Dynamic Highway Impacts on Economic Development

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Economic development is increasingly used by state departments of transportation as a criterion in highway funding. However, past studies of the interactions between highways and development provide little or no evidence justifying the use of such a criterion. Existing techniques usually rely on cross-sectional analysis, which only determines correlations between highways and development. In this paper, a time series methodology is developed to differentiate the effects of highways on development from the effects of development on highways. This methodology, which includes both structural plot analysis and causality tests, is based on pooled time series and cross-sectional data on highway construction expenditures and county employment. The results indicate that increases in highway expenditures do not in general lead to increases in employment other than temporary increases in the year of construction. However, in the counties that are economic centers of the state, highway expenditures do have a positive long-term effect, that is, employment increases more than it would for the normal trend of the economy.

Possible economic effects of highways influence highway funding decisions either directly through stated objectives or indirectly through the political arena. For example, departments of transportation in 36 states explicitly consider regional economic development in their highway program selection *(1)*. In this paper, the question of whether highway projects have a definite and foreseeable effect on economic development, increasing the number of jobs more than would the normal trend of the economy, is studied. If highway projects lack such an effect, then in certain states some funds are being inefficiently allocated. On the other hand, if highway projects significantly affect economic development and if the aim is to stimulate the economy, more use of highway funds for economic development purposes may be justified.

Although transportation historically has had undeniable effects on economic development by opening up the frontier, some studies indicate that now that the highway system is mature additional highway improvements in transportation have little, if any, effect on economic development. Unfortunately, the existing empirical evidence when investigated with cross-sectional or input-output analysis is mixed and inconclusive. The purpose of this work is to address the causality issue more directly by using statistical time series techniques instead of wholly cross-sectional techniques.

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The analysis uses annual data on highway expenditures and employment for all 87 Minnesota counties from 1964 to 1982. Although cross-sectional data are pooled with time series data, the time series aspects of the data are analyzed. By first paneling the data, the cross-sectional element for each county is removed. Causality tests of Granger-Sims type *(2, 3)* are used to test whether highway expenditures affect employment levels and whether employment levels affect highway expenditures. Structural time series analysis supplements these causality tests by quantifying the dynamics associated with these relationships.

The evidence indicates that causality from highway expenditures to employment is weak. However, when counties that are economic centers of the state (regional center counties) are separately analyzed, the evidence indicates that higher highway expenditures in these counties lead to a statistically significant increase in employment levels, larger than the normal trend of the economy.

LITERATURE REVIEW

Historically, transportation in the United States has had undeniable effects on economic development. The location of communities has often been determined by the location of transportation, be it a river or railroad. However, today's mature highway network provides a high degree of accessibility relative to what existed 100 years ago. Thus, today's highway projects may lack the stimulative economic effects experienced as the country was developed.

Possible ways that highways may be able to affect economic development include

1. Residential location. In response to changes in the transportation infrastructure, people may change their residences to take advantage of the new transportation facilities. In urban areas this effect has been well studied and its existence verified *(4)*.
2. Work place location. A transportation facility may enable people to work far from where they reside *(5)*.
3. Enterprise location resulting from change in labor supply. Stephanedes and Eagle *(6)* argue that if new transportation facilities allow people to participate in the labor market of an area to which they previously lacked accessibility, then that area's labor supply may increase. The increased labor supply may attract new industry to the area.
4. Enterprise location resulting from decreased transportation costs. An improvement in transportation often will de-

crease the transportation costs of companies in the area served by the transportation facility. These decreased costs may attract new firms to the area *(7)*.

In this paper, the validity of Points 3 and 4 is tested, that is, whether changes in the transportation network affect enterprise location or expansion. Moreover, enterprise location or expansion with employment levels is determined in the counties where highway changes take place.

Several investigators have studied the effects of Interstate highways on population and employment growth *(8–10)*. These investigators have found that counties with Interstate highways have an advantage over other counties with regard to population and employment growth but only in counties within 25 mi of a metropolitan area. The effects on employment are primarily related to industries servicing those using the highways (e.g., service stations, restaurants, and motels) and are not related to manufacturing or wholesale operations. Research in the Atlantic region of Canada (which includes New Brunswick, Newfoundland, Nova Scotia, and Prince Edward Island) has shown that increased investment in transportation infrastructure and freight subsidies would attract few industries because "a reasonably mature transportation system [is] properly in place and maintained" *(11)*. Similarly, in a study of the region around the Ozark Plateau in Arkansas, little correlation was found between highways and economic development *(12)*.

