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VERTICAL CONNECTIONS IN THE MIDWEST ECONOMIES: THE ROLE OF INTERNAL AND EXTERNAL TRADE

by

John J.Y. Seo, Geoffrey J. D. Hewings and
Michael Sonis

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John J.Y. Seo
Regional Economics Applications laboratory, University of Illinois, 607 S. Mathews, Urbana, IL 61801-3671

Geoffrey J.D. Hewings
Regional Economics Applications laboratory, University of Illinois, 607 S. Mathews, Urbana, IL 61801-3671

Michael Sonis
Regional Economics Applications laboratory, University of Illinois, 607 S. Mathews, Urbana, IL 61801-3671 and Bar Ilan University, Ramat Gan, Israel.

Abstract:
An earlier paper (Hewings *et al*., 1998), evidence suggested that the Chicago metropolitan region was *hollowing out*, namely becoming less dependent on internal-to-the-region sources of inputs and sales of products and services. The findings raised the question about where this spatial dependence had relocated and the current paper explores the process of structural interdependence for the Midwest economy using a REIM (Regional Econometric Input/Output Model). The model examines the Midwest, the constituent states of Wisconsin, Illinois, Indiana, Ohio and Michigan, and the Rest of the US in a six-region formulation. Based on the flow matrix from the model, a feedback loop analysis is first conducted to identify the spatial geographic structure of trade flows. This study further examines industrial interdependencies in a sequential production process, by applying Maddigan's vertical connection index to the multi-region framework with a particular focus on the role of interregional and inter-activity trades.

Key words: spatial dependence, vertical connection.
JEL classification codes: R1, D5, L6.

1. Introduction

For the past two decades, changes in the spatial inter-connections in the production process have been one of the more visible characteristics defining the reorganization of both international and interregional trade. In international trade, the process of globalization find firms specializing production in establishments, often in different countries, to exploit locational advantages, such as proximity to markets and easier access to relatively advantageous production inputs (see Hummels *et al*., 2001). Within countries, regional trade appears to be motivated less by notions of comparative advantage associated with cheaper input costs, labor immobility, etc., than by centripetal forces generated by cumulative causation, such as the interactions of scale economies, transportation costs, and specialized labor pools (see Fujita and Thisse, 1996; Krugman, 1998; Ciccone and Hall, 1996; Wheeler, 2001). Hence, this self-reinforcing process may result in greater "spatial disaggregation" of production across regions suggesting that vertical integration of production may now more spatially sophisticated than in decades past (see Parr *et al*., 2002).

In the next section, some background perspectives are provided. Section three explores industrial and Midwest interregional flows while section 4 explores ways of capturing vertical connections. The results are presented in section 5 and the paper concludes with a summary section.

2. Background Perspectives

To capture industrial interdependencies in sequential production processes, this study utilizes Maddigan's (1981) proposed method for measuring vertical industry connections and applies it to a multi-region general equilibrium model. The methodology utilizes an input-output matrix to capture industrial interdependencies in this sequential production process, in which the forward/backward linkage is established in the matrix. By doing so, the production relationships in the measure have simultaneous, network characteristics, relating to all macro and micro economic factors. A recent series of geographic concentration measures (see Maurel and Sedillot, 1999; Ellison and Glaeser, 1997) are basically modifications of the Herfindahl index, and thus limits a firm's or an industry's participation in a linear succession of production. More importantly, these measures cannot utilize the abundant information on interconnections embedded in an input-output table, and may generate misleading interpretations about industrial structural changes.

As an alternative, feedback loop analysis, elaborated by Sonis and Hewings (1999, 1995, 1993) offers another way of interpreting the sequential production process, when input-output tables or a trade flow matrix is available. A complementary methodology, structural path analysis, has the great advantage in identifying the spatial geographic structure of trade flows and in examining the nature and strengths of interregional connectivity. However, while the analysis highlights the value of trade flows of interregional and/or interactivity feedback loops, it has difficulties in measuring the degree of sequential production linkage in detail at the industry level.

