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INTERINDUSTRY LINKAGES AND THE AGGLOMERATION OF MANUFACTURING INDUSTRIES IN THE CANADIAN ECONOMY

by

© BERND EBEL

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "Interindustry Linkages and the Agglomeration of Manufacturing Industries in the Canadian Economy", submitted by Bernd Ebel in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

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External Examiner

Date August 17, 1973

ABSTRACT

In this dissertation the locational impact of interindustry linkages is examined.

Together with other externalities input-output linkages are characterized as agglomerative locational factors and an assessment of their importance is attempted.

Through correlation analysis it is then established that there exists a systematic relationship for manufacturing industries in metro areas between interindustry linkages and the spatial association of industry pairs. The nature of this relationship is further analyzed through tests of hypotheses.

Focus of the investigation on specific industries reveals that many manufacturing industries are much more attracted to their linked industries than to a random sample of manufacturing industries.

Using the linkage and association measures of this study several industrial complexes are identified. These are characterized by strong linkage connections and close geographical proximity of their component industries.

The usefulness for regional policy purposes of some of the results obtained in this study is also indicated.

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TABLE OF CONTENTS

TABLE OF CONTENTS--Continued

LIST OF TABLES

1. INTRODUCTION

The first four sections of this chapter deal with some aspects of the spatial dimension in economics. The intent here is not that of providing a comprehensive review or discussion of the literature, but to sketch a framework in which the study can be seen.

Direction and purpose of this study will be indicated in the final section of this chapter.

1.1 Economic Theory and the Time-Space Continuum

Economic activity -- as all other human activity -- takes place in a continuum of time and space. If there is an a priori reason for considering one dimension to be more fundamental and pervading than the other, it may be the fact that time is inescapably passing and thus inherently dynamic whereas space is not. Movement through space always involves also movement through time, but not vice versa. The former can be avoided, the latter cannot.

It may also be observed that, ignoring gravity, all movements through space entail the expenditure of energy -- time just passes whereas the "friction of space" has to be overcome.

Turning from physical to economic considerations the question to be answered is how the characteristics of time and space affect the behaviour of the economic agents and the performance of the economy. Despite the applicability of von Thünen's model to a self-sufficient, agricultural economy,[1] it would appear that the availability of goods and problems of consumption and accumulation were more important in primitive economies than spatial problems. No efficient means of transportation existed and so locations were rather fixed and exchange over longer distances was limited. Modern economies could not arise until technological progress made possible both the division of labour and the development of an efficient transportation system as a prerequisite for it.[2] In addition to the temporal optimization of resource allocation, a spatial optimization problem comes into existence. From an abstract theoretical point of view the two problems appear to be quite similar if it is assumed that economic decisions can be made over a continuum of time and space. For contrary to purely physical movements, economic movements through time also have a price; the interest rate may be thought of as performing the same purpose in temporal analysis as the transport rate in spatial analysis.[3] However, while time has been incorporated into economic theory early and in various ways, e.g. short-run vs. long-run, differential equation time, etc., the spatial dimension has been all but ignored in traditional economics before the last few decades.

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[1]See Johann H. von Thünen, Der Isolierte Staat in Beziehung auf Landwirtschaft und Nationalökonomie (2nd ed.; Jena: G. Fischer, 1921). First ed. 1842.

[2]See George J. Stigler, "The Division of Labor is Limited by the Extent of the Market", in W. Breit and H. M. Hochman, Readings in Micro-Economics (New York: Holt, Rinehart and Winston, Inc., 1968), pp. 151-159.

[3]See also Walter Isard, Location and Space Economy (Cambridge, Mass.: M.I.T. Press, 1968), pp. 83-85, where he points out the analogy between time and space preference. For example, with an interest rate of 5% and a transport rate of $1.025 per mile a $100 goods available here 2 years from now is identical in costs to the same goods available now 10 miles away.

Ideally one would wish for an economic theory that was general and "dynamic" not only with respect to time but also with respect to space. At present there is no theory that treats both dimensions explicitly.

1.2 The Anglo-Saxon Bias

There were contributions to economic theory prior to von Thünen's "Isolated State" that had distinct locational connotations, although the spatial question was peripheral and transport costs were not explicitly taken into account.[1] Smith's principle of the division of labour, primarily designed to explain the 'wealth of nations', was nevertheless tied to industrial locations with transportation playing an important role.[2] Given the relative immobility of capital and labour, Ricardo's principle of comparative advantage explains an inter-regional and international specialization and a pattern of location of industries that is economically, not merely technically, optimal.[3]

Perhaps von Thünen's greatest contribution to economic theory is the development of a spatial model in which locational questions are analyzed and in which the values of economic variables, such as price and rent, are also influenced by distance. Thünen's theoretical and

[1]See Wolfgang Meyer, Die Theorie der Standortwahl (Berlin: Duncker und Humblot, 1960), pp. 16-18.

[2]See Adam Smith, The Wealth of Nations (Modern Library ed.; New York: Random House Inc., 1937), Book I, Chapt. III, pp 17-21. First ed. 1776.

[3]See H. Meinhold, "Zahlungsbilanztheorie und Standorttheorie", Jahrbuch für Nationalökonomie und Statistik. First edition of Ricardo's Principles of Political Economy and Taxation in 1817.

empirical work was followed by a large number of writings in the area of location theory, notably in Germany and Sweden.[1]

However, in the development of economic theory spatial considerations were soon overshadowed by the profound influence of Marshall's Principles.[2] Spatial questions are touched upon when he considers the localization of industry as a prerequisite for the division of labour, or when the extent of the market is related to the value of the goods and the transport costs they can bear.[3] Being more concerned with market equilibrium of supply and demand, Marshall finds the influence of time to be more fundamental than that of space,

> "for the nature of equilibrium itself, and that of the causes by which it is determined, depend on the length of the period over which the market is taken to extend."[4]

It cannot be denied that, despite (or because of?) the bias of Marshall and subsequent generations of economists, there exists today a well-developed body of economic theories and analytical tools that can be fruitfully applied to a great variety of problems. It is unnecessary to argue today whether questions of production, growth and stability of the economy are more important than the problems of optimal location of economic activities and population.[5] They all have welfare implications

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[1] Walter Isard, Space Economy, pp. 15-20; Wolfgang Meyer, Standortwahl, pp. 19ff; Gerhard Stavenhagen, Geschichte der Wirtschaftstheorie (Göttingen: Vandenhock und Ruprecht, 1964), chapt. 15.

[2] Walter Isard, Space Economy, pp. 24-27.

[3] Alfred Marshall, Principles of Economics, Papermac 16 (8th ed.; London: Macmillan and Co. Ltd., 1962), Book IV, Chapt. 10, Sect. 1, pp. 222-223 and Book V, Chapt. 1, Sect. 3, pp. 270-271, 1st ed. 1890.

[4] Ibid., Book V, Chapt. 1, Sect. 6, p. 274; also Book V, Chapt. 15, Sect. 1, p. 411.

[5] Harry W. Richardson, Regional Economics (London: Weidenfeld and Nicolson, 1969), pp. 2-3.

and are thus properly the subject of economic study. It would appear that spatial economic problems are of greater relative concern today than they ever were and the greater attention they receive is bound to contribute to a correction of the imbalance.

1.3 The Spatial Dimension in Location Theory

Two methods have been open to economists for including space, with the physical variable of distance and the economic variable of transport costs, into the analysis: the partial and the general equilibrium approach. In partial equilibrium theory, as exemplified by, for example, Weber,[1] attention is focused on a few relationships that are considered to be of primary importance and able to explain a large part of the question. The other relationships are relegated into the realm of the "*ceteris paribus*" from which they are assumed to have no influence on the phenomenon under study. In a supply oriented Weberian model demand is taken as given and then the optimum location of a firm or an industry is determined essentially by minimizing costs, i.e. by substituting, say, transport outlays for labour outlays. There remained the need to supplement partial location theories by general equilibrium analysis,[2] because the partial equilibrium approach will only yield a correct answer as long as the behaviour of one firm does not influence that of any other.

Lösch primarily used the tools of traditional economics in his treatment of locational choice and market areas but he attempted to

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[1]Alfred Weber, Theory of the Location of Industries (2nd impression; Chicago: University of Chicago Press, 1957).

[2]Walter Isard, Space Economy, pp. 31-36.

incorporate the effects of the spatial interdependence of economic units into his locational analysis.[1] This approach has been severely critized, primarily for the extreme degree of abstraction which cannot yield useful solutions to the problem.[2]

A more successful attempt at developing a general location theory by fusing location theory with general equilibrium analysis was made by Predöhl and Isard.[3] Basically, this approach involves the utilization of the well-known substitution principle "by means of which a general equilibrium approach could be systematically applied to location analysis".[4] Substitution takes place between transport inputs and between various types of outlays and revenues. Isard's ultimate objective is to express the spatial equilibrium in an input-output model by incorporating his distance inputs into the equation system. This involves, among other complications, the decomposition of the national economy into a large number of regions. The main criticisms levelled against Isard's substitution approach concern his assumption of a continuous transport plane, reminiscent of Lösch's, and his treatment of transport inputs as intermediate products;[5] both create difficulties in general

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[1] August Lösch, The Economics of Location (Science Editions; New York: John Wiley and Sons, 1967) pp. 6-9; Stefan Valavanis, "Lösch on Location" American Economic Review, Vol. XLV, No. 4, Sept. 1955, pp. 637-644.

[2] Louis Lefeber, Allocation in Space (Amsterdam: North-Holland Publishing Company, 1968), p. 3.

[3] Walter Isard, Space Economy, pp. 31-36, Andreas Predöhl, "The Theory of Location in its Relation to General Economics", Journal of Political Economy, Vol. 36 (1928), pp. 371-390 and "Von der Standortslehre zur Raumwirtschaftslehre", Jahrbuch für Sozialwissenschaften, Vol. 2 (1951), pp. 97-102.

[4] Walter Isard, Space Economy, p. 32.

[5] Louis Lefeber, Allocation, pp. 3-5.

equilibrium analysis of location.

On an operation level input-output methods have been used in industrial complex analyses to estimate the direct and indirect impact of an industry locating in the region; a separate location study was used to determine the optimal plant location, as this was beyond the scope of the inter-industry model.[1] These limited applications fall, of course, far short of the aforementioned general location theory concept.

In order to avoid some of the rigidities of input-output models, especially their inability to explain trade patterns and to optimize the distribution of production, inter-regional linear programming models have been developed.[2] Some of them, notably Lefeber's model, are able to derive optimal locations, an optimal allocation of resources, determine optimal flows of the output to markets, and to maximize outputs for final demand in a Walrasian general equilibrium framework (with the familiar assumptions of perfect competition, perfect knowledge, and no institutional rigidities).[3] The main weakness of programming models appears to be the treatment of the demand side: prices for final goods and transport services are not provided as a solution by the model, as they ideally should be, but must be given as data on the basis of which optima and equilibrium conditions are determined.

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[1]Walter Isard and Robert E. Kuenne, "The Impact of Steel upon the Greater New York - Philadelphia Industrial Region", Review of Economics and Statistics, 35 (1953-54), pp. 289-301. Frederick T. Moore and James W. Petersen, "Regional Analysis: An Interindustry Model of Utah", Review of Economics and Statistics, 37 (Nov. 1955), pp. 368-383.

[2]For example Louis Lefeber, Allocation. For further reference see Leon N. Moses, "The General Equilibrium Approach", in Spatial Economic Theory, ed. by Robert D. Dean, William H. Leahy, and David L. McKee (New York: The Free Press, 1970), pp. 23-28.

[3]Harry W. Richardson, Regional Economics, pp. 112-116.

Besides input-output and programming models there exists another type of "mutual-interdependence models"[1] which must be mentioned briefly. These are highly abstract constructs which avoid the questions posed by the introduction of the spatial dimension and transport costs by taking refuge in formal generalizations with little explanatory value with respect to spatial problems.[2] By regarding identical goods at different locations (and times) as entirely different economic objects the commodity space is simply enlarged and the analysis can proceed as though time and space did not exist. While this approach allows concentration on the determination of prices in competitive markets and their role in the economy, it does not provide any insights into the workings of the space economy.

It may be appropriate at this point to make a few remarks about two related assumptions commonly made in general equilibrium theory and usually upheld in spatial models: perfect competition and perfect divisibility of factors and commodities. With respect to the market form the criticism is that the mere presence of space, intervening in the flow of economic objects (factors and commodities), confers some degree of monopoly power to economic agents; transport costs reduce economic mobility. For this reason it may be contended that "... theories of the space-economy and of monopolistic competition (broadly conceived) are inextricably bound together."[3] While some writers, for

[1] Leon N. Moses, "The General Equilibrium Approach", p. 15.

[2] See, for example, Gerard Debreu, Theory of Value (New York: John Wiley and Sons, Inc., 1959), pp. 29-30.

[3] Walter Isard, Space Economy, p. 49.

example Lösch and Palander,[1] have attempted to develop their theories of location by explicitly recognizing the imperfectly competitive character of the economy, others, for example Lefeber,[2] defend the retention of the pure competition assumption in their analysis by pointing out that it permits the derivation of an optimal or ideal system. Against this optimal allocation the deviations of the real world can be appraised and corrective measures can be planned.[3]

The two assumptions are related because of the implications of indivisibility for the maintenance of perfect competition.[4] Noting that most of the literature on location theory assumes divisibility, Koopmans points out that this approach fails to grasp an essential point in the explanation of urban agglomerations. His view is supported by preliminary investigation of the properties of a locational model.[5] The welfare significance of these considerations lies in the fact that a relaxation of the assumptions results in a departure from the optimum.

