TOTAL WAGE-INCOME CHANGE BETWEEN 1980 AND 1988, 1988$, MILLIONS
SEMP = SERVICE EMPLOYMENT CHANGE BETWEEN 1980 AND 1988
SWAGINC = SERVICE WAGE-INCOME CHANGE BETWEEN 1980 AND 1988, 1988$, MILLIONS
OTHER VARIABLES AS SPECIFIED EARLIER.

FIGURE 1 Forecasting models.

identified that had no heteroscedasticity associated with them after transformation, according to Glejser's test. In the manufacturing sector, this problem was still present in all models after transformation.

A total of eight models were identified for forecasting purposes. The models include alternatively the total highway mileage density (ROAD80) and the multilane mileage density (G2LN80), with total and service employment and wage-income change individually as response variables. Figure 1 presents these models with regression parameter values and other pertinent statistical parameter values. It is clear from the table that in each sector, the multilane mileage density parameter exceeded considerably the total highway mileage density parameter. Also the total employment highway parameter values were higher than the values in corresponding models in the service sector. The parameter values for highway infrastructure indicated that mean county employment had an average increase of 1,220 jobs associated with one unit increase in the total highway mileage density per county, all other variables being held constant. This translates into a mean employment increase of three jobs for the mean county with an area of 391 mi^2, over the 9-year period of the study. Using the same assumptions, the following can be derived from the other models:

- The mean county had an average increase of 18 jobs associated with every mile increase in multilane highways;
- The mean county wage-income in 1988 dollars had an average increase of $66,500 (in 1988 dollars) associated with every mile increase in highways in the total system; and
- The mean county wage-income had an average increase of $419,000 associated with every mile increase in multilane highways.

In the service industry sector, the associated values were as follows:

- The mean county had an average increase of 1.5 jobs associated with every mile increase in total highway mileage;
- The mean county had an average increase of 13 jobs associated with every mile increase in multilane highways;
- The mean county wage-income had an average increase of $38,400 associated with every mile increase in highways in the total system; and
- The mean county wage-income had an average increase of $207,000 associated with every mile increase in multilane highways.

These values are only estimated mean economic development increases associated with increments in highway infrastructure and should not be used for estimating economic growth overall or in individual counties. In Table 1, the 95 percent confidence intervals for the above-mentioned parameters are presented, also adjusted from highway mileage density to highway mileage in the relevant class of total mileage or multilane mileage. The wide intervals of the parameters provide evidence of the large variances associated with the data.

TABLE 1 Confidence Intervals for Estimated Highway Parameters Indicating Wide Range of Estimated Effects of Highways on Economic Development

DEPENDENT VARIABLE	INDEPENDENT VARIABLE	95% CONFIDENCE INTERVAL	
		LOWER LIMIT	UPPER LIMIT
TOTEMP	ROAD80	0.59	5.65
TOTEMP	G2LN80	4.09	32.61
TOTWAGINC	ROAD80	16	116
TOTWAGINC	G2LN80	27	811
SVCEMP	ROAD80	0.32	2.57
SVCEMP	G2LN80	2.88	22.71
SVCWAGINC	ROAD80	18	60
SVCWAGINC	G2LN80	99	315

TOTEMP = TOTAL EMPLOYMENT CHANGE PER COUNTY, 1980-88
TOTWAGINC = TOTAL WAGE-INCOME CHANGE PER COUNTY, 1980-88
SVCEMP = SERVICE EMPLOYMENT CHANGE PER COUNTY, 1980-88
SVCWAGINC = SERVICE WAGE-INCOME CHANGE PER COUNTY, 1980-88

EMPLOYMENT CHANGES IN JOBS PER MILE
WAGE-INCOME CHANGES IN $'000 PER MILE, 1988 $
ROAD80 = TOTAL HIGHWAY MILEAGE PER COUNTY
G2LN80 = MULTI-LANE MILEAGE PER COUNTY

Total employment had adjusted R^2 values that were much lower (0.14 to 0.18) than the service industry's values (0.38 to 0.65). The result is that forecasts using the total industry model will have a wider confidence interval than the service industry model.

The models that were developed for the total employment and service sectors could, however, be used to estimate the economic development impact that the construction of a new two-lane road, the upgrading of a two-lane to a four-lane road, or the construction of a new four-lane road would have on a county in Indiana. The caveats that should be kept in mind at all times are the limitations associated with the data and methodology that were used.

SUMMARY AND CONCLUSIONS

This study was aimed at investigating quantitatively the relationship between highway infrastructure and economic development in Indiana from 1980 to 1988.

The total highway mileage was found to be significantly associated with economic development in most cases. Multilane highways were found to have an association of between 5 and 10 times that of the total highway system. This finding emphasizes the importance of this type of facility, as often addressed in the literature concerning location theory and the attraction of manufacturing industry to a region (*20*).

Highway expenditures were not identified as a good determinant of economic growth in Indiana; this is partly because of the relatively short period of the study. Highway expenditures may not be a good measurement of highway facility availability if the study period does not include the 1960s and 1970s, when massive disbursements were made toward the construction of the highway infrastructure.

Several models were developed in this study that could be used to estimate the economic development impact of constructing new two-lane highways, upgrading two-lane roads to four-lane highways, and the construction of new four-lane highways. The limitations of the methodology—the fact that the models were based on the data for a relatively short period and were subject to specific economic changes in Indiana's history—should be kept in mind when comparing these figures to those of other studies. The models only provide estimates of previous trends; they will not necessarily hold in future years.

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