Other sources have found that a significant relationship exists between highways and economic growth. Expressway investments in north England have been found to lead to greater regional employment growth *(13)*, although this greater growth was minimal. In Connecticut, manufacturing employment and population increased more in towns close to the new turnpike than in towns farther away *(14, 15)*.

Regional economic forecasting and policy analysis using large-scale regional models *(16)* often based on the input-output method *(17–22)* have indicated that some economic effects do result from changes in transportation. The implications of these models, however, often depend critically on the users' assumptions. An important variable in input-output models is market share, the amount of the total final demand that is produced locally. In some models, such as SIMLAB *(21)*, the user determines market share. In other models, such as the Amherst Model *(22)*, market share is estimated using an equation relating variables of the model.

When models estimate market share, the parameters of the estimation are often based on statistical cross-sectional studies and, therefore, merely represent correlation. However, by their very existence within the large-scale models, these parameters are used as if they did represent a causal relationship. The direction and nature of that relationship often follow from an ad hoc model structure. For example, Modeler A may specify market share as a function of the number of highways in the region relative to the rest of the country. On the other hand, Modeler B may specify the number of highways in the region as a function of the market share. Both modelers use the same data and cross-sectional analysis. The correlation they obtain is therefore the same, but the two modelers will interpret that correlation as two different causal relationships.

Most of the studies discussed use cross-sectional techniques. However, time series techniques address the issue of causality more directly than do cross-sectional techniques. Because time series techniques can test whether changes in one series (such as highway expenditures) statistically precede changes in another series (such as employment levels), this time series investigation into the causal links between highway investment and economic development was undertaken.

DATA

In this section, the data, the groupings of counties, and the normalization of the data to filter out the effects of inflation, regional or national trends, and other factors common to each particular grouping are described. The data consist of annual observations of state highway system construction expenditures and employment for all 87 Minnesota counties. The expenditure data, provided by the Minnesota Department of Transportation, are broken down by county for the fiscal years 1957–1982. The employment data from the *County Business Patterns (23)* for the years 1964–1982 represent the employment in the middle of March each year. (These data do not include self-employed workers, railroad workers, or governmental employees.) Because the majority of each fiscal year's highway budget (a fiscal year is from July 1 of one year to June 30 of the next) is spent before March, the yearly expenditure data are viewed as preceding the employment data.

The length of each county's employment time series is 19 years; the length of each county's highway expenditures time series is 26 years. Traditional time series analysis could accomplish little with such short series. However, by pooling the cross-sectional data with the time series data, the data elements increase from 19 to 1,653 for employment and from 26 to 2,262 for highway expenditures.

Before the analysis, changes reflecting regional or national trends, inflation, and other effects that are common to the grouping of counties are filtered out. To accomplish this filtering, variables for the statistical analysis are defined as follows.

Let $\bar{\bar{x}}_{i,t}$ be the basic variable (such as expenditures or employment) for county i in year t. Then,

$$\hat{x}_{i,t} = \frac{\bar{\bar{x}}_{i,t}}{\sum_{j \text{ in } G} \bar{\bar{x}}_{j,t}}; \text{ for each } i \text{ in } G,$$

where G is the grouping of counties considered. The $\hat{x}_{i,t}$ variables relate each county in a grouping to the total of the counties in the grouping.

The groupings of counties considered are defined in Figure 1. These groupings are

1. Statewide. All 87 Minnesota counties.
2. Urban. Counties in the Twin Cities seven-county metropolitan area and counties containing a city with a population of 28,000 or larger. (This definition is followed strictly. Thus, even St. Louis County, which includes the city of Duluth and a very large rural area, is classified as an urban county.)
3. Next-to-urban. Counties bordering the urban counties.
4. Regional center. In the Twin Cities metropolitan area, these counties include Hennepin and Ramsey counties, which

