

SYSTEMATIC RELATIONSHIPS BETWEEN INDUSTRIAL LINKAGES AND THE AGGLOMERATION OF MANUFACTURING INDUSTRIES

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A recent empirical study has identified industrial linkages as an agglomeration economy.¹ The purpose of the present paper is to focus attention upon more specific relationships between industrial linkages and the agglomeration of manufacturing industries.

This study consists of posing and testing four hypotheses pertaining to relationships between linkages and agglomeration. The first hypothesis examines whether strong linkages between pairs of manufacturing industries are more important locational forces than weaker linkages. Supply and demand linkages² are then evaluated in two respects. A test is conducted to determine whether or not supply and demand linkages are equally potent locational influences on all of the manufacturing sectors considered together. Another test is devised to determine if primary resource users tend to be material oriented while producers in the latter stages of manufacturing processes are demand oriented. The final hypothesis considers whether the final demand sales of manufacturing sectors influence the dispersions of their employment proportions located in large metropolitan areas.

In order to test these hypotheses, cross-sectional employment data³ were collected for each of 51 manufacturing sectors in each of 57 metropolitan areas.⁴ The 51 sectors are composed of the same combinations of two-, three-, and four-digit SIC categories as those found in the 1958 input-output table.⁵ Industrial linkages are defined on the basis of the sizes of input-output coefficients. If there are n sectors in an input-output table, Leontief considered there to be a special relationship between two sectors if one sells one n 'th or more of its output to the other or if one purchases one n 'th or more of its inputs from the other.⁶ The former is a demand linkage, the latter a supply linkage. Since there are a total of 82 sectors in the 1958 input-output table, two sectors are linked if one sells at least 1.2 per cent of its output to the other or if one buys at least 1.2 per cent of its input from the other.

The 51 by 57 matrix of employment figures is used to determine which sector pairs locate in geographic proximity. This is accomplished by computing 2550 correlation coefficients between the sector pairs.⁷ Sector pairs whose corresponding correlation coefficients are significantly greater than zero at the .10 level of significance are defined as being geographically associated. In my earlier article, it was found that the manufacturing sectors which are linked are more likely to be geographically associated than those which are not linked.

The measure of geographic association just established serves as a convenient tool to examine some agglomerative implications of industrial linkages. This measure is frequently employed in the remainder of this paper to assist in testing the four previously posed hypotheses.

Strong Linkages are More Important than Weak Ones

The first hypothesis is that strongly linked sectors are more likely to locate close together than those which are weakly linked. By finding the percentages of geographic associations accompanying linkages of varying strengths, the hypothesis can be accepted or rejected. The 517 linkages among manufacturing sectors are classified by their strengths in Table 1. Since it was difficult to decide upon a method of classifying linkages by their strengths, a few groupings were attempted. All yielded similar results; the percentages of geographic associations accompanying stronger linkages consistently exceeded the

percentages accompanying weaker linkages. This can be seen by examining Table 1. If another category were inserted in the table for linkages representing at least 15 per cent of intersectoral transactions, 43 per cent of these could be seen to be accompanied by geographic associations. It can be concluded that the data support the hypothesis as stated. As might be expected, stronger linkages appear to be more potent locational forces on sector pairs than weaker linkages.

TABLE 1

NUMBER AND PERCENTAGE OF ASSOCIATED
LINKAGES BY LINKAGE STRENGTH GROUPS

<u>Strength of linkage (percentage of inputs or outputs)</u>	<u>Number of linkages</u>	<u>Number of Associated linkages</u>	<u>Per cent of associated linkages</u>
1.2 to 2.9	307	71	23.1
3.0 to 7.4	149	41	27.4
7.5 and over	61	19	31.1

Supply and Demand Linkages are Equally Important

The second hypothesis states that interindustry supply linkages and demand linkages are equally important locational influences on the 51 manufacturing sectors when all of them are considered together. More specifically, an attempt is made to determine whether sector pairs joined by supply linkages are more, less, or equally likely to be located in geographic proximity as sector pairs connected by demand linkages.

