"INDUSTRIAL STRUCTURE AND SPATIAL INPUTS AND OUTPUTS IN THE AMERICAN ECONOMY"

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INTRODUCTION

The purpose of this paper is to examine the connection between industrial linkages of the input-output (I-0) variety and the spatial relationships exhibited by the nations industrial structure.[1] The existence of high backward or forward linkages of produced inputs and outputs for particular industries, or a block triangular input-output transactions table, indicates the presence of industrial complexes.[2] However, this does not mean that the industrial complexes are associated with spatial concentration. In the course of examining these relationships an attempt will be made to discover whether declining transportation costs have reduced the importance of the "transportation location factor."

It is the hypothesis of this paper that spatial concentration is related to industrial structure. Spatial concentration is measured by average shipment distance of raw materials and components and the average shipments distance of finished products. The arguments presented in this paper will establish the relationships between the average shipment distance of outputs and inputs associated with forward linkage and backward linkage for 50 manufacturing industry groups appearing in the 1963 input-output study of the United States economy. In the context in which it is used here backward linkage is the ratio of interindustry purchases to total output of a particular industry while forward linkage refers to the ratio of interindustry sales to total output of a particular industry as determined from the direct coefficients of an I-0 transactions table. The average shipment distance of finished product outputs were obtained by aggregating data found in the 1963 Census of Transportation. The weights utilized in compiling these averages were the appropriate tonnage figures for each industrial category. The average shipment distance of raw material inputs for each industrial process was obtained by weighting the appropriate shipment distance of final products by the column of the direct and indirect I-0 coefficients which represents each industry production function.

There are a number of procedures related to the manipulation of input-output type data which produce summary measures (e.g., forward linkage, backward linkage, and I-0 multipliers) of the relationship between particular industry groups and the overall industrial structure of the nation.[3] However, what is required is a measure which allows us to examine the extent to which an industry, having particular structural characteristics, is likely to belong to a spatial industrial complex. A spatial industrial complex is comprised of industries which use one anothers products and are geographically located in close proximity to one another. From a technical standpoint one way of defining such a complex would be to reorder the positions of the industry groups in an I-0 table so as to obtain a bloc-triangular matrix of direct I-0 coefficients. If the matrix of coefficients can be decomposed in such a way as to obtain a triangular ordering of production blocks it would be possible to suggest that each block is an industrial complex.[4] It remains of course to be shown that the presence of an industrial complex is also associated with spatial concentration of the industry groups comprising the industrial complex.

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A first approximation to a triangular ordering is usually achieved by ranking the industries according to the extent of their backward or forward linkage. Previous work dealing with the problem of triangularizing the elements of an I-0 table suggests that the triangularity of the matrix is improved by first arranging the manufacturing industry groups into a number of categories reflecting the physical attributes of the products being processed: (1) metal products servicing final demand, (2) basic metal industries, (3) non-metal industries servicing final demand, and (4) basic non-metal industries.[5] These categories may be discussed in terms of the structural characteristics of particular industries--that is, the relative strengths of their forward and backward linkages. The categories (1) and (3) are associated with industry groups having low forward linkages. Categories (2) and (4) conversely are characteristic of industries having high forward linkages. The 50x50 I-0 table did not lend itself well to block triangularization and for this reason the principle measures of industrialization used in this analysis are the backward and forward linkages for each of the 50 industries.

LOCATION THEORY AND SPATIAL INDUSTRIAL COMPLEXES

The locational factors important to a firm may be generally described by the terms market orientation, raw material orientation, and agglomeration economies. Since Alfred Weber, location theory has placed great importance on transportation inputs as a regulating influence of economic activity occurring over space. This of course stems from the fact that a rational tariff rate structure for the various modes of transportation would reflect a positive relationship between transportation costs and distance. Thus, high transportation costs associated with the collection of inputs causes raw material orientation and high distribution costs produce market orientation.