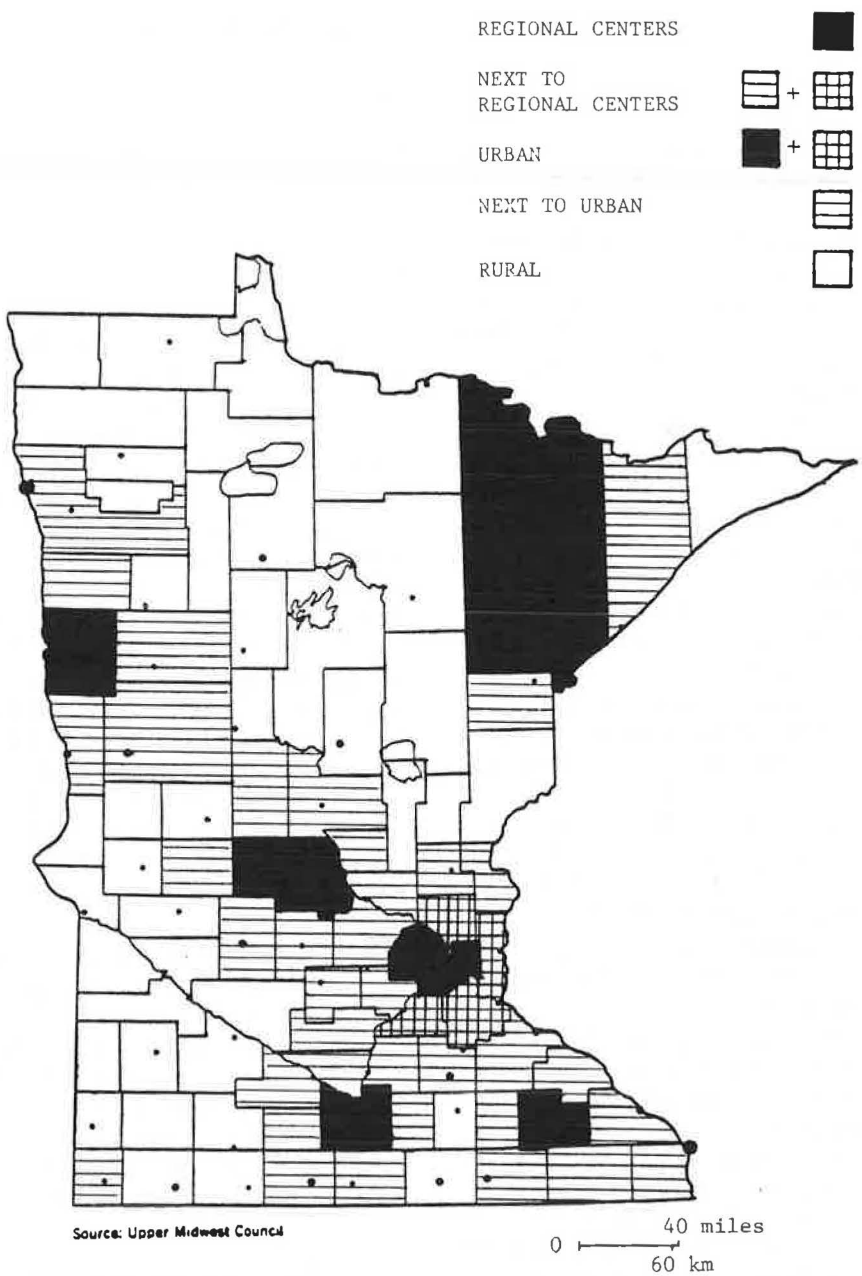

FIGURE 1 County groupings.

include the cities of Minneapolis and St. Paul. Outside this metropolitan area, counties are included if they contain a city the size of Mankato (located in south Minnesota and having a population of 28,000) or larger. These counties are the economic centers of the state as they employ two-thirds of the state workers and contain approximately one-half of the population.

5. Next-to-regional center. Next-to-urban counties plus the Twin Cities metropolitan counties other than Hennepin and Ramsey.

6. Rural. Counties not included in Categories 2 or 3.

Naturally, other types of groupings are possible, for example, counties whose economy is agriculturally based, light manufacturing based, or border counties. However, such groupings have not yet been analyzed.

EQUATIONS

The variables $y_{i,t}$ and $x_{i,t}$ (e.g., employment and highway expenditures) are assumed to be stationary stochastic processes having the following form for some q and constants α_i for each county i in the grouping:

$$\hat{y}_{i,t} = \alpha_i + a_1\hat{y}_{i,t-1} + a_2\hat{y}_{i,t-2} + \ldots + a_q\hat{y}_{i,t-q} + b_1\hat{x}_{i,t-1} + b_2\hat{x}_{i,t-2} + \ldots + b_q\hat{x}_{i,t-q} + \mu_{i,t} \quad (1)$$

where $\mu_{i,t}$ is the error term assumed to be serially uncorrelated.

