Tracking Midwest manufacturing and productivity growth

Philip R. Israilevich, Kenneth N. Kuttner, and Robert H. Schnorbus

After years of lagging economic performance that led to the region's characterization as a "rust belt," Midwest manufacturers have exhibited increasing competitiveness in the last several years, compared with the rest of the nation and with their own earlier performance.* Evidence of this strong performance is the fact that the Midwest's output grew faster on average than the nation's, given observed rates of capital and labor usage.

A common explanation for this resurgence has been that in the 1980s, Midwest manufacturers undertook aggressive modernization programs in an attempt to reverse their fortunes. This explanation, however, rests largely on anecdotal evidence; data have been hard to come by. With the help of annual production models, the mixed-frequency Midwest Manufacturing Index (MMI) developed by Israilevich and Kuttner (1993), and annual capital expenditure data from the U.S. Commerce Department, we are beginning to reach a clearer understanding of the region's improvements in productivity and competitiveness as Midwest manufacturers move into the 1990s.

In this article, we explore the reasons for the so-called takeoff in Midwest manufacturing productivity, tracing its growth to significant modernization efforts in several key industries. Investment data and estimates of production models both suggest that productivity gains were higher in the region than in the rest of the nation. We then use the mixed-frequency MMI to assess the quantitative significance of the increased productivity growth for current estimates of Midwest output.

The productivity takeoff identified in this analysis has important implications for the MMI model, which relies on historical rates of productivity growth to account for the divergence of output and employment data, and to compute current estimates of the index. In light of the evidence, we reconsider the assumption of a constant rate of productivity growth for each industry, and suggest a modification to the MMI model that will allow it to capture the technical progress that resulted from modernization of core Midwest industries.

Investment and the productivity takeoff in the Midwest

The key to regional growth is improving competitiveness, and the key to increasing a region's competitiveness is productivity growth relative to other regions. Such productivity gains can be achieved in at least two ways: faster withdrawal of the least productive capital stock (downsizing) than elsewhere, and faster introduction of new, more technologically advanced plant and equipment than elsewhere. While both measures can yield increased output per worker, they have different implications for

*The Midwest is defined here to include the five states in the Seventh Federal Reserve District: Illinois, Indiana, Iowa, Michigan, and Wisconsin.

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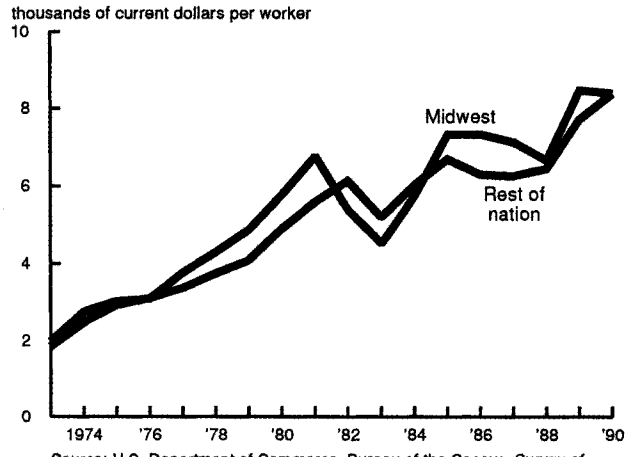
future growth. If the recent productivity gains in the Midwest were achieved only by shrinking the manufacturing base without modernizing, the region would be vulnerable to further declines as other regions improve their competitiveness and increase their market share at the Midwest's expense. However, if Midwest manufacturers were modernizing while they were closing antiquated facilities, they might offset any net reductions in capital stock with productivity gains sufficient to allow output growth relative to the rest of the nation.

FIGURE 1

Capital expenditures per worker



Source: U.S. Department of Commerce, Bureau of the Census, *Survey of Manufacturers* and *Census of Manufacturers*, various issues.

In the early 1980s, manufacturers were under severe financial stress, particularly in the Midwest. A relatively deep recession in 1980–82 was followed by an intensification of global competition caused in part by a strong dollar. Many well-known companies such as Caterpillar, USG, and Chrysler were pushed dangerously close to bankruptcy; virtually all manufacturers in the Midwest scrambled to cut costs in order to be as competitive as possible in an increasingly tough global market. As part of that effort, many old or marginally profitable plants were closed under the banner of "rationalization"—a term which in the 1990s would be dubbed "re-engineering."