With regard to dynamic adjustment mechanisms it may be pointed out that both partial and general equilibrium models employ the notion of differential adjustments to restore a condition of disequilibrium to

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[1]Walter Isard, Space Economy, pp. 49-50.

[2]Louis Lefeber, Allocation, p. 11.

[3]For a critical view of pure competition as a basis for comparison of welfare implications, see Edward H. Chamberlin, "The Theory of Monopolistic Competition (6th ed.; Cambridge: Harvard University Press, 1948), pp. 214-215. Also see Walter Isard, Space Economy, p. 50.

[4]Tjalling C. Koopmans, Three Essays on the State of Economic Science (New York: McGraw-Hill Book Company, 1957), pp. 150-154. Also Gerard Debreu, Theory of Value, p. 30.

[5]Tjalling C. Koopmans and Martin Beckmann, "Assignment Problems and the Location of Economic Activities", Econometrica, 25 (Jan. 1957), pp. 53-76. But see also Louis Lefeber, Allocation, p. 8.

equilibrium. A spatial equilibrium model would have to allow for marginal spatial adjustments--a questionable proposition.

Finally it must be noted that the data requirements for spatial general equilibrium models--already large for the non-spatial variety of, say, the input-output type--are formidable. Recognition of all possible locations in the general equilibrium system of equations adds a "bewildering" number of variables.[1] As in the case of industries, this problem may be alleviated for operational purposes by aggregating individual locations into regions within which no locational problems and choice are assumed to exist. In fact, the one-point economy of traditional economics may be regarded as the extreme aggregation.

1.4 Regional Economic Problems

Many of the present economic problems are regional in nature. They are "problems of spatial organization"[2] and their understanding requires the study of man's economic behaviour in space. The presence of such problems is usually indicated by a divergence of regional per capita incomes from the national average. While such regional income disparities may be the effect of some problem, the causes can vary from inferior resources, imperfect mobility, or lack of demand to an economically unjustified underestimation of the development potential of the area, resulting in an over-all reduction of social welfare.

Connected with the problems of spatial organization and their welfare aspects are the issues of efficiency and equity. Efficiency relates to the maximizing of some economic variable and the marginal

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[1]Louis Lefeber, Location and Regional Planning, Training Seminar Series 7 (Athens: Center of Planning and Economic Research, 1966), pp. 15-16.

[2]John Friedman, "Regional Economic Policy for Developing Areas", Papers and Proceedings of the Regional Science Association, XI (1963), p. 41.

conditions are extended to allocation and distribution in space. The equity issue extends beyond the economic to the social and political systems and reflects the normative concept of the "rights of people". Often social and economic goals seem to conflict;[1] but the conflicts may not be as serious as it appears, for many of the trade-offs of economic actions are social and political in nature. When looked at in the light of social welfare maximizations such concomitants of regional disparities as waste of human and non-human resources, personal unhappiness, crime, tension, and political unrest may render invalid simple efficiency considerations.

Of importance to regional economics is the fact that growth is not only a scale phenomenon with differential sectoral effects, but also with uneven geographic impact, i.e. it is basically unbalanced.[2] Both its concentrated presence in some areas and its absence in others create problems, and many economists are therefore concerned with the factors determining the location of industries and the transmission of growth.

Underlying economic planning and policy are slowly changing and changeable structural elements of the economy and the economic landscape. Economic and non-economic patterns tend to persist,[3] and policies that

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[1]See also Stephan Robock, "Strategies for Regional Economic Development", in Regional Economics: Theory and Practice, ed. by David L. McKee, Robert D. Dean, and William H. Leahy (New York: The Free Press, 1970), p. 246.

[2]Niles M. Hansen, "Development Pole Theory in a Regional Context", ibid., pp. 134-135; Francois Perroux, "Note on the Concept of 'Growth Poles'", ibid., p. 102; Albert O. Hirschman, The Strategy of Economic Development (New Haven and London: Yale University Press, 1958), p. 184.

[3]John R. P. Friedman, The Spatial Structure of Economic Development in the Tennessee Valley, Department of Geography, Research Paper No. 7 (Chicago: The University of Chicago Press, 1955), pp. 94-96.

do not recognize this often result in large amounts of money being frittered away on infrastructure and the unsuccessful subsidization of industries. Then the damage is double in that not only equity is not enhanced but efficiency is lost.

1.5 Purpose and Direction of this Study

The purpose of this thesis is an analysis of the locational significance of inter-industry linkages in the Canadian economy. The general hypothesis is that input-output linkages, because of the technical relationships they represent and the spatial flows of commodities they imply, will induce the linked industries to locate in close proximity to one another, i.e. they will tend to cause agglomerations of economic activity. It has also been suggested elsewhere[1] that the explanation of such industrial agglomeration is of focal interest in spatial analysis.

Stigler points out that one would expect

> "...to find some relationship between the functional structure of an industry and its geographical structure -- after all, reductions in transport costs are a major way of increasing the extent of the market."[2]

A similar view is advanced by Leontief when he says that

> "Economic systems tend naturally to combine the international division of labor with the minimization of transportation costs. The latter costs can be kept down if an industry is located or developed in close proximity to the largest *direct* customers for its outputs or the suppliers of its inputs. Quite independently of transportation costs, however, a growing economy derives a considerable, although less measurable, advantage from developing whole families of structurally

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[1]Louis Lefeber, Allocation, p. 130.

[2]George J. Stigler, "The Division of Labor", p. 158.

> related industries rather than isolated industries that depend on foreign trade for supplies and markets."[1]

It is interesting to note that Leontief does not only refer to the existing spatial structure of the economy but also to the development aspect of inter-industry relationships. This point will be dealt with in greater detail at a later stage.

The model used in the analysis is partial; it concentrates on the role of linkages in the explanation of industrial agglomeration. There are, of course, a number of other factors contributing to a concentration of economic activities in certain places. Some of them will be mentioned below. One of the analytical problems is that they are difficult, if not impossible, to separate and quantify. This study thus is restricted to an analysis of the locational impact of linkages.

In order to provide systematic information on the relationship between input-output linkages and the geographic association of industries a number of hypotheses will be tested. They are general hypotheses and relate to all manufacturing industries taken together. The importance of linkages to specific industries will also be investigated. Using the tools of analysis applied in this study an attempt will then be made to delineate industrial complexes.

Finally, in the conclusion, some policy aspects of the analysis will be noted and possibilities for further research will be indicated.

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[1]Wassily Leontief, "The Structure of Development", in: Input-Output Economics (New York: Oxford University Press, 1966), p. 65; italics mine. The reference to the international scene does not detract from the applicability of the quotation, for the distinction between international and interregional is less one of kind than one of convenience.

2. AGGLOMERATION AND THE LOCATION OF INDUSTRIES

Casual observation suggests that, in the process of economic development, countries do become both more industrialized and increasingly urbanized. Indeed, industrialization and urbanization appear to be different aspects of the same process.[1] It is obvious that the forces at work are highly complex and interrelated and the direction of causality is not always clear. While industries producing finished products may be attracted to centres of population because these centres not only constitute ready markets for labour inputs but also markets for their output, the locational optimum for intermediate producers may be less apparent. Their production too, however, appears to be concentrated in large urban centres.[2]

In this chapter a number of agglomerative factors will be discussed after a definition of the term has been provided. The works of several writers in the field of agglomeration will be mentioned and characterized.

2.1 Definition and Description of Agglomeration

Following Weber, an agglomerative factor may be defined as "an

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[1]Hendricus C. Bos, Spatial Dispersion of Economic Activity (Rotterdam: Rotterdam University Press, 1965), p. 4.

[2]See Table 1.

TABLE 1

EMPLOYMENT DATA AND POPULATION CORRELATION COEFFICIENTS BY INPUT-OUTPUT INDUSTRY FOR CENSUS METROPOLITAN AREAS, 1961[a]

IOIC-L Number	IOIC-L Industry[b]	CMA Employment	Percentage of Total Cdn. Industry Empl.	Population Correlation Coefficient
12	Slaughtering & Meat Processors	22,787	77.40	.8271
13	Poultry Processors	693	25.72	.5624
14	Dairy Factories	16,869	44.69	.9827
15	Process Cheese Manufacturers	1,048	75.07	.7628
16	Fish Products Industry	3,572	17.46	.0961
17	Fruit & Veg. Canners & Preservers	5,190	37.39	.7724
18	Feed Mills	1,490	20.39	.8109
19	Flour Mills	2,673	48.66	.8644
20	Breakfast Cereal Manufacturers	983	49.52	.0491
21	Biscuit Manufacturers	5,883	85.73	.8821
22	Bakeries	24,210	62.79	.9882
23	Confectionery Manufacturers	6,948	83.73	.8866
24	Sugar Refineries	2,292	78.33	.6734
25	Vegetable Oil Mills	379	66.84	.7857
26	Miscellaneous Food Industries	8,873	75.00	.9691
27	Soft Drink Manufacturers	7,902	57.07	.9735
28	Distilleries	5,583	74.15	.5864
29	Breweries & Wineries	7,431	67.22	.6792
30	Leaf Tobacco Processing	106	13.68	.7572
31	Tobacco Products Manufacturers	6,970	86.50	.7631
32	Rubber Footwear Manufacturers	1,920	43.73	.1898
33	Tire & Tube Manufacturers	7,513	83.24	.5079
34	Other Rubber Industries	3,192	58.82	.8561
35	Leather Tanneries	1,595	43.63	.6807
36	Shoe Factories	13,422	63.20	.7575
37	Glove & Luggage Manufacturers	6,218	75.18	.9283
38	Cotton Yarn & Cloth Mills	5,996	32.25	.6414
39	Wool Yarn & Cloth Mills	2,398	29.19	.4444
40	Synthetic Textile Mills	1,588	10.57	.7633
41	Carpet, Mat & Rug Industry	732	41.40	.8078

TABLE 1-Continued

IOIC-L Number	IOIC-L Industry[b]	CMA Employ-ment	Percentage of Total Cdn. Indus-try Empl.	Population Correlation Coefficient
42	Linoleum & Coated Fabrics I.	1,872	84.63	.8758
43	Text. Bags & Canvas Products I.	2,114	80.23	.9610
44	Other Textile Industries	9,208	57.49	.9240
45	Hosiery Mills	4,191	47.05	.8404
46	Other Knitting Mills	5,659	52.21	.9618
47	Clothing Industries	72,503	78.87	.9084
48	Sawmills	11,008	18.93	.1390
49	Veneer & Plywood Mills	5,004	47.86	.1820
50	Sash & Door and Planing Mills	7,312	38.43	.9616
51	Other Wood Industries	4,767	42.46	.9229
52	Household Furniture Industry	13,353	56.15	.9752
53	Other Furniture Industries	8,964	75.24	.9541
54	Pulp & Paper Mills	11,277	15.63	.3967
55	Asphalt Roofing Manufacturers	1,756	68.33	.7718
56	Paper Box & Bag Manufacturers	14,149	81.95	.9617
57	Other Paper Converters	7,104	73.52	.8030
58	Printing, Publ., & Engraving	65,031	77.17	.9295
59	Iron & Steel Mills	20,856	53.80	.1327
60	Steel Pipe & Tube Mills	1,267	36.43	.7568
61	Iron Foundries	4,761	48.61	.8457
62	Smelting & Refining	5,539	22.81	.3001
63	Aluminum Roll., Cast. & Extrud.	2,602	34.33	.8331
64	Cu & Alloy Roll., Cast. & Extrud.	3,541	87.37	.9621
65	Metal Roll., Cast. & Extrud. n.e.s.	1,475	67.01	.8663
66	Boiler & Plate Works	5,180	72.47	.7509
67	Fabricated Struct. Metal I.	11,292	80.35	.9591
68	Orn. & Architect. Metal Industry	6,757	78.84	.9800
69	Metal Stamp., Press. & Coat. I.	17,821	82.32	.9288
70	Wire & Wire Products M.	7,135	72.28	.6332
71	Hdwe., Tool & Cutlery M.	6,429	64.37	.8369
72	Other Metal Fabricating I.	21,403	67.02	.9480
73	Machinery & Equipment M.	27,017	65.07	.8183
74	Refrig., Office & Store Mach. M.	6,983	84.09	.7000
75	Aircraft & Parts M.	24,728	83.92	.9166
76	Motor Veh. & Trailer M.	19,605	54.28	.1573

TABLE 1-Continued

IOIC-L Number	IOIC-L Industry[b]	CMA Employ-ment	Percentage of Total Cdn. Indus-try Empl.	Population Correlation Coefficient
77	Motor Vehicle Parts M.	6,821	41.54	.5636
78	Other Transport. Equip. I.	23,273	64.62	.6861
79	M. of Electrical Appliances	14,537	62.02	.5108
80	M. of Communication Equip.	21,543	74.71	.9238
81	M. of El. Industrial Equip.	10,142	75.53	.7428
82	Other El. Products M.	14,929	77.67	.8928
83	Cement & Lime Products M.	2,20[illegible]	47.39	.7537
84	Concrete & Gypsum Products M.	8,627	56.01	.9306
85	Clay, Stone & Refract. Prod. M.	3,753	41.77	.7068
86	Glass & Glass Products M.	8,030	70.93	.9029
87	Other Non-Met. Mineral Prod. I.	2,683	40.32	.9567
88	Petrol. & Coal Products I.	12,060	71.11	.8941
89	Explosives & Ammunition M.	1,328	28.05	.3754
90	M. of Mixed Fertilizers	733	32.15	.8704
91	M. of Plastic Resins	2,134	41.57	.7992
92	M. of Pharm. & Medicines	8,560	77.05	.9568
93	Paints & Varnishes M.	7,041	90.73	.9607
94	M. of Soap & Cleaning Compounds	5,010	92.50	.7390
95	M. of Toilet Preparations	3,712	65.71	.9398
96	Industrial & Other Chem. I.	13,528	49.32	.9656
97	Misc. Manufacturing Industries	37,702	74.20	.8833

[a]Calculated from: Canada, D.B.S., Census of Canada, 1961: Labour Force: Industries, Vol. III, Part 2, Cat. No. 94-519.