The data confirm the stated hypothesis. As seen in Table 2, 58 of the 230 demand linkages and 73 of the 286 supply linkages are accompanied by geographic associations.⁸ These figures represent 25.2 per cent of the demand linkages and 25.5 per cent of the supply linkages. Since the two percentages differ by so little, less than one percentage point, neither type of linkage appears to be a more potent locational force than the other.⁹ Therefore, the hypothesis is confirmed. Note that the hypothesis was stated for all sectors considered together; as seen below, it does not hold when the sectors are grouped according to their uses of primary resources.

First Stage Resource Users are Supply Oriented;
Third Stage Users are Demand Oriented

The third hypothesis is that earlier stages of manufacturing are generally material oriented while latter stages tend to be market oriented. Edgar Hoover implied that this hypothesis would be accepted after noting that primary industries usually handle bulky weight-losing raw materials, and industries comprising the more advanced stages of manufacturing processes are confronted by discriminatory freight rates against their finished goods.¹⁰

If the hypothesis is true, it is likely that more group III sectors (those to which primary resources have the least direct importance) are located inside urban areas than group I sectors (primary resource users).¹¹

TABLE 2

DEMAND LINKAGES, SUPPLY LINKAGES, GEOGRAPHIC
ASSOCIATIONS, AND PROPORTIONS OF EMPLOYEES IN THE 57
METROPOLITAN AREAS FOR THE 51 MANUFACTURING SECTORS

<u>Sector</u>	<u>Demand linkages</u>		<u>Supply linkages</u>		<u>Geographic associations</u>		<u>Metropolitan employment percentage</u>
	<u>Total</u>	<u>Geographi- cally associated</u>	<u>Total</u>	<u>Geographi- cally associated</u>	<u>Total</u>	<u>Linked</u>	
Food & kindred products	0	0	2	2	14	2	52.14
Tobacco	0	0	3	2	8	2	36.35
Broad & narrow fabrics, yarn & thread mills	5	3	3	1	8	3	26.03
Miscellaneous textile goods & floor coverings	8	2	3	1	6	2	51.79
Apparel	0	0	3	2	8	2	56.95
Miscellaneous fabricated textile products	4	2	5	1	12	3	77.61
Lumber & wood products, except containers	3	3	0	0	9	3	14.30
Wooden containers	8	3	2	1	9	4	32.37
Household furniture	1	0	9	4	9	4	43.88
Other furniture & fixtures	0	0	11	2	4	2	70.65
Paper & allied products except containers	5	2	4	1	8	3	43.30
Paperboard containers & boxes	13	7	1	0	13	7	72.17
Printing & publishing	0	0	2	1	9	1	72.52
Chemical & selected chemical products	11	2	4	1	6	2	58.22
Plastics & synthetic materials	11	1	4	0	3	1	35.98

TABLE 2 Contd.

<u>Sector</u>	<u>Demand linkages</u>		<u>Supply linkages</u>		<u>Geographic Associations</u>		<u>Metropolitan employment percentage</u>
	<u>Total</u>	<u>Geographi- cally associated</u>	<u>Total</u>	<u>Geographi- cally associated</u>	<u>Total</u>	<u>Linked</u>	
Drugs, cleaning, & toilet preparations	1	1	5	2	9	2	81.40
Paints & allied products	7	2	4	1	12	3	88.89
Petroleum refining & related industries	1	0	1	1	6	1	65.07
Rubber & miscellaneous plastics products	9	0	4	1	2	1	79.73
Leather tanning & indus- trial leather products	3	1	2	1	4	2	54.95
Footwear & other leather products	0	0	5	1	5	1	54.61
Glass & glass products	11	1	4	1	8	2	61.81
Stone & clay products	1	0	3	0	9	0	44.43
Primary iron and steel	14	2	3	1	5	3	67.07
Primary nonferrous metals	13	2	1	1	6	2	68.18
Metal containers	5	1	6	1	6	2	86.07
Heating, plumbing & structural metal products	1	0	4	1	11	1	62.79
Stampings, screw machine products & bolts	15	4	4	2	11	4	76.77
Other fabricated metal products	12	2	4	1	9	3	74.87
Engines & turbines	4	0	11	2	5	2	67.24

TABLE 2 Cont.