<<insert table 1 here>>

In this study, a flow analysis is first conducted to explore the spatial geographic structure of trade flows, and then Maddigan's index is applied to data from the regional model for the industry level analysis. This study focuses on the Midwest, consisting of the states of Wisconsin, Illinois, Indiana, Ohio and Michigan, and their interactions with the rest of the U.S. The industrialized Midwest should be a good example in examining interconnection among regions and activities, since the region can still claim to be experiencing the benefits of regional agglomeration, especially in intra-sector activity in the durable manufacturing sector to explore its scale and scope economy (Swonk, 1996; Sonis *et al*., 2002; Parr *et al*., 2002). In 1996, the Midwest economy achieved a gross regional product of $1.1 trillion, representing about 20% of the US economy.

Also, the contribution of the region's economy to the US total is similar in other categories such as total industrial output and income, while exhibiting a higher labor productivity (output per employee) than the rest of the nation. The Michigan auto industry is often used as a popular example of an industrial cluster (see, for example, Klier, 1998). The industry requires a high level of scale economies due to its high sunk costs, and thus, by clustering in the auto belt, takes geographical advantages of scope economies (e.g., interactions of scale economy with differentiated products) and regional infrastructure (e.g., transaction costs and pool of skilled labor). However, the overall economic agglomeration in the Midwest region should be more carefully specified, based on inter-linkage of all industries. To what degree can other industrial clusters be identified in the Midwest?

For a comprehensive coverage of internal and external effects among industries and regions, the Midwest Regional Input-Output Econometric Model (MW-REIM)[1] is utilized. The model is based on a 1992 and 1997 multiregional input-output tables that were complied using state input-output tables and interstate trade derived from the Commodity Flow Survey for 1993 and 1997 and annual regional data available from 1969 to 1996. The primary focus of the model is on manufacturing sectors. MW-REIM is a multi-regional, dynamic general equilibrium model, which incorporates five Midwest states and a single rest of the US region, and 13 industrial sectors for each region. This model provides the capability for developing quantitative economic

[1]. For details on the REIM system, see Israilevich *et al*. (1997).

linkages among the system variables, via its two major components, the input-output module and the time-series module, and visualizing a comprehensive industrial and regional connection. One can also extract forward and backward linkages by generating input-output tables and annual forecasts for the period 1998-2022 for 13 sectors specified in the model. The procedure for extracting the annual (derived) input-output tables is explained in Israilevich *et al*. (1997). The sectors are described in the Appendix together with the aggregate trade flows for 1980, 1990 and 2000.

3. Industrial and The Midwest Interregional Flows

Using this 13-sector, 6-region model framework, a flow analysis was used to identify major linkages within the system. The methodology used to estimate the interstate trade flows is identical to Sonis *et al*. (2002). Table 2 summarizes the analyses of interregional and inter-activity flow matrix. The top portion of the table shows that the intraregional trade flows for the six regions, the diagonal sum of regional flow matrices, reached \$4.8 trillion in 2000 and accounts for more than 80% of total trade flow in the US. Within the diagonal summation, intra-activity (i.e., intraindustry flow, or flows between establishments within the same sector) has sharply increased from 37.3% (= 31.0/83.23) of intraregional flow in 1980 to 46.4% in 2000, while the interactivity in intraregional flow has been reduced to 53.6% from 62.7% in the same period. These findings are consistent with trade theory that would suggest that trade between regions with high levels of per capita income, similar endowments and with good connectivity would move from domination by interindustry to intraindustry trade as firms exploit scale economies at the establishment level and produce multiple products to meet consumer demands for greater choice in goods that are near substitutes for each other. Using a more diaggregated set of trade flows for interaction between the Midwest states only, Munroe *et al*. (2003) found a similar domination by intraindustry trade.

<< insert table 2 here>>

Interregional flows are also decomposed into intra- and inter-activity, from the off-diagonals of the flow matrix, and the results are shown in the second part of the table. The total trade flows were identified through five feedback loops, hierarchically ordered according to the intensity (sum of flows) of trade through the loops. Sonis *et al*. (2002) identified the five interregional trade loops for the six regions for year 1992, and showed that the Midwest economy is well developed and bilaterally balanced; to each flow, there corresponds the equivalent counter-flow. In table 2, one thing to note is that, although the interregional trade is increasing only gradually, intra-activity has jumped to 10.0% of total interregional trade in 2000 from 7.5% in 1980, while the inter-activities remained about the same at around 9.2% during the same period.