That the as and bs are the same across counties is a crucial assumption of this formulation, implying that the processes behave similarly across counties. However, the αs do reflect differences among the counties. Although a joint estimation of all the coefficients in Equation 1 would be most efficient, a two-step procedure enables the estimation of the *a*s, *b*s, and αs in a manner that reduces the statistical efficiency slightly but greatly saves computer time.

In the first step of the procedure, the sample mean of each variable over time is subtracted out. This subtraction panels the data, forming the following new variables:

$$\bar{x}_{i,t} \equiv \hat{x}_{i,t} - \frac{\sum_{s=k}^{m} \hat{x}_{i,t}}{m - k + 1}$$

where k and m are the first and last years, respectively, of the data. Because the sample mean is the estimate of the true mean of each variable, the αs are then eliminated from the equation. Therefore, Equation 1 can be rewritten as

$$\begin{aligned}\bar{y}_{i,t} = {} & a_1\bar{y}_{i,t-1} + a_2\bar{y}_{i,t-2} + \ldots + a_q\bar{y}_{i,t-q} \\ & + b_1\bar{x}_{i,t-1} + b_2\bar{x}_{i,t-2} + \ldots + b_q\bar{x}_{i,t-q} + \mu_{i,t} \qquad (2)\end{aligned}$$

The absolute variation of employment and highway expenditures is expected to be greater in large counties than in small counties. If the statistical methods do not adjust for this difference in variation, the largest two counties containing the Twin Cities would dominate, giving biased results. To eliminate this bias, a county's $\mu_{i,t}$ is considered to be the sum of n independent and identical random variables; then the variance of $\mu_{i,t}$ equals n times the variance of one of the individual random variables. Next, it is assumed that the number of the random variables in a county is proportional to its total employment E_i; then $\varepsilon_{i,t} \equiv \mu_{i,t}/\sqrt{E_i}$ is serially uncorrelated and has variance σ^2, which is independent of the county. This specification is reasonably consistent with the data.

The final transformation of dividing both sides of Equation 2 by $\sqrt{E_i}$ filters out the effects of county size on data fluctuations:

$$\begin{aligned}y_{i,t} = {} & a_1y_{i,t-1} + a_2y_{i,t-2} + \ldots + a_qy_{i,t-q} \\ & + b_1x_{i,t-1} + b_2x_{i,t-2} + \ldots + b_qx_{i,t-q} + \varepsilon_{i,t} \qquad (3)\end{aligned}$$

where $y_{i,t} \equiv \bar{y}_{i,t}/\sqrt{E_i}$ and $x_{i,t} \equiv \bar{x}_{i,t}/\sqrt{E_i}$. Because this two-step procedure is not perfectly efficient, a constant term independent of the county is added to Equation 3, yielding a standard regression form:

$$\begin{aligned}y_{i,t} = {} & \gamma + a_1y_{i,t-1} + a_2y_{i,t-2} + \ldots + a_qy_{i,t-q} \\ & + b_1x_{i,t-1} + b_2x_{i,t-2} + \ldots + b_qx_{i,t-q} + \varepsilon_{i,t} \qquad (4)\end{aligned}$$

Equation 4 is the process to be estimated.

METHODOLOGY

Two methods are used to investigate the link between transportation and economic development: (a) Granger-causality tests, and (b) structural time series plots.

Granger-Causality Tests

The direct Sims test of whether a variable x Granger-causes a variable y first formulates the null hypothesis that x does not Granger-cause y. Then, x is regressed on past, present, and future values of y.

$$\begin{aligned}x_{i,t} = {} & \gamma + a_1x_{i,t-1} + a_2x_{i,t-2} + \ldots + a_qx_{i,t-q} \\ & + b_0y_{i,t} + b_1y_{i,t-1} + \ldots + b_qy_{i,t-q} \\ & + c_1y_{i,t+1} + c_2y_{i,t+2} + \ldots + c_ky_{i,t+k} + \varepsilon_{i,t} \qquad (5)\end{aligned}$$

for some integers q and k.

Under the null hypothesis of no causality, all future coefficients of y should be zero, that is, $c_h = 0$ for $h = 1, 2, \ldots, k$. An F-test is used to test whether these coefficients are zero. If the F-test indicates the observed data are unlikely to have occurred if all the future coefficients of y were zero, then the null hypothesis is rejected and it is concluded that x does Granger-cause y.

