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Introduction

The Midwest's economy has undergone a remarkable recovery from the devastating twin recessions of the early 1980s. The back-to-back recessions that greeted the 1980s cut deeply into the region's manufacturing. Manufacturing employment declined by 19.3% between 1979 and 1982, the depths of the recession. In contrast, manufacturing employment in the rest of the United States fell by only 5.6%. The contrast between the economic performance of the Midwest and the rest of the country is even more vivid when manufacturing output growth is compared. From 1979 to 1982, output in manufacturing value added (adjusted for price changes) fell 21.1% compared to a decline of 4.1% in the rest of the country.

Since then, Midwest manufacturing has demonstrated extraordinary resiliency. Manufacturing output has bounced back, increasing 68.1% from 1982 to 1992 (the latest figures available by state). The rest of the country has also rebounded but at a slower pace of 47.9%. Furthermore, manufacturing has been the propelling force behind the Midwest's recovery. While the Midwest's share of all output has remained constant since 1982, its share of the nation's manufacturing value added has increased.

Assessing the factors contributing to the Midwest's economic recovery and the resurgence of manufacturing is a complex process and is the topic of the Federal Reserve Bank of Chicago's multiyear project. This paper examines one regional asset that is essential for the efficient operation of the region's manufacturing: a well-maintained and efficient highway system. Manufacturers use highways to ship a large share of their products, with businesses in the Midwest relying more on highways than businesses in other parts of the country.

Manufacturers have adopted many productivity-enhancing changes in their operations, such as just-in-time delivery, that depend heavily on an efficient highway system. Therefore, while highways are only one of many factors that contribute to manufacturing output growth, it is important to understand their role in the resurgence of Midwest manufacturing and the region's future vitality.

The paper is organized in several parts. First, I will provide an overview of the empirical research linking highways to regional growth. Second, I will trace where midwestern manufacturers ship their goods and by what modes of transportation. Third, after establishing that highways carry a large share of the goods manufactured in the Midwest, I will look at the condition of highways in the Midwest. Fourth, I will explore the statistical relationship between measures of highway infrastructure and manufacturing output. Finally, I will offer some perspectives on policies related to highway investment that may affect the performance of midwestern manufacturers.

Highways and Regional Growth

There can be little doubt that highways are essential for regional growth. Highways are the primary means by which businesses transport their products and by which markets are linked together. More than 70% of the nation's manufactured goods are transported by trucks along the nation's highways. Well-maintained highways are critical for cities and states to retain and attract businesses. CEOs list access to major highways as a key factor in their location decisions.[1] The importance of highways in retention and location decisions has increased in recent years. No more than five years ago, CEOs placed highways farther down the list of important factors.

In addition to providing direct services to businesses and households, highways affect economic performance and thus regional growth by enhancing the productivity of other factors of production, such as labor or private capital, and by creating an attractive economic climate. In addition, highway construction contemporaneously stimulates local economies.

Research in recent years has focused on the impact of an additional dollar of highway investment on economic growth. Some initial estimates found extraordinary returns to public capital investment, which indicated significant underfunding of public capital stock, particularly highways. These estimates promised almost immediate payback in terms of higher output growth from investment in public capital.[2]

Recent refinements to these earlier estimates show a much more modest overall impact of additional highway investment on economic productivity. While consensus has yet to be reached, recent studies show that a 1% increase in highway capital stock reduces business costs from 0.03 to 0.08% overall. These estimates vary by industry and by state. For industries such as primary metals and motor vehicles, which are concentrated in the Midwest, a 1% increase in highway capital stock reduces production costs 0.21 and 0.18%, respectively.[3] Based on these estimates, additional highway investment in the Midwest would enhance productivity in key industries and promote economic development. However, estimates of the nonmanufacturing sectors suggest that additional highway investment would not reduce costs in these industries, as evidenced by positive cost elasticities of highways.

Commodity Shipments

Highways have become the primary means by which manufacturers ship goods to customers. Of the 12 billion tons of products shipped in 1992, 53% were shipped by trucks traveling the nation’s 3.9 million miles of public roads. In terms of the value of shipments, trucks account for an even larger share—73% of the $6.3 trillion of products shipped in 1992. Truck use has increased significantly over the last decade. Between 1980 and 1991, truck ton-miles (the distance one ton is shipped) increased 37%, whereas total ton-miles shipped by all modes increased only 21%. Manufacturers rely even more heavily on trucks than businesses in general. Approximately 80% of the four-digit manufacturing industries ship at least 80% of their tonnage by trucks.

Efficient highways can reduce production costs in several ways. First, the increased reliance on highways has changed the way many manufacturers operate. For example, with the flexibility and timeliness of truck transportation, manufacturers have found it possible to integrate just-in-time delivery systems into their operations. By reducing the need to keep large inventories of materials and intermediate products, businesses are able to reduce their need for warehousing. Consequently, the decline in inventory costs reduces firms’ out-of-pocket costs.