The time trend of these interregional flows is summarized in the third part of table 2 at the aggregated level in Midwest and non-Midwest regions. Absent detailed analyses of these tables (i.e., with more sectoral disaggregation), there is no clear evidence of the time-trends of interregional trade. A case might be made that there is a trend of regional agglomeration in the overall Midwest economy: the sum of Midwest trade flows (MW-to-MW matrix) has increased in a logarithmic manner as both the diagonal sum and the off-diagonal sum increased. Interregional flows in both directions also increased for the period. Meanwhile, the portion of intra-region trade in the rest of US has dipped over time, which mainly appears to be due to the larger geographical scope of the region. This finding partially reflects the increased international trades over these decades, since the original input-output table is designed on the basis that the national exports is involved only through the trade in the rest of US region.

The flow analysis in this section provides a clear outlook that, for the past decades, intra-industry trade has grown noticeably in intraregional, and even in interregional trade. Secondly, the MW-to-MW flow is increasing over time, providing a possible interpretation that while hollowing out may be occurring at the metropolitan or state level, the process appears not to be in evidence at the regional (Midwest) level. Reductions in real transportation costs (see Parr *et al.*, 2002) associated with the increased density of the freeway network have increased the geographical range over which it is economically feasible to ship products – even for just-in-time production regimes. However, the flow analysis would need to be extended to the detailed sectoral level, since an aggregated sector analysis has seriously limited usage in measuring the strength of sequential production linkage.

4. Measuring Vertical Connections

In order to capture industrial interdependencies in the sequential production process, Maddigan's method is utilized with the multi-region framework. Her approach is based on the input-output matrix and advances a method of linking industries through production functions, established as forward/backward linkages in the matrix. Production relationships in the measure thereby capture simultaneous, network characteristics (for instance, two industries often serve as input suppliers to each other), relating to all macro and micro economic factors. Traditional methods, analyzing relationship among output, or value-added-to-sales ratio, limit a firm's or an industry's participation in a linear succession of production stages. Simply put, in reality, it would be too narrow to define an industry's production function in a single processing chain. Meanwhile, recently released measures of geographic concentration (e.g., Maurel and Sedillot, 1999; Ellison and Glaeser, 1997) reflect both vertical and horizontal integration. The measures can be over-estimated as a consequence of a horizontal merger, for example, and most importantly cannot utilize the abundant information on interconnection embedded in input-output table.

The crux of Maddigan's index is in its utilization of the forward- and backward-matrix manipulated from the Leontief framework. Her method can be applied in the multi-region model framework in the following way. In her paper, two matrices, *A* and *B*, represent relative net inputs and relative net outputs respectively, and capture all net production relationships for industries' upstream and downstream linkage:

$$A = I - [x_{ij} / (z_j - x_{jj})] + [y_{ij}]$$

$$B = [x_{ij} / (z_i - x_{ii})] - [y_{ij}] - I$$

where

I = identity matrix, m x m;

x_{ij} = the value of the i^{th} industry's output used as an input to the j^{th} industry;

z_j = the total value of output of the j^{th} industry; $j = 1, \dots, m$;

$y_{ij} = \{ x_{ii} /(z_i - x_{ii})$ if $i=j$; o if $i \neq j$; $i, j = 1, \dots, m\}$.

The dimension of m is 78 in the model (13 sectors in each of the 6 regions), and thus each i and/or j represents an industrial sector in a region. The elements in matrix *A* are negative, as vertically-linked input values reduce the value of net output consumed internally, and the matrix *B*'s elements are positive values, representing the allocation of industrial outputs. An index synthesizing these two matrices now can be formulated for an explicit expression of this industry's production line linkage. Using the rows and columns of matrices *A* and *B*, respectively, an industry is characterized by two matrices, *C* and *D*, where the column vector of

$c_{ij} \in C$ is the column *i* of industry *j*'s input matrix, and the row vector of $d_{ij} \in D$ is the row *i* of industry *j*'s output matrix. Formally, each element is defined as, for *i*, *j*=1, …, *n* ($n \le m$),

$$c_{ij} = a_{s(i)s(j)}$$

$$d_{ij} = b_{s(i)s(j)}$$

where

$s(i)$ = one of the regions in which the industry established, indexed by *i*;

c_{ij} = the percentage of the value of industry $s(j)$'s net output contributed by industry $s(i)$;

d_{ij} = the percentage of the value of industry $s(i)$'s net output used as an input to industry $s(j)$.