<u>Sector</u>	<u>Demand linkages</u>		<u>Supply linkages</u>		<u>Geographic associations</u>		
	<u>Total</u>	<u>Geographi- cally associated</u>	<u>Total</u>	<u>Geographi- cally associated</u>	<u>Total</u>	<u>Linked</u>	<u>Metropolitan employment percentage</u>
Farm machinery & equipment	0	0	9	1	6	1	29.03
Construction, mining, & oil field machinery	0	0	9	1	4	1	57.49
Materials handling machinery & equipment	1	0	12	5	11	5	72.73
Metalworking machinery & equipment	8	3	7	4	8	4	77.11
Special industry machinery & equipment	3	2	8	2	8	4	68.80
General industrial machinery & equipment	11	2	8	2	10	3	71.06
Machine shop products	7	1	5	1	8	2	69.43
Office, computing & accounting machines	0	0	4	1	6	1	67.67
Service industry machines	2	1	10	1	4	1	65.78
Electric industrial equipment & apparatus	9	3	7	2	7	4	69.46
Household appliances	0	0	9	4	12	4	52.64
Electric lighting & wiring equipment	4	2	10	4	10	5	76.98
Radio, television & communication equipment	2	0	6	0	5	0	76.34
Electronic components & accessories	5	2	8	0	10	2	68.39
Misc. electrical machinery equipment & supplies	5	0	11	1	4	1	42.90

TABLE 2 Cont.

<u>Sector</u>	<u>Demand linkages</u>		<u>Supply linkages</u>		<u>Geographic associations</u>		<u>Metropolitan employment percentage</u>
	<u>Total</u>	<u>Geographi- cally associated</u>	<u>Total</u>	<u>Geographi- cally associated</u>	<u>Total</u>	<u>Linked</u>	
Motor vehicles & equip- ment	0	0	5	1	4	1	77.32
Aircraft & parts	0	0	6	0	1	0	84.91
Other transportation equipment	0	0	9	2	7	2	60.41
Scientific & controlling instruments	4	1	10	4	7	5	76.65
Optical, opthalmic & photographic equipment	2	0	6	0	3	0	94.78
Miscellaneous manufacturing	1	0	10	1	3	1	76.88
SUMS	230	58	286	73			

TABLE 3

PERCENTAGES OF EMPLOYEES OF EACH SECTOR
GROUP LOCATED IN THE 57 METROPOLITAN AREAS

	<u>Group I^a</u>	<u>Group II</u>	<u>Group III</u>
Group A ^a	51.2	61.3	76.6
Group B	44.0	64.9	64.9
Weighted mean of A and B	46.7	63.2	66.9

a. See the appendix for sector groupings

By examining Table 3, it is seen that the advanced stages of manufacturing are more concentrated in the 57 metropolitan areas than the earlier stages. About 46.7 per cent of the group I employees work in these areas as contrasted with a much higher percentage, 71.4 per cent, of the group III workers. The percentage of group II's employees (second stage resource users) working in the metropolitan areas lies between the other two percentages. An analysis of variance test, based on the metropolitan area employment proportions in Table 2, shows that the means presented in Table 3 are significantly different.

TABLE 4

SUMMARY TABLE FOR ANALYSIS OF VARIANCE

<u>Variations</u>	<u>Degrees of freedom</u>	<u>Sum of squares</u>	<u>Variance</u>
Between groups	2	12,165	6,082
Within groups	48	2,970	62

A summary table for the analysis of variance appears in Table 4. The ratio of the variance between groups to the variance within groups of 98.4 is considerably greater than 5.08, the critical value of F-statistic at the .01 level of significance with two degrees of freedom in the numerator and 48 in the denominator.¹² Therefore, the more advanced stages of manufacturing processes are the most likely to locate in metropolitan areas. This conclusion offers some support to the first part of the hypothesis that earlier stages of production processes are material oriented and the latter stages market oriented.