It is assumed that the positive relationship between transportation cost, inputs and distance is the basic regularity manifest in spatial economic activity which usually determines the general geographic area that will be chosen as the location of a manufacturing plant.[6] However, in so far as value added is an index to the extent to which industries may be influenced by spatial agglomeration effects or effects produced by factor orientation, the importance of value added in the composition of costs of a particular industry could modify the importance of the primary location factor--transportation cost inputs. We might expect that high value added industries would be subject to spatial concentration because the transportation costs associated with the procurement of inputs and/or with the distribution of finished products will be relatively unimportant in relation to the costs of fabrication. Again going back to Weber we might say that spatial concentration is related to the difference between the costs of material inputs in the production process and the value of the final product.[7] It should be noted that because of their method of calculation from the I-0 table that backward linkage and value added (as a percentage of industry output) have a negative unitary correlation. Inputs in the production process fall into two categories: produced inputs and value added; and for this reason, the locational effects associated with value added and backward linkage cannot be easily differentiated. It is also clear that forward linkage and final demand linkage (the ratio of industry sales to final demand to total output) similarly have a unitary negative correlation; for by definition a sale must be made either to intermediate demand or to final demand. Thus, the locational effects of final demand sales cannot be directly disentangled from the effects of forward linkages.

In this analysis the average shipment distances of both inputs and outputs will be treated as the dependent variables because we are interested in the role industrial structure plays in manufacturing plant location and ultimately in the spatial concentration of industry. Various summary measures of the national industrial structure are treated as independent variables (See Table 1).

We can begin the analysis by testing the hypothesis that there are no differences between the average shipment distances of manufactured inputs going to and manufactured outputs being shipped from particular manufacturing industries. The average shipment distance of specific industry groups for both material requirements inputs and outputs of finished products were cross classified with regard to the degree of their backward and forward linkage. The purpose of this exercise was to determine whether or not there was a significant statistical difference between the distances which product inputs and outputs are shipped for industries having common structural characteristics. A failure to show the existence of statistically significant differences would indicate that the I-0 characteristics of an industry are independent of the locational characteristics of the industry.

EMPIRICAL RELATIONSHIPS

Table 2 shows the results of the t-tests of the paired average distances for incoming shipments of material and outgoing shipments of final products for selected manufacturing industry groups. The t-tests presented indicate that the differences between the average shipments distance of raw material, components, etc., and the average shipments distance of finished products for the same industry are statistically significant. Furthermore, it appears that the industry groups having high forward linkages, tend to have relatively shorter shipments distances of their outputs than industry groups characterized by low forward linkages. This indicates that industrial market orientation is an important locational factor to industries making sales to areas other than final demand. Industry groups having high backward linkage tend to have relatively longer distance hauls for raw materials, components, etc., than for finished products. The implication here is that even manufacturing firms that have large manufactured input requirements tend to be market oriented. The material presented in Table 2 clearly suggests a relationship between industrial structure and the spatial location of industrial activity.

The relationship between industrial structure and the spatial concentration of industry is in line with what would be expected from the literature of location theory. Since the time of Alfred Weber it has been suggested that particular location factors (labor wage rate differentials, raw material cost differentials, transportation cost differentials) between alternative site locations have differential effects on the location of firms and that these decisions are made in a hierarchial order. That is, some location factors (primary) tend to be important in the firms decision to locate in a particular broad geographic area, other factors (secondary and tertiary) have an impact on the selection of a particular city or county within the broad geographic area, and still different factors determine the specific site at which the firm chooses to locate.

It has historically been argued that transportation inputs are a primary location factor determining, within rather broad limits, the geographic area in which a firm locates. However, it has been alleged that as transportation costs have declined historically and thus must play a declining role as a primary location factor.[8] It cannot be questioned that transportation costs have declined, nevertheless, this does not mean that they do not still play a relatively important role as a primary location factor. In fact it is the position of this paper that the industrial structure is related to the spatial concentration of industry and this spatial concentration itself is reflective of the importance of transportation inputs.

In testing the hypothesis presented in this paper two regression arguments were investigated, both having the same general form:

$$I = f(BL, FL, PB).$$

For our purposes, I, is treated as the dependent variable representing spatial concentration and refers respectively to the shipments distance of inputs in equation 1, Table 3, and outputs in equation 2, Table 3. The terms, BL, and FL, refer to backward linkage and forward linkage, PB refers to production blocks to which an industry belongs. The PB variable is a dummy variable referring either to the metal or non-metal production blocks. The three variables (BL, FL, PB) constitute a measure of industrial strúcture.