Structural Plots

To estimate a structural specification of employment, it is hypothesized that, for some q and k,

$$\begin{aligned}E_{i,t} = {} & \gamma_1 + a_{20}H_{i,t} + a_{21}H_{i,t-1} + \ldots + a_{2q}H_{i,t-q} \\ & + b_{21}E_{i,t-1} + b_{22}E_{i,t-2} + \ldots + b_{2k}E_{i,t-k} + \varepsilon_{i,t} \qquad (6)\end{aligned}$$

All variables on the right-hand side of Equation 6 are hypothesized to be predetermined, and thus the structural Equation 6 is identified. The only variable that can be viewed as not being predetermined is $H_{i,t}$. However, the highway expenditure data are available by fiscal year, that is, from July 1 to June 30, whereas each year's employment data represent employment in the second week of March. Because the vast majority of the highway expenditures have already been expended (and certainly appropriated) by the second week in March, the vast majority of $H_{i,t}$ values are predetermined when $E_{i,t}$ occur.

To interpret the structures of Equation 6, an exogenous change in highway expenditures is simulated. In the resulting structural plot (see Figure 2 for examples), which explains employment, highway expenditures are exogenously increased 10 percent for one period and then the expenditures are returned to their original level. The reason the change in highway expenditures for Equation 6 is taken as temporary is that the effects of highways after construction, not the effects from the construction of the highway, are of interest.

Although Equation 6 can be viewed as the structural equation representing employment, clearly highway expenditure is not the only variable that affects employment. Thus, a degree of misspecification in Equation 6 is expected. Also, part of the justification of no simultaneity bias in Equation 6 stems from properties of the data rather than from true structural properties. To address these issues, vector autoregressions that complement the structural equations are being developed.