[b]For complete industry names see Appendix 2.

'advantage' or a cheapening of production or marketing which results from the fact that production is carried on to some considerable extent at one place, while a deglomerative factor is a cheapening of production which results from the decentralization of production (production in more than one place)."[1] It is noteworthy that Weber meant his theory of agglomeration to deal with 'pure' or 'technical' agglomeration only,[2] i.e. with those aspects of concentrations of economic activity that are due to the influence of spatially passive factors. Technical agglomerative economies or diseconomies are dependent upon the magnitude of activities carried out at a certain location,[3] not upon the influence of transportation facilities and costs or labour markets. As the lines of distinction between pure and, for example, transport agglomeration are not only fine but also appear to be somewhat artificial, this classification has not been upheld in later writings.[4] The concept of agglomeration used in this study is also the wider one, embracing, in particular, also the effects of transportation on the concentration of industries.[5] It is then possible to distinguish between at least two types of agglomeration economies: transfer economies and externalities.

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[1]Alfred Weber, Theory of the Location of Industries, trans. by Carl J. Friedrich (Chicago: University of Chicago Press, 1957), p. 126.

[2]Ibid., pp. 134-135.

[3]Walter Isard, Space Economy, pp. 139-140.

[4]See, for example, Bela Balassa, The Theory of Economic Integration (Homewood, Illinois: Richard D. Irwin, Inc., 1961), pp. 194-196.

[5]The term 'concentration', as used here, refers to concentrations of economic activity in space and not to the degree of concentration in any particular industry in the sense of market forms; the concern is with the locational juxtaposition of different industries.

2.2 Transfer Economies

Transfer costs may be defined to include not only transportation costs (the costs of movement through space of commodities) and storage costs (the costs of movement through time of commodities) but also communication costs, i.e. the costs of transferring information from one location to another.[1] Florence points out that "juxtaposition allows lower transport cost and easier communication: (a) from the suppliers to the demanders of materials or products, and (b) between one specialized process in production and another; and (c) allows specialized auxiliary services on the spot to be fully utilized."[2] Examples may be as varied as reduced transportation costs on intermediate material inputs and outputs, being able to talk to suppliers and clients quickly and in person, discussing business problems over lunch, close contact to banks and other financial institutions, immediate access to repair services for machinery and equipment. By locating in close geographical proximity to one another, interrelated industries are thus able to take advantage of agglomerative economies through the reduction of transfer costs. The field of transportation contains several aspects some of which should be treated in more detail.

2.2.1 Fundamental Role of Transportation. The production of transportation services has characteristics uncommon to other industries. These

[1]See Edgar M. Hoover, The Location of Economic Activity (New York: McGraw-Hill Book Company, Inc., 1948), pp. 117-120 and Harry W. Richardson, Regional Economics, pp. 420-421.

[2]P. Sargant Florence, Investment, Location, and Size of Plant (Cambridge: University Press, 1948), p. 52.

services are generally not desired for their own sake[1] but needed to bring together inputs and to distribute outputs of all other industries. The role of the transportation sector is fundamental in that transport costs appear to be the only relevant locational factor[2] related to overcoming the friction of space; they vary systematically with distance and impart a regularity to the spatial setting of economic activities.[3] All other locational factors may be considered to receive their locational significance through their relationship to movements through space, i.e. transportation costs determine the degree of mobility of inputs and outputs. The greater the ease of mobility, the lower the transportation costs and the lower the polarizing force of a commodity, v.v. Complete immobility, for example in the case of mines, is equivalent to infinitely high transportation costs,[4] and the location is imperatively fixed. Financial capital, on the other hand, is highly mobile because of its low transportation costs. Ubiquitous materials, as an extreme, have no locational significance at all. Labour inputs may be cited as a final example: their mobility, relatively high for short distances, decreases rapidly beyond a certain distance.[5]

Thus as a result of differing degrees of mobility or, economically, varying transportation costs, locational factors have associated with them

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[1]Except for "joy rides" in the field of passenger transportation.

[2]Weber defines a locational factor as a monetary advantage realized by locating at a certain point and not elsewhere. See Alfred Weber, Location, p. 18.

[3]Walter Isard, Space Economy, p. 140.

[4]See also Hendricus C. Bos, Spatial Dispersion, p. 13.

[5]The difference between long-run and short-run behaviour will not be considered here.

centrifugal or centripetal forces, i.e. they tend to disperse or concentrate economic activity.

2.2.2 Level of Transportation Costs. The level of transportation costs generally is an increasing function of the weight of the commodity and the distance over which it is to be transported. However, discrimination against certain commodities, subsidies, and noncompetitive agreements create actual transportation rate schedules that do not only reflect economic circumstances. As a result rate schedules are not only very complex, but only a small proportion of the total volume of freight is transported according to posted rates for classified commodities.[1] The two most common features of rate schedules are the downward-sliding scale of block rates as distance and weight increase and lower rates for low value/high volume raw materials as opposed to high value/low volume manufactured products.[2] While the former is mainly due to fixed terminal charges that can be spread over a larger variable cost share, the latter appears to be only partially due to cost differences. The main reason may be found in the higher transporation cost elasticity of low-value bulk products. Both tend to favour a concentration rather than a dispersion of manufacturing industries.

[1]Moreover, this proportion has declined in recent years. See Canada, Board of Transport Commissioners for Canada, Waybill Analysis Carload All-Rail Traffic: 1965 (Ottawa: Queen's Printer, 1966), p. 35 and ibid., 1969, p. 43.

[2]See United Nations, Department of Economic and Social Affairs, Economic Commission for Europe, Economic Survey of Europe in 1954 (Geneva: United Nations Publication, 1955), p. 153; Archibald W. Currie, Economics of Canadian Transportation (Toronto: University of Toronto Press, 1954), pp. 195-198. Benjamin Chinitz, "The Effect of Transportation Forms on Regional Economic Growth, Traffic Quarterly, 14 (1960), pp. 136-138.

Besides the various influences of the transportation rate structure on the level of transportation costs and, thereby, on the agglomeration tendencies of industries, there are a number of characteristics of the production process itself that affect the agglomerative behaviour of industries, for example, weight loss of the product in the course of production and use of ubiquities. While the former tends to attract an industry to the location of its weight-losing input, the latter tends to pull an industry towards a market location because transportation costs can be reduced. If an industry is footloose, i.e. the proportion of material inputs to total inputs is very low, it will not be transport-oriented in its locational choice at all; external economies or non-economic amenities may determine its location.

The level of transportation costs is, *ceteris paribus*, also affected by the availability and quality of transportation facilities. Indeed, many cities owe their existence to the presence of natural transportation routes. Changes in transportation technology and costs can have a profound impact on a city's hierarchical rank in a region by diverting economic activity elsewhere.[1] Barring exceptional cases, an urban-metropolitan region may be viewed as a network of transport interconnections[2] with strong agglomerative effects.

The case of transportation facilities may serve as an example for the difficulty of keeping apart agglomeration economies due to transportation costs from those due to externalities. Transportation facilities are usually lumped together with gas, electricity, water supply,

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[1]See Hugh O. Nourse, Regional Economics, p. 223.

[2]See Walter Isard, Space Economy, p. 11.

etc.[1] under the heading of infrastructure or economic overhead capital[2] and the agglomerative effect is taken to accrue via pecuniary external economies.' This point will be discussed in some more detail below.

2.2.3 Transport Innovation and the Importance of Transportation Costs. Technological progress in the transportation sector can have two different effects on agglomeration. Assuming the extreme of infinitely high transportation costs, the result would be self-sufficiency in all regions. In this abstract case economic activities would be distributed according to the distribution of population. A reduction in transportation rates would facilitate polarization of the economic landscape by freeing industries from their previously fixed locations and allowing them to take advantage of scale economies and other locational factors. Lower transport costs enhance the importance of other locational factors and the market for both inputs and outputs is widened.

However, starting with a given uneven distribution of economic resources and activities, lower transportation costs may lead to greater relative specialization of regions in those activities in which they have a production advantage. This ability of distant production centres to compete in large central markets constitutes a depolarizing effect. Through a reduction of economic distances lower transportation rates

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[1]Bela Balassa, Economic Integration, p. 195.

[2]For a definition of economic and social overhead capital see Niles M. Hansen, "Unbalanced Growth and Regional Development", in Regional Economics, ed. by David L. McKee, Robert D. Dean, and William H. Leahy (New York: The Free Press, 1970), pp. 231-232.

enlarge the set of feasible locations in the economy, "because a given level of profit may now be reached at a greater number of spatial points."[1] Already these simple examples show that no unequivocal statements can be made about the locational impact of a reduction in transportation costs. The matter becomes even more complicated if the decrease is not general but applies only--as it likely would--to certain modes of transportation and, thereby, to certain industries.

In the absence of a detailed study it is almost impossible to make generalizations on the importance of transportation costs for the location of industries. Some parts of this question, the agglomerative aspects, will receive more detailed study below. An examination of the relevant input coefficients of the Canadian input-output tables readily reveals the greatly differing proportions of transfer costs in the total value of production among the various industries.[2] Moreover, transportation costs are, of course, but one of a large number of locational factors and, as some writers contend, one of declining significance in the selection of industrial locations.[3] Notwithstanding this assertion, it has been shown that past trends in the transportation sector have encouraged a greater market orientation of industries.

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[1]Horst Siebert, Regional Economic Growth: Theory and Policy (Scranton, Pennsylvania: International Textbook Company, 1969), p. 40.

[2]Canada, Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy 1961 (Ottawa: The Queen's Printer, 1969), Vol. 2, Table 14.

[3]Marvin J. Barloon, "The Interrelationship of the Changing Structure of American Transportation and Changes in Industrial Location", Land Economics, 41(1965), pp. 169-170.

In general one may point out that technological advances have changed consumption patterns in the past and will probably continue to do so in the future.[1] With increasing affluence the trend is to more complex and sophisticated consumer goods whose transportation costs form a lower proportion of the total value of the product than those of low-price staple products. The locational impact of a reduction in the weight of transportation costs on the total costs of a product is and increase in the importance of other locational factors. This trend may be weaker in the Canadian economy than in, say, European countries because distances are relatively large and markets comparatively narrow.

2.3 External Economies

The second group of agglomeration economies to be considered comprises externalities. While undoubtedly of locational significance, external economies and diseconomies so far have escaped direct quantitative measurement because of the difficulty of separating individual external economies as location factors and measuring them under *ceteris paribus* conditions. These data problems have prevented a systematic analysis of externalities before and no attempt will be made here to take them into account directly. It is possible, however, to characterize these agglomerative forces and to indicate how they tend to affect the location of industries.

The following brief list of frequently cited external economies

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[1]See Louis Lefeber, Location and Regional Planning (Athens: Center of Planning and Economic Research, 1966), pp. 26-27.

illustrates the diverse nature of these locational factors[1]: the existence of infrastructure such as gas, water, and transportation facilities, output or costs of a given firm are favourably affected by an increase in activity of other firms, creation and utilization by many firms of a common pool of skilled labour, and the existence of specialized service facilities.

In the following section an attempt will be made to classify externalities, to relate them to the spatial variable and to indicate a common denominator.

2.3.1 Classification of Externalities. Externalities may be classified by placing them into a somewhat wider framework and relating them to the scale of economic activity. External economies are then, in essence, one type of scale economy. The reference point is the firm and economies are characterized as internal or external to the firm. The former comprise the well-known cases of returns to scale, especially increasing returns to scale, which result in decreasing long-run average costs. The reasons commonly advanced for the existence of these internal scale economies are specialization through division of labour and the ability to use a more efficient technology.[2]

External economies of scale may be subdivided again by taking the industry as an additional criterion and distinguishing between scale

[1]The focus on external economies is merely a matter of convenience here and does not mean to imply that external diseconomies are of lesser importance.

[2]Richard H. Leftwich, The Price System and Resource Allocation (4th ed.; Hinsdale, Ill.: The Dryden Press Inc., 1970), pp. 162-163.

economies external to the firm but internal to the industry and scale economies external to the firm and to the industry (but internal to the national economy). Contrary to internal scale economies which are both caused and received by the firm, scale economies external to the firm but internal to the industry accrue to the firm upon an increase in industry output while economies of scale external to firm and industry are caused by a general increase in economic activity, i.e. an increase in the output of all industries. Both types of external economies may be pictured as downward shifts of the long-run average cost curves of the individual firm.

While both types of externalities are transmitted because of interdependencies among productive units, it is necessary to point out one fundamental difference in the origin of the interdependencies. Following Scitovsky's terminology,[1] we may distinguish between technological and pecuniary externalities. Technological externalities are based in the characteristics of production functions; these are the "spill-over effects" that cause problems in the static model of optimum resource allocation. They are present, given outputs x, output prices p, inputs v, and activities 1, 2, 3, ..., n, if output x_1 is not only dependent upon inputs into that activity v, but also upon the scale of operation of other activities:

$$x_1 = x_1(v_1;\ v_2, \ldots, v_n, x_2, \ldots, x_n).$$

The function indicates that technological externalities are non-market interdependencies, i.e. they are physical influences that are not

[1]Tibor Scitovsky, "Two Concepts of External Economies", The Journal of Political Economy, 62 (1954), pp. 143-151.

accounted for through prices. Examples are, for external diseconomies, the adverse effects of pollution caused by one producer upon another or a reduction in agricultural output due to a lowering of the water table because of strip-mining.[1] The bee-orchard case may serve as an example for an external economy.