Finally, in the multi-regional framework, the vertical connection index for an industry *k* can be defined as

$$VC_k = 1 - \left[1 \Big/ \prod_{r=1}^{6} \left(\sum_{R=1}^{6} \sum_{j=1}^{13} c_{kr,jR}^2 \right) \cdot \left(\sum_{R=1}^{6} \sum_{j=1}^{13} d_{jR,kr}^2 \right) \right].$$

The diagonal elements of *C* and *D* are 1's, as *j*=*k* and *R*=*r*. The index lies between 0 and 1, and maintains the three properties[2] noted in her paper. By its construction, the VC index does not cover intra-activity in intraregional trade. However, in the multi-regional setting, it is a comprehensive measure covering an industry's forward and backward interconnection to different industries (inter-activity in intra- and interregional trade) and to the same industry (intra-activity in interregional flows). Another advantage of using the index is that it can be modified easily for a particular region of concern. In other words, for flow analysis of the Midwest alone, *R* and *r* reduces to 5 Midwest states, not 6, and the two matrices are reduced into 65x65, rather than 78x78, dimension by excluding the rest of US region. This partitioning can be applied to a state or a single region level, or even to intra-activity flow analysis, even though the index will become significantly smaller as the total value of in-and out-flow reduces for smaller *C* and *D* matrices.

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[2]. Three propositions in Maddigan's paper are:

(1) The index increases (decreases) when an input industry linked by the industry becomes relatively more (less) important by accounting for a larger (smaller) percentage of the total value of output.

(2) The index increases (decreases) when relatively more (less) of the output of an industry in which the industry established is used as an input to another industry in which the industry produces output.

(3) The index increases if there is any increase in vertical interconnections, other than pure conglomerate activity, between new industry and the industry's established product line.

5. Result and Interpretation of the VC Measures

The estimation of the vertical integration measures is summarized in table 4 for the nation and the Midwest for the years 1980, 1990 and 2000, while the actual output level is introduced in table 3. The VC index lies between zero and one for all sectors in the three selected years. The indices for the Midwest economy are lower than for the U.S., as the total value of the input coefficients decrease. Perhaps, the time interval of twenty years, from 1980 to 2000, is not long enough to judge structural changes for all industries, but their trend overall is consistent with intuition and results from previous studies. In the table, the hierarchy of vertical integration among the 13 sectors is displayed in the row denoted 'Rank,' while the darker shaded areas (the less dark areas) denote the top (bottom)-four ranked sectors in 2000. The third part of the table shows intraregional and intra-activity flow as a percentage of total output distribution. The same analysis is also applied to the 6-region level and displayed in table 5.

<<insert tables 3 and 4 here>>

As can be seen from the table 4, although the flow analysis showed a significant growth in internal effects (intra-industry, intraregional trade) over the two decades at the aggregated one-sector level, it is only sectors 13 and 5 that have contributed to such internal trade expansion within the nation. That is, activity has actually diminished percentage-wise in the other eleven sectors in the US trade flow. Note that sector 13 covers all private and government service, as well as transportation, communication, and utility industries. The industry occupies about 60% of total output produced, and, given its upward growth trend, the industry must have been the major force to boost the total value of internal (intra-activity and intra-region) trade. Focusing on the flow matrix for the Midwest region alone, it can be seen that the activity has increased in not only in sector 13 and but in most of the manufacturing sectors.

On the other hand, the VC index measures the strength of sequential production linkage other than intraregional and intra–activity trade flow for each sector. Overall, the indices show that vertical connection is high in resources (sector 1, 2, and 3) and low in service (sector 13), and varies widely for manufacturing industries. The low rank of the service sector is mainly because, final consumers demand most of its production, and thus, its output linkage becomes less important, accounting for a smaller percentage of the total value of output. The number however is increasing significantly in both regional specifications; implying that its outflow and inflow are becoming more linked to other industries' production. This upward trend is also observed in sectors 5, 2 and 3, while there is a downward trend in sectors 1, 4, 8 in US and 1, 4, 6, 8 and 9 in the Midwest. Overall, the table provides the strong impression that the increase in the Midwest-to-Midwest flow that has contributed to the hollowing-out process in individual states resulted from (1) a significant increase in intra-activity, intra-region trade for sector 13 and (2) steady increases in such activity in most manufacturing sectors, and also (3) increased vertical connections in sectors 13, 5, 2 and 3.