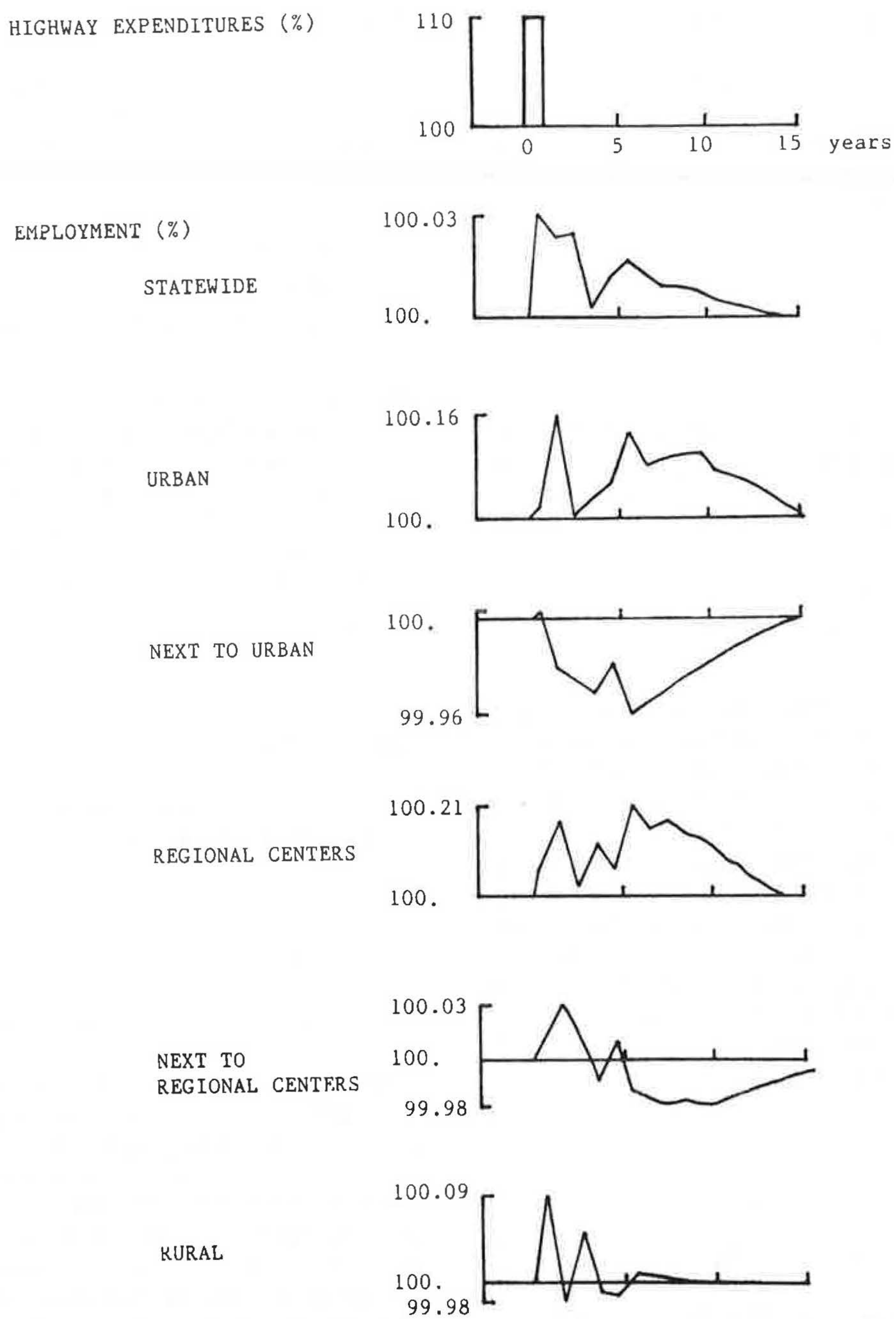

FIGURE 2 Effect of a change in highway expenditures on employment.

RESULTS

The causality tests and structural plots were used to analyze the possible impacts of highway expenditures on employment for statewide, urban, next-to-urban, regional centers, next-to-regional centers, and rural groupings of counties.

Because a lag structure of three to five lags usually captures most of the dynamics of a system, an autoregressive structure of five lags is used for the structural plots, that is, $q = 5$ and $k = 5$ in Equation 6. However, because of leads in Equation 5, the causality tests require more data for a given autoregressive structure than do the structural plots. Therefore, because the length of the time series is only 19 years and each additional lag decreases the degrees of freedom by the number of counties, three lags are used in the causality tests, that is, $q = 3$ in Equation 5.

Corresponding to the three-lag autoregressive structure, three leads are initially used in the causality tests, that is, $k = 3$ in Equation 5. However, the major effects of highways on economic development may occur beyond 3 years into the future. Thus, the causality tests were also performed for six leads. Table 1 presents both the three-lead and six-lead causality tests. A low significance level in the three-lead tests indicates the existence of a short-term effect, whereas a low significance level in the six-lead tests indicates the existence of a long-term effect.

The results of the causality tests and structural plots are given in Table 1, and the structural plots are shown in Figure 2.

TABLE 1 EFFECT OF HIGHWAYS ON EMPLOYMENT

	F-Statistic[a]					
	Three Leads	Significance Level (%)	Six Leads	Significance Level (%)	Increase in No. of Jobs[b]	Elasticity
Statewide	0.43	>20	0.37	>20	7.5	0.001
Urban	1.26	>20	1.66	12.86	52.0	0.008
Next-to-urban	0.49	>20	0.47	>20	−14.0	−0.002
Regional centers	2.51	4.82[c]	3.31	0.60[d]	107.6	0.013
Next to regional centers	0.24	>20	0.77	>20	−3.1	−0.001
Rural	2.10	7.83[e]	0.83	>20	5.3	0.001

[a]The hypothesis H_0 is that construction of highways does not cause additional employment.
[b]Due to $1 million in highway expenditures. The number of jobs represents the average annual increase of jobs over the base year's employment for a typical county in each grouping. The structural plots simulate the direct effects on employment of a 1-year impulse in highway expenditures. Thereafter, highway expenditures are exogenously set at base level. However, after the first period, the VAR treats highway expenditures as endogenous; thus, the VAR reflects feedback effects in addition to the direct effects.
[c]Significant at the 5 percent level.
[d]Significant at the 1 percent level.
[e]Significant at the 10 percent level.

Effect of Highway Expenditures on Employment

Based on the results from the causality tests and structural plots, Table 1 summarizes for each grouping how highway expenditures lead to employment. For the causality tests, the lower the significance level the greater the indication of causality. In particular, a significance level around 1 percent or less is considered as strong indication of causality. A 5 percent significance level may indicate causality, but such a significance level would have about a 50 percent chance of occurring for at least one of the groupings if no causality existed. A 10 percent significance level provides a small indication of causality, but results with such a significance level would have more than a 70 percent chance of occurring in the absence of causality. Significance levels greater than 10 percent provide little indication of causality.