Pecuniary externalities exist whenever the profit of one producer does not only depend upon his own inputs and output but also upon those of other firms. These interdependencies are transmitted through the market mechanism via price changes resulting from a change in the scale of economic activity:

$$\pi_1 = \pi_1(x_1, v_1; x_2, v_2, \ldots, x_n, v_n)$$

for profits π, outputs x, inputs v, and activities 1, 2, 3, ..., n.[2] Unlike technological external economies, pecuniary external economies are a dynamic phenomenon and occur in the process of economic growth.[3] While a more detailed discussion of their implication for optimal resource allocation would lead too far afield,[4] it may be noted that their existence requires modification of private profitability as a sole in-

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[1]Horst Siebert, Regional Economic Growth: Theory and Policy (Scranton, Penn.: International Textbook Company, 1969), p. 125.

[2]This formulation which follows Scitovsky's, appears to be preferable to that of Siebert whose function gives the misleading impression that price changes cause output changes; the correct interpretation is that scale changes of one producer result in changes of his prices (input and/or output) which, in turn, cause profit changes for another producer. This may or may not result in output changes of the affected producer; his profits will be affected in any case.

[3]Paul H. Cootner, "Social Overhead Capital and Economic Growth", in The Economics of Take-off into Sustained Growth, ed. by W. W. Rostow (New York: St. Martin's Press, 1965), pp. 262-263.

[4]See Tibor Scitovsky, "Two Concepts", pp. 248-250.

vestment criterion and points the way toward an analysis of the feasibility of an entire interdependent group of industries.

Direct interdependencies through pecuniary external economies are important and occur frequently; examples are reduction in input prices for a producer because of economies of scale realized and passed on by his supplier, or cost reductions due to improvements of economic overhead capital such as roads, municipal services, railways.

2.3.2 Relation of Externalities to Location. So far externalities were treated without particular reference to the spatial dimension. In order to discuss the locational significance of external economies it is necessary to relate them to space. For only if, in order to appropriate the external economies, it is necessary to locate in the same place in which the industry generating them is located, will they constitute an agglomerative force. Robinson's distinction between mobile and immobile external economies is fruitful in this context.[1] Some external economies, such as certain technological advances, are immediately dispersed world-wide, becoming, as it were, common property. These are perfectly mobile and cannot be considered locational factors. Other economies, such as the availability of infrastructure facilities, the existence of a skilled labour pool, or the advantages of close proximity to suppliers and customers will only be realized by the 'juxtaposition' of industries in the same location. Thus only immobile economies qualify as agglomeration economies.

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[1]E. A. G. Robinson, The Structure of Competitive Industry, Cambridge Economic Handbooks CEH 6 (Chicago: The University of Chicago Press, 1964), pp. 124-126.

Incorporating spatial considerations Hoover has advanced the following classification of agglomeration economies:

"(a) *Large-scale economies* within a firm, consequent upon the enlargement of the firm's scale of production at one point.

(b) *Localization economies* for all firms in a single industry at a single location, consequent upon the enlargement of the total output of that industry at that location.

(c) *Urbanization economies* for all firms in all industries at a single location, consequent upon the enlargement of the total economic size (population, income, output, or wealth) of that location, for all industries taken together."[1]

The relationship between this classification and the above-mentioned distinction between internal and external economies of scale can be seen by noting that the three types of economies à la Hoover correspond to the immobile components of their scale economy counterparts.

2.3.3 The Cause of Externalities. It has been pointed out above that both internal and external economies are basically economies of scale. A common denominator for and a fundamental cause of these scale economies may be found in the existence of indivisibilities.

At the level of the firm increasing returns may result from the use of a more efficient but indivisible production technology or the use of more efficient but indivisible inputs, such as a blast furnace.[2]

External economies, and agglomeration economies in particular, are similarly rooted in indivisibilities. The trained labour pool, the

[1]Walter Isard, Space-Economy, p. 172.

[2]Edwin Mansfield, Microeconomics: Theory and Applications (New York: W. W. Norton and Company, Inc., 1970), p. 138.

specialized auxiliary service, the 'industrial climate', or the piece of infrastructure[1] will only be possible at a certain size of operation. There is thus a definite relationship between indivisibilities and the factors that affect the locational decisions of firms. Indeed,

> "... without recognizing indivisibilities--in the human person, in residences, plants, equipment, and in transportation--urban location problems, down to those of the smallest village, cannot be understood."[2]

While the theoretical implications of the widespread existence of indvisibilities cannot be further explored here, it may be pointed out how both the existence of space and the existence of indivisibilities lead to a departure from perfect competition and contribute to a concentration of economic activity.[3] The flow sequences may look as follows (the arrows indicate "if-then"):

a) space → spatial separation → market power → trend towards industrial and geographical concentration;

b) indivisibilities → scale economies → market power → trend towards industrial and geographical concentration.

While these sequences are only a very rough and incomplete indication of the processes involved, they may partially explain the stress placed upon market structure and 'industrial climate' by proponents of the growth pole approach to regional development.[4]

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[1]Tibor Scitovsky, "Two Concepts", p. 247.

[2]Tjalling C. Koopmans, Three Essays on the State of Economic Science (New York: McGraw-Hill Book Company, 1957), p. 154.

[3]Walter Isard, Space Economy, pp. 49-50, 158-159.

[4]Francois Perroux "Note on the Theory of Growth Poles", trans. by Linda Gates and Anne Marie McDermott, in Regional Economics: Theory and Practice, ed. by David L. McKee, Robert D. Dean, and William H. Leahy (New York: The Free Press, 1970), pp. 100-102.

2.3.4 Assessment of Importance. Given the present state of the arts with regard to the measurement of external economies, it is not easy to make any definite statements about their importance as a locational factor. While some of the authors to be mentioned address themselves more to external economies in general and their development effect, the statements would appear to apply *a fortiori* to agglomeration economies, i.e. immobile external economies, and their locational effect.

The difficulty in incorporating external economies into the analysis partly stems from the fact that their estimation requires a *ceteris paribus* world where everything which can possibly influence output or profits remains constant, except the factor 'external economies'. Moreover, pecuniary external economies are so broadly defined--they include, for example, the effects of technical progress--that quantification becomes extremely difficult.[1]

As in the case of transfer costs, the opinions also differ widely with regard to the importance of external economies as a locational factor. One extreme position is occupied by Rosenstein-Rodan who suggests that underdeveloped regions should invest 70-80% of the capital needs of that region into social and economic overhead capital in order to realize the agglomeration economies needed to attract other industries.[2] While these figures are considered to be exaggerated by Balassa he nevertheless ascribes an important role to infrastructure as a

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[1]Horst Siebert, Regional Economic Growth, p. 126.

[2]Poul N. Rosenstein-Rodan, "Les besoins de capitaux des pays sous-développés", Economie Appliquée, (January-June, 1954), p. 82.

locational factor.[1] Commenting on the difficulties of measurement and the inconclusiveness of empirical studies, Serck-Hansen nevertheless feels that "these advantages and disadvantages (connected with agglomerations) are real and important."[2] This view is shared by Hansen who points out that new industry could not be attracted to a designated growth pole "because of the presence of vastly greater external economies in other regions."[3] These agglomeration economies apparently were of a sufficient magnitude to compensate for the ensuing increase in transport costs.

Hirschman contends that the external economies that producers can appropriate by locating at centres of economic activity are consistently overestimated by them.[4] While Hirschman's view does not amount to a negation of the importance of external economies, he considers the agglomeration economies that can be generated by investing in economic overhead capital as an unreliable stimulus for the inducement of directly productive activities in general, and an unreliable locational factor for the attraction of these activities to certain localities in particular. This led to his formulation of the permissive and the compulsive sequences of investment.[5] Robock is in substantial agreement with this view and points out that any infrastructure investment must be related to identified potentials for investment in directly produc-

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[1]Bela Balassa, Economic Integration, p. 195.

[2]Jan Serck-Hansen, Optimal Patterns of Location (Amsterdam: North-Holland Publishing Company, 1970), pp. 12-13.

[3]Niles M. Hansen, "Development Pole Theory", p. 132.

[4]Albert O. Hirschman, Strategy, pp. 184-185.

[5]Ibid., pp. 81 ff.

tive activities.[1] This again amounts to a discounting of the efficacy of the immobile economies spun off by economic overhead capital. Examining the role of infrastructure in a slightly different context Cootner concludes that the argument with regard to the importance of pecuniary external economies--and infrastructure in particular--depends on the assumption of lack of foresight on the part of the investors.[2] For if there was no uncertainty private profit opportunities would not be underestimated.

Examining external economies other than infrastructure, Robinson reaches the conclusion that the proportion of mobile to immobile external economies is steadily increasing.[3] The tendency toward a geographical concentration of industries would consequently be lessened. Wilkinson has observed that the adoption of mass production techniques for standardized products results in a decreasing importance of external economies created by the ready availability of specialized auxiliary services.[4] As these advantages are localized, the 'mature product stage' involves a decline in the role of agglomeration economies as a locational factor.

Florence may be cited as a final reference on the importance of external economies. His extensive investigations into the structure of

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[1]Stefan H. Robock, "Economic Development", p. 255

[2]Paul H. Cootner, "Social Overhead Capital and Economic Growth", pp. 263, 265. Cootner's article deals with the role of uncertainty in decision-making.

[3]E. A. G. Robinson, Competitive Industry, p. 124.

[4]Bruce W. Wilkinson, Canada's International Trade: An Analysis of Recent Trends and Patterns (Montreal: Private Planning Association of Canada, 1968), pp. 116-117.

British and American industries led him to conclude that much of the spatial juxtaposition in British metal and textile industries was due to the immobile external economies resulting from a high degree of specialization of interdependent plants.[1]

Before concluding this section a few remarks should be made about the measurement of external economies. For any particular industry backward and forward linkages may be used as a guideline for the possible existence of external economies.[2] The effect of a price change in this industry (on the output of linked industries) would have to be followed through successive rounds.[3] For a group of industries taken together Isard and Schooler have attempted to take account of external economies by performing an industrial complex analysis.[4] Being concerned with the feasibility of the entire complex and stressing the quantification of variables, little attention is paid, however, to economies external to the complex. These wider effects could be investigated in a growth pole analysis which concerns itself not only with developments at the location of the growth centre but also involves the surrounding 'hinterland'. However, the various obstacles

[1]Philip Sargant Florence, Investment, Location and Size of Plant, pp. 69, 53,66. Florence's original study is now quite outdated. But see also his Post-War Investment, Location and Size of Plant, The National Institute of Economic and Social Research, Occasional Papers 19 (Cambridge: Cambridge University Press, 1962).

[2]Albert O. Hirschman, Strategy, pp. 103-105.

[3]Horst Siebert, Regional Economic Growth, p. 126.

[4]Walter Isard and Eugene W. Schooler, "Industrial Complex Analysis, Agglomeration Economies, and Regional Development", Journal of Regional Science, I (Spring 1959), pp. 19-33.

to the application of the growth pole approach appear to have hampered progress in this direction.

2.4 Interindustry Linkages

After briefly discussing transfer economies and external economies as locational factors, it is now necessary to relate them to interindustry linkages and to indicate in which manner these linkages can be utilized as proxy measures for a tendency toward agglomeration of industries.

2.4.1 Locational Aspects of the Division of Labour. As an economy develops, a greater degree of specialization and a division of functions among industries will substantially increase inter-firm transportation of commodities. Spatial separation from complementary and auxiliary industries becomes a costly 'luxury', giving rise to transport agglomeration as a locational consideration.[1]

However, greater specialization does not only lead to agglomeration via transfer economies; the process of growth and maturation of industries is accompanied by a 'farming out' of functions that were all carried out in one firm before.[2] The resulting technological interdependence of activities carried out in different firms or industries may lead to technological and pecuniary externalities of the immobile type. As mentioned above, their appropriation requires spatial juxtaposition. Both types of agglomeration economies,

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[1]George Stigler, "The Division of Labor", p. 158.

[2]*Ibid.*, p. 154.

transfer economies and external economies, can thus be viewed as a result of specialization and division of labour--the result of the development of the economy.

2.4.2 Reflection in Input-Output Table. Interindustry linkages can be computed from a square, i.e. interindustry, input-output table. Such a table shows, in matrix form, the values of commodity flows between producers and users. Linkages are coefficients that relate the size of particular input (output) flow to the total size of the input (output) flow of an industry. While a more detailed discussion of interindustry analysis, as it relates to this study, and of various linkage measures may be found below, it is sufficient to point out here that linkages are percentage figures that give an indication of the relative magnitude of a commodity flow between two industries either as a proportion of total inputs of the purchasing industry (backward linkage) or as a proportion of the total output of the producing industry (forward linkage). These linkages will exist only in a developed economy where division of labour has led to an abandoning of certain functions and the establishment of new, specialized industries that are structurally related to the original industry. Linkages are thus numbers which indicate the existence of multi-faceted interdependencies in an economic system.

2.4.3 Linkages, Transportation, Agglomeration. While input-output linkages express structural relationships between industries and thus indicate the channels along which we can expect immobile external economies to flow, their primary locational significance appears to derive from the fact that the existence of strong linkages implies large flows of inputs or outputs and thus, with some qualifications, high transfer costs. High transfer costs mean great advantages from agglomeration. A direct, systematic relationship between industrial linkages and the locations of the linked industries would establish these linkages as locational factors, or more precisely, as agglomerative locational factors.

2.4.4 Assessment of Importance. Dealing with interdependencies in the locational decisions of firms in a theoretical context, Koopmans has pointed out that "...there is no doubt about the existence and importance of transportation cost or of intermediate commodities."[1] As the empirical test of this statement is the subject of the subsequent analysis, an assessment of the importance of linkages as agglomeration economies will have to await the results of the tests.