Second, the extensive interstate highway system typically puts manufacturers within a day’s trip of major markets. For instance, a recent survey of manufacturers in southwest Michigan revealed that 57% of their customers are within 500 miles of their facility and 71% of their suppliers are within a 500-mile radius.[4] Consequently, with the expansion of truck transportation, firms are more footloose and thus have more options in locating their facilities and can take greater advantage of differentials in costs of other inputs, such as labor and land. One obvious trend as the interstate highway system neared completion was the movement of manufacturing facilities out of the central city and into the suburbs and rural areas. Rail shipments require firms to be close to large, centralized terminals for loading and unloading. In contrast, smaller, more decentralized loading facilities can accommodate truck shipments, and these can be interspersed in areas outside the urban cores.

A study by the U.S. Department of Commerce argued that with the widespread adoption of computer-integrated flexible manufacturing, production will become much more of a local matter.[5] Plants will be able to make a batch of differentiated products almost on demand. These manufacturing centers will have the capability of manufacturing nearly an infinite variety of classes of products. Major cities will tend to become ringed by companies operating these systems instead of importing products from other regions. The same study also cited evidence supporting the notion that future economic growth will require less in the way of transportation of heavy industrial raw material per unit of output. This shift from heavier inputs and outputs to lighter high-value products will tend to increase the demand for truck transportation.

However, some cities have found that their access to truck shipments is impeded by antiquated highway access. As truck usage has increased, fleet operators have moved to longer and wider trailers, saving on fuel and labor costs. Trailer lengths have increased from 48 feet to 53 feet in recent years, and some states have allowed 57-foot trailers. Trailer widths permitted on interstate highways have increased from 96 to 108 feet in recent years. Cities with bridges, tunnels, and arterial highways that cannot accommodate the larger-size trucks may not be in a position to benefit from the highway network.

As part of a highway network, a state's investment in roads and highways serves two purposes: It provides manufacturers (and households) access to the larger national network, and it maintains and upgrades the state's share of the network. Access to the interstate highway system requires adequate interchanges in interstates and other limited-access highways as well as an efficient system of feeder roads. The more access to the interstate system without impeding vehicular flow, the more beneficial the interstate system is to firms within a region. An extreme case would be a segment of interstate highway running through a region without any access. In this case, the region benefits little from its proximity to the highway system.

A highway network provides services efficiently so long as bottlenecks do not occur at the various nodes where the various segments come together. One of the issues confronting Congress during deliberations over the 1992 reauthorization of the surface transportation bill (ISTEA) was the formation and administration of a national highway system. The issue centered around state and local autonomy versus the maintenance of a well-coordinated network. Similar issues have been raised at hearings for the 1997 reauthorization of the surface transportation bill. From a state's perspective, implicit in these considerations is the trade-off between free-riding off highway investments by another state or states and providing highway infrastructure for firms and residents within its own state.[6]

The significance of this trade-off depends upon how much of a state's highway system is used by firms located within its borders. Recently released information on the flow of commodities within and between states provides some insight into the extent to which firms use the highway infrastructure in their own state versus other states. Table 1 displays a matrix of commodity flows, measured in tons shipped, within and between selected midwestern states. For all the states included, a majority of goods originating in a state are shipped within the state. For example, 57% of commodities originating within Illinois are shipped to destinations within the state, and 60% of these commodities are shipped by trucks. For Michigan, the percentage of shipments within the state is much higher, 74% with 77% shipped by truck.

Conversely, the percentage of commodities shipped to other states is relatively small and typically widely dispersed. For example, the largest percentage of commodities shipped out of Illinois to any one state goes to Indiana, but this accounts for only 8.5% of the commodities originating in Illinois. Wisconsin, Illinois's neighbor to the north, receives only 3.6% of Illinois's total tonnage of commodities, and Missouri to the west receives only 4.4%. Similar patterns are found for other states. The largest concentration of goods shipped out of Michigan is destined for Ohio (8.3%), with Illinois and Indiana tied for a distant second (2.8%). To reciprocate, Ohio ships 3.4% of its commodities to Michigan.

Shipments within states typically travel only short distances, and most of these are by truck. For example, the average distance of shipments within Illinois is 45 miles; within Indiana, 39 miles; and within Ohio, 45 miles. Michigan's shipments are trucked slightly farther, with an average distance of 60 miles. Distances of

Table 1 Commodity Shipments between Selected Midwest States, 1992

	Tons					
From/To	**Ohio**	**Indiana**	**Michigan**	**Illinois**	**Rest of Country**	**Total**
Ohio	328,679 69.98%	11,901 2.53%	15,994 3.41%	7,295 1.55%	105,783 22.52%	469,652
Indiana	11,258 3.94%	160,453 56.14%	11,271 3.94%	35,333 12.36%	67,490 23.61%	285,805
Michigan	26,873 8.30%	9,140 2.82%	239,272 73.89%	9,188 2.84%	39,334 12.15%	323,807
Illinois	11,745 2.24%	44,487 8.4%	7,882 1.50%	301,608 57.43%	159,454 30.36%	525,176

Source: Bureau of the Census, Commodity Flow Survey.

commodities originating in the Midwest but shipped out of the Midwest range from 628 miles for Ohio commodities to 868 for Michigan commodities. Therefore, while shipments of midwestern commodities use much of the national highway system, the majority of shipments remain within the state of origin. State investment in highway infrastructure directly benefits firms located within their own state.