Regarding the hierarchy of the VC level, sectors 6, 10, 1 and 2 are the highest ranked sectors in year 2000 in both the US and the Midwest. In the same year, the smallest linkage occurs in sectors 8, 12, 13 and 4 in the nation and in 9, 13, 12 and 8 in the Midwest. From 1980 to 2000, most industries exhibit smooth transitions. But in 1990, the US transportation equipment industry (sector 10) shows a large, temporary retreat toward less integration; a downturn of production by US auto makers in the 1990s and foreign-owned-auto makers' more dispersed direct investment in the US in areas other than Detroit area in the same time period. However, along with two metal industries of sector 6 and 7, automakers have remained one of the most vertically connected industries. For the downward trend of agricultural products (sector 1), this result might be explained by more direct exports of agricultural production as agricultural business becomes more dependent on international trade and becomes more internally integrated (Frank and Henderson, 1992).[3]

An alternative way to look at the sectoral VC in the Midwest is to take the ratio of VC of the Midwest series over US series. Then the industries are ordered as (10, 1, 8, 6, 3, 7, 11, 2, 12, 4, 9, 5, 13) in 1980 and as (10, 8, 3, 1, 6, 2, 7, 11, 4, 5, 12, 13, 9) in 2000. While the index inherently has no absolute criterion on its measure of numerical significance, the ratios provides a sense of the significant integration level and trend, for instance of sector 10 and 1, among Midwest industries. Simply put, along with its high production level shown in table 3, it appears to be heavy manufacturing (sector 10 & 8) that provides the underpinning for the interdependence in the Midwest.

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3. For the past decades, vertical coordination has been progressed significantly in the US agricultural industry to exploit scale economy and monopolistic market power for final products, which become more versatile and differentiated.

<<insert table 5 here>>

As a general rule, the VC indices register low values in industries having high levels of either product diversification (sector 9), which leads to high monopolistic competition, or sunk cost (sector 8, 5), or final-stage consumption (sector 13). For instance, the electronic industry of sector 9 represents the area of horizontal interaction effect with output differentiation, and thus its value-added to the economic system is less dependent upon intermediate products (many of these components are imported). However, their trend appears to be somewhat different: the VC measure of sector 9 decreases significantly in the Midwest, while still rising in the rest of US, and sector 5 increases in Midwest, but decreases in the rest of the region.

<<insert table 6 here>>

Finally, we reduced the *A* and *B* matrices into a 6x6 dimension to examine intra-activity flows between the six regions, and derived the interregional, intra-industrial integration measure for the 13 sectors in the nation. This modification allows one to visualize major industries that lead to the increase in intra-activity in interregional flow in feedback loop analysis. Table 6 shows, in year 2000, that in the US, sector 10 records the highest value, followed by sector 13, and the rest in the order of (1, 8, 11, 6, 9, 4, 5, 7, 2, 12, 3). The order is about the same in other selected years, but only the service sector shows an increasing trend in a significant manner. Sector 13 is the major industry, which occupies about 60% of the total output, and it must have been the major force to boost up the total value of such trade, as shown in table 2. Sector 10, the auto industry, also exhibits a very high integration level of trade. This intra-activity, interregional trade appears to be not very active in many manufacturing industries, especially in sector 5, 7, 9 and 12, and overall in the Midwest.

6. Summary

This paper introduces and compares some alternative, complementary methods for measuring inter-connection of production process in the Midwest economy. Employing a flow analysis, it first presents the value of intra- and interregional trade flows over the past two decades. Being consistent with previous literature, this method provides a clear evidence that intra-industry trade has grown noticeably in intraregional, and even in interregional trades. Further, the Midwest-to-Midwest flow is on the increase during the period of estimation (1980-2000); it remains to be seen whether the hollowing out process observed for the Chicago metropolitan region represents a spatially hierarchical process, evident first at smaller geographic scales. It would seem reasonable to expect that continued improvements in logistics and communications would effectively undermine any (short-term) advantages offered by the Midwest as a region; between 1990 and 2004, the Midwest region lost 12% of its manufacturing jobs (for Illinois, the loss was much higher, almost 24% while for the nation, the loss was 19%). However, as has been noted, job losses may not be entirely reflective in losses of production, as productivity gains in the Midwest have been dramatic.[4]