For the structural plots, highway expenditures are temporarily increased by 10 percent as indicated in the top graph of Figure 2; the increase occurs completely within 1 year. The resulting effect on employment is illustrated in the remaining graphs of Figure 2.

The statewide structural plot indicates that for the typical Minnesota county a 1-year increase of highway expenditures of $274,000 (10 percent) leads to an annual average increase of two jobs (0.01 percent) over the 10 years following the first change in highway expenditures. This calculation is based on measuring the area under the curve. As summarized in Table 1, this result implies that 7.5 new jobs statewide follow a $1 million increase in highway construction expenditures (an elasticity of 0.001).

As indicated by the causality tests in Table 1, the effects of highway expenditures on employment depicted in the structural plots are statistically insignificant; neither the three-lead nor the six-lead tests indicate any evidence of highways Granger-causing employment. This insignificance is due to the small magnitude of these effects.

In the evaluation of the statewide data set, the model assumes that all counties behave the same. If, in fact, they behave differently, then the above results may only be true on average, but not for every type of county. To isolate differences in behavior, different groupings of counties were analyzed according to their urbanization.

The causality tests indicate strong causality only for the regional centers, although a small degree of causality is indicated for rural counties. For the regional centers, the six-lead significance level of 0.60 percent strongly indicates a long-term employment effect of highways on employment.

The structural plot for regional centers indicates that two effects occur. The first is the construction effect, which lasts 2 to 3 years. The effect of the construction effect on the economy is due to the road construction. For example, construction jobs are created, the workers spend some of their earnings in the county, and the construction companies make local purchases, causing multiplier effects throughout the county's economy. The second effect is the longer-term employment effect that results because the highway improvement exists. The latter effect is the more sustaining effect of highways and the one primarily of interest here.

Some causality is also indicated for the rural counties. The structural plot for the rural counties indicates that the effects of highway expenditures on rural economies are short term and primarily due to the construction effect. That the construction effect and not a longer-term effect of highways takes place in rural economies is also indicated by the causality tests. In particular, the causality for three leads (short-term) has a significance level of 7.83 percent, but the significance level for the six-lead test is greater than 20 percent, that is, there is no evidence of long-term causality.

Although causality is not indicated for the other groupings, the structural plots do indicate that the effects of highways on employment are not always positive. For the next-to-urban counties, for instance, analysis of Figure 2 indicates that a $274,000 (10 percent) increase in highway expenditures over 1 year is followed by an average decline of 3.5 jobs (0.02 percent) over the next decade. As summarized in Table 1, this effect amounts to −14 jobs per $1 million of new highway expenditures (an elasticity of −0.002). One explanation of this negative employment effect is that improved highways into a regional center allow business activity to move from the next-to-urban counties to the regional centers. This explanation also may be the reason that employment in regional centers significantly increases following an increase in highway expenditures.

In summary, the statewide data set did not indicate any significant effect of highway expenditures on employment levels. Nevertheless, in regional centers, higher levels of expenditures did lead to significantly greater levels of employment. In counties next to urban areas, employment actually dropped following increases in expenditures, although this effect lacks statistical significance. A possible explanation of these results is that improved highways in or around urban areas cause business activity to be drawn into the regional centers from counties near the urban area.

CONCLUSIONS

The time series analysis indicates that increases in highway expenditures do not in general lead to increases in employment levels. Some previous observers have mistaken high correlation between highway expenditures and employment as an indication that highway expenditures do have a substantial effect on economic development. However, analysis indicates that this correlation stems from two other factors: (a) higher employment levels attract higher levels of expenditures, and (b) during the year of construction, employment levels do increase. However, this effect is only temporary and disappears when the period of construction ends.

Thus, it is concluded that highway expenditures do not Granger-cause total employment to increase. However, in counties that are economic centers of the state (defined as regional center counties—these counties employ two-thirds of the state workers and approximately one-half of the population), highway expenditures do have an effect on total employment, exceeding the normal trend of the economy. In these counties, a 1-year, $1-million increase in highway expenditures leads to approximately 108 new jobs.

Although the analysis implied that in general highway expenditures do not Granger-cause total employment to increase, highway expenditures may Granger-cause employment to increase within a specific economic sector. Results from ongoing work in this area indicate that for some sectors the Granger-causality of highway expenditures is significant even for groupings other than the regional centers.

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