However, in the survey of the literature below the findings of of other studies on linkages and location are reported and discussed.

[1]Tjalling C. Koopmans, Three Essays, p. 154.

3. EMPIRICAL FOUNDATIONS OF THE ANALYSIS

This chapter falls into four major parts: a characterization and discussion of the data, a discussion of the measures of linkage and spatial concentration, an outline of the methodology employed in the analysis, and a brief survey of the literature on agglomeration in general and linkages and agglomeration in particular.

3.1 Interindustry Data

3.1.1 Data Source and Comments on Data. The interindustry data used in this study are based on the published 1961 input-output tables for the Canadian economy.[1] The 1961 input-output tables differ from conventional interindustry models in that a dual classification of inputs and outputs according to industry and commodity is employed.[2] Moreover, the one-to-one correspondence between an industry and its principal product has been abandoned, allowing for more than one characteristic product for each industry. Hence the basic transaction matrices, listing intermediate commodity inputs into industries

[1]Canada, Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961, Vols. 1 and 2 (Ottawa: The Queen's Printer, 1969).

[2]These remarks are based on Canada, D.B.S., The Input-Output Structure, Vol. 1, p. 34.

and industries' intermediate outputs of commodities, and the coefficient tables derived from them, are rectangular rather than square, the number of commodities exceeding the number of industries. Inputs and outputs of the various industries are shown in separate tables. This arrangement, advantageous for many analytical uses of the tables,[1] has some technical implications for this study.

The calculation of linkage coefficients requires, as a starting point, an interindustry flow matrix. The procedure for obtaining this matrix will be outlined after a discussion of the industry and commodity classifications used and of the importance of the aggregation level.

3.1.2 The Degree of Aggregation. The input-output industrial classification at the worksheet detail IOIC-W, is an aggregation on the basis of the Canadian Standard Industrial Classification (S.I.C.).[2] There are 187 input-output industries at the level of detail of IOIC-W; many of them correspond to "three-digit" and "four-digit" S.I.C. industries while others are aggregations of S.I.C. industries. From the worksheet detail industries were further aggregated into IOIC-L (110 industries), IOIC-M (65 industries), and IOIC-S (16 industries; for these classifications certain tables have been published.

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[1]See Canada, D.B.S., The Input-Output Structure, Vol. 1, chapt. 3 and App. B.

[2]See Canada, D.B.S., Standard Industrial Classification Manual (Ottawa: The Queen's Printer, 1960), Cat. No. 12-501 and Canada, D.B.S., The Input-Output Structure, Vol. 1, p. 97, pp. 113-114, and p. 119.

With few exceptions the input-output commodity classification at the worksheet detail, IOCC-W, represents an aggregation of commodities from the Standard Commodity Classification. Commodities are also classified according to the Import Commodity Classification and the Export Commodity Classification.[1] The input-output commodity classification number consists of a sequential listing of the commodities; each commodity number is preceded by the number of the principal producing industry.[2] Since a commodity may be produced by more than one industry, a grouping of commodities may not correspond to any one particular industry. From the detail of IOCC-W commodities were further aggregated into IOCC-L (197 commodity groups), IOCC-M (65 commodity groups), and IOCC-S (40 commodity groups).

In this study the industry detail of IOIC-L, i.e. 110 industries, is used. The reasons for this choice are threefold; firstly, this aggregation is the one with the largest industrial detail for which published tables are available or obtainable; secondly, it is the smallest aggregation that can be made to conform with the geographical data discussed below; thirdly, and most importantly, it still shows industries as relatively homogenous bodies which is important--if not imperative--in linkage analysis, especially when the industrial data are to be combined with geographical data for the purpose of a locational study. Greater aggregation leads to heterogeneous industry

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[1]See Canada, D.B.S., Standard Commodity Classification Manual (Ottawa: The Queen's Printer, 1959), Cat. No. 12-515, Canada D.B.S., Import Commodity Classification (Ottawa: The Queen's Printer, 1964), Cat. No. 12-524, Canada, D.B.S., Export Commodity Classification Ottawa: The Queen's Printer, 1961), Cat. No. 12-521.

[2]See Canada, D.B.S., The Input-Output Structure, pp. 119-120.

groups or sectors with the result that interindustry linkages may be created or eliminated merely by virtue of pooling intermediate commodity flows.[1] This clearly would be an undesirable situation. The greater the degree of aggregation the less meaningful will be any statements on the agglomerative effect of interindustry linkages.

The analyst must also be aware of the fact that both backward and forward linkages are affected by the degree of aggregation. This applies particularly to linkages emanating from primary industries and having their destination in the manufacturing sector, or vice versa. Especially forward linkages may be distorted early in the production sequence since the industrial detail of any input-output table typically increases from the early to the late stages of production.

Thus a forward linkage from, say, a primary industry to a secondary-manufacturing industry may disappear when this latter industry is split into two in a way that also divides the commodity flow into equal parts. Neither flow may then be of the required size relative to the total output of the primary industry to constitute a linkage. The increase in the number of industries will not usually compensate for the disaggregation.[2] While this problem is inherent in the data,

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[1]E.g., for industries i, j, k, l: Linkage eliminated: i just has forward linkage (f) to k, j has no f to k, (i+j) has no f to k; linkage established: i has no f to k, i has no f to l, but i has f to (k+l).

[2]A backward linkage (b) or a forward linkage (f) may be defined to exist if b, f $\geq 1/n$, where n is the number of industries in the input-output table. See the discussion of linkage measures for more detail.

it is not as serious here because this study, for reasons explained below, confines itself to linkage relationships within the manufacturing sector.

While it is beyond the scope of this study to treat problems of aggregation in detail, it may be pointed out that the degree of aggregation greatly affects the accuracy of an input-output analysis.

> "The hypothesis that the inputs of industries will be proportional to their outputs irrespective of the commodity composition of these outputs becomes less tenable as the definition of industries broadens. When industries are defined narrowly so that each produces only a few commodities which have similar input structures the industry technology assumption is more justifiable."[1]

These remarks apply not only to one of the fundamental assumptions of input-output, the invariability of the technological input coefficients, but also to other coefficients that can be computed from the basic transaction matrix.

3.1.3 The Interindustry Transaction Matrix. In order to show how the basic interindustry flow matrix was obtained, it is necessary to make a few remarks about the 1961 Canadian input-output model. Since the Canadian input-output publications contain an excellent and detailed outline of the input-output models the discussion here may be kept quite brief.[2] The D.B.S. notation will be used.[3] As was noted above

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[1]Canada, D.B.S., The Input-Output Structure, Vol. 1., p. 95.

[2]The following discussion is based on Canada, D.B.S., The Input-Output Structure, Vol. I, Appendix A which provides a detailed account of the 1961 Canadian input-output framework.

[3]For a list of symbols see Canada, D.B.S., The Input-Output Structure, Vol. I, pp. 157-164. See also the remarks on p. 134.

in Section 3.1.1, the 1961 input-output model differs in several respects from the conventional interindustry framework.[1] Parallels between the two frameworks will be pointed out.

Leaving aside the assumption which rules out externalities the two fundamental assumptions of Leontief models are:

> "(1) *Each commodity (or group of commodities) is supplied by a single industry or sector of production.* Corollaries of this assumption are (a) that only one method is used for producing each group of commodities; and (b) that each sector has only a single primary output.
>
> (2) *The inputs purchased by each sector are a function only of the level of output of that sector.* (The stronger assumption is usually made that the input function is linear, but this is a matter of convenience.)"[2]

The adoption in the Canadian model of the dual classification industries/commodities results in abandonment of the first assumption above. Not only may a certain commodity be supplied by several industries using different technologies, but each industry may have more than one principal product or output. The second assumption above has a direct parallel in the Canadian input-output model; this will become clear after the following discussion.

The basic 1961 input-output model involves two fundamental assumptions: the market share assumption and the industry technology assumption. The market share assumption, which may be given mathematical expression as

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[1]A description of the conventional Leontief model may be found, for example, in Hollis B. Chenery and Paul G. Clark, Interindustry Economics, chapt. 2.

[2]Hollis B. Chenery and Paul G. Clark, Interindustry Economics, pp. 33-34.

(3.1) $g = Dq$

where[1]: g - column vector of total industry outputs classified by industry

q - column vector of total commodity outputs classified by commodity

V - matrix containing the outputs of industries classified by industry (rows) and by commodity (columns)

D - market share matrix of domestic production obtained by dividing each element in a column of the output matrix V by the corresponding total commodity output, i.e.

$$D = V(\hat{q})^{-1},$$

allocates the production of commodities among industries ("^" indicates a diagonal matrix). This assumption states that industries will preserve their observed share of the market for each commodity at any level of commodity production. The industry technology assumption, which may be expressed mathematically as

(3.2) $Ui = Bg$

where: i - column vector all of whose elements are equal to one

U - matrix containing the intermediate inputs of industries classified by commodity (rows) and by industry (columns)

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[1]See Appendix 1 for a complete list and definition of symbols used in this study. The above symbols have been defined in Canada, D.B.S., The Input-Output Structure, Vol. 1, pp. 157-164; a diagram of the interindustry framework may be found on p. 136 of this volume.

B - technology matrix containing the intermediate input coefficients of industries obtained by dividing each element in a column of matrix U by the corresponding total industry output, i.e.

$$B = U(\hat{g})^{-1},$$

specifies the production functions of industries. This form of production function states that "the values of commodity inputs of each industry are fixed proportions of the value of the total output of the industry and are thus independent of the composition of this output."[1] It should be noted that a combination of the industry technology assumption and a modified version of the market share assumption are equivalent to the conventional assumption in interindustry models which states that the flows from producing industries are proportional to the levels of output of the purchasing industries.[2]

A modification of the market share assumption is required because interindustry models assume that industries and imports will retain their share of the market for each commodity sold to each industry and each category of final demand while the market share assumption of the 1961 model states that industries and imports will preserve their overall share of the market for each commodity.[3] This latter assumption appears to be much more flexible and realistic.

By combining the above equations with the accounting balance between commodity production and intermediate plus final demand less

[1]Canada, D.B.S., The Input-Output Structure, Vol. 1, p. 137.

[2]Ibid., p. 146.

[3]Ibid., p. 147.

imports, the basic input-output models may be defined.[1] The accounting equation may be written as

$$(3.3) \quad q = Bg + e$$

where: q - column vector of commodity outputs

B - technology matrix

g - column vector of industry outputs

e - column vector containing total final demand for competing commodities classified by commodity, less competing imports classified by commodity.

Substitution of (3.1) into (3.3) yields

$$(3.4) \quad q = BDq + e$$

which states that total commodity output is equal to intermediate commodity use plus final demand commodity use. The matrix product BD may be termed the direct intercommodity coefficient matrix in analogy to the matrix of direct interindustry input coefficients. Coefficients of BD specify commodity inputs per unit of commodity output. The dimensions of this square matrix are thus equal to the number of commodities (e.g. 197 x 197 for Aggregation L). By contrast, the matrix of direct interindustry input coefficients would have the dimensions of the number of industries (e.g. 110 x 110 for Aggregation L); this would

[1]For further detail see Canada, D.B.S., The Input-Output Structure, Vol. 1, p. 138.

be the matrix product DB.

Modification of (3.4) yields the following expressions

$$q - BDq = e$$

$$q(I - BD) = e$$

and finally

3.5 $$q = (I - BD)^{-1}e$$

which may be called the commodity input-output model. To obtain the industry input-output model (3.5) may be substituted into (3.1) to yield

3.6 $$g = D(I - BD)^{-1}e$$

or, alternatively, by substituting (3.3) into (3.1)

3.7 $$g = (I - DB)^{-1}De.$$

Having provided the basic assumptions and equations of the 1961 input-output model it is now necessary for the purpose of this study to proceed to an endogenous treatment of competing imports.[1] This is desir-

[1]For a more detailed treatment of competing imports in the input-output model see Canada, D.B.S., The Input-Output Structure, Vol. 1, pp. 141-144.

able because it makes the interindustry flow table and the coefficient matrix comparable to those of other studies and to the 1949 Canadian interindustry transaction matrix X and the direct coefficient matrix A. The endogenous treatment of competing imports in the 1961 model involves an extension of the market share assumption to competing imports, i.e. the imports of competing commodities will constitute a fixed proportion of the total supply of each commodity; mathematically,

$$(3.7) \quad m = \hat{\mu}(q + m)$$

where: m - column vector of competing imports classified by commodity

$\hat{\mu}$ - diagonal matrix of coefficients indicating the ratio of total imports to total supply for each

and the vector sum $(q + m)$ denoting the total supply of commodities.

The incorporation of (3.7) into the model formed by (3.1) and (3.3) results in the interindustry model

$$(3.8) \quad g = [I - D^*B]^{-1}D^*e^*$$

where: $D^* = D(I - \hat{\mu})$

$e^* = e + m.$

In this model the market share matrix is $D^* = D(I - \hat{\mu})$ which expresses the market share of industries as a proportion of the total supply of each commodity rather than as a proportion of the domestic production of each commodity, i.e. import leakages are built into the market share matrix.

It may be pointed out that model (3.8) is comparable with the conventional input-output model

$$X = (I - A)^{-1}Y.$$

Comparable to the interindustry transaction matrix X is thus the matrix product D*U (where U is the matrix of intermediate inputs of industries classified by commodity and by industry) and D*B is equivalent to the interindustry matrix of direct input coefficients A.[1] These matrices had to be obtained as the starting point for the purpose of this study.

For Aggregation L the published tables include the matrices U and B. Matrices D* or D and $\hat{\mu}$ are not published because of confidentiality requirements. However, the matrix products D*U and D*B were made available by Statistics Canada.[2] They form the basic interindustry data.