The hypothesis receives additional support from the data presented in Table 5. These data indicate that a supply linkage is more likely to have a locational influence on a group I sector, while a demand linkage is more likely to have a locational influence on a group III sector. For the group I sectors, one-half of the supply linkages are accompanied by geographic associations, compared to 27.0 per cent for the demand linkages. Since these linkages do not include those with extractive industries, the data lend little support to a hypothesis stating that sectors using primary resources are oriented toward extractive industries. Nevertheless, group I manufacturers do appear to be clearly supply

TABLE 5

NUMBERS AND PERCENTAGES OF LINKAGES ACCOMPANIED BY
GEOGRAPHIC ASSOCIATIONS FOR RESOURCE-USE SECTOR GROUPS

Group	Demand Linkages			Supply Linkages		
	No. of linkages	Number of associated linkages	Percent	No. of linkages	Number of associated linkages	Percent
I	37	10	27.0	16	8	50.0
II	125	31	24.8	199	52	26.1
III	68	16	23.5	71	13	18.3

oriented. As one progresses from group I to group II sectors, the importance of both demand and supply linkages drops, but demand linkages acquire more relative importance than supply linkages for the sectors to which primary resources have the least direct importance. The group III sectors has 23.5 percent of their demand linkages and 18.3 percent of their supply linkages accompanied by geographic associations.

In summarizing the findings of this section, it is seen that the data do support the stated hypothesis. The primary resource users may prefer locations outside the metropolitan areas in order that they can be near their sources of supply. On the other hand, latter stage manufacturers may find urban locations profitable. Within urban areas there is certainly a large source of demand for finished goods which probably attracts those manufacturers who produce goods for the final demand sector. Further support for the hypothesis is achieved by noting that the locational decision of earlier stage manufacturers appears to be more strongly influenced by supply linkages to other manufacturers while latter stage producers are more oriented toward their markets. As would be expected, primary resource users are material oriented and latter stage producers are market oriented.

Final Demand Sales and Employment Dispersions

The last of the four hypotheses concerns the distributions of sector employment proportions in the 57 metropolitan areas. One column of Table 2 contains the proportion of each sector's employees working inside the 57 metropolitan areas. The hypothesis states that the dispersion of employment proportions for industries which do not sell large proportions of their output to final demand equals the dispersion of the employment proportions of industries which sell larger proportions of their output to the final demand sector.¹³ This hypothesis is expected to be discredited with the former dispersion exceeding the latter. It is likely that the industries which sell larger proportions of their output to the final demand sector locate near the populace to whom they sell much of their output. Consequently, these employment figures may be sensitive to the populations of the sampled metropolitan areas. On the contrary, sectors which are not linked to the final demand sector would supposedly be less sensitive to population. Accordingly, some of these sectors may employ most of their labor forces outside the metropolitan areas while other of these manufacturers may be strongly attracted toward the skilled labor forces frequently found in large cities.

As expected, the hypothesis is discredited. The sectors which are strongly linked to the final demand sector have a mean of 64.6 per cent of their employees inside the 57 metropolitan areas. The variance about this mean is 227 percentage points. Those sectors which are not strongly linked to final demand have a mean of 61.7 percent of their employees in the metropolitan areas and a variance of 345 percentage points about this mean. The ratio of the variance of the latter sectors to that of the former is 1.52. Thus the employment dispersions of the sectors which do not sell much of their output to the final demand sector exceeds that of the sectors which sell larger proportions of their output to the final demand sector.

Conclusions

In this paper, relationships between industrial linkages and the agglomeration of manufacturing industries were examined. It was found that strong linkages are more important locational forces than weak linkages. Supply and demand linkages are equally potent locational forces on all manufacturing sectors considered together. However, supply linkages are relatively more important locational influences on the industries in the earlier stages of production processes; demand linkages are more important for the latter stage producers. Finally, it was found that the final demand sales of manufacturing sectors influence the dispersions of these sectors' employment proportions in metropolitan areas.

APPENDIX

SECTOR GROUPS

In order to evaluate third and fourth hypothesis posed in this paper, it is necessary to combine the 51 manufacturing sectors into a smaller number of groups. A two-way classification system is used for the 51 sectors. The first classification refers to the importance of primary resources, and the second is by the importance of sales to the final demand sector.