The results of the regression analysis indicate that the only independent variable exercising any significant influence on either the average shipments distance of inputs or the average shipments distance of outputs was forward linkage. This suggests that firms are market oriented with regard to their location decisions. In the case of the average shipments distance of outputs, we have a case in which the shipments distance declines with increase in forward linkages. This suggests that manufacturing industries are attracted to the site of their industrial markets. Thus, it is the marketing and distribution structure rather than the industrial requirements, as exhibited by an input-output production function, that has the greatest impact on the average shipments distance of outputs. Since forward linkage and final demand linkage are inversely related, there is a positive relation between average distance of outputs and final demand linkage. Thus, we can conclude that manufacturing plants are, on average, oriented toward centers of intermediate demand rather than centers of final demand, although in many cases the two types of demand centers coincide.

In the case of average shipments distance of inputs we find no significant relationship between the dependent and the independent variables except in the case of forward linkages. Again the relationship is an inverse one as forward linkage declines the average shipments distance of inputs increases. What is implied here is that those industries which sell very little to intermediate demand by definition by servicing the final demand sectors. As forward linkage declines and as sales to final demand increase the manufacturing industries, on average, must obtain their manufacturing inputs from ever greater distances, providing that these industries tend to be market oriented, and this appears to be the case.

The preceeding analysis suggests the presence of some interesting problems where regional analysis is concerned. No less an authority than Albert Hirschman has cogently argued that development strategies would best be devised that take advantage of both forward and backward linkage.[9] He further suggests that, where underdeveloped nations are concerned, import substitution in the final stages of manufacture may be the "best" way to maximize induced investment in directly productive industries.

However, where regional analysis is being undertaken it is not just the impact of the national industrial structure on investment decisions, but also the spatial incidence of investment decisions that is of interest. Although it has been argued that at the national level of reference that desirable development characteristics of an industry would include both high backward and forward linkages (See first column Table 2), it is usually backward linkage effects that have been emphasized in the development of investment criterion for underdeveloped countries.[10]

However, the arguments in this paper suggest that high forward linkage is the most meaningful summary measure associated with the average shipments and it is primarily forward linkage that is on average associated with spatial industrial concentrations. However, this contradiction between the forces associated with induced investment flows and spatial concentration may be more apparent than real. A consideration of backward linkage and forward linkage relationships suggests that forward linkage is itself dependent upon backward linkage and because it is the latter which is based upon derived demands and it is upon derived demand that forward linkage must ultimately rest.

This study suggests that spatial concentration is associated with forward linkage; however, no explanation has been made of the casual factors underlying this relationship. The rational behind spatial concentration must to some extent involve the spatial relations between satellite industries and master industries. The satellite industry may be defined as an industry that enjoys a strong locational advantage from close geographic proximity to the master industry. The satellite industry uses as a principle input an output of the master industry and the minimum economic capacity of the satellite industry is smaller than that of the master industry. The locational advantage alluded to here refers to either transportation costs, savings, or agglomeration economics. The master industry tends to be a net exporter of externalities so far that it is the transportation costs associated with distribution that cause industries to locate in proximity to industrial or final demand markets. Market orientation and spatial concentration reflecting market orientation have been associated with a freight rate structure which results in higher tariffs on finished materials. Such locational patterns also tend to reduce inventory requirements of high valued goods and allow the use of truck transportation which gives more operational flexibility to plant managers. It has been widely argued that the trend toward lower stock sales ratios set during the early 1960's reflected improvements in the way in which inventories were handled. However, it should be realized that this reduction of stock sales ratios in the durable goods industries also reflects a movement away from the dependence of shippers on railways and an increase in the use of trucks for transporting durable goods.

Since forward linkage is dependent upon backward linkage and since spatial concentration is associated only with forward linkage a sound investment criterion for any regional development strategy would be to encourage intermediate manufactures--those activities which are characterized by both high backward and high forward linkages. High backward linkage is required not because of its relation to locational decisions of firms but because of the role it plays in the investment decisions of firms. This strategy turns out to be the same one that would be used in the case of an underdeveloped nation. Presumably it is intermediate manufacturing industries having the highest backward and forward linkages that would be most likely to produce an industrial complex as well as a spatial industrial complex.