Despite these financial problems, many Midwest manufacturers met the increasing competitive pressures of the early 1980s with aggressive capital spending programs. While withdrawing older capital stock, they also invested in new plants and equipment. The only question was whether these adjustments were occurring at a faster pace in the region than they were elsewhere in the nation.

Before 1985, the Midwest tended to invest at roughly the same rate as the rest of the nation. Investment in the region picked up in the late 1970s but slowed again with the onset of the 1980-82 recession. Thereafter, Midwest investment lagged the rest of the nation until a push resumed in 1985.[1] As figure 1 shows, between 1986 and 1990, average capital expenditure per worker in the Midwest was 9 percent above the amount for the rest of the nation.

The Midwest contains a high proportion of capital-intensive industries, notably auto and steel, yet the difference between investment per worker in the Midwest and in the rest of nation does not appear to be due to differences in industrial mix. Indeed, both the auto and steel industries show higher investment per worker in the region than in the rest of the nation. For example, between 1986 and 1990, investment per worker in the transportation industry was 16 percent higher on average in the Midwest than in the rest of the nation; in primary metals it was 22 percent higher on average. While these two industries show larger differentials than other industries, they demonstrate that the pattern observed at the aggregate manufacturing level reflects a widespread commitment to modernization among Midwest manufacturers.

A closer look at the auto and steel industries reveals the dual nature of the adjustments that manufacturers made in response to competitive problems. During the 1980s, automakers closed seventeen car and truck assembly plants, of which six were in the Midwest. At the same time, they constructed seventeen plants, seven of them in the Midwest. Some of the new plants were essentially replacements of existing Big Three plants, for example, Chrysler's Jefferson Avenue plant in Detroit. But some were entirely new plants built by foreign auto companies, often in conjunction with a Big Three producer. Among the foreign-owned plants are the Diamond Star Plant in Illinois (Chrysler and Mitsubishi) and the Flat Rock Plant in Michigan (Ford and Mazda).

A somewhat similar pattern of investment occurred in the Midwest steel industry, where

integrated mills were closed and the remaining mills modernized. Inland Steel, for example, has invested roughly $1 billion since 1985 to modernize its Indiana Harbor Works in East Chicago, Indiana (which included converting to continuous casting). The company spent another $1 billion on a new mill in Indiana, a joint venture with a Japanese producer. While integrated steel producers were modernizing, they were also opening mini-mills that brought a wholly different production process to U.S. steelmaking.

The result was that both the auto and steel industries saw more productivity gains in the Midwest than in the rest of the nation. These gains made Midwest producers more competitive and allowed industry in the region to grow faster than elsewhere.

Productivity growth in the Midwest: evidence from annual data

The investment patterns noted above suggest that Midwest manufacturers began to modernize aggressively around 1986. What is lacking is some measure of how much efficiency increased as a result. How much has Midwest manufacturing output grown, compared with the growth that would have occurred using pre-1986 technology?

One way to address this question is simply to compare the out-of-sample forecasts from a production function estimated on data from 1973 through 1985 with observed output from 1986 to the present. A natural and intuitive measure of the size of the takeoff is the difference between the Midwest's observed output and the model's prediction: that is, the amount by which actual output exceeds what would have been produced had pre-1986 technology been applied to the actual factor inputs.

A convenient production function for this analysis is the Cobb-Douglas specification,

$$x_t = \gamma \cdot t + \theta l_t + \phi e_t + \eta_t,$$

where x represents output of a given industry measured by the logarithm of real value added (VA), t indexes the year, l is the logarithm of payroll employment, and e is the logarithm of electricity consumption. For applications such as this, energy consumption is widely interpreted as a proxy for the utilized stock of capital.[2] The γ coefficient on the time trend represents the rate of Hicks-neutral technological change (i.e., productivity not embodied in either labor or capital inputs), θ and ϕ are the elasticities of output with respect to labor and capital, and η is a random error term. The Cobb-Douglas specification is also consistent with the mixed-frequency MMI introduced subsequently, as well as a variety of other indices discussed in Israilevich *et al.* (1989).

We first estimated the production function over the sample running from 1973 through 1985, dates chosen on the basis of the Midwest investment patterns discussed above. Using this estimated function, we then projected output for the 1986–90 period on the basis of pre-1986 "old" technology, and compared the projection to the actual VA data, the result of production with "new" technology.