Highway Investment

State and local governments put in place most of the nation's highway system. While considerable money comes from the federal government through the federal gas tax and the highway trust fund, actual construction and maintenance and much of the planning are done by state and local governments. Highways comprise a significant part of the nation's fixed nonresidential capital stock. Highway capital stock exceeds $600 billion, valued in 1987 dollars, which is about two-thirds of the nation's manufacturing capital stock and a little over a tenth of all private nonresidential capital.

Highway expenditures are the largest single capital outlay of state and local governments. Nationwide, 27% of state and local governments' capital outlay budget goes to highways, with education (both K-12 and higher education) a close second at 23% (table 2). The Midwest, considered in this paper as Illinois, Indiana, Iowa, Wisconsin, Michigan, and Ohio, follows the national pattern fairly closely. These states spend 31% of their capital outlay budget on highways and 26% on education. Among the Midwest states, Iowa devotes the largest share of its capital budget to highways at 49%, while Michigan spends the least at 22% (based on 1992 figures).

Table 2 Percentage of Total State and Local Capital Outlays by Category, 1992

	Midwest	United States
Highways	31%	27%
Education	26	23
Health	3	3
Protection	2	2
Sanitation	13	13
Utilities	5	9
Other	19	22

Source: U.S. Bureau of the Census, Government Finance, 1991-92.

In recent years, capital outlays for highways, measured on a per capita basis and adjusted for inflation, have increased considerably for both the United States and the Midwest. From 1980 to 1992, highway capital outlays per person increased 51% after declining during the previous two decades (figure 1). Highway capital outlays per person grew even faster in the Midwest during this time, climbing 65%. Some of this faster growth in per capita outlays in the Midwest is associated with a slightly faster increase in the use of highways. Vehicle miles per person rose 35% in the Midwest compared to 31% nationwide. The result is a 22% increase in highway outlays per vehicle miles for the Midwest as opposed to a 15% increase for the United States.

Even with this greater increase in highway expenditures in the Midwest, there is considerable variation in the quality of midwestern highways and in the level of highway congestion. According to 1992 interstate highway assessments displayed in figure 2, midwestern states were rated as having some of the worst and some of the best stretches of interstate highways. Michigan had the highest percentage among all states of interstate highways in poor condition. Around 25% of its interstate system was rated as having pavement that needs immediate attention or attention in the next few years. Wisconsin had the lowest percentage of interstates that need immediate attention. On the other hand, among the midwestern states Wisconsin had the largest percentage of miles of congested urban interstates at peak hours, while Indiana had the smallest proportion, according to recent Federal Highway Administration statistics