AN INVESTMENT CRITERION FOR SPATIAL INDUSTRIAL COMPLEXES

In summary it would seem that one of the most important elements of a stretegy for regional economic development would be an investment criterion which would encourage not only the process of induced capital formation but which would also recognize the importance of the spatial incidence of this investment flow. Furthermore, a sound investment criterion must be operational. That is, the variables contained in the formulation of the criterion must be relatively easy to measure.

The first step in developing a regional investment criterion is to isolate the intermediate manufacturing sectors from the rest of the industrial structure of a region. For purposes of description this can best be done by beginning with a national I-0 table in which the sectors have been arranged according to backward linkage. This assumption underlying the use of the transactions table of a national I-0 study is the region is likely to develop along lines similar to that of the nation. We can describe intermediate manufacturing as g... k manufacturing sectors. According to Hirschman this concentration on the intermediate manufacturing sector will maximize induced DPA investment and the formation of industrial complexes; however, we know nothing of the spatial incidence of these investment flows.

The next step is to devise a Spatial Industrial Complex Index (SICI). The following example of an SICI for industry, G, is given below. The SICI index is comprised of two basic components describing both backward and forward linkage. In the case of the first inducement mechanism, backward linkage, we have:

(1) $A_G = \sum_{g}^{k} X_i W_i P_i$, where;

X_i = direct input requirements

W_i = the reciprocal of the average shipments distance of inputs required in industry, G

P_i = y/a, where, y, is the inputs of a particular industry going into the production process of industry, G, and where, a, is the minimum economic size of the production unit. It should be noted that P_i is treated as a probability statement.

In the case of the second inducement mechanism, associated with forward linkage, we have:

(2) $B_G = \sum_{g}^{k} X_j W_j P_j$, where;

Xj = direct sales to intermediate demand by, G

Wj = the reciprocal of average shipments distance of outputs of, G,

P_j = the ratio of the sales of, G, to each purchasing industry to the total output of each purchasing industry. P_j is also treated as a probability statement.

This formulation of backward and forward linkage follows Hirschman except for the addition of the terms W_j and W_i which are necessary in order to incorporate space into the argument.[12] The SICI for each industry takes this form:

(3) $$SICI_G = \frac{(A + B) / 2}{\dfrac{\sum_{g}^{k} (A + B) / 2}{n}}$$; where, n, refers to the number of industries.

This produces an index number, the base of which represents the average linkage effects of all industries appearing in the transactions matrix of the I-0 table.

CONCLUSION

In conclusion it may be argued that the very aggregated data used in this analysis suggests that spatial industrial concentrations are closely associated with one element of industrial structure--forward linkage. The importance of forward linkage and the form which is taken by the relationship between this variable and average shipments distance of both inputs and outputs suggests that it is transportation inputs rather than agglomeration factors that are important in attracting manufacturing industries toward their markets.

An adoption of Hirschman's development strategy for directly productive investments, which includes a "space variable," allows the planner to view the spatial as well as the investment implications of the expansion of economic activity associated with the expansion of economic activity in a particular industry. This investment criterion presented in this paper has the merit of jointly representing an investment inducement mechanism as well as providing some idea of its spacial incidence. The model is operational in that data exist that can be plugged into equation 3.

Table 1. Average Shipments Distances Of Material Inputs And Final Outputs Of Manufacturing Industry Groups As Defined By The 1963 Input-Output Study And The 1963 Census Of Transportation

Industry Number	Industry Name	Average Shipment Distance Inputs	Backward Linkage	Average Shipment Distance Outputs	Forward Linkage	Value Added Output Ratio	Final Demand Linkage
14	Food and Kindred Products*	341.2	.73	333.4	.29	.27	.71
15	Tobacco Manufacturers*	573.9	.51	595.6	.26	.49	.74
16	Broad & Narrow Fabrics, Yarn & Thread Mills*	425.1	.74	421.7	.92	.26	.08
17	Misc. Textile Goods*	468.0	.82	504.3	.67	.18	.33
18	Apparel*	464.5	.62	491.0	.22	.38	.78
19	Misc. Fabricated Textiles*	466.3	.76	504.8	.49	.24	.51
20	Lumber & Woods Pds.*	561.3	.64	588.6	.95	.36	.05
21	Wooden Containers*	398.1	.66	307.9	.98	.34	.02
22	Household Furniture*	407.0	.60	372.2	.20	.40	.80
23	Other Furniture & Fixtures*	400.3	.58	391.8	.20	.42	.80
24	Paper & Allied Products*	426.5	.63	422.5	.86	.37	.14
25	Paperboard Containers*	298.9	.60	199.0	.96	.40	.04
27	Chemicals*	371.0	.59	343.4	.83	.41	.17
28	Plastics*	445.3	.60	491.1	.90	.40	.10
29	Drugs*	388.6	.59	395.2	.30	.41	.70
30	Paints*	344.9	.64	308.5	.96	.36	.04
31	Petroleum*	609.0	.77	645.1	.54	.23	.46
32	Rubber*	439.0	.55	446.7	.74	.45	.26
33	Leather*	333.0	.74	321.6	.96	.26	.04
34	Footwear*	446.3	.56	478.4	.12	.44	.88

Table 1. Average Shipments Distances Of Material Inputs And Final Outputs Of Manufacturing Industry Groups As Defined By The 1963 Input-Output Study And The 1963 Census Of Transportation (Continued)

Industry Number	Industry Name	Average Shipment Distance Inputs	Backward Linkage	Average Shipment Distance Output	Forward Linkage	Value Added Output Ratio	Final Demand Linkage
35	Glass*	299.8	.45	271.3	.85	.55	.15
36	Stone, Clay Products*	209.4	.52	148.1	.95	.48	.05
37	Primary Iron & Steel	296.2	.58	264.2	.97	.43	.03
38	Primary Nonferrous	513.1	.72	531.5	.96	.28	.05
39	Metal Containers	267.7	.66	221.6	.97	.34	.03
40	Heating and Plumbing	353.0	.63	330.1	.89	.38	.11
41	Machine Products	349.9	.55	327.4	.92	.45	.08
42	Fabricated Metal Products	383.3	.58	376.3	.86	.42	.14
43	Engines	418.5	.61	417.1	.57	.39	.43
44	Farm Machinery	419.1	.67	442.4	.26	.33	.74
45	Machinery	567.9	.60	717.1	.29	.40	.71
46	Machinery	504.4	.63	577.1	.48	.37	.52
47	Metal Working	389.3	.51	383.0	.55	.49	.45
48	Special Machinery	427.2	.59	437.1	.29	.41	.71
49	Industrial Machinery	453.1	.55	485.5	.62	.45	.38
50	Machine Shop Products	418.7	.50	431.3	.95	.50	.05
51	Office Machines	609.4	.49	678.6	.33	.52	.67
52	Service Machines	486.7	.68	543.4	.46	.32	.54
53	Electrical Transmission	459.4	.54	479.3	.58	.46	.42
54	Household Appliances	513.0	.68	602.6	.30	.32	.70

Table 1. Average Shipments Distances Of Material Inputs And Final Outputs Of Manufacturing Industry Groups As Defined By The 1963 Input-Output Study And The 1963 Census Of Transportion (Continued)

Industry Number	Industry Name	Average Shipment Distance Inputs	Backward Linkage	Average Shipment Distance Output	Forward Linkage	Value Added Output Ratio	Final Demand Linkage
55	Electrical Lighting	480.5	.59	539.9	.79	.42	.21
56	Radio	553.7	.52	628.8	.25	.48	.75
57	Electronic Components	408.3	.53	390.2	.81	.47	.19
58	Miscellaneous Electrical	386.5	.57	340.0	.65	.43	.35
59	Motor Vehicles	400.8	.70	406.3	.39	.29	.61
60	Aircraft	593.2	.54	664.7	.36	.46	.64
61	Other Transportation Equip.	420.5	.64	432.9	.22	.37	.78
62	Scientific Instruments*	544.1	.57	610.1	.53	.43	.47
63	Optical*	559.6	.44	618.2	.48	.56	.52
64	Miscellaneous*	457.4	.10	476.8	.42	.40	.58

*refers to all non-metal industries.

Table 2. t-Tests Of Paired Average Distances Of Commodity Shipments Of Material Inputs And Final Product Outputs Of Selected Industry Groups Classified By Characteristics Of The Industry Structure Of The Industry Groups

t-Tests	High Backward (60-100) High Forward (60-100)	High Backward (60-100) Low Forward (0- 59)	Low Backward (0- 59) High Forward (60-100)	Low Backward (0-59) Low Forward (0-59)
	Industry #'s: 33, 17, 24, 40, 28, 16, 20, 25, 30, 38, 39, 21	Industry #'s: 22, 18 61, 44, 45, 54, 59, 64, 52, 46, 19, 31, 43, 14	Industry #'s: 41, 49, 57, 36, 50, 35, 58, 37, 42, 27, 32, 55	Industry #'s: 53, 47 23, 34, 62, 63, 56, 48, 29, 51, 60, 15
$\bar{d}$	15.550	-26.610	10.870	-34.600
$s_{\bar{d}}$	4.243	4.359	3.106	2.891
t	3.665	-6.105	3.499	11.967
$t_{.05}$	2.201	2.160	2.201	2.201
Ho	rejected	rejected	rejected	rejected
D.F.	11	13	11	11

Note: t-tests were performed on paired data of average shipments distance of inputs compared with average shipment distance of final products for industry groups classified according to backward or forward linkage. The term, $\bar{d}$, refers to the mean of the differences of the paired observations, $s_{\bar{d}}$, is the standard deviation of the differences, $t_{.05}$, is the .05 confidence level of the t-distribution.

Table 3. Regression Relationships Between Two Dependent Variables Average Shipments Distance Of Inputs, Y_1, And Average Shipments Distance Of Outputs, Y_2, And Selected Independent Variables

Dependent Variables	Constant	Independent Variables			Multiple R	Standard Error of Estimate	Number of Observations
		X_1	X_2	X_3			
Y_1	524.796	-148.099 (40.629)	N.S.	N.S.	.465	81.059	50
Y_2	587.344	-232.067 (57.071)	N.S.	N.S.	.506	113.863	50

Note: X_1 refers to forward linkage, X_2 refers to backward linkage, and X_3 refers to the production block.

FOOTNOTES

[1]Charles Richter, "The Impact of Industrial Linkages on Geographic Association," Journal of Regional Science, Vol. 9, (April 1969), pp. 19-28.

[2]David Simpson and Jinkichi Tsukui, "The Fundamental Structure of Input-Output Tables, An International Comparison," The Review of Economics and Statistics, XLVII (November 1965), pp. 436-440.

[3]I-0 type multipliers would not be particularly relevant here as it would be hard to explain why a particular value of a national I-0 multiplier could contribute in any way to spatial concentration within the region; however, a high regional multiplier value might well depend upon whether or not the industry was a member of a spatial industrial complex. There is a relationship at the national level between the measure of backward linkage and the Type II multiplier. Using updated 1967 data we have IY = 0.370 + 10.698 X and r = .501; the Type II multiplier is, Y, and backward linkage is represented by, X. For a discussion of the 1967 I-0 table upon which this simple regression is based see: Robert H. Elrod and Reston E. LaFerney, Sector Income and Employment Multipliers: Their Interactions on the National Economy, Technical Bulletin No. 1421, Economic Research Service, U.S. Department of Agriculture.

[4]Hollis B. Chenery and Tsunehiko Watanabe, "International Comparisons of the Structure of Production," Econometrica Vol. 26 (October 1958), pp. 494-496.

[5]Op Cit, David Simpson and Jinkichi Tsukui, p. 437. For a concise statement of the more general meaning in Economics of a triangular structure see: K. C. Kogiku, An Introduction to Macroeconomic Models, (New York, McGraw-Hill Book Company, 1968), pp. 18-31.

[6]Alfred Weber, Theory of the Location of Industries, (Chicago: University of Chicago Press, 1929), pp. 17-36.

[7]For a recent statement of this position see: Allan Pred, "The Concentration of High-Value-Added Manufacturing," Economic Geography, Vol. 41, No. 2, 1965, pp. 108-132.

[8]For a general discussion of the importance of "transportation orientation" see: Gerald J. Karaska and David F. Bramhall, Locational Analysis For Manufacturing, (Cambridge: The MIT Press, 1969), pp. 65-107.

[9]Albert O. Hirschman, The Strategy of Economic Development, (New Haven: Yale University Press, 1958), pp. 116-117.

[10]Benjamin Higgins, Economic Development, Revised Edition (New York: W. W. Norton & Company, 1968), pp. 400-404.