The Midwest versus the nation

Table 1 reports the difference between projected and observed output growth for 15 key manufacturing industries in the Midwest, aggregated into five sectors: transportation, metalworking, machinery, chemicals, and consumer products. Table 2 shows the composition of these sectors and a breakdown of Midwest output by industry. For comparison purposes, similar calculations were done for the rest of the nation. According to these estimates, between 1986 and 1990, Midwest manufacturing sectors improved efficiency by 8 percent more than the corresponding sectors in the rest of the nation. Given the capital-intensive nature of most Midwest industries and their relative maturity, such a gain is substantial. It would also help explain why output has been growing faster in the region than in the nation since the late 1980s.

Figure 2 displays the efficiency gains graphically, showing the Midwest's lead as a function of time. While the gap between observed and

TABLE 1

Efficiency gains, 1986-90
(percent)

Sector	Midwest	Rest of nation
Transportation	7.94	3.83
Metalworking	2.03	2.38
Machinery	2.01	0.89
Chemicals	0.76	3.10
Consumer products	–3.33	–0.58
Total	**1.38**	**1.28**

TABLE 2

Composition of Midwest manufacturing output, 1990

Sector	Share (%)	Industry	Share (%)
Transportation	14	Transportation (SIC 37)	14
Metalworking	14	Primary metals (SIC 33)	5
		Fabricated metals (SIC 34)	8
Machinery	36	Nonelectrical (SIC 35)	26
		Electrical (SIC 36 and 38)	10
Chemicals	15	Chemicals (SIC 28)	8
		Petroleum (SIC 29)	1
		Rubber and plastic (SIC 30)	5
		Clay, glass and stone (SIC 32)	1
Consumer products	22	Food (20)	11
		Lumber and wood (SIC 24)	1
		Furniture and fixtures (SIC 25)	2
		Paper products (SIC 26)	3
		Printing and publishing (SIC 27)	4
		Miscellaneous (SIC 39)	1

Note: Industry subtotals may not equal sector totals because of rounding.

predicted output remained positive, it flattened out in 1989 and declined in 1990. Only in 1990 did the rate of improvement in efficiency seem to subside, both in the Midwest and elsewhere. This pattern suggests that the shift in the national economy from a mini-boom in 1988–89 (roughly 4 percent real GDP growth) to virtual stagnation (roughly 1–2 percent real GDP growth) had an impact on efficiency gains. Perhaps the cyclical drop in output growth prior to the 1990–91 recession led to underutilization of labor and capital, which reduced the measure of efficiency gains over the second half of the 1980s. Moreover, the commitment to efficiency gains even in a sluggish economy may help explain why manufacturers have been able to expand output since the 1990–91 recession even though employment growth has been virtually nonexistent.

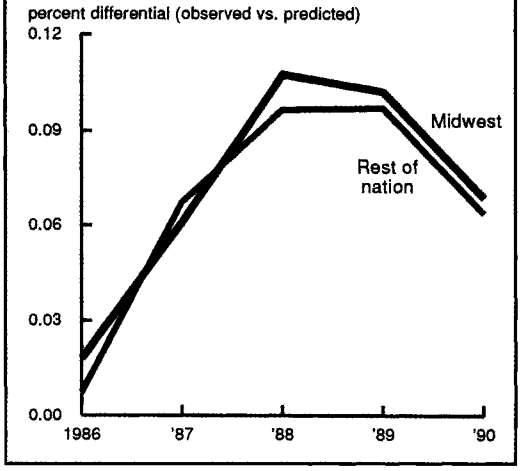
Comparisons between Midwest industries

The efficiency gains identified in table 1 were clearly not uniform across the Midwest's industries. How widespread were they, and how much of the total gain was due to the industrial structure of the region relative to the rest of the nation? The gains did seem to be concentrated in the region's core manufacturing sectors, transportation and machinery.