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[1]D*e* becomes the final demand vector of a dimension equal to the number of industries.

[2]The matrix products were made available in magnetic tape form by Mr. C. Gaston, Input-Output Research and Development, Statistics Canada, Ottawa in November 1971.

3.2 Spatial Data

3.2.1 Data Source and Comments on Data. The spatial information is supplied by data derived from the Census of Canada, 1961.[1] Inter-industry data and spatial data are thus based on the same year. The data show the number of employed, i.e. labour force fifteen years of age and over,[2] by three-digit S.I.C. industries for Census Metropolitan Areas (CMAs) in Canada. The employment figures, as all 1961 Census data, are based on the place of residence rather than the place of employment. As this study is concerned with the latter, i.e. the location of the firm, which is not necessarily coincident with the place of residence of the employed, a bias might be introduced into the analysis. The choice of areal units, however, mitigates the problem; this issue will be discussed further below. The employment data thus are taken to express the magnitude of an industry's operation in a particular geographical area. It should be noted that, to the extent that regional differences in productivity exist, employment data will not accurately reflect an industry's capacity or value added. It is assumed that this problem will not seriously affect the results of this study.

3.2.2 Types of Regions. The regions include the eighteen Canadian

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[1]Canada, D.B.S., Census of Canada, 1961: Labour Force: Industries, Vol. III, Part 2, Cat. No. 94-519.

[2]This excludes a few persons seeking work who have never been employed.

Census Metropolitan Areas.[1] Except for two areas their population is well over 100,000. While minute in area compared to the rest of the settled part of Canada, they contain almost half of the total Canadian population (45.83 per cent). Their share of manufacturing employment is even larger: almost sixty per cent of all Canadian manufacturing is located in these centres (58.45 per cent). Clearly, manufacturing industries are concentrated in these urban regions and a study of agglomeration must be primarily a study of these areas.

The spatial extent of the study areas themselves is disregarded and a location of two industries in the same CMA is considered to be a location at the same point. The industries are then said to be geographically associated.

The detrimental effect of the aforementioned divergence between place of residence and location is minimized in this study. For contrary to the boundaries of municipalities or counties which are determined by political jurisdictions, the boundaries of CMAs are drawn according to economic criteria.[2] Theoretically two possible biases could result. Firstly, two linked industries i and j may be located in the same area; the employees of i also live in the area while those of j do not. Analysis would show i and j not to be geographically associated while in reality they are. Secondly, the employees of both i and j live in the area but j is located outside the area.

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[1]See Table 2, p. 53; there are a number of M.U.A.'s with a population of over 100,000 but the required industrial detail is not available for these urban centres.

[2]See Canada, D.B.S., Census of Canada, 1961: Population: Introductory Report to Volume I (Part 1), Vol. I, Part 1, Cat. No. 92-540, p. XI.

TABLE 2

POPULATION AND MANUFACTURING EMPLOYMENT DATA

FOR CENSUS METROPOLITAN AREAS, 1961[a]

Census Metropolitan Area	Population	Population as Percentage of Total Cdn. Pop.	Manufacturing Employment	Manuf. Empl. as Percentage of Total Cdn. Manuf. Empl.
Calgary	279,062	1.53	13,065	0.93
Edmonton	337,568	1.85	17,574	1.25
Hamilton	395,189	2.17	61,035	4.34
London	181,283	0.99	18,328	1.30
Montreal	2,109,509	11.57	254,697	18.10
Ottawa	429,750	2.36	17,845	1.27
Quebec	357,568	1.96	23,780	1.69
Regina	112,141	0.61	4,537	0.32
Toronto	1,824,481	10.00	233,681	16.61
Vancouver	790,165	4.33	57,725	4.09
Windsor	193,365	1.06	24,597	1.75
Winnipeg	475,989	2.61	38,439	2.73
Halifax	183,946	1.01	74,720	0.53
Kitchener	154,864	0.85	29,343	2.09
St. John's	90,838	0.50	2,808	0.20
Saint John	95,563	0.52	6,744	0.48
Sudbury	110,694	0.61	4,998	0.36
Victoria	154,152	0.85	6,412	0.42
Total	8,276,129	45.83	890,328	58.45

[a]Calculated from: Canada, D.B.S., Census of Canada, 1961: Labour Force: Industries, Vol. III, Part 2, Cat. No. 94-519; Canada, D.B.S., Census of Canada, 1961: Population: Geographical Distributions, Vol. I, Part 1, Cat. No. 92-535.

The result would show the linked industries to be geographically associated while in reality they are not. Casual observation would suggest that the former case is more important; it would result in a conservative bias, i.e. in an understatement of the relationship between interindustry linkages and the location of industries. This is preferable to the opposite case which would involve an overstatement of the results. Moreover, the boundary considerations for metro areas suggest that the problem would be of little importance. It will therefore subsequently be ignored.

3.2.3 Comparability of Aggregations. The industrial detail of the Census material for CMAs is greater than that of IOIC-L. As the industrial breakdown in the Census is also based on the Standard Industrial Classification, it was possible to aggregate Census data further and arrive at an industrial detail equivalent to Aggregation L with 110 industries, 86 of which are manufacturing industries.[1] The Census category "Industry unspecified or undefined" was ignored for the purpose of this study.

3.2.4 Alternatives to the Use of Employment Data. The selection of the variable that will measure the phenomenon to be investigated is an issue requiring brief discussion. The magnitude to be measured is the volume of manufacturing in the various industries. Given two linked industries, it is this volume which determines the interindustry flow of commodities between them.

[1]See Appendix 2 for a comparison of industrial classifications.

From the above it is obvious that the "number of persons employed" by the various industries has been chosen as the variable. An alternative variable, judged superior by some authors,[1] is the "value added in manufacturing". It may be argued that value added is a variable more directly associated with the phenomenon under investigation. However, as is so often the case in social sciences, also here data availability forces adoption of the second-best variable.[2] This is not a serious matter because studies have shown a high degree of correlation between "number of workers employed" and "value added".[3] This result is reinforced by Fuchs who found--studying the importance of manufacturing among industries and geographical areas in a somewhat different context--that both variables correctly indicated the locational changes that had occurred.[4]

A final variable to be mentioned is the number of firms. This variable must be disqualified on two grounds: firstly, no sufficient data are available; secondly, and more fundamentally, the mere number of firms does not reflect great variations in the size of the firms and is therefore not a suitable measure for the volume of manufacturing.

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[1]Victor R. Fuchs, "Changes in the Location of U.S. Manufacturing Since 1929," Journal of Regional Science, Vol. I, No. 2 (Spring 1959) p. 4.

[2]Canada, D.B.S., The Manufacturing Industries of Canada, 1961: Geographical Distribution (Ottawa: The Queen's Printer, 1964), Cat. No. 31-209 and Canada, D.B.S., General Review of the Manufacturing Industries of Canada, 1961 (Ottawa: The Queen's Printer, 1965), Cat. No. 31-201.

[3]See Harold H. McCarty, John C. Hook, and Duane S. Knos, The Measurement of Association in Industrial Geography (Iowa City: State University of Iowa, n.d.), p. 17.

[4]Victor R. Fuchs, "U.S. Manufacturing", Table 6.

3.2.5 The Matrix of Employment Figures. Compilation of the employment data by industry (rows) and geographical areas (columns) yields the matrix of spatial data L of the dimension 86 x 18 with the typical element ℓ_{ik}, denoting the employment in industry i in region k. A row sum, i.e. summing over the columns, gives the total employment in industry i, where $\ell_{i.} = \sum_k \ell_{ik}$. A column sum shows total manufacturing employment in region k, where $\ell_{.k} = \sum_i \ell_{ik}$. L is the basic matrix for the calculation of measures of spatial association between manufacturing industries.

3.3 Measures of Industrial Linkage

In this section a number of linkage coefficients will be discussed and some properties of the linkage measure adopted will be indicated.

3.3.1 Types of Linkage Measures. On the basis of an interindustry transaction matrix, or on the basis of matrices derived from it, indices may be devised that measure the strength of the relationship between one industry and one or more other industries.

Constructing the linkage concept in an economic development context Hirschman has defined backward and forward linkage effects as follows:

> "1. The input-provision, derived demand, or *backward linkage effects*, i.e. every nonprimary activity, will induce attempts to supply through domestic production the inputs needed in that activity.
> 2. The output-utilization or *forward linkage effects*, i.e., every activity that does not by its nature cater exclusively to final demands, will induce attempts to utilize its outputs as inputs in some new activities."[1]

[1]Albert O. Hirschman, Strategy, p. 100.

These linkage effects have been given quantitative expression by Chenery and Watanabe in a comparative study that sought to determine how the various sectors "scored" with regard to the development stimulus (via linkage effects) that can be expected from them.[1] The backward linkage of industry j may be defined as

$$u_j = \frac{U_j}{X_j} = \frac{\sum_i X_{ij}}{X_j}$$

and the forward linkage of industry i as

$$w_i = \frac{W_i}{Z_i} = \frac{\sum_j X_{ij}}{Z_i}$$

where: U_j - total use by industry j of inputs purchased from other industries (i.e. column sum j of flow matrix)

X_j - total production by industry j; $X_j = U_j + V_j$, where V_j is the total of primary inputs, or value added, of j.

X_{ij} - interindustry flow from industry i to industry j, with i, j = 1, 2, ..., n

W_i - total use by other industries of the output of industry i (i.e. row sum i of flow matrix)

Z_i - total supply of commodity i; for imports M and final demand Y, $Z_i = W_i + Y_i = M_i + X_i$.[2]

Thus u_j shows the extent to which industry j draws directly on the system by relating the sum of inputs purchased by industry j from all

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[1] Hollis B. Chenery and Tsunehiko Watanabe, "International Comparisons of the Structure of Production", Econometrica, Vol. 26, No. 4 (Oct. 1958), p. 492.

[2] For a more detailed interindustry accounting system see Hollis B. Chenery and Paul G. Clark, Interindustry Economics (New York: John Wiley & Sons, Inc.), pp. 14 ff.

other industries (including itself) to the total value of inputs. The coefficient w_i indicates the importance of industry i to the system of industries by expressing the proportion of the total supply of commodity i that constitutes sales to other industries (including industry i itself). These indices reflect only direct relationships between one industry and its linked industries.

A more complex set of linkage coefficients has been developed by Rasmussen.[1] These are the "power of dispersion" (analogous to backward linkage) and "sensitivity of dispersion" (corresponding to forward linkage). But instead of being based on the transaction matrix X, they are based on, respectively, the column and row sums of the inverse of the direct and indirect coefficient matrix $(I-A)^{-1}$. Both indices are expressed in the form of normalized averages in order to make them suitable for interindustry comparisons. A power of dispersion coefficient $D_j > 1$ indicates then that industry j draws heavily on the system, both directly and indirectly. A sensitivity of dispersion coefficient $S_i > 1$ shows that the output of industry i will have to be increased more than that of other industries in response to an increase in demand for the product of any industry. It has been shown that there is a high degree of coincidence in the presence of u_j and D_j on the one hand and of w_i and S_i on the other hand.[2]

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[1]These remarks are based on Paul N. Rasmussen, Studies in Intersectoral Relations (Amsterdam: North Holland Publishing Company, 1957), pp. 133-140.

[2]See Dimitri Sakellariou, "Industrial Linkages: A Case Study" (unpublished Ph.D. dissertation, University of Alberta, 1972), p. 95.

It will be noted that both sets of linkage coefficients are summary measures, relating one industry to all of its linked industries. They are, as it were, multilateral indices which conceal the strength of the technological links between any pair of industries. The summation of the interindustry flows, while perhaps establishing an industry as a key industry, destroys detailed information on the nature of the relationship between any two industries; it is this information that is of locational significance. Needed then is a set of bilateral linkage coefficients.

Following a suggestion by Leontief,[1] an industry j may be considered to have a backward or supply linkage to industry i if, in an input-output table of size n x n, the purchase of intermediate inputs of j from i are at least 1/n of the total inputs of j. Correspondingly, industry j may be said to have a forward or demand linkage to industry k if, in an input-output table of dimension n x n, the sales of j to k are equal to or larger than 1/n of the total output of j. Given the 110 industries in the Canadian input-output table, two industries are considered to be linked if the linkage coefficient is at least 0.0091 (b_{ij}, $f_{ji} \geq 0.0091$), i.e. industry j has a backward linkage to industry i if it buys at least .91 per cent of its intermediate inputs from i; it has a forward linkage to i if it sells at least .91 per cent of its output to industry i. While the basic idea of Leontief's proposal is retained, a modification is made with regard to the 'Bezugsgrösse', i.e., the denominator, in the definition of the

[1] Wassily Leontief, "The Structure of the U.S. Economy", in Wassily Leontief Input-Output Economics, p. 163.

backward linkage. In order not to have this coefficient distorted by peculiarities in the primary input field, e.g. extremely high or low labour intensity, the denominator chosen is the sum of all intermediate inputs U_j, rather than total of all inputs X_j.[1] The backward linkage coefficient of industry j to industry i may then be defined as

$$b_{ij} = \frac{X_{ij}}{U_j} .$$

As the forward linkage coefficient addresses itself to the importance of an interindustry flow in the disposition of total output, including final demand, the forward linkage of industry j to industry k is expressed as

$$f_{jk} = \frac{X_{jk}}{X_j} .$$

These two indices, used to measure interindustry linkages in this study, may be briefly contrasted with two other types of bilateral linkage coefficients. Richter adopted coefficients that relate the size of an interindustry flow to gross inputs or gross outputs.[2] In fact, these coefficients are simply the direct input coefficients and the percentage figures showing the distribution of gross output.[3]

[1]This adjustment was also made by Manfred E. Streit, Über die Bedeutung des räumlichen Verbunds im Bereich der Industrie (Köln: Carl Heymanns, Vertag K.G. 1967), p. 48.