The classification of sectors by resource use is similar to a classification techniques used by Perloff, Dunn, Lampard, and Muth.¹ Each sector was placed in one of three groups. The first group (group I) includes first stage resource users. The second group (group II) includes second stage resource users, and the third (group III) is composed of sectors to which primary resources are of the least direct significance. If a sector spends at least 7.5 percent of its input dollar on the products of extractive industries, the sector is classified as a group I sector. The figure of 7.5 percent was chosen in order that most of the industries which are usually considered to be primary manufacturers would be included among the first stage resource users. A lower figure would result in too many sectors being placed in group II if the same percentage is used to separate the group II and III sectors as is used to separate the groups I and II sectors. By arbitrarily retaining the 7.5 percentage figures, the second stage resource users are defined such that they purchase at least 7.5 per cent of their inputs (in dollar terms) from the first stage resource users. The remaining sectors (group III) which are not included among those in the first two groups are the sectors to which primary resources have the most indirect significance.

The above three groups are subdivided depending on the proportion of each sector's output which is destined for final demand. If a sector sells at least 7.5 per cent of its output to the final demand sector, it is defined as strongly linked to final demand. Sectors are placed in subgroup A of the resource use groups if they are strongly linked to final demand; those in subgroup B are not strongly linked to the final demand sector.

The classifications of the sectors into six groups are found in the table included in this appendix. These data were obtained from the 1958 input-output table. Group I-A includes the first stage resource users whose sales to final demand are important. The first stage resource users which are not linked to final demand are in group I-B. Second stage resource users are classified in groups II-A or II-B depending on their sales to final demand. Of the sectors to which primary resources have the most indirect importance, those in group III-A are strongly linked to final demand while those in group III-B are not. There

are three sectors in group I-A, five in I-B, thirteen in II-A, fifteen in II-B, seven in III-A, and eight in III-B. Thus eight sectors are first stage resource users, 28 are second stage resource users, and to the other 15 primary resources are of the most indirect importance. Twenty-three of the sectors are strongly linked to final demand, twenty-eight are not.

SECTOR GROUPS BY RESOURCE USE
AND SALES TO FINAL DEMAND

<u>Sector</u>	<u>Group</u>	<u>Input per cent from resource extractors</u>	<u>Input per cent from stage I sectors</u>	<u>Output per cent to final demand</u>
Food & kindred products	I-A	34.3	17.2	70.6
Tobacco manufactures	I-A	18.3	19.9	71.3
Broad & narrow fabrics, yarn & thread mills	I-B	11.9	35.2	6.6
Miscellaneous textile goods & floor coverings	II-A	2.8	16.9	29.7
Apparel	II-A	1.0	27.4	78.7
Miscellaneous fabricated textile products	II-A	----	44.2	48.1
Lumber & wood products, except containers	I-B	11.8	29.8	1.8
Wooden containers	II-B	----	41.8	0.1
Household furniture	II-A	0.1	22.7	74.9
Other furniture & fixtures	II-A	----	17.2	17.1
Paper & allied products, except containers	II-A	1.2	9.2	8.2
Paperboard containers & boxes	III-B	----	0.8	1.0
Printing & publishing	III-A	----	0.2	20.7
Chemicals & selected chemical products	II-B	4.9	9.0	3.8
Plastics & synthetic materials	III-B	0.6	1.9	0.2
Drugs, cleaning & toilet preparations	III-A	0.2	4.2	58.6
Paints & allied products	III-B	----	5.7	0.9
Petroleum refining & related industries	I-A	52.0	7.2	42.4
Rubber & miscellaneous plastics products	III-A	0.3	3.2	20.1
Leather tanning & industrial leather products	III-B	0.4	1.6	----
Footwear & other leather products	III-A	----	3.7	83.7
Glass & glass products	III-B	1.3	4.9	5.9
Stone & clay products	I-B	7.9	14.0	2.8
Primary iron & steel	I-B	8.4	26.8	0.1
Primary nonferrous metals	I-B	8.3	32.7	0.1