Parr *et al*. (2002) have argued that traditional notions of agglomeration of economies as being the dominant factor in location may need to be revised by consideration of economies that are less spatially constrained. With lower transaction costs, firms can optimize production at establishments located in different states through specialization to take advantage of economies of scale. Intermediate goods that previously may have undergone two or more transformations within an establishment located in another state. Thus, vertical connections in the commodity chain are now more spatially scattered; the evidence provided in the analysis in this paper would suggest that there still exist some agglomeration benefits but these are realized at the scale of the Midwest rather than an individual metropolitan area or state. The evidence for this is derived from the substitution of interregional for intraregional trade in the states of the Midwest.

Examining the structure of trade at the national level, although a significant growth in internal effect (intra-activity in intraregional trade) is derived in the flow analysis, it is the service sector (covering about 60% of total output) that has heavily contributed to such an expansion. The activity in percentage has actually diminished in the US trade flow in most other sectors. Compared with the rest of the country, vertical integration in Midwest is the most significant in heavy manufacturing industries (such as auto and industrial machinery). Other than the auto sector, the intra-activity in interregional trade has not been very active in many manufacturing industries in the nation, nor in the overall Midwest economy.

Like other methodologies used to measure industrial activity, this approach has limitations of losing details of inter-industry relationships, and difficulty of measuring the index's statistical significance level or allocating scale differences. Yet, the index approach, combined with the

[4] For example, in the Chicago region over the period 1970-1990, manufacturing production fluctuated but the 1990

information on internal flow, provides a useful tool for analysis at the sectoral level and some important insights on structural change in the Midwest economy.

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Table 1. Basic Economic Statistics, Midwest and the Rest U.S., 1996

	GRP	*Output*	*Employment*	*Income*	*Intra-Flow*
Midwest	1,119,158	1,965,876	22,610	682,445	16.7% *[1]
(%)	19.1	22.7	17.8	20.2	24.9
Rest US	5,875,182	8,646,034	126,986	3,384,501	67.2% *[1]

Note: Monetary units are measured in 1992 million $, and 1000 full- and part-time number of employees for Employment. The percentages in 'Intra-Flow' account for the monetary value of intraregional commodity flow, relative to the sum of the flow within US. The rest 16.1% (100-16.7-67.2) is the interregional flow between two regions.

Table 2. Regional, and Inter- and Intra-Activity Flows

	1980	1990	2000
Total Flow	4,688,314	4,964,328	5,933,438
Intraregional Flow			
	3,901,955 (83.2%)	4,090,943 (82.4%)	4,796,029 (80.8%)
Intra-activity	31.0% *[1]	35.5%	37.5%
Inter-activity	52.2%	46.9%	43.3%
Interregional Flow			
	786,359 (16.8%)	873,385 (17.6%)	1,137,409 (19.2%)
Intra-activity	7.5% *[2]	8.5%	10.0%
Inter-activity	9.3%	9.1%	9.2%
Midwest vs. Rest US flows(%) *[3]			
MW-to-MW	13.7	15.0	17.3
MW-to-RU	8.2	8.4	8.8
RU-to-MW	6.1	6.5	7.0
RU-to-RU	72.0	7.1	66.8

Note:

A. *[1]. The sum of 31.0% and 52.2% is 83.2%. *[2]. The sum of 7.5% and 9.3% is 16.8%: Sum of Intra-activity within the interregional flow.

B. *[3]: Percentages are relative to the sum of the US flow matrix.

Table 3. Actual Output Levels (%, Total Output), 1996

Sector	*Illinois*	*Indiana*	*Michigan*	*Ohio*	*Wisconsin*	*Rest US*
1	1.7	1.8	0.7	1.1	1.3	2.7
2	0.4	0.4	0.3	0.5	0.2	1.3
3	5.4*	5.5	4.9	5.1	5.7	6.0*
4	5.1	3.7	2.6	3.9	8.3*	3.7
5	3.3	4.3	2.4	3.3	1.9	3.2
6	1.8	6.8*	1.9	3.9	1.8	1.2
7	2.8	3.9	4.3	4.4	3.4	1.3
8	5.7*	5.3	5.5*	5.6*	8.9*	2.5
9	3.9	4.2	1.1	3.7	5.2	2.5
10	2.9	11.7*	22.1*	11.9*	4.8	2.5
11	7.2*	7.2*	5.5*	6.2*	9.9*	7.8*
12	2.5	4.5	3.8	3.6	4.9	3.7*
13	57.3	4.7	44.8	46.6	43.6	61.6
Total (m$)	562,573	264,978	425,662	485,934	226,729	8,646,034