[2]See Charles E. Richter, "The Impact of Industrial Linkages on Geographic Association" (unpublished Ph.D. dissertation, University of Illinois, 1968), pp. 19 and 22.

[3]See Morris R. Goldman, Martin L Marimont, and Beatric N. Vaccara, "The Interindustry Structure of the United States", Survey of Current Business, XLIV, (Nov. 1964), Tables 1 and 2.

This approach is judged less preferable on a number of grounds. Firstly, both backward and forward linkages are affected by not having imports treated endogenously, i.e. by not having import leakages built into the input-output matrix; this may seriously distort the coefficients for industries with high import shares. Secondly, the backward linkage coefficients, being the same as the direct input coefficients, are related to X_j rather than U_j. This leaves them open, as was mentioned above, to unpredictable distortions due to industrial differences in the relative size of primary input items, e.g. wages and salaries, taxes and subsidies, profits, etc. These influences may greatly impair interindustrial comparability of the coefficients. It would appear preferable to express the linkage measures in a manner which confines their component parts to magnitudes that have significance as locational factors and attempt to exclude as many non-relevant influences as possible. The coefficients adopted for this study meet these requirements.

A final linkage coefficient to be mentioned is the one used by Streit.[1] This is a symmetric bilateral coefficient that may be written as

$$s_{ij} = \frac{1}{4}\left[\frac{X_{ij}}{U_j} + \frac{X_{ji}}{U_i} + \frac{X_{ij}}{X_i} + \frac{X_{ji}}{X_j}\right].$$

It was adopted in order to parallel the symmetric coefficient measuring geographic association (to be discussed below). This type of weighting is of course very arbitrary and it is not altogether clear what impact it may have on the summary values of s_{ij}, given various

[1]Manfred E. Streit, Verbunds, p. 49.

combinations of backward and forward individual linkage values. In any case, the weighting will alter and conceal the true magnitude of each individual linkage relation.

3.3.2 Some Comments on Properties of the Linkage Measures. A number of remarks on linkage properties were made above. These related to the meaning of linkage coefficients and the effects on them of aggregation.[1] The final part of Section 3.1.2 alluded to the invariance of input coefficients under scale changes due to the specialized fundamental input-output technology assumption. The invariability also extends to the backward linkage coefficients b_{ij}. This means that if a commodity flow X_{ij} increases because of a scale change in industry j, industry i will appear as having a stronger forward linkage f_{ij} to industry j while the strength of the supply linkage relation appears unchanged; it is solely determined by the production function. The increase in X_{ij} can be effected by industry i in two ways: firstly, industry i raises its output and sells the additional output to j and/or secondly, industry i, keeping its output constant, sells more to i and less to its other customers. Static input-output assumptions allow, *cet. par.*, only for the first possiblity. The point to be noted is that an increase in X_{ij} raises the relative size of this flow for industry i, *cet. par.* This change should be, and is, reflected in an increase in the forward linkage. The scale change in industry j, however, leaves the relative magnitudes of its various input flows undisturbed. There is thus no reason for the value of b_{ij} to change.

[1]See Sections 2.4.2 and 3.1.2 resp.

Two points must be made regarding the accuracy with which linkage coefficients can express the locational importance of particular commodity flows.[1] First, since the entries in the transaction matrix are expressed in value terms rather than in terms of weight or volume, the linkage measure may misrepresent the agglomerative importance of any flow of commodities that differs with respect to its ease of transportation from an "average" or "standard" commodity. Underestimation will occur in the case of weight-losing materials, low-value commodities, and bulky or fragile goods requiring relatively high transportation costs. On the contrary, agglomerative tendencies may be overestimated in the case of light-weight, compact, or high-value commodities. Second, it may be possible that a comparatively weak link of an industry seems to exert a much greater locational pull than that industry's stronger linkages. The reason may be found in certain characteristics of the production technology that require spatial proximity without primary regard to the value flow of commodities. This may be the case for satellite industries in a petrochemical complex.[2] These problems were not judged to be serious for the purpose of this study. In any case, they could not be avoided because their solution would require consideration in the analysis of

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[1]These remarks are based on Manfred E. Streit, Verbunds, pp. 50-51.

[2]See Manfred E. Streit, "Spatial Associations and Economic Linkages Between Industries", Journal of Regional Science, Vol. 9, No. 2 (August 1969), p. 179.

transport input data[1] and of data on the transport sensitivity of industries. Such data do not exist.

3.3.3 Restriction of Analysis to Manufacturing Industries. The analysis of the impact of input-output linkages on the agglomeration of industries had to be restricted to manufacturing industries. The primary sector was excluded because the location of its industries is pre-determined--industries are perfectly immobile and their location is tied to the source or location of the natural resource.

While the location of service industries is not fixed by physical necessity, as is the case for agricultural or mining activities, their location may be considered pre-determined because of economic factors. Compared with primary and secondary industries, the physical input-output flows of tertiary industries are very small[2] and inter-industry linkages will be of little locational significance for them. These industries are strongly market- or population-oriented. Together with the construction industry the tertiary sector was excluded from the analysis. Dummy industries were, for obvious reasons, ignored.

3.4 Measures of Spatial Association of Industries

After a brief description of an alternative measure of spatial association the measure adopted, and statistical issues connected with it, will be discussed in greater detail.

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[1]Published input-output data on transportation costs cannot be used because they merely reflect, in aggregated form, the actual transportation costs incurred by the various industries during a particular year in the production process. They do not provide any information on the transportation characteristics of commodities or the transport sensitivity of industries.

[2]See Canada, D.B.S., The Input-Output Structure, Vol. 1, pp. 264-265.

3.4.1 Types of Spatial Measures. While a great number of coefficients have been designed to measure the geographic distribution of economic activities,[1] the only possible alternative to the measure adopted here is the coefficient of geographic association.

The coefficient of geographic association (g) was developed by P. Sargant Florence in 1939 and applied in industrial location studies by Florence as well as by other authors.[2] The coefficient of geographic association, intended to show the locational closeness between pairs of industries, may be calculated as

$$g_{ij} = 1 - \sum_k d_k \qquad d_k > 0$$

where: $d_k = \frac{\ell_{ik}}{\sum_k \ell_{ik}} - \frac{\ell_{jk}}{\sum_k \ell_{jk}}$ is the difference in employment proportions for industries i and j in region k $(k = 1, 2, \ldots, m)$

ℓ_{ik} - employment in industry i in region k

ℓ_{jk} - employment in industry j in region k.

The range of the coefficient of geographical association is $0 \leq g_{ij} \leq 1$, with 0 indicating complete absence of association and 1 indicating perfect association. There are various ways of stating this coefficient, resulting in differences in ranges and po[illegible]

[1]See Walter Isard, Methods of Regional Analysis: an Introduction to Regional Science (Cambridge, Mass.: M.I.T. Press, 1960), pp. 249ff.

[2]Political and Economic Planning, Report on the Location of Industry (London: Political and Economic Planning, 1939), pp. 292-293; Florence's study will be commented on in the review of the literature below. This coefficient will not be employed here.

reversal of the maximum value to zero; the essential feature, however, the comparison of the percentage distributions of employment by regions for pairs of industries, is common to all.

McCarty, Hook, and Knos, in a thorough study on the measurement of geographic association, advanced several criticisms of the coefficient of geographic association.[1] First, this coefficient neither measures the extent to which the employment proportions vary together nor does it indicate the degree of association between them.

> "Contrary to its name, the coefficient of geographic association does not measure association as such; it is simply a value which indicates the reciprocal of that portion of one variable which would have to be moved across statistical unit boundaries in order to make its distribution identical with that of the other variable."[2]

McCarty, Hook, and Knos show that even if two series vary in an unsystematic manner, a high coefficient may be obtained. Second, while the value of the coefficient should not be affected by differences in the absolute sizes of the variable, a higher coefficient can in fact be obtained by adding a constant to each variable of one series, e.g. to the employment in industry i in all regions. Third, the coefficient of geographic association cannot indicate inverse relationships between the two series. Finally, fourth, the authors list an objection raised by Kendall.[3] He pointed out that no statist-

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[1]The subsequent discussion is based on Harold H. McCarty, John C. Hook, and Duane S. Knos, <u>The Measurement of Association in Industrial Geography</u> (Iowa City: State University of Iowa, n.d.), pp.31-44.

[2]<u>Ibid.</u>, p. 31.

[3]See Maurice G. Kendall's comment on Florence's "The Selection of Industries Suitable for Dispersion into Rural Areas", <u>Royal Statistical Society Journal</u>, Vol. 107 (1944), pp. 93-116.

ical inferences could be drawn using g because nothing was known about its sampling distribution. A further criticism by Kendall--that any value of g could be obtained by shifting the boundaries of regions covering a country--should be discounted since such boundaries usually remain fixed over long periods of time. McCarty, Hook, and Knos conclude that the coefficient of geographic association, while performing well under certain circumstances, is definitely inferior as a measure of locational closeness and covariability to the Pearson product moment coefficient of correlation.

As noted above, the objective is to measure the extent of spatial association between pairs of industries. The classical tool for determining the association between two sets of variables is the correlation coefficient. In this study the correlation coefficient expresses the locational affinity between pairs of industries by measuring the degree of covariability in industry employments[1] over the metro regions. Whenever employment in industry j is large when it is large in industry i, and low in j when it is low in i, the correlation coefficient will be large and positive. The correlation coefficient between industries i and j (r'_{ij}) may be calculated as

$$r'_{ij} = \frac{\sum_k (\ell_{ik} - \bar{\ell}_i)(\ell_{jk} - \bar{\ell}_j)}{\sqrt{\sum_k (\ell_{ik} - \bar{\ell}_i)^2 \sum_k (\ell_{jk} - \bar{\ell}_j)^2}} = \frac{\sigma_{\ell_i \ell_j}}{\sigma_{\ell_i} \sigma_{\ell_j}}$$

where: ℓ_{ik} - employment in industry i in region k

[1]For reasons explained below, employment proportions rather than absolute employment figures will be used in the analysis.

$\bar{\ell}_i$ - mean employment in industry i

ℓ_{jk} - employment in industry j in region k

$\bar{\ell}_j$ - mean employment in industry j

$\sigma_{\ell_i \ell_j}$ - covariance between ℓ_i and ℓ_j

σ_ℓ - standard deviation.

The range of the correlation coefficient is $-1 \leq r'_{ij} \leq +1$, with +1 indicating complete association, 0 showing no association, and -1 expressing complete inverse association. The correlation coefficient does not have, at least under favourable circumstances, any of the weaknesses connected with the coefficient of geographic association.

Given the number of regions (m = 18) and the type of data used the question of the distribution must be raised, for "much of the statistical theory concerning the coefficient of correlation is based on the assumption that the distributions in the problem are normal."[1] McCarty, Hook, and Knos discuss this issue at length.[2] Their conclusion is that practical considerations often point towards proceeding with the analysis as if distributions were normal, even if the distribution curve indicates skewness. The problem is lessened if it is possible". . . to consider the coefficient of correlation only as a means of describing the observed associations in the universe immediately at hand."[3] This can be achieved if the entire universe enters into the calculations. In this study it is, however, desirable to

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[1]Harold H. McCarty, John C. Hook, and Duane S. Knos, Measurements, p. 21.

[2]Ibid., pp. 21-26. These remarks are based on their discussion.

[3]Ibid., p. 22.

make statistical inferences by submitting the correlation coefficients to tests of significance. Any inferences for other areas must be drawn very cautiously. The analysis will proceed, then, on the assumption that the correlation coefficients measure correctly the strength of the locational association between pairs of industries in metro areas.

3.4.2 Some Comments on the Correlation Coefficient as a Measure of Spatial Association. It cannot be avoided that the boundaries of statistical area units are, from any single aspect, of an arbitrary nature. The effect of this arbitrariness on the correlation coefficients has to be touched upon. To the extent that all industry employees within the metro areas are considered in the calculation whereas those immediately outside are not, the correlation coefficient would tend to understate the degree of spatial association between two industries. In principle, the smaller the area units the greater will be the chance of cutting through natural commodity flows of agglomerated industries. On the other hand, the larger the regions the less meaningful will it become to consider locations within that region as locations in the same place. The former may be the case when county or municipal district data are employed; the latter would occur when provinces are used as geographical units. The adoption of Census Metropolitan Areas minimizes this problem for these areas are, as was noted above, delineated according to economic as well as administrative criteria.

It does not seem possible to make any a priori statements about the effect on the correlation coefficients of variations in the level of aggregation. In the rather unlikely event that industry i, to be aggregated with industry j, would have the same number of employees in every region, the coefficient would be invariant. In general, however, the correlation coefficient could change either way depending upon the magnitudes of the individual employment figures involved.

Contrary to the linkage measures the correlation coefficient is symmetric, i.e. $r'_{ij} = r'_{ji}$. The coefficient thus tends to understate the importance of locational proximity in certain cases. For example, satellite industries, because of the nature of their economic or technological relationships with the 'master industry' may be found wherever the master industry is located, but not vice versa.[1] This problem could not be avoided.

3.4.3. Coefficient Matrices and Statistical Problems. By correlating absolute employment figures for pairs of industries over the metro regions an 86 x 86 matrix of coefficients is obtained. Excluding the diagonal elements this matrix contains 7310 interindustry correlation coefficients r'_{ij}. The coefficients in this matrix were generally very large with only a few negative ones. This upward tendency has to be expected in cross-section analysis when units of observation of substantially different size are considered. In this case the correlation is artificially increased because, generally, large values of the variables will be associated with the large units and small values with small units. The expected value of the correlation coefficient

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[1]See Albert O. Hirschman, Strategy, p. 102 and Manfred E. Streit, Verbunds, pp. 45-46.

for non-associated industries will not be zero anymore as it should be. The common solution is to eliminate the influence of size by selecting an appropriate size variable as a deflator.[1] This procedure may have the undesirable effect of introducing spurious correlation into the analysis because now the correlated variables are ratios. The implications of correlating ratios have been examined in detail by Kuh and Meyer.[2] Their results will be used here in chosing a deflator and testing for spurious correlation.