The Midwest's transportation sector scored the most impressive gains in efficiency. Output in this sector was 7.9 percent higher than forecast on the basis of pre-1986 technology, compared to 3.8 percent higher in the rest of the

FIGURE 2

Efficiency gains



nation. In the Midwest, the transportation sector is dominated by automobile manufacturers and parts suppliers, both of which were troubled industries throughout the 1980s. Japanese imports and nameplates produced in the U.S. had been gaining market share for many years, leaving the domestic industry with tremendous overcapacity. The first wave of restructuring took place in the early 1980s when Ford and Chrysler began closing plants. GM began closing assembly plants in the late 1980s and is currently in a second wave of closings that will extend into 1995. At the same time that Big Three automakers were closing plants, both they and the Japanese were opening state-of-the-art assembly plants in the Midwest as well as elsewhere. Over the 1980s, the region's share of total car production actually rose from 39 to 44 percent, although its share of truck production declined from 40 to 28 percent.

The Midwest's machinery sector also outpaced the rest of the nation. While in the rest of the nation machinery was on average 0.9 percent above its predicted level of output over the 1986–90 period, in the Midwest it was 2 percent higher than predicted on the basis of the pre-1986 technology. The region's machinery sector is largely focused on the auto industry and exports. As suppliers of the new capital, this sector has been in the forefront of the recent wave of investment targeted to meet global competition. Machinery producers themselves have faced stiff competition from foreign competitors, particularly the Japanese. Moreover, some machinery producers have been bought out by foreign companies, a change that often brings an infusion of fresh capital that improves productivity. It is encouraging to see that machinery producers, especially in the Midwest, have accepted the challenge of heightened global competition by increasing capital expenditures rather than by closing or shifting to other markets.

In the aggregate, the Midwest's metalworking sector displayed efficiency gains roughly in line with the rest of the nation. However, disaggregating the sector into its two constituent industries, fabricated metals and primary metals (the steel industry in the Midwest) reveals an interesting contrast. While the pace of technical change lagged the nation in fabricated metals, productivity growth in primary metals exceeded the nation's—a divergence that also appears in the MMI results presented later in this article. Interestingly, the major downsizing in the steel industry was over by the mid-1980s, leaving the Midwest as the dominant integrated steel-producing region. Midwest firms continued investing in modernization, and even mini-mills were expanding in the region. It is the Midwest's continued modernization, and perhaps its dominance in the high-quality steel produced by integrated mills, that allowed the region to outpace the rest of the nation in productivity. In contrast to primary metals, the metal fabrication industry, which produces finished parts from raw steel, never experienced any significant consolidation. The small size of producers in this fragmented industry may have limited the adoption of technical advances.

While efficiency gains were clearly widespread in the Midwest, not all the region's industries outpaced their counterparts elsewhere in the nation. The Midwest's chemical and consumer products sectors actually lagged the rest of the nation in efficiency gains over the 1986-90 period. In fact, efficiency in the latter sector was lower during the period than in previous years. While these industries are important to the Midwest, it is interesting that they are generally outside the auto-steel-machinery complex that comprises the heart of the region's manufacturing. It is perhaps unfortunate that strength in this "heart" seems not to spill over into other industries, yet by the same token, it seems that weakness in some sectors does not retard efficiency gains in other sectors.

The productivity takeoff and the MMI

The preceding section discussed measuring Midwest productivity gains by comparing annual VA data with predictions from estimated production models. An alternative method is to apply a similar analysis to predictions generated by the mixed-frequency MMI, as described in the appendix. The main advantage of the mixed-frequency MMI is that it tracks actual VA more precisely than other purely annual indices, such as the annual Cobb-Douglas or Atlanta methods, when projected out of sample.[3] Hence, the MMI should yield a more accurate assessment of Midwest efficiency gains than the annual model.

A second reason to use the MMI in this context is to examine any implications the hypothesized productivity takeoff might have for current estimates of Midwest output. Although the production model underlying the mixed-frequency MMI is re-estimated as new annual VA data become available, an increase in the

rate of technical progress may require structural modifications to the model to enable it to track manufacturing output more accurately in the future.

Out-of-sample comparisons

To construct a quantitative measure of Midwest efficiency growth, we first estimated the mixed-frequency MMI using annual data from 1973 through 1985. We then used monthly energy, labor, and nationwide Industrial Production (IP) data to project the MMI forward over the 1986–90 period, in which annual real VA data for the Midwest are available. Comparing the projected series with the actual VA data yields an index of efficiency gains that is comparable to the measures reported earlier. As before, an increase in the rate of productivity growth would imply that the projected MMI would underpredict output growth. This shortfall, therefore, represents the region's gains expressed in terms of the additional output produced as a result of increased manufacturing productivity.

Table 3 reports these gains, classified by industries and sectors. The results are expressed as the average percentage deviation between observed real VA growth and the annualized growth rate of the projected MMI. In metalworking, for example, the reported 0.6 percent figure signifies that on average, the MMI underpredicted VA growth by 0.6 percent for each year in the 1986–90 period.

The results are broadly similar to those based on the annual estimates reported above. Most striking is the spectacular productivity growth in the transportation sector, which consists entirely of SIC 37. Here, annual productivity growth over 1986–90 was roughly 9 percent higher than in the preceding 13 years. To restate this in cumulative terms, by the end of 1990, output in the transportation sector was about 40 percent higher than it would have been had firms applied pre-1986 technology to the same labor and energy factor inputs. Such are the quantitative effects of the investment flows and modernization efforts identified earlier.

Although there are a few bright spots, none of the other sectors showed the kind of spectacular growth detected in transportation. Echoing the earlier annual results, within metalworking, primary metals (SIC 33) did well, turning in a robust average 2.8 percent per year increase in

TABLE 3

Efficiency gains based on the MMI, 1986-90

Sector	Gain (%)	Industry	Gain (%)
Transportation	9.0	Transportation (SIC 37)	9.0
Metalworking	0.6	Primary metals (SIC 33)	2.8
		Fabricated metals (SIC 34)	–0.8
Machinery	–0.6	Nonelectrical (SIC 35)	–0.9
		Electrical (SIC 36 and 38)	0.2
Chemicals	–0.9	Chemicals (SIC 28)	–0.3
		Petroleum (SIC 29)	–5.7
		Rubber and plastic (SIC 30)	0.4
		Clay, glass and stone (SIC 32)	–4.0
Consumer products	–1.6	Food (SIC 20)	–0.1
		Lumber and wood (SIC 24)	5.5
		Furniture and fixtures (SIC 25)	–3.7
		Paper products (SIC 26)	–6.0
		Printing and publishing (SIC 27)	–0.6
		Miscellaneous (SIC 39)	–9.6

its rate of productivity growth. The slight deterioration in fabricated metals (SIC 34) partly offset this gain, however, resulting in a modest overall gain for metalworking of only 0.6 percent.

Neither machinery nor chemicals displayed any significant evidence of a productivity acceleration. The small improvement in machinery sector productivity evident in the annual results is not apparent in the MMI. The rates of technical change in both nonelectrical (SIC 35) and electrical machinery (SICs 36 and 38) remained close to pre-1986 levels. The rate of technical change also appeared stable in the chemical sector, with chemicals (SIC 28) and rubber and plastic (SIC 30) indices tracking VA quite closely. The exceptions were petroleum (SIC 29) and clay, glass and stone (SIC 32), whose performance appeared to deteriorate significantly. However, given the poor quality of the data and the very small size of these industries in the Midwest (each only about 1 percent of 1990 VA), little weight should be given to these results.

Performance within the consumer products sector was rather disappointing overall. All industries showed some diminution in their rate of technical change, with the exception of lumber and wood (SIC 24). Since that industry currently accounts for only 1 percent of the Midwest's output, its impact on the region is small.

TABLE 4

Estimated shift in Midwest rate of productivity growth
(annualized percentage)

	1973-85	1986-90	Difference
Transportation (SIC 37)	0.1	10.0	9.8*
Primary metals (SIC 33)	0.4	4.1	3.7

* significant at the .05 level.

Modeling the productivity takeoff

How important are these results statistically? How might the mixed-frequency MMI model be extended to allow a changing rate of productivity growth? What is the impact of more rapid technical change on current estimates of the MMI? To address these three issues, we re-estimate the MMI for the transportation and primary metals industries—the two industries that show significant acceleration in the region—allowing a shift in the productivity growth rate in 1986. The significance of this shift can then be evaluated statistically.

The results of this exercise, as reported in table 4, generally support the out-of-sample findings. Again, the evidence for a productivity takeoff is strongest for transportation, which experienced a statistically significant increase in annual productivity growth of 10 percent relative to the 1973–85 period. If this more rapid growth were extrapolated into 1993, then with the same inputs, output (measured by VA) would be roughly 70 percent higher than it would have been using 1973–85 technology.

The results for primary metals also provide some evidence for a higher productivity growth rate, although the statistical significance is weaker. While the estimated shift coefficient implies an increase in annual productivity growth of 4 percent, it is not statistically significant at the traditional .05 level.

Extending the MMI

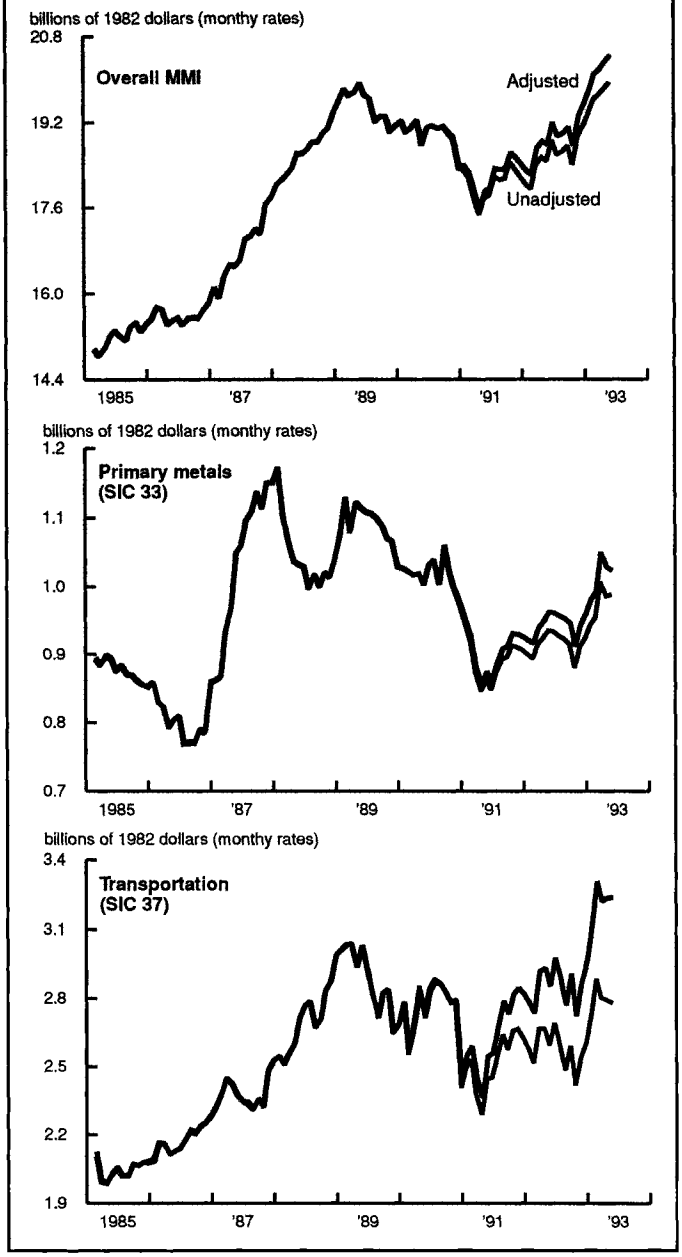
These findings have potentially important implications for current appraisals of Midwest output. One of the purposes of the MMI is to assess the level of manufacturing activity prior to the release of VA data, which become available after a two- to three-year lag. Contemporaneous estimates of the growth of industry output incorporate a weighted average of energy and labor inputs, plus the rate of productivity growth relevant for that industry. Updates of the MMI, therefore, depend critically on whether this rate of productivity growth is stable. Projections that did not take into account any productivity acceleration might as a result seriously understate current output levels.

To assess the consequences on the MMI, we perform one final exercise, comparing post-1990 MMI projections with and without a shift in productivity growth in 1986. Rather than re-estimate the model for every industry, we again concentrate on the two showing some evidence of a productivity takeoff: primary metals (SIC 33) and transportation (SIC 37). The results appear in figure 3.

The top panel shows the impact of this change on the aggregate MMI. The effect is small but perceptible. The cumulative discrepancy relative to the unadjusted index was

FIGURE 3

Effect of the productivity takeoff on the MMI



2 percent as of April 1993. Naturally, the effects on the individual industries, depicted in the middle and bottom panels, are larger. As expected in light of the earlier results, the most pronounced effect is in transportation, where the adjusted MMI is 15 percent higher than the unadjusted by April 1993. The cumulative impact on primary metals is a smaller but still substantial 3 percent.

These results demonstrate that if the productivity acceleration had continued from 1990 to the present, it may have had a noticeable impact on the MMI; accordingly, the existing MMI would have understated the Midwest's actual output from 1991 to 1993. Should the index then be modified to incorporate higher rates of productivity growth in certain industries? Clearly, the answer depends on recent productivity developments. For example, if we assumed that the 1986–90 rate of change had continued into 1993 but it had actually levelled off, then modifying the MMI would introduce an upward bias into it. For this reason, the appropriate incorporation of changes to the MMI model requires an ongoing, disaggregated examination of the structure of the economy.

Conclusion

Despite falling levels of employment, Midwest manufacturing output expanded rapidly during the 1980s. This growth, which surpassed national output growth over the period, suggests improved competitiveness among the region's manufacturers. The evidence confirms this impression. Comparing the predictions of production models applied to annual Midwest data with similar predictions for the rest of the nation showed that the region's brisk expansion was due in large part to strong productivity growth. The main cause of this growth appears to have been the aggressive modernization efforts of Midwest manufacturers, as reflected in the region's higher rate of investment per worker relative to the national average.

Using the MMI to evaluate the size and scope of the productivity gains, we found that they were largely confined to a few key industries, particularly transportation and primary metals. However, given the prominence of these industries in the Midwest, their impact on overall manufacturing output is substantial, possibly raising current

estimates in excess of 2 percent if the productivity growth observed from 1986 through 1990 continued into 1993. This finding underlines the importance of incorporating higher rates of technical change for certain industries into future updates of the MMI to reflect the continuing modernization of Midwest manufacturing.

APPENDIX

Tracking Midwest manufacturing with the mixed-frequency MMI

A useful tool for analyzing Midwest manufacturing is the mixed-frequency Midwest Manufacturing Index (MMI) developed by Israilevich and Kuttner (1993). While this technique uses the Cobb-Douglas production function employed in the annual results, it differs from this specification in its use of a *monthly* production model. At the same time, it constrains the estimated monthly production series in such a way as to be consistent with the observed *annual* value added (VA) data; hence the "mixed-frequency" designation.

Incorporating monthly data yields two significant advantages over annual models. First, it makes it possible to track high-frequency fluctuations in Midwest output. Second, the mixed-frequency MMI has been shown to provide more accurate out-of-sample projections of manufacturing activity than pure annual models. Since annual VA data are not yet available for the Midwest, this benefit is particularly useful for assessing the effects of accelerated technical change on the current output of the region's manufacturing sector.

The foundation of the mixed-frequency MMI is a Cobb-Douglas production equation applied to monthly data. Expressed as first differences of natural logarithms, the monthly change in the real output of any Midwest industry, $\Delta x^7_{t,s}$, is the weighted sum of the change in employment hours, $\Delta l^7_{t,s}$, and energy usage, $\Delta e^7_{t,s}$:

$$\Delta x^7_{t,s} = \gamma + \theta \Delta l^7_{t,s} + \phi \Delta e^7_{t,s} + \eta_{t,s}\,.$$

As in the annual model, γ is the (constant) rate of Hicks-Neutral technical change, θ and ϕ represent the elasticity of output with respect to labor and capital (energy), and η is a stochastic error term. The superscript 7 is used to denote Midwest data. Note that with the shift to monthly data, each variable now receives two subscripts. The first, t, denotes the year, while the second, s, represents the month within that year. Thus the change in output between the second and third months of the 13th year of the sample would be denoted $\Delta x^7_{13,3}$.

A difficulty with this approach is that while monthly energy and labor data are available for the Midwest, no monthly output measure exists. The only available measure of region's production is the real value added (VA) data used in the annual results. In light of this data limitation, estimating the monthly model might appear to be a lost cause, since traditional regression techniques require the observations on the left-hand variable to be available at the same frequency as those for the right-hand variables. Using regression methods, therefore, requires that energy and labor be aggregated to an annual frequency. This is the approach used earlier to compare productivity growth in the Midwest and in the rest of the nation.

Fortunately, there are ways around this obstacle. Techniques exist to combine data of differing frequencies into a single model. For the mixed-frequency MMI, we use a state-space econometric model that treats Midwest output growth as a latent variable. Given some additional relationships between the unobserved $\Delta x^7_{t,s}$ and other data series, the monthly model can be estimated even in the absence of direct information on Midwest output.

One key link between $\Delta x^7_{t,s}$ and something observable is the "adding up" relationship between the monthly growth of output and the annual growth of the real VA data. Because the annual VA observations correspond to the sum of the output produced in each month, the year-to-year change in real VA is actually a weighted average of the monthly output growth in the current and preceding 23 months. Thus, constraining the monthly growth rates to produce an annual pattern consistent with the VA data implies that

$$\ln(\mathrm{VA}^7_t) - \ln(\mathrm{VA}^7_{t-1}) = \frac{1}{12} \cdot \sum_{s=1}^{12} \sum_{j=0}^{11} \Delta x^7_{t,s-j}\,,$$

Imposing this equation enforces consistency between the estimated MMI and the annual VA data.This relationship alone is not enough for the monthly approach to yield any dividends, since all the available information is still coming at an annual frequency. In order to make inferences about fluctuations within the year, we need an additional source of *monthly* information. One source of such information is the monthly index of industrial production (IP) prepared by the Federal Reserve Board. Besides the energy and labor inputs used as inputs to the MMI, the IP typically incorporates some information on actual output, such as the dollar value or physical quantity of goods shipped. Thus the IP index con-

tains information on industry output not captured by energy and labor inputs alone. However, the information in the IP index pertains to the nation, not to the Midwest. Therefore we cannot simply use IP to compute $\Delta x^7_{t,s}$. Instead, we relate national to regional fluctuations by using an equation to describe the comovement of the two series:

$$\Delta x^N_{t,s} = \mu + \delta \Delta x^7_{t,s} + \nu_{t,s}.$$

As before, $\Delta x^7_{t,s}$ represents the growth in Midwest output; $\Delta x^N_{t,s}$ is the growth of national output in the same industry as measured by industrial production. The coefficient δ relates the magnitude of the national fluctuations to those of the region, and ν is random "noise" in the relationship.

Unlike the production model introduced earlier, this equation does not describe any fundamental economic or structural relationship between the region and the nation. Neither is the national IP in any way a determinant of regional output in the same way that regional labor and energy inputs are. Rather, this equation describes how Midwest economic fluctuations have historically been paralleled by movements on a national scale.

Clearly, the fact that Midwest industry comprises a portion of the national total, implies a positive correlation between the region and the nation, represented by a positive value of δ. But to the extent that industries within and outside the region are subject to similar demand conditions, one might expect the correlation to be even greater than suggested by the industry's share in total output. It is unlikely, however, that δ would exceed 1, since many regional fluctuations will be damped by offsetting fluctuations in the rest of the nation. While the δ parameter picks up the relative magnitudes of industrial fluctuations, the standard deviation of ν captures the amount of "noise," or unpredictable variation, in the link between regional and national output.

TABLE 5

Mixed-frequency MMI model estimates for primary metals (SIC 33)

Production model	IP indicator equation
$\phi = 0.33$*	$\mu = 0.00$
$\theta = 1.11$*	$\delta = 0.54$*
$\gamma = 0.001$	Standard deviation of $\nu = 0.025$
Standard deviation of $\eta = 0.038$	

Note: Based on the 1973-90 sample.
* significant at the .01 level.

Table 5 shows the results from estimating the mixed-frequency MMI model for one representative industry: primary metals (SIC 33). The estimates of the production function's parameters all fall within the range of economically reasonable values, although the sum of ϕ and θ imply increasing returns to scale. The estimate of γ (which is constant throughout the sample) suggests only very modest productivity growth of 1.4 percent per year. The very small estimate of μ indicates that output has grown at roughly the same rate in the nation as in the Midwest. The estimated δ of 0.54, however, suggests that IP fluctuations in the nation are approximately half the magnitude of fluctuations in the Midwest.

FOOTNOTES

[1]Estimates of Midwest capital expenditures for the years 1979–81 are not available in the Commerce Department's Annual Survey of Manufacturing (ASM). Values were calculated by first comparing a sample of 480 Midwest firms with 100 or more employees, taken from the Longitudinal Research Data (LRD) base for the years 1985–88, with the reported ASM data for those years and, second, applying the average proportions to the LRD base to generate ASM-equivalent data.

[2]Moody (1974) discusses the use of energy as a proxy for capital services.

[3]A description of the Atlanta method appears in Israilevich and Kuttner (1993).

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