Figure 1 Midwestern Highway Expenditures

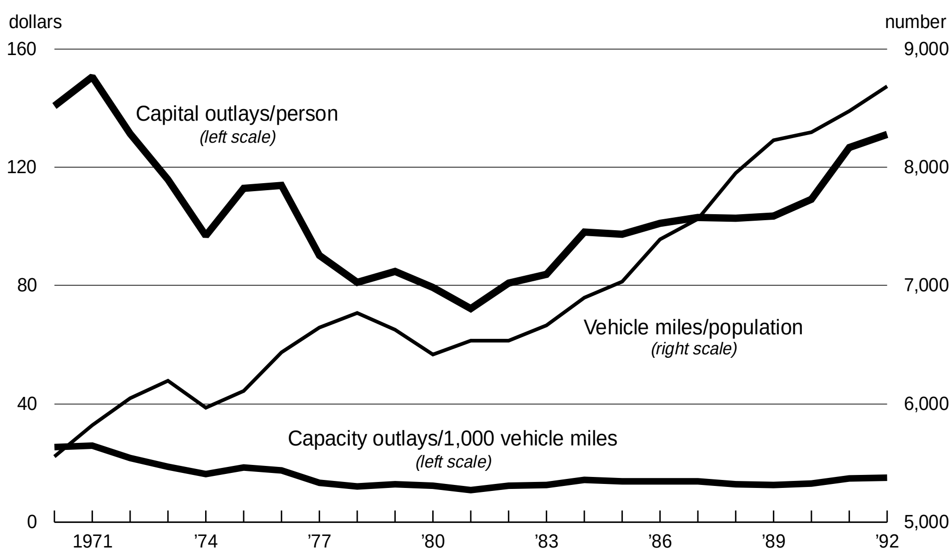
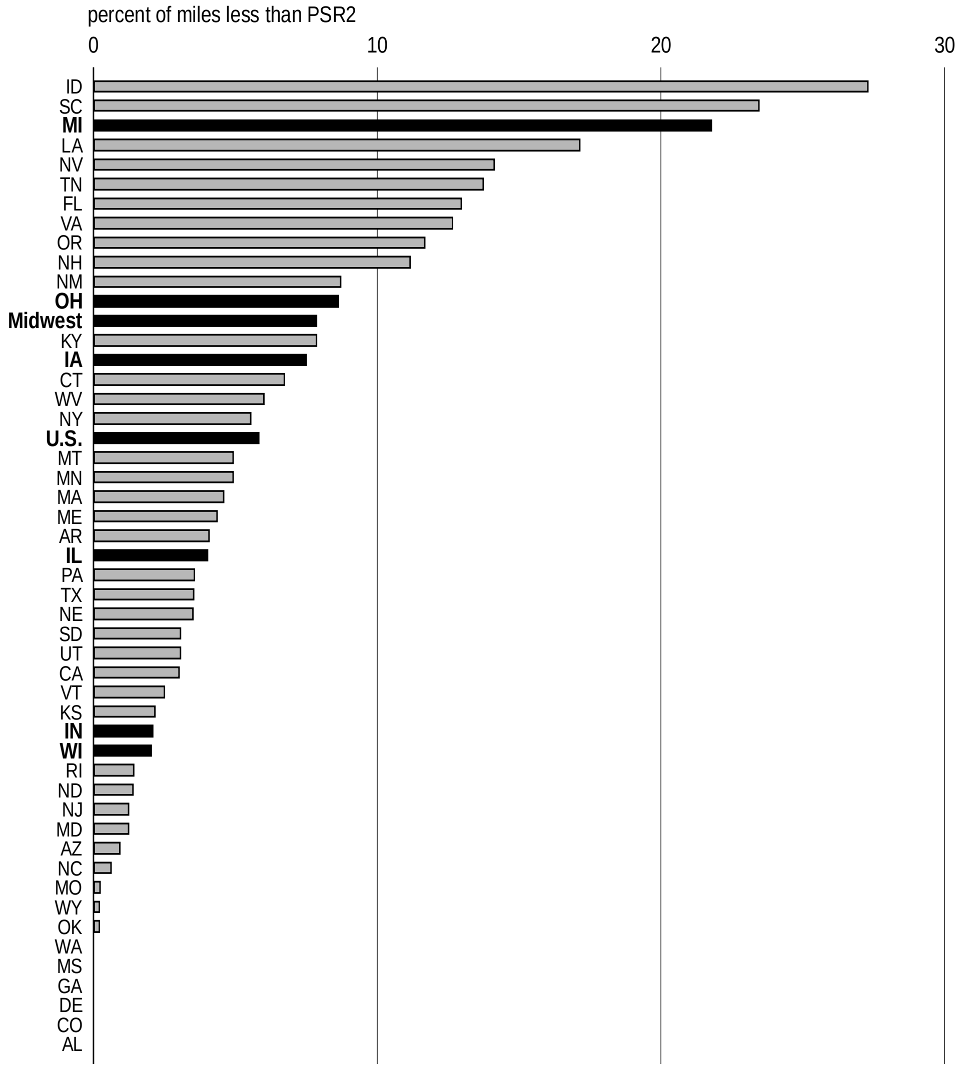
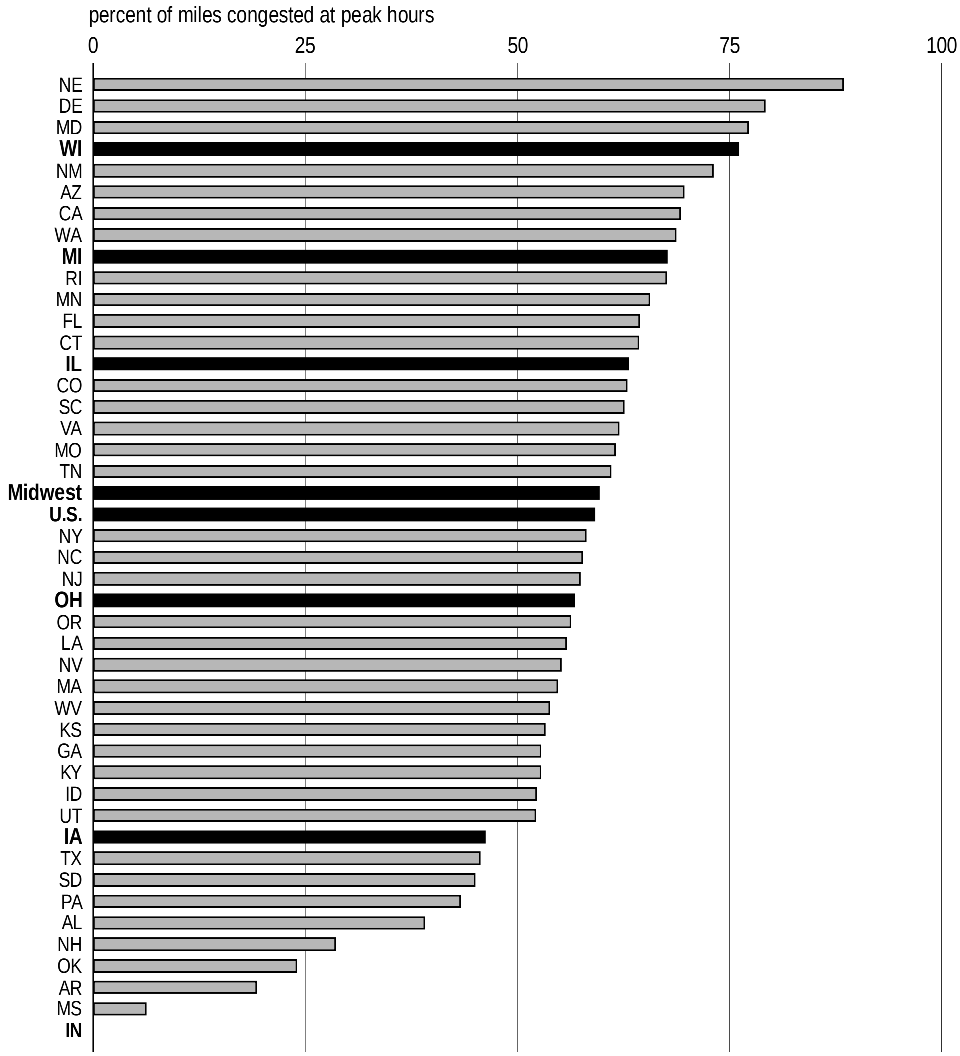


Figure 2 Interstate Pavement Condition



(figure 3). Wisconsin's ranking with respect to these two highway characteristics are likely because of its low percentage of interstate miles in urban areas, 28% in 1992. Furthermore, these estimates are based on samples of highway segments, and the extent to which these segments represent the state's highway system may vary by state. Nonetheless, the conclusion to be drawn from these data is that highway conditions, and thus service levels, vary by state.

Figure 3 Congestion on Urban Interstates



Midwest Manufacturing Performance

The Midwest's economy relies heavily on manufacturing. Before the 1980 recessions, manufacturing accounted for 32% of all output in the Midwest, compared with only 21% for the rest of the country. The recession reduced this share by 5 percentage points to around 27% in 1982, but manufacturing quickly bounced back in only a few years to regain its dominant role in the Midwest's economy. In 1992, manufacturing output accounted for 30% of total midwestern output, while manufacturing comprised only 20% of the output in the rest of the country.

Table 3 Manufacturing Performance (percent change)

	1979-82		1982-92		1979-92	
	Midwest	Rest of US	Midwest	Rest of US	Midwest	Rest of US
Value added (1982$)	–21.1	–4.1	68.1	47.9	32.6	41.8
Manufacturing employment	–19.3	–5.6	–.6	–5.3	–19.7	–10.7
Production-worker hours	–28.3	–12.9	8.1	–2.0	–22.5	–14.7
Private capital stock	3.0	11.1	6.2	17.4	9.4	30.4
Highway capital	–.7	1.3	15.0	24.2	14.1	25.7
Value added/hours	10.0	10.2	55.5	50.9	71.1	66.2
Hourly production worker						
Hourly wages (1982$)	–1.0	.6	25.9	22.6	24.6	23.3
Population	–.3	4.0	2.6	11.9	2.2	16.4

Source: Census and Surveys of Manufacturers, 1979-92.

Therefore, the economic fate of the Midwest depends largely upon the health of its manufacturing sector. As the 1980s began, the economic base of the Midwest appeared to be in serious jeopardy. From 1979 to 1982, output (as measured by real value added) fell by 21% (see table 3). Much of the rest of the country was also entering a recession, but manufacturing output outside the Midwest declined by only 4% during that three-year period. Accompanying its precipitous fall in output, employment in the Midwest declined 19%, compared to only 6% elsewhere, and the number of hours worked by production workers in the Midwest dropped 28%, which was more than double the decline in the rest of the country.

The subsequent recovery after 1982 saw manufacturing output in both the Midwest and the rest of the nation rebound significantly. Output in the Midwest grew 68% during the next ten years; output elsewhere in the country grew 48%. However, manufacturing employment remained flat in the Midwest and declined elsewhere. Instead of adding more workers as output expanded, manufacturers asked workers to spend longer hours on the job. Hours of production workers in the Midwest increased 8% from 1982 to 1992. Consequently, employment remained far below the levels achieved in 1979 despite the gains in output. Furthermore, as of 1992, manufacturing employment had not returned to the levels reached prior to the depths of the 1980-82 recessions for either the Midwest or the rest of the nation.

Components of Output Growth

Determinants of output growth can be seen within a simple production function framework. Applying this framework to a region’s economy, output is a function of privately provided inputs, such as hours of labor and private capital, and publicly provided inputs, such as highway infrastructure. In addition, output growth results from technological change, which allows a firm to produce more output with the same amount of inputs. In our simple framework, I will consider increases in labor productivity to be the result of technological change and other labor-enhancing factors.

The relative contribution of these three factors to output is estimated by regressing the log level of output on the log levels of inputs using state-level data from 1988 to 1992. The relationship is shown in the following equation:

$$LnQ = a_o + a_H \ln H + a_K \ln K + a_G \ln G,$$

when Q is value added, H is hours worked by production employees, K is private manufacturing capital stock, and G is highway capital stock. Estimates of the relative effects of these inputs on output are obtained from a pooled data set of state observations from 1988 through 1992. The weights on each of the inputs are output elasticities, which are interpreted as the percentage effect on output of a 1% increase in each of the inputs. Table 4 shows the estimates of these coefficients. For example, as shown in column 1, a 1% increase in hours worked increases output by 0.56%, while a 1% increase in the stock of private capital increases output by 0.38%. In addition, a 1% increase in highway capital stock is associated with a 0.15% increase in output.

Production function estimates of this kind have been criticized for several technical reasons, including spurious correlation among time series, nonstationarity of time series, the endogenity of inputs, and the inability to determine the direction of causation between output and public capital stock. Despite these criticisms, the production function framework is beneficial in illustrating the relationship between output and inputs. This formulation is easy to interpret, and since the estimates are driven largely by variation across states and very little by variation over time, many of the criticisms do not apply.

Furthermore, when the estimation procedure takes into account state-specific variations by using region dummy variables and state characteristics, and accounts for differences in production relationships over time, estimates of highway capital stock approach estimates derived from statistical methods, such as the cost function, which are not as vulnerable to these criticisms. The second and third columns of table 4 include estimates with region dummy variables and region dummy variables with state characteristics, respectively. State characteristics include energy costs, union membership, a proxy for tax rates (state and local tax revenues divided by gross state product), and average years of education. These factors are thought to affect manufacturing costs. All estimates appear to have the right sign except for energy costs, which are positively related to output. However, including these state-specific variables lowers the estimate of highways on output only marginally from what it is when only region dummy variables are included. In either case, these estimates are within a few percentage points of what Nadiri and Mamuneas (1996) found for various manufacturing sectors using a cost function at the national level. Moreover, controlling for these state-specific characteristics does not change significantly the estimated contributions of hours and private capital.

The estimates indicate that highway capital stock has a positive and statistically significant effect on manufacturing. Increasing highway capital by 1% is associated with a 0.15% increase in output. According to table 3, highway capital stock in the Midwest grew 15% between 1982 and 1992. Based on the production function estimates, this increase would have been related to a 2.25% increase in manufacturing output, holding all other factors constant. In contrast, the same percentage increase in private capital stock would have been associated with a 5.7% increase in output,

Table 4 Estimated Effects of Highways on Manufacturing Productivity

Variable	Model 1	2	3	4	5
Production-worker hours	0.557**	0.538**	0.540**	0.595**	0.526**
Private capital stock	0.379**	0.442**	0.455**	0.436**	0.508**
Highway capital stock (all states)				0.050**	
(within state)	0.149**	0.138**	0.104**		0.042
(weighted sum outside state)					0.014
Energy costs ($/mil. btu)			0.060**	0.050**	0.055**
Union membership (%)			0.001	0.002	0.003
State & local tax rev / GSP			–1.28	0.875	0.485
Average years of education			0.220**	0.239**	0.210**
Regional dummy variables	No	Yes	Yes	Yes	Yes
Time dummy variables	No	Yes	Yes	Yes	Yes
R squared	0.99	0.99	0.99	0.99	0.99

Notes: Dependent variable is the manufacturing value added by state. All level variables are in log form except population. **Denotes statistical significance at the 0.01 level. Columns 1-3 include highway capital stock estimates within the state for which we observe manufacturing output; column 4 includes highway capital stock estimates weighted by the percentage of commodities shipped to various states; column 5 includes highway capital within the state and highway capital from states outside the specific state weighted by the percentage of commodities shipped to various states.

Source: Census and Surveys of Manufacturers, 1988-92.

more than twice the effect of highway capital stock. Of the three inputs, labor is most correlated with output, with an output elasticity of 0.56. If labor would have increased 15% during this period, output would have increased 8.4%. Therefore, while highway infrastructure has a positive effect on output, its effect is much smaller than the other two key inputs.

Examining the production relationships does not provide information about the rate of return of highway capital stock nor whether it is optimally provided. Using a cost function methodology which incorporates prices and rates of return in the estimation, Nadiri and Mamuneas provide estimates of the rate of return of highway capital stock at the national level. They estimate that the net rate of return of highway capital is about 5% in 1989, which is about the same as the net rate of return of private capital. For the 1960s and 1970s find when the interstate highway system was under construction, Nadiri and Mamuneas found the net rate of return of highways was in the neighborhood of 30%, at least twice as high as the rate of return of private capital. The higher rate of return of highways compared with private capital stock during that period supports the decision to invest in highway capital. However, today, with the two rates of return about the same, it appears that for the nation at least, highway capital stock may be at an optimal level.

Even though the highway stock may be optimal from a national perspective, highway needs vary widely across regions, and the supply of highways may not necessarily meet demand. According to one study based on a methodology similar to that used by Nadiri and Mamuneas, many cities have more than adequate highway infrastructure, but others face severe bottlenecks and need to expand their network of roads and highways.[7]

Relative Effects on Output of Various Highway Measures

While several refinements could be made to the estimates, this framework will suffice for the purpose of examining the relative effects on output of various measures of highway capital stock. Following the previous discussion, I will consider what happens to the effect of highways on output when the capital stock of other states are included whether congestion and pavement conditions affect as well as the contribution of highway capital stock to output.

I measure a state's highway infrastructure using the perpetual inventory approach. Highway investment expenditures are summed over a sufficiently long period of time so that all investment in the current highway infrastructure can be taken into account with the appropriate depreciation and discards.[8] Using this approach, the contribution of highways to output takes into account only highways within the state in which the manufacturing establishment is located. According to the commodity flow data discussed in the previous section, establishments ship commodities outside the state and in doing so use and benefit from highways in other states. To account for this network effect for each state, I use the percentage of commodities shipped from each state to weight the capital stock in all the other states. Therefore, a state's highway capital stock is the weighted average of highways from all the states to which they ship. It should be pointed out that this approach underestimates to some extent the amount of highway capital used to ship commodities, because it does not include the states through which the goods are shipped to reach their final destination. Nevertheless, this approach offers initial insights into the network effects of highways on productivity.

Using this measure of highway capital stock, we find that the effect of highways on output is reduced by roughly half, from 0.10 to 0.05, as shown in column 4 of table 4. The interpretation of these results is not straightforward. One would expect that including highway infrastructure from other states would augment that highway capital stock already present in the state within which the manufacturing establishment is located. Increasing the supply of highway stock may reduce the marginal product as manufacturing establishments move down the demand curve for highway services. However, including the highway stock of other states may increase or decrease the stock of highways estimated for any particular state. At the same time that we added the highway stock of other states, we reduced the amount of the highway stock of the specific state of origin, since we used only that portion of commodities shipped within the state, which is less than 100% for all states. Therefore, we may attribute more highway capital stock under this weighted method than under the nonweighted method for some states and less highway stock for others. Nevertheless, taking the elasticity estimates at face value would suggest that including the highway network increases the highway stock for each state at the margin, reducing the contribution of an additional dollar of highway infrastructure to output.

To further explore the relationship of within-state and out-of-state highway stock with output, we enter each measure separately into the production function. As shown in column 5 of table 4, the within-state component was three times as large as the out-of-state component, although neither one was statistically significant. The magnitude of these estimates added together is consistent with the estimates obtained when the two components were combined into one measure, lending some credence to the estimates. The estimates are consistent with the position that a state's investment in highways benefits its own manufacturing establishments, even within a network system.

So far, these highway measures have not taken into account the effect of congestion on the contribution of highways to output. We have assumed that congestion is the same everywhere and that it has no differential effect on the contribution of highway infrastructure to output. However, as noted in a previous section, congestion of the interstate highway system varies considerably across states. Therefore, one would expect that the benefits of highways to firms in areas in which bottlenecks occur and delivery is slow and unreliable is lower than in other areas.

Congestion measures are compiled by the Federal Highway Administration through a monitoring program called the Highway Performance Monitoring System(HPMS). Characteristics of more than 100,000 representative highway sections are collected by state transportation departments. Congestion is measured on urban highways by estimating the volume of traffic actually using the highways and the theoretical capacity of that facility to accommodate this traffic.

Historically, a ratio of 0.80 is used as a threshold of congestion. At ratios higher than 0.80, stop-and-go conditions begin to occur, and speeds begin to drop significantly. Ratios approaching 1.0 indicate gridlock conditions with little to no traffic movement. Obviously, as ratios increase, the service levels of highways decrease.

Pavement conditions are classified into five categories, referred to as pavement serviceability ratings. A rating of 5 indicates new pavement, whereas a rating of 1 means that the pavement is in extremely deteriorated condition and the highway segment is passable only at reduced speeds and with considerable rider discomfort. The measure of pavement quality used here includes the percentage of pavement with a 2.5 rating and below. This measure includes pavement considered fair to very poor.

To account for differences in congestion across states, I interact the simple highway measure (not the weighted one) with the congestion measure. Both the interaction measure and the highway capital stock measure are entered together in the regression. The estimates, displayed in the first column of table 5, show that congestion has an unexpected effect on output. Instead of reducing effectiveness, congestion enhances it slightly. One possible explanation is that congestion is associated with urban areas, and manufacturing establishments are more productive in urban areas than elsewhere. Anticipating this effect, we included the population of the state as a proxy for urbanization. Even with this variable, congestion had a slightly positive effect on highways' contribution to productivity. Perhaps a more precise measure of urbanization within a state would reverse these estimates.

Poor pavement condition may reduce the benefits of highways to manufacturing establishments as it could slow delivery because of reduced travel speeds and cause considerably more wear and tear on trucks. Similar to congestion, interacted the state's highway stock with the percentage of interstate highways within each state below an acceptable level of pavement condition, and included both the interacted term and the highway capital stock in the production function. Estimates of the output elasticity of highways, shown in the second column of table 5, show that pavement condition does not significantly affect highways' contribution to productivity. Including only

Table 5 Effects of Highway Congestion and Pavement Conditions on Highways' Contribution to Manufacturing Productivity

Variable	Model: Congestion	Model: Pavement Condition
Production-worker hours	0.540**	0.561**
Private capital stock	0.438**	0.442**
Highway capital stock	0.107*	0.117*
(Highway capital stock)* (road characteristic)	0.012**	0.009
Energy costs ($/mil. btu)	0.050**	0.052**
Union membership (%)	–0.0001	0.001
State & local tax rev / GSP	–1.748	–1.365
Average years of education	0.241**	0.268**
State population*1000	–0.010	–0.016
State population squared	4.45 E-07	6.23E-07
Regional dummy variables	Yes	Yes
Time dummy variables	Yes	Yes
R-squared	0.99	0.99

Notes: Dependent variable is the manufacturing value added by state. All level variables are in log form except population.
*Denotes statistical significance at the 0.05 level;
**Denotes statistical significance at the 0.01 level.

Source: Census and Surveys of Manufacturers, 1988-92

highways with greater deterioration may have a more detrimental effect on performance. But our more inclusive, but less restrictive, measure of fair to poor pavement condition does not seem to affect highways' contribution to output.

Conclusion

Highways are the major means by which midwestern manufacturers ship goods within the region and across the country. Preliminary estimates presented in this paper suggest that the region's highways have a significant impact on the manufacturing sector. Therefore, the Midwest, along with the rest of the country, is faced with the task of maintaining and upgrading its present highway infrastructure. But the challenge is more than simply maintaining its existing system, although the expenditure to do so is significant. The Midwest must meet the future infrastructure needs of an economy that is undergoing dramatic changes with the restructuring of both manufacturing and service industries and the spatial redistribution of these activities. Access to an extensive highway system more than likely allowed manufacturers in the Midwest to adopt new technologies that improved their competitiveness with the rest of the country and world and helped foster the resurgence of the Midwest's economy. Future competitiveness and prosperity requires equal, if not more, attention to assuring that the Midwest is well served by an efficient highway system and is well linked to the rest of the world.

As current estimates suggest, the nation overall has not underinvested in its highway system. Highway investment, while making a significant contribution to manufacturing productivity, does not yield large payoffs. Highway investment has a positive effect on productivity but no more than the effect of private capital, and some estimates indicate less. Also, highway infrastructure accommodates growth more than it stimulates it. By expanding capacity where bottlenecks develop, highway investment reduces impediments to growth. However, building or expanding a highway system in a region that does not have other growth factors in place is unlikely to stimulate growth.

However, each year an increasing amount of money is required to simply maintain the existing highway network. According to depreciation assumptions used to construct highway capital stock, $18.5 billion were needed in 1989 to simply maintain the stock of highways and roads at their current level. Moreover, as regional needs change, additional dollars are required to upgrade existing highway systems to meet these needs.

Yet states and the federal government are under increased pressure to spread their scarce resources to other activities. Innovative methods must be considered to alleviate bottlenecks and to replace antiquated structures. It is important for state and local transportation planning organizations to have more responsibility and flexibility in determining the levels and types of transportation projects for their regions. At the same time, a balance should be struck between allowing local jurisdictions to enhance their nodes on the nation's integrated transportation networks and ensuring that the federal government retains the means and expertise to maintain and improve the network that links the regional markets comprising the complex national economy. Wise investment at the regional and national levels calls for all levels of government to come together and identify, assess, and undertake infrastructure investment that will pay the greatest dividends for the Midwest and for the nation in the future.

Footnotes

1 *Area Development*, December 1995.

2 For a comprehensive summary and critique of the literature, see Therese McGuire, "Highways and Macroeconomic Productivity: Phase Two," Final Report to Federal Highway Administration, 1992.

3 For the latest estimates based on a cost function methodology, see M. Ishaq Nadiri and Theofanis P. Mamuneas, "Contribution of Highway Capital to Industry and National Productivity Growth," prepared for the Federal Highway Administration Office of Policy Development, March 1996.

4 *Economic and Fiscal Impact of a Proposed International Tradeport at the W.K. Kellogg Regional Airport*, W.E. Upjohn Institute for Employment Research, October 6, 1995, p. 43.

5 U.S. Department of Commerce, *Effects of Structural Change in the U.S. Economy on the Use of Public Works*, prepared for the National Council of Public Works Improvement, Washington, DC, 1987.

6 The free ridership issue is mitigated to a large degree because of the funding arrangements in which the federal government contributes up to 80% of the total cost of the state's investment in a national highway system.

7 Douglas Dalenberg and Randall W. Eberts, "Estimates of the Manufacturing Sector's Desired Level of Public Capital: A Cost Function Approach," mimeo, June 1992.

8 I assumed that discards followed a truncated normal distribution, with truncation occurring at one-half the average life and at one and one-half times the average life. I used an efficiency depreciation schedule with a depreciation parameter of 0.9, which is relatively close to the "one-hoss shay" depreciation schedule with a parameter value of 1.

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