Important for this study is that Kuh and Meyer derive the result that "under a wide range of circumstances, the ratio estimates should not be greatly biased in applications to cross-section data."[3] More specifically, the authors show that, if several deflators are available with similar properties from an economic aspect, the analyst should select the one with the smallest ratio of standard deviation to the mean (V) in order to minimize the possibility of spurious results.

The two variables that offer themselves as deflators are population (p) and employment (ℓ) of the metro regions.[4] For both of these

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[1]The deflation process was adopted by Richter and rejected by Streit; see Impact, p. 23 and Verbunds, p. 44 resp.

[2]Edwin Kuh and John R. Meyer, "Correlation and Regression Estimates when the Data Are Ratios", Econometrica, Vol. 23, No. 4 (October 1955), pp. 400-416.

[3]Ibid., p. 406.

[4]It may be pointed out that Richter obtained identical results using alternatively, population and total manufacturing employment of the region as size variables. See Charles E. Richter, Impact, pp. 24-25 and Charles E. Richter, "The Impact of Industrial Linkages on Geographic Association", Journal of Regional Science, Vol. 9, No. 1 (1969), pp. 22-23. This is an extremely unlikely result.

size variables the coefficient of variation (V) was computed, resulting in a $V_p = 1.21$ and a $V_\ell = 1.58$. Consequently population was adopted as the deflator variable. A second requirement to be met is that the variables deflated, here employment in industry i in region k ($i = 1, 2, \ldots, n$; $k = 1, 2, \ldots, m$), be homogeneous functions of the size variable p. Homogeneity checks were performed by calculating the regression functions of the employment variables on the deflator. The null-hypothesis,

$$H_o : a = 0$$

was tested against the alternative in a two-tail test

$$H_1 : a \neq 0.$$

If H_o is accepted, i.e. the employment variable is a homogenous function of the size variable, spurious correlation is not a problem in the analysis. The t-test at the 1% level of significance for n = 18 and n-1 = 17 degrees of freedom (d.f.)

$$P(-2.898 < t < + 2.898 \ (d.f. = 17) = .99$$

shows that 78 out of 86 of the constant terms are not significantly different from zero. Thus the regression lines are generally homogenous and the null-hypthesis is accepted. Spurious correlation will not bias the results of this study significantly.

b) Correlation of pairs of employment proportions p_{ik}

$$p_{ik} = \frac{\ell_{ik}}{p_k}$$

where: ℓ_{ik} - employment in industry i in region k

p_k - population of region k

p_{ik} = proportion of population of region k employed in industry i

yields the 86 x 86 matrix of correlation coefficients R. The 7310 non-diagonal elements of this matrix, i.e. the correlation coefficients r_{ij} $(i \neq j)$, measure the geographical association between industries i and j.

The correlation coefficients are significant if, at the 0.1 level of significance $r_{ij} \geq 0.400$, at the 0.05 level $r_{ij} \geq 0.468$, and $r_{ij} \geq 0.590$ at the 0.01 significance level. If the correlation coefficients are equal to or greater than 0.400 the industries are defined to be geographically associated.

3.4.4 Rank Correlation Coefficients. A method sometimes employed to measure the degree of association between two variables is rank correlation. Two coefficients are most common: the Spearman rank order coefficient (r_S) and variations of the Kendall rank correlation coefficient (r_τ). These are nonparametric statistics, i.e. they do not depend on any specific distribution of the variables. Both r_S and variants of r_τ were computed.[1] These were compared with the product moment correlation coefficients in order to determine their suitability.

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[1]The rank correlation coefficients may be calculated as $r_S = 1 - \frac{6\Sigma d^2}{n(n^2-1)}$ and, for example, $r_\tau = \frac{P - Q}{\frac{1}{2}n(n-1)}$ where d denotes differences in the ranks of the variables and P, Q are positive and negative scores, resp.; see Maurice G. Kendall, Rank Correlation Methods (London: Charles Griffin and Co. Ltd., 1962), p. 8 and pp. 4-5.

for the purpose of this study. Visual inspection of the rank correlation coefficient matrices and comparison with matrix R reveals that the rank coefficients generally show much higher values and in many cases seriously overstate the degree of spatial association. Except for r_S they show a smaller range of values. According to McCarty, et al. this should be expected because the rank correlation method does not take into account the magnitude of differences between the units.[1] Because of their inferior properties rank coefficients were not further considered in this study.

3.5 Methodology

While the results of other studies will be reviewed in greater detail below, a few words may be in order about the approach used to determine the agglomerative impact of interindustry linkages. In this study the main part of the statistical analysis contains a series of hypotheses designed to test the location importance of input-output linkages to the manufacturing sector as a whole,[2] followed by an investigation into their effect on individual secondary industries.[3]

The approach of using hypotheses to test propositions with regard to locational factors or the locational characteristics of industries was first used by McCarty, Hook, and Knos. They tested three hypotheses relating to the machinery industry.[4] This method was also

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[1]See Harold H. McCarty, John C. Hook, and Duane S. Knos, <u>Measurement</u>, p. 27.

[2]See Chapt. 4.

[3]See Chapt. 5.

[4]See Harold H. McCarty, John C. Hook, and Duane S. Knos, <u>Measurement</u>, pp. 67-68.

adopted by Richter whose hypotheses concentrate more on the locational factor than on the specific industry.[1] The same approach is used in this study. However, while the hypotheses are essentially similar to those employed by Richter, the results of the tests are not directly comparable because of several modifications made. The differences lie mainly in the greater degree of disaggregation, the improved backward linkage measure, and a more suitable classification of manufacturing industries for test purposes.

The six hypotheses of the general approach, to be introduced in the following chapter, always involve a contrasting of the input-output linkage coefficients with the corresponding spatial association measures. These hypothese are tested using basic statistical techniques. The industry-specific approach examines the locational affinity between the subject industry and all its linked industries in chapter five using correlation analysis. Also provided in Chapter 5 are a determination of the population attraction of the various manufacturing industries through correlation analysis and a delineation of industrial complexes using input-output linkages and coefficients of spatial association.

3.6 Survey of the Literature on Agglomeration

In this section some results obtained by other investigators will be briefly cited. The survey is not comprehensive.

[1]See Charles E. Richter, Impact, pp. 71 ff.

3.6.1 Writers on Agglomeration in General. Some of the earliest empirical studies on industrial location were carried out by Florence.[1] In his more comprehensive later study he found that many structurally related industries tend to agglomerate in the same geographical area.[2] Florence cited the common utilization of a labour pool and structural interrelations between industries as the main reasons for localization. In his study on the shoe and leather industries Hoover determined that linkage through the complementary use of labour was an important agglomerative locational factor.[3] Isard and Schooler attempted to take into account economies obtained from spatial juxtaposition by posing the locational problem for industrial complexes rather than individual industries.[4] Following the traditional Weberian approach to locational analysis they incorporate scale economies, localization economies, and urbanization/regionalization economies into their comparative cost study. However, while some agglomeration economies may be quantified, especially those arising from technical links between industries, many spatial juxtaposition advantages are of an intangible nature which limits somewhat the effectiveness of the industrial complex approach. Nevertheless, the quantification of several

[1] Political and Economic Planning, Report, p. 292.

[2] P. Sargant Florence, Investment, Location, and Size of Plant, pp. 69, 53, 66 and P. Sargant Florence, "The Selection of Industries Suitable for Dispersion into Rural Areas", Royal Statistical Society Journal, Vol. 107 (1944), pp. 100-103.

[3] Edgar M. Hoover, Location Theory and the Shoe and Leather Industries (Cambridge, Mass.: Harvard University Press, 1937), chapt. 8.

[4] Walter Isard and Eugene W. Schooler, "Industrial Complex Analysis, Agglomeration Economies, and Regional Development", Journal of Regional Science, I (Spring 1959), pp. 19-42, esp. p. 33.

agglomeration economies is a positive step;[1] these economies are, of course, location- and complex-specific.

3.6.2 Writers on Linkages and Location. In an early study Hoover drew attention to the locational impact of interindustry linkages by noting that location in close proximity to suppliers was a dominant factor in the localization of the leather industry of the United States.[2] In order to minimize transportation costs the leather industry tended to concentrate in ports and meat-packing centres. As it was Hoover's objective to develop tools of analysis, the importance of linkages to the manufacturing sector in general was not investigated.

McCarty, Hook, and Knos[3] investigated locational issues of one industrial sector, the machinery group. Of particular interest in this context is their "related-industries hypothesis" which states that the machinery industry will be more closely associated with technologically linked industries than with non-linked industries. Industries are split into metals industries and non-metals industries; the group of related industries was formed by eliminating the less significant variables (industries) from the group of metals industries. The authors then performed multiple correlation and regression analyses of the associations between the machinery group and the non-metals group

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[1]Walter Isard and Eugene W. Schooler, "Complex Analysis", Table 4, p. 31; but note also the qualifications on p. 29.

[2]Edgar M. Hoover, "The Measurement of Industrial Localization", Review of Economics and Statistics, Vol. 18 (November 1936), p. 167.

[3]Harold H. McCarty, John C. Hook, and Duane S. Knos, Measurement, chapts. 4-7.

on the other hand. The calculations were made for various regions of the United States and Japan. The results of the analysis, while not very strong in some cases,[1] lead the authors to accept the related-industries hypothesis.

In his analysis of the impact of industrial linkages on the location of manufacturing sectors Richter ascertained that there exists a significant relationship between linkages and geographic association.[2] Using linkage coefficients as discussed in Section 3.3.1 above, Richter found that manufacturing sectors tend to cluster in the metropolitan areas of the United States and that linkages appear to induce clustering. About double as many linked sectors are geographically associated than are non-linked sectors. Also double as many geographically associated sectors are linked than are non-associated sectors. The results of further tests regarding the effects of linkages on manufacturing industries as a whole generally agree with results obtained in this study and will therefore not be repeated here; any deviations in the results and in the definitions will be noted below. Richter then determined how closely each sector is associated with all of its linked sectors by comparing the correlation coefficient of employment proportions between subject sector and the sum of all linked industries with that between the subject sector and an equal number of random industries. The results indicate that the manufacturing sectors are frequently found in the same location with sectors to which they are linked.

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[1]See Harold H. McCarty, John C. Hook, and Duane S. Knos, Measurement, Table 72, p. 138 for numerical results.

[2]See Charles E. Richter, "Impact", pp. 24-26.

Streit's results are less immediately comparable to those obtained here than the results of the preceding author. By correlating his symmetric linkage coefficients[1] with the spatial association coefficients over all governmental districts of West Germany and départements of France, Streit obtained a low but significant-coefficient for West Germany (1 per cent level); the coefficient for France was not significant.[2] Given the fact that Streit used undeflated employment data and that his universes were comprised of regions of greatly varying size,[3] much higher correlation coefficients would have been expected. Two explanations may be offered: first, as mentioned above, the arbitrary nature of the linkage coefficient may have influenced the results; second, the inclusion of immobile primary industries[4] may have contributed to the reduction of the correlation coefficients. In dealing with the explanation of spatial associations of separate industries Streit uses his linkage coefficient as an explanatory variable in regression models. The dependent variable is the spatial association coefficient and for n industries the regression is based on n-1 observations. For 26 industries he obtains five significant coefficients for West Germany and one for France (level of significance between 0.1 and 0.01). The explanatory power of the regression model must thus be judged as quite small. In an expanded model Streit uses in addition

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[1]See Sect. 3.3.1 above.

[2]See Manfred E. Streit, "Associations", pp. 178-181.

[3]Combined in the respective universes were largely agricultural regions with such heavily industrialized areas as the Ruhr and Paris.

[4]See Manfred E. Streit, "Associations", p. 187.

an agglomeration variable as an exogenous variable.[1] This general agglomeration variable is somewhat tautological as it includes again the influence of linkages; by not identifying any separate agglomerative factors it is also very non-transparent and therefore of limited usefulness. However, the model containing this catch-all agglomeration variable produced good results for a number of industries in West Germany and France.[2] More complicated models did not yield any better results. The weakest elements in Streit's analysis would appear to be the extremely high degree of aggregation (only 26 sectors), the arbitrary nature of his linkage coefficient, and the generality of the agglomeration variable.

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[1]See Manfred E. Streit, "Associations", p. 181.

[2]See *ibid.*, Table 1, p. 182.

4. TESTS OF HYPOTHESES -- GENERAL APPROACH

The matrices of backward linkage coefficients B and of forward linkage coefficients F were calculated according to the linkage definitions set out in Section 3.3.1; to the matrices thus obtained, the linkage criterion

$$b, f \geq \frac{1}{110} \geq .0091$$

was applied to yield the linkage coefficient matrices.

The matrix R of spatial coefficients was obtained by first correlating the employment proportions of industry pairs over the eighteen metro areas and then accepting as geographical associations only those coefficients for which, at the 0.1 level of significance,

$$r_{ij} \geq .4000.$$

4.1 Importance of Linkages

The data provided in Table 2[1] indicate that the major share of Canadian manufacturing takes place in the large urban areas. Theoretical considerations point to interindustry linkages as one possible agglomerative factor. If linkages indeed contribute to a concentration of manufacturing industries in cities, then there must exist a

[1]See Table 2, p. 53.

significant relationship between the two attributes of industry pairs: