Time-Series Analysis of Interactions Between Transportation and Manufacturing and Retail Employment

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ABSTRACT

Using data on state highway expenditures and employment from 30 Minnesota nonmetropolitan counties over a 25-year period, possible interactions between transportation and employment are investigated. Although cross-sectional analysis suggests no significant interactions, causality tests and time-series analysis indicate that highway expenditures affect manufacturing and retail employment, and employment influences expenditures. Although increases in expenditures cause employment improvements in the short term, long-term effects are less favorable. Highway expenditures respond quickly to increased needs caused by retail improvements.

Federal budget deficit increases and spending reductions are likely to significantly restrict the flow of federal aid to regional economic development programs during the next several years. As such programs are phased out, state assistance to economically distressed regions will become increasingly important. Responding to this challenge, states will be encouraged to seek efficient ways to stimulate regional economic development in distressed areas. Although there exists a wide range of policy options for providing stimuli directly within the economic sector, the effectiveness of such policies depends, in part, on the availability of a supporting infrastructure. Transportation investment has long been an important factor contributing to the condition of the infrastructure nationally and at the state level.

Use of resources in transportation investment may, of course, preclude their concurrent use in other types of investment. Similarly, transport investment in a particular region may deprive other regions of useful resources. Therefore, although a given investment may be beneficial when viewed from a strictly local perspective, its net contribution to the economy of the state or a larger region may be negligible. On the other hand, the reallocation of resources accompanying the investment may lead to improved efficiencies and net gains within the larger system as well. Such effects play an important role in project evaluation and should be taken into account in the short-term and long-term assessment of transport policies. To accomplish this, state decision makers should identify and measure any possible impacts of transportation projects on economic development.

Identification of such impacts in nonmetropolitan areas is the major objective of this paper. By employing state trunk highway expenditures and county employment indicators in Minnesota over a 25-year period, this work investigates the existence and direction of causality between expenditures and employment for counties both near and far from large cities. Where causality may exist, time-series analysis develops relationships that explain any possible interactions between expenditures and employment.

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BACKGROUND

Despite the wealth of literature analyzing ways to improve the economy, relatively little of it has examined whether such improvements can be accomplished through selection of appropriate transportation policies. Yet, the literature has recognized (1,2) the quality and cost of transportation as one of the primary barriers to economic development. Most of the literature on transportation and economic development is descriptive or empirically oriented and has been undertaken to address the potential interactions between the two fields in the course of assessing specific project and policy impacts in both freight and passenger transportation. Such interactions include, for instance, the potential influence of transportation costs and accessibility to inputs and markets on the location of firms. Transportation may also permit or make economical the development of certain resources that otherwise would not have been developed. In addition, passenger transportation improvements may increase the labor pool that is available and attract more firms to an area.

Recent empirical evidence about whether changes in freight transportation can have impacts on economic development is mixed. Several studies claim to have found such influence, whereas others conclude that any impacts are insignificant. Even when these effects occur, the industries affected are not manufacturing firms but firms whose function is to service highway users. These firms often are merely relocating from areas where such users previously stopped. The literature points out, for example, that counties with Interstate highways consistently have an advantage over other counties with regard to population and employment growth (3-5). Further, the effect on population growth varies inversely with the distance from a metropolitan area and does not exist in areas farther than 25 mi from a metropolitan area. The effect on employment is primarily with regard to service (tourist-related) employment and is not found in manufacturing and wholesale activities. Research in the Atlantic Region of Canada (6) concluded that increased investment in transportation infrastructure and freight subsidies would attract very few industries because "a reasonably mature transportation system [is] properly in place and maintained." Similarly, a study of the region around the Ozark Plateau (7) concluded that there is little correlation between highways and economic development. Even if there is a correlation, the direction of causality could be economic development leading to highway investment rather than highway investment leading to economic development.

Whereas the research reviewed thus far did not reveal any significant links between highways and economic growth, other sources claim to have found such links. For instance, a strong relationship between regional employment growth rate and transportation cost resulted from motorway investments in North England (8). In Connecticut manufacturing employment and population increased more in the towns close to the new turnpike than in towns farther away (9).

Freight transportation may directly affect enterprise location, and passenger transportation can do so indirectly through its effect on labor conditions. For instance, transportation costs and accessibility can affect where jobseekers look for work (9-11), and firms are affected by the size of the labor pool available to them (11-13). As a hypothetical example, a public transport system from a region with few job opportunities to nearby centers with an excess number of job openings may decrease the unemployment rate (14,15), but the cost of providing the service may not make the investment attractive. Transportation changes may also affect local sales (16), but upgrading transit between communities of different sizes tends to siphon sales away from the smaller communities toward the larger ones.

To summarize, the empirical literature on transportation and economic development is contradictory. However, the majority of the studies indicates that, as long as today's well-developed transportation system provides good accessibility, transportation improvements no longer contribute significantly to economic development. Nevertheless, the literature on large-scale regional models presents a different picture.

Large-scale regional models have been used for regional economic forecasting and policy analysis (17-23). Most are based on the input-output method and several include a transportation sector that plays an important role in the analysis. Although the small-scale empirical studies on freight transportation conclude that transportation has little effect on today's economy, the large-scale regional models indicate that transportation can affect the economy. There are three possible explanations for this apparent contradiction.

- The large-scale regional models estimate transportation coefficients for specific sectors, whereas the small-scale studies are more generally oriented. With different sectors of the economy changing in different directions as a result of transportation changes, the net overall effects may be insignificant even though, by sector, the transportation effect is significant. The few small-scale studies that conclude that freight transportation has economic effects do specifically define a particular part of the economy for study.
- Because different sectors of the economy affect each other, an identification problem, which the large-scale models take into account, may exist in the small-scale models.
- The effect identified by the large-scale models may be passenger-transportation related; if so, they would not contradict the small-scale empirical studies on freight transportation.

Although these are plausible explanations for the apparent contradiction among past findings, a rigorous analysis is needed to resolve this issue. The results from such an analysis of the manufacturing and retail sectors in nonmetropolitan areas are presented in this paper.

DATA ANALYSIS METHODS

Although many methods exist for analyzing the data, here two major methods are distinguished according to the manner time is treated in the analysis:

1. Cross-sectional analysis employs data from different areas but for the same point in time. The analysis assumes that all variables are in equilibrium during the planning period. Any delayed interactions (e.g., between transportation and the economy) are overlooked. Results are applicable to long-term assessment.
2. Time-series analysis employs data from one area but for different points in time. The analysis makes no assumption about long-term equilibrium. Results can point to relations among variables as they occur through prespecified time increments and, therefore, this method is applicable to short-term analysis.

Both methods, by definition, exclude a large part of the available data from the analysis. In particular, the cross-sectional method excludes any data collected over time and the time-series method excludes data from all areas except the one under study. As a result, with either method the analysis may not benefit from additional information, even when such information exists. Nevertheless, this limitation can be overcome by combining the two methods via use of panel data. In particular, when it is desired to consider effects as they occur through time, as is the case here, time-series analysis with panel data can be used. Following this method, data from different time periods and areas are pooled together; however, the cross-sectional differences are eliminated from the data before analysis.

DESCRIPTION OF DATA

Two major sets of data were developed, one for cross-sectional and one for time-series analysis. For each type of analysis, data on both transportation expenditures (only state trunk highway expenditures are analyzed in this paper) and the economy of the areas targeted by these expenditures were collected. The economic indicators included county manufacturing employment, retail sales, unemployment, and family income for cross-sectional analysis and manufacturing and retail employment for time-series analysis.

Before analysis, the data were transformed in two ways. The gross national product (GNP) deflator was employed to adjust the sales and income data for inflation. Further, the data were normalized (however, the normalized variables kept their original names) in order to make the counties comparable. Without such normalization, larger counties would naturally be expected to have more employment and sales and receive more highway expenditures. The resulting high correlations would mask any causal effects between highway expenditures and the economy and, therefore, would make assessment of such effects impossible. To avoid such problems, highway expenditures and sales were normalized by population, and manufacturing employment by employment for cross-sectional analysis. For time-series analysis, county highway expenditures and employment were normalized by total state highway expenditures and employment, thus representing the fraction of the state expenditures and employment in a county, respectively. Normalized time-series data from two representative Minnesota counties, Freeborn and Kandiyohi, are shown in Figures 1 and 2, respectively.

Thirty of 87 Minnesota counties were randomly selected for this analysis. Several criteria led to the selection of the appropriate economic indicators and data source. In particular, to include time explicitly in the analysis, the selected indicators had to be available in the form of a time series, the longer the better. In addition, because state highway expenditures are only available on a yearly basis, there was little need for economic data on periods shorter than a year. Further, to determine whether transportation affects individual economic sectors, easy access to economic data by sector was necessary, at least for the sectors of the economy that are of greatest interest. Of course, the data needed to be reliable. A summary of the different data and their sources is given in Table 1. The reasons for using the employment figures from the County Business Patterns are their ease of access, their availability yearly since 1964, and their existence by county and by sector (or better) for almost all sectors. This study employs both manufacturing and retail employment.

CROSS-SECTIONAL RESULTS

No significant or consistent correlation between state highway expenditures and either manufacturing or retail employment could be determined from the cross-sectional analysis of the data. This result was not surprising and, indeed, was in agreement with findings from previous analyses of this nature mentioned earlier. Such a conclusion refers to absence of relationships in the long term (e.g., at equilibrium beyond a 20-year horizon); it does not consider possible interactions occurring within this

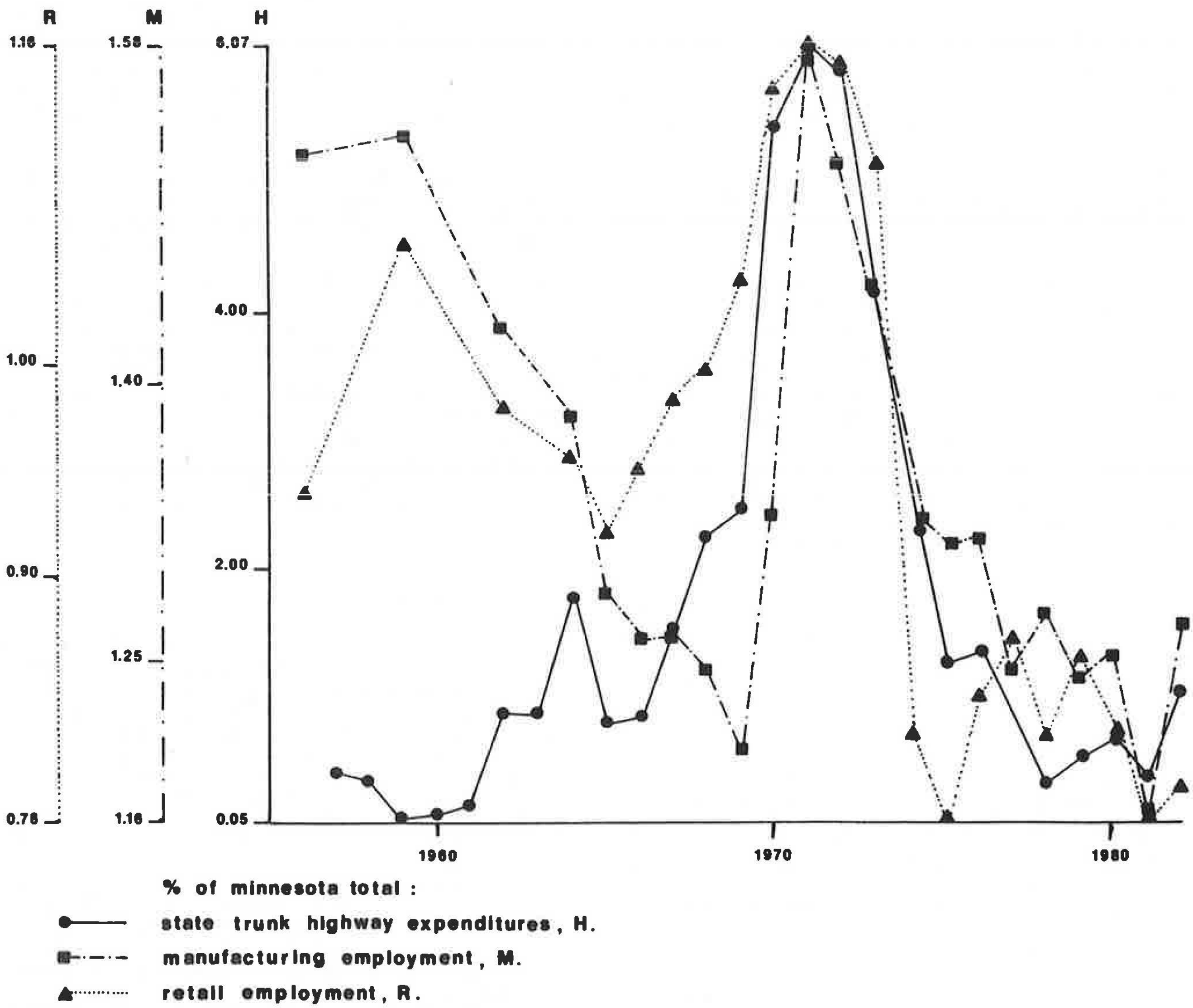

FIGURE 1 Normalized time-series data for Freeborn County.

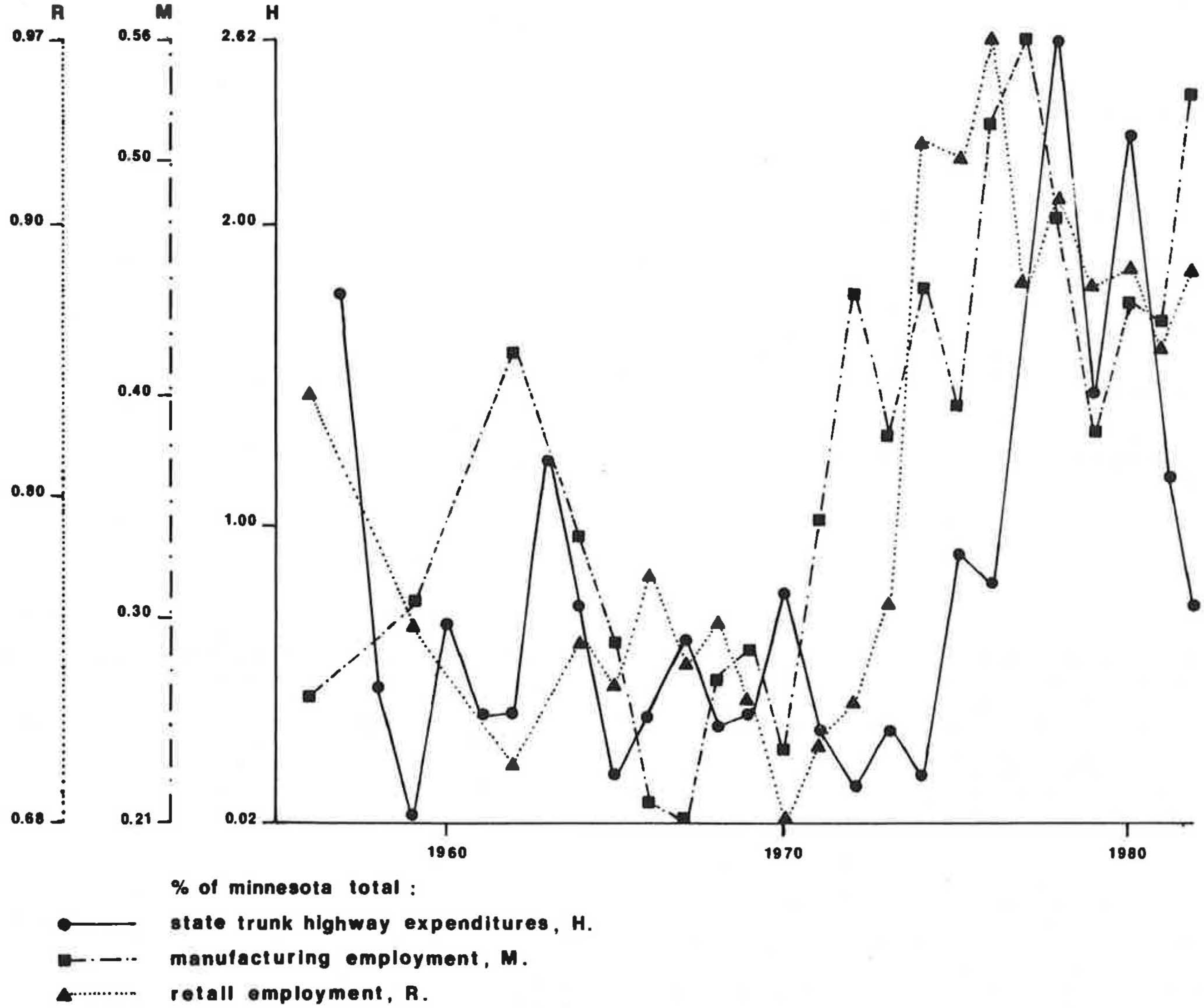

FIGURE 2 Normalized time-series data for Kandiyohi County.

period. Because evidence exists that any possible effects of transportation on the economy may occur within shorter time periods, such as in 1 to 8 years (11,12), time-series analysis of the data was performed next.

To fully use the available data, the data were paneled before the time-series analysis by eliminating the cross-sectional element for each variable and for each county i over all years t. The transformed manufacturing (M_{it}) and retail employment (R_{it}) and state highway expenditures (H_{it}) were derived from the raw data $\bar{M}_{it}$, $\bar{R}_{it}$, and $\bar{H}_{it}$ following the general formula:

$$V_{it} = \bar{V}_{it} - \left[\sum_{s=k}^{s=m} \bar{V}_{is}/(m - k + 1) \right] \quad (1)$$

TABLE 1 Data Characteristics

Characteristic	Employment CBP[a]	Employment DES[b]	Unemployment DES	Median Family Income
Access	Very good	Poor	1966-1978, very good 1978- , poor	Very good
Time series	1964-	Unknown	1966-	Unknown
Time basis	Yearly	Monthly	Monthly	Yearly
All counties	Yes	Unknown	No; excludes counties with cities above 30,000 population	Yes
By sector	Yes except agriculture, mining; may also include 3- and 4-digit SIC	Yes except agriculture, mining; no additional SIC detail	No	No

[a]County Business Patterns.
[b]Department of Economic Security.

where V is any variable and k = 1957 (for employment data, k = 1964), m = 1982, and i = 1, . . . , 30.

CAUSALITY TESTS

Two hypotheses were tested, as the previous section suggests:

Hypothesis 1: $M_{it} = M(H_{it})$ (2)

Hypothesis 2: $R_{it} = R(H_{it})$ (3)

where M_{it} and R_{it} represent the county-to-state employment ratio using data reported by employers on FICA reports (excluding the self-employed) for 1 week in the middle of March each year and H_{it} represents the county-to-state ratio for expenditures on state trunk highways for that year. Regressing the employment on the same year's highway expenditures leads to the following simple specifications (t-statistic in parentheses):

$$M_{it} = \underset{(8.9)}{0.05}\, H_{it} \qquad \text{correlation} = 0.36 \qquad (4)$$

$$R_{it} = \underset{(14.6)}{0.10}\, H_{it} \qquad \text{correlation} = 0.53 \qquad (5)$$

For the average Minnesota county, the coefficients 0.05 and 0.10, respectively, represent the elasticities of manufacturing and of retail employment with respect to highway expenditures. If highway expenditures in the county increase by 1 percent ($25,600), these coefficients imply that manufacturing employment will increase by 0.05 percent (2.0 employees) and retail employment will increase by 0.10 percent (3.6 employees).

It is important to note that, even with such strong correlation between the variables, Equations 4 and 5 do not indicate causality in either direction. A high correlation between employment and expenditures could equally well imply that changes in employment cause changes in expenditures or that both employment and expenditures change in response to a third variable.

To determine the existence and direction of causality between employment and expenditures before formulating any relationships between the two, a series of causality tests was performed. The methodology for these tests was developed by Sims (24) following the concept of Granger (25).

The first step in determining whether a variable x "causes" a variable y consists of formulating the null hypothesis that x does not "cause" y. Next, x is regressed on past, present, and future values of y. Under this hypothesis, all future coefficients of y should be zero. If they are all zero by an F-test, no causality is likely. On the other hand, if even one future coefficient is not zero, then x is said to cause y. To be sure, even this test cannot replace the experimental demonstration of a causal relationship. The test only implies that changes in one variable precede, in a statistical sense, changes in another variable; such precedence is necessary but not sufficient for true causality. It should be noted that spectral analysis, as described by Box and Jenkins (26) is inadequate for the determination of causality because the cross spectrum of x and y can be composed of two cross spectra, one representing x causing y and the other representing y causing x (25). The Granger causality test, as applied here, goes beyond spectral analysis.

Using the 30-county time-series data, causality was tested between state trunk highway expenditures and manufacturing and retail employment. Six causality tests were performed. Each test was repeated three times: (a) for the whole data set, (b) for that part of the data set that included counties within 25 mi of a "large city," (defined here as one with more than 30,000 population), and (c) for the remainder of the data set. A summary of the test results is given in Table 2. The data in the table indicate that

TABLE 2 Causality Tests

	Probability Hypothesis is Correct		
Hypothesis	Complete Set	Near Large City[a]	Far from Large City
Manufacturing employment does not affect expenditures	0	0	0.37
Expenditures do not affect manufacturing employment	0.09	0.05	0.47
Retail employment does not affect expenditures	0	0	0.32
Expenditures do not affect retail employment	0.09	0.13	0.77

[a]Defined here as one with more than 30,000 population.

- For the complete data set, all causalities are accepted. However, the significance of employment changes causing changes in highway expenditures is much higher than that of changes in expenditure causing changes in employment.
- The set of counties near a large city behaves similarly to the complete data set.
- There exist no causalities in counties more than 25 mi away from a large city.

TIME-SERIES RESULTS

On the basis of the results from the causality tests, the vector autoregressive method (26) was used to develop three specifications for the complete data set. The three specifications can express (a) manufacturing employment as a function of state highway expenditures, (b) retail employment as a function of state highway expenditures, and (c) state highway expenditures in terms of manufacturing and retail employment. Following this analysis, a second set of three specifications was developed for areas within 25 mi of a large city, as discussed hereafter.

The vector autoregressive method employed is of the general form

$$\hat{y}_t = \theta_n(B)x_t + \phi_p(B)y_t + c \qquad (6)$$

where

y_t = the dependent variable in year t;
x_t = the independent variable in year t (x_t and θ_i can be vectors);
$\theta_n(B) = \theta_0 B^0 + \theta_1 B^1 + \theta_2 B^2 + \ldots + \theta_n B^n$;
$\phi_p(B) = \phi_1 B^1 + \phi_2 B^2 + \phi_3 B^3 + \ldots + \phi_p B^p$;
B = the lag operator (i.e., $B^s x_t = x_{t-s}$);
n and p = the number of lags for x_t and y_t, respectively; and
c = a constant.

Note that following certain transformations (see earlier discussion) the highway expenditure and employment data used in developing the following specifications are stationary. For each specification, the parameters for three time lags for the dependent and independent variables were identified and are presented together with the standard error, the R^2, and the mean square error (MSE) where

$$MSE = \sum(y_t - \hat{y}_t)^2/K \quad (7)$$

where

y_t = the observed dependent variable in year t,
$\hat{y}_t$ = the estimated dependent variable in year t, and
K = the number of observations.

Time-series analysis of the county data led to the following specification for the manufacturing employment county-to-state ratio (M_t) as a function of the expenditures ratio (H_t):

Lag t	Parameter	Standard Error
	H_t	
0	θ_0 0.011	0.0072
1	θ_1 0.020	0.010
2	θ_2 -0.019	0.010
3	θ_3 0.013	0.0078
	M_t	
1	ϕ_1 0.76	0.048
2	ϕ_2 0.0021	0.059
3	ϕ_3 0.021	0.048
Constant	0.000097	0.000053

$R^2 = 0.64$
$MSE = 1.23 \times 10^{-6}$ (8)

This specification can be written as an equation as follows:

$$M_t = 0.011\,H_t + 0.020\,H_{t-1} - 0.019\,H_{t-2} + 0.013\,H_{t-3} + 0.76\,M_{t-1} + 0.0021\,M_{t-2} + 0.021\,M_{t-3} + 0.000097 \quad (9)$$

Similarly, time-series analysis of the data on retail employment (R_t) as a function of H_t resulted in the following specification:

Lag t	Parameter	Standard Error
	H_t	
0	θ_0 0.017	0.0053
1	θ_1 -0.0036	0.0071
2	θ_2 -0.019	0.0071
3	θ_3 0.0139	0.0056
	R_t	
1	ϕ_1 0.92	0.046
2	ϕ_2 0.23	0.062
3	ϕ_3 -0.25	0.047
Constant	0.000066	0.000038

$R^2 = 0.88$
$MSE = 6.14 \times 10^{-7}$ (10)

Finally, the results on expenditures (H_t) as a function of M_t and R_t were

Lag t	Parameter	Standard Error
	M_t	
1	θ_1 0.31	0.34
2	θ_2 0.29	0.40
3	θ_3 -0.23	0.33
	R_t	
1	θ_1 0.82	0.44
2	θ_2 0.64	0.59
3	θ_3 -0.27	0.47
	H_t	
1	ϕ_1 0.88	0.048
2	ϕ_2 -0.082	0.065
3	ϕ_3 -0.22	0.050
Constant	0.00027	0.00034

$R^2 = 0.72$
$MSE = 4.93 \times 10^{-5}$ (11)

Additional time lags (i.e., more than 3 years) could have been included in the analysis. However, because such inclusion would not have improved forecasting accuracy significantly, it was decided to adopt the simpler specifications.

APPLICATION

The purpose of this section is to demonstrate how the specifications developed in this work can be used to forecast the effects of highway expenditures and county employment on each other. Because the analysis employed time-series data from Minnesota counties to develop the specifications, the forecasts deal with the varying effects that highway investment options would have on county employment in that state. This application uses the complete Minnesota data set. A simple example follows.

Let highway expenditures in a typical Minnesota county change by a one-time 10 percent increase this year (i.e., at t = 0). Use Equation 9 to forecast the resulting changes in manufacturing employment this year (t = 0), next year (t = 1), and in the years beyond.

If the equation did not contain any autoregressive (i.e., lagged values of the dependent variable M) terms, the answer would be that, in year zero, manufacturing would be 1.1 percent higher than the initial base, in year 1 it would be 2 percent higher than the initial base, and so forth. However, because of the additional M terms, the calculations become cumbersome and are completed in a microcomputer. The manufacturing forecasts are shown in Figure 3. As the figure indicates, county manufacturing employment increases by a maximum of 0.3 percent in the year following the 10 percent investment increase. Manufacturing employment drops to approximately its original value in the third year but then increases to an intermediate range and falls back to its original level in the long term. Thus the data indicate that state highway expenditures within a county favorably influence manufacturing in that county but the effect occurs in two stages. The primary, and more substantial, positive influence occurs the year after the highway funds are spent. A less substantial, long-term secondary effect implies that manufacturing employment in the county is still better off with the transportation improvement; the duration of this effect is approximately 10 years.

The effects of highway expenditures on county retail employment, determined with the specification given by Equation 10, are shown in Figure 4. As the figure suggests, a 10 percent increase in highway expenditures results in a maximum 0.17 percent retail increase that same year. However, retail drops 0.04 percent below its initial base by the third year, and, although it later recovers, it falls back to its initial level in the long term, probably drained by better access to metropolitan areas, an effect that is in agreement with previous findings (12).

In the final example, the specification given by

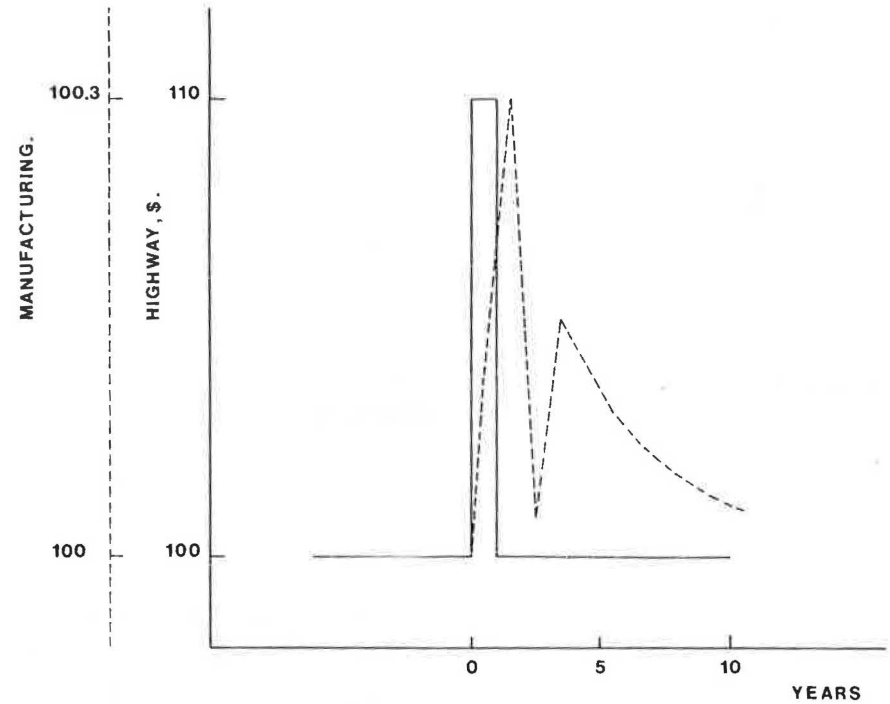

FIGURE 3 Influence of transportation on manufacturing employment.

Equation 11 is used to determine how a 10 percent increase in county manufacturing and retail employment will influence state highway expenditures in that county. The results, shown in Figure 5, indicate that highway expenditures respond to the higher needs of the county by beginning to increase a year after the employment increase. The expenditures peak in the fourth year with a 49 percent increase and then drop but still remain at a level well above the initial base. Although the expenditure increase is higher than the employment improvement in percentage terms, highway funding may be responding to changes in additional economic sectors, such as services, that usually improve with the retail sector.

Using the data set from counties near a large city (as defined earlier), the analysis developed three new specifications that correspond to those developed with the complete data set. In summary, although the results were similar to those for the complete set, manufacturing and retail employment dropped severely following their short-term peak, which indicates that the long-term draining effect

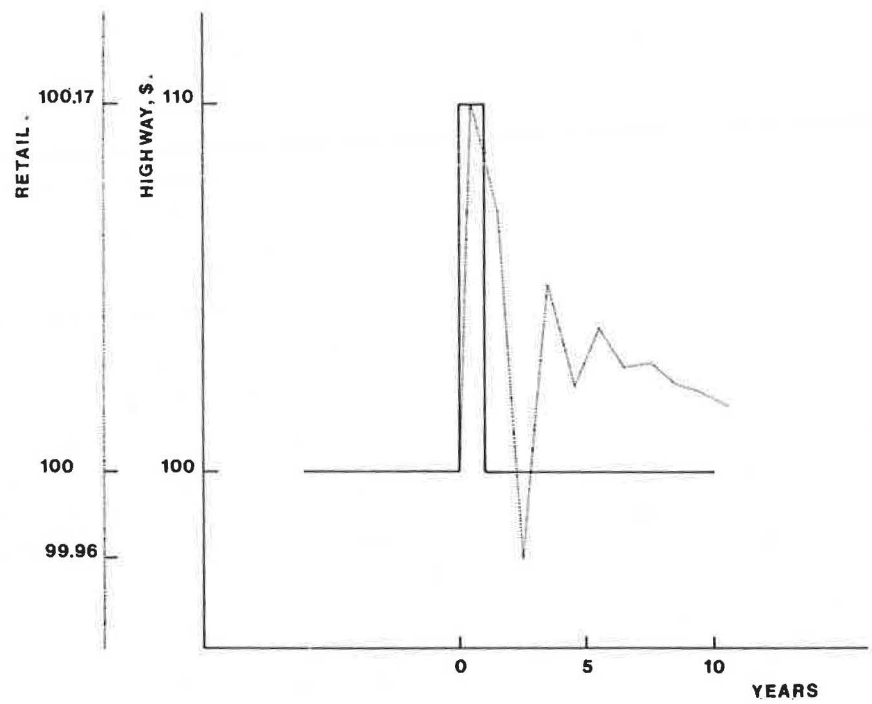

FIGURE 4 Influence of transportation on retail employment.

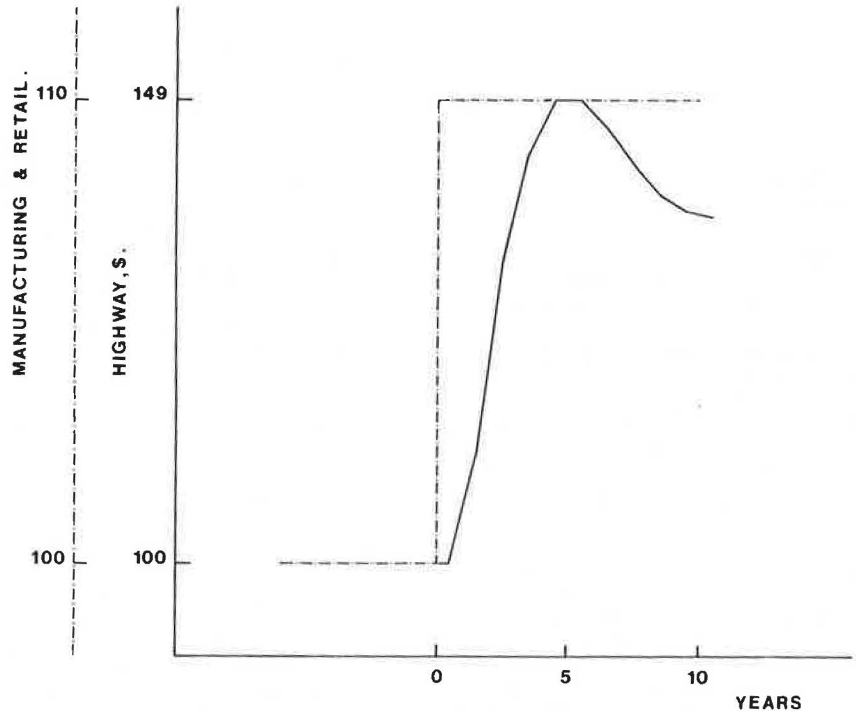

FIGURE 5 Influence of manufacturing and retail employment on transportation.

caused by better access to metropolitan areas is more substantial when a county is near such an area.

CONCLUSIONS

State trunk highway expenditure and employment data from 30 Minnesota nonmetropolitan counties are analyzed and possible interactions between highway expenditures and employment are investigated. In agreement with some previous research, cross-sectional analysis of the data suggests no significant interactions. However, more rigorous causality tests identify such interactions (i.e., highway expenditures influence manufacturing and retail employment, and employment affects highway expenditures). Nevertheless, causality is not indicated for counties located more than 25 mi from large cities (defined here as cities with more than 30,000 population).

Using time-series data from the period 1957-1982, the vector autoregressive method developed specifications for the cases in which causality existed, both for the complete data set and, separately, for the counties located near large cities.

From the specifications it is concluded that, although state trunk highway expenditures influence both manufacturing and retail county employment, the short-term effects differ from the long-term ones. In particular, although employment increases in the first 2 or 3 years following highway improvements, it then drops and, by approximately the 10th year, is back to its initial base, possibly drained by better access to metropolitan areas. Further, highway expenditures respond to county needs by improving service within a year after employment begins to increase. Finally, it is found that counties within 25 mi of a large city behave much like the complete data set except that, in their case, the draining effect to metropolitan areas is more severe.

Although these findings shed some light on the existence, direction, and size of causal effects between highway investment and the regional economy, several questions still remain unanswered and are currently under investigation. For instance, the possibility of interactions between transportation and additional sectors of the economy, such as the service sector, must be investigated, and more economic indicators can be employed to complete such assessment. Further, large highway construction projects, such as the Interstate program, can be distinguished from the rest of the projects and each set evaluated separately. Finally, more work in isolating the effects of large cities on their surrounding regions will aid in clarifying the interactions between highway expenditures and the economy of those regions.

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