Note: The projected output levels are obtained from the MW-REIM, and monetary units are in 1992 million dollars. * indicates the top three major industries, other than sector 13, in each state.

Table 4. Vertical Connections and Internal Consumption in U.S. & Midwest, 13 Sectors, 1980, 1990 & 2000

VC						*Sectors*							
US	1	2	3	4	5	6	7	8	9	10	11	12	13
1980	.92	.64	.62	.55	.54	.90	.67	.48	.58	.74	.60	.49	.40
1990	.84	.69	.66	.51	.56	.88	.65	.40	.57	.71	.60	.50	.45
2000	.77	.71	.67	.51	.58	.87	.66	.37	.56	.73	.62	.48	.48
Trend	-	+	+	-	+	-	-	-	-	-	+	-	+
MW													
1980	.83	.45	.49	.37	.33	.74	.51	.41	.38	.67	.43	.34	.23
1990	.72	.53	.53	.33	.35	.69	.47	.35	.33	.64	.41	.33	.27
2000	.62	.56	.54	.33	.37	.69	.49	.32	.29	.66	.43	.30	.29
Trend	-	+	+	-	+	-	-	-	-	-		-	+

Rank													
US						*Sectors*							
1980	1	6	10	7	2	3	11	9	4	5	12	8	13
2000	6	1	10	2	3	7	11	5	9	4	13	12	8
MW													
1980	1	6	10	7	3	2	11	8	9	4	12	5	13
2000	6	10	1	2	3	7	11	5	4	8	12	13	9

Intra-Region, Intra-Activity (%)

						Sectors							
US	1	2	3	4	5	6	7	8	9	10	11	12	13
1980	39	9	3	19	22	28	6	18	15	15	30	17	48
2000	35	4	3	14	23	20	5	14	12	14	21	13	58
Trend	-	-		-	+	-	-	-	-	-	-	-	+
MW													
1980	26	6	2	11	19	27	5	6	10	12	13	6	30
2000	15	1	2	12	21	21	5	9	11	14	14	7	34
Trend	-	-		+	+	-		+	+	+	+	+	+

Note: The hierarchy of VC, vertical connection, among the 13 sectors is displayed in the row of 'Rank,' while the darker shaded areas denote the top-four ranked sectors in 2000, and the less dark shaded area denote the bottom-four industries. Trend indicates the direction of changes from 1980 to 2000. Intra-Region, Intra-Activity shows such flow as a percentage of total output distribution in flow matrix. Meanwhile, the US total internal consumption, which is Intra-Region, Intra-Activity as relative value (%) of total output, accounts for 17.8, 18.6, 19.1% in year 1980, 1990, 2000, respectively, while MW accounts for 15.1, 15.4, 15.7%. The trend of sectoral internal consumption is about the same as for Intra-Region, Intra-Activity in the table.