<u>Sector</u>	<u>Group</u>	<u>Input per cent from resource extractors</u>	<u>Input per cent from stage I sectors</u>	<u>Output per cent to final demand</u>
Metal containers	II-B	----	45.4	----
Heating, plumbing & structural metal products	II-B	----	32.5	0.9
Stampings, screw machine products & bolts	II-B	----	28.3	6.8
Other fabricated metal products	II-B	0.1	28.0	6.5
Engines & turbines	II-B	0.1	14.5	5.8
Farm machinery & equipment	II-B	0.2	16.3	1.0
Construction, mining & oil field machinery	II-B	0.1	17.3	0.7
Materials handling machinery & equipment	II-B	----	12.8	4.5
Metalworking machinery & equipment	II-B	----	11.8	0.9
Special industrial machinery & equipment	II-B	----	15.0	2.0
General industrial machinery & equipment	II-B	0.3	15.0	0.1
Machine shop products	II-B	----	18.3	2.2
Office, computing & accounting machines	III-B	----	4.5	6.5
Service industry machines	II-A	----	13.1	11.9
Electric industrial equipment & apparatus	II-B	0.1	14.1	0.4
Household appliances	II-A	----	13.2	67.2
Electric lighting & wiring equipment	II-A	0.1	12.9	14.0
Radio, television & com- munication equipment	III-A	----	3.5	23.5
Electronic components & accessories	III-B	----	7.4	5.6
Miscellaneous electrical machinery & supplies	II-A	0.2	14.4	18.8
Motor vehicles & equipment	II-A	0.1	10.4	41.1
Aircraft & parts	III-B	----	6.8	0.2
Other transportation equipment	II-A	0.1	17.2	20.2
Scientific & controlling instruments	III-A	0.2	7.4	12.1
Optical, ophthalmic & photographic equipment	III-A	0.2	5.3	29.8
Miscellaneous manufac- turing	II-A	0.2	11.3	48.9

FOOTNOTES

¹Charles Richter, "The Impact of Industrial Linkages on Geographic Association," Journal of Regional Science 9, No. 1.

²Sector A is connected to sector B via a demand linkage if A sells a large proportion of its output to B. Conversely, A is linked to B via a supply linkage if A purchases a large proportion of its inputs from B. These definitions are made more specific later.

³Employment figures were either taken directly or estimated from data in the U. S. Bureau of the Census, U. S. Census of Manufactures: 195, Volumes III and IV, (Washington, D. C.: U. S. Government Printing Office, 1963).

⁴Fifty-four of the metropolitan areas are large SMSA's and the remaining three are whole states. A more complete description of the data and sampled regions is found in Richter, op. cit.

⁵Morris R. Goldman, M. L. Marimont, and B. L. Vaccara, "The Interindustry Structure of the United States," Survey of Current Business 44 (November 1964): 10-29.

⁶Wassily Leontief, "The Structure of the U. S. Economy," Scientific American 212 (April 1965): 25-35.

⁷To avoid upward biases the employment figures were deflated by total manufacturing employment in their corresponding metropolitan areas.

⁸It is not unusual that the number of supply linkages exceeds the number of demand linkages. Because many sectors sell large amounts of their output to the final demand sector, they have relatively small proportions of their output available for interindustry transactions. Consequently, these sectors tend to have fewer demand than supply linkages.

⁹Since the sample includes an entire population, all manufacturing sectors in 57 of the largest metropolitan areas, any difference is statistically significant. However, it may be subjectively stated that the difference of 0.3 per cent is not very important.

¹⁰Edgar M. Hoover, The Location of Economic Activity (New York: McGraw-Hill, Inc., 1948), p. 118.

¹¹See the appendix for sector classifications by resource usage.

¹²For reasons mentioned in footnote 9, a significant difference could be ascertained without a statistical test.

¹³The latter group of sectors may be considered linked to the final demand sector.

APPENDIX FOOTNOTE

¹Harvey S. Perloff, E. S. Dunn, E. E. Lampard, and R. F. Muth, Regions, Resources, and Economic Growth (Baltimore: Johns Hopkins University Press, 1960), p. 680.