Table 5. Vertical Connection, 5 Midwest States and the Rest US, 1980 & 2000

	1	2	3	4	5	6	7	8	9	10	11	12	13
1980													
IL	.56	.08	.12	.09	.08	.28	.16	.06	.09	.06	.10	.11	.010
IN	.14	.03	.12	.08	.05	.07	.11	.05	.08	.05	.07	.06	.012
MI	.05	.04	.09	.05	.09	.34	.15	.08	.09	.03	.11	.05	.010
OH	.07	.06	.07	.06	.10	.27	.12	.08	.12	.08	.08	.10	.009
WI	.06	.01	.07	.08	.02	.09	.02	.01	.01	.01	.01	.01	.004
RU	.27	.23	.09	.19	.15	.15	.12	.05	.11	.14	.14	.11	.015
2000													
IL	.18	.12	.13	.08	.10	.25	.13	.05	.07	.07	.11	.09	.008
IN	.12	.04	.12	.10	.07	.09	.14	.04	.05	.05	.08	.05	.012
MI	.08	.06	.07	.05	.11	.30	.14	.08	.06	.04	.12	.05	.012
OH	.10	.09	.09	.06	.10	.23	.13	.08	.09	.07	.09	.08	.010
WI	.13	.02	.08	.02	.02	.11	.02	.01	.01	.02	.02	.01	.004
RU	.20	.27	.10	.17	.12	.11	.09	.03	.13	.15	.16	.11	.017
Direction of VC change													
IL	-	+	+	-	+	-	-	-	-	+	+	-	-
IN	-	+		+	+	+	+	-	-		+	-	+
MI	+	+	-		+	-	-		-	+	+		+
OH	+	+	+		+	-	+		-	-	+	-	+
WI	-	+	+	-		+				+	+		-
RU	-	+	+	-	-	-	-	-	+	+	+		+

Note: The '+/-' notations indicate the increase/decrease of vertical integration of each sector in each region from 1980 to 2000. VC is on average high in IL, followed by OH and MI.

Table 6. Interregional, Intra-Activity Connection Measure, US & Midwest

US

Sector												
1	2	3	4	5	6	7	8	9	10	11	12	13
1980												
.402	.026	7E-6	.041	.018	.140	.018	.170	.050	.550	.133	.008	.334
2000												
.143	.004	4E-6	.033	.015	.059	.009	.083	.039	.521	.072	.004	.434
Trend												
-	-	-	-	-	-	-	-	-	-	-	-	+

Midwest

Sector												
1	2	3	4	5	6	7	8	9	10	11	12	13
1980												
.073	.009	7E-9	.005	.002	.054	.005	.008	.001	.475	.019	.001	.001
2000												
.019	1E-4	5E-9	.009	.004	.032	.004	.012	.001	.485	.023	.001	.001
Trend												
-	-	+	+	+	-	-	+	+	+	+	+	+

Note: 4E-6 indicates .000004.

Appendix

Table A. Sector Mnemonics in the Midwest-REIM

Mnemonic	*Sector Title*	*SIC*
1	Agriculture, Forestry and Fisheries	01,02,07,08,09
2	Mining	10,12,13,14
3	Construction	15,16,17
4	Food and Kindred Products	20
5	Chemicals and Allied Products	28
6	Primary Metal Industries	33
7	Fabricated Metal Industries	34
8	Industrial Machinery and Equipment	35
9	Electronic and other Electric Equipment	36
10	Transportation Equipment	37
11	Other Non-durable Manufacturing Products	21-23,26,27,29-31
12	Other Non-durable Manufacturing Products	24,25,32,38,39
13	TCU, Service, and Government Enterprises	40-42,44-65,67,70,72,73,75,76

1, 2, 3	Primary	Aggregation Scheme
4, 5, 11	Durable Manufacturing	
6, 7, 8, 9, 10, 12	Non-Durable Manufacturing	
13	Service	

Table B. Interregional Flow over time (1992m$)

1980	IL	IN	MI	OH	WI	RU
IL	166,547	5,265	6,454	3,008	7,360	108,959
IN	5,556	67,589	7,834	4,283	1,639	42,983
MI	5,629	5,377	111,447	8,650	4,050	85,895
OH	3,187	3,646	16,729	141,792	1,671	71,706
WI	12,525	1,715	7,725	2,631	38,944	74,011
RU	66,399	28,981	79,177	55,792	57,524	3,375,637

1990						
	194,114	5,129	7,503	3,374	8,407	114,071
	5,888	80,577	9,057	5,149	2,009	45,116
	6,445	6,244	129,992	10,899	4,097	95,311
	3,739	4,632	21,846	166,148	1,980	78,525
	14,248	2,345	8,534	3,430	39,437	85,095
	75,465	33,485	84,414	61,209	65,737	3,480,674

2000						
	250,092	6,575	11,074	4,831	12,750	138,268
	7,667	117,757	15,072	7,331	3,341	55,170
	8,830	9,980	182,003	15,648	7,130	119,586
	4,940	6,813	32,691	225,379	3,135	94,225
	17,354	3,680	14,351	5,216	54,958	114,564
	94,582	44,694	108,467	77,607	91,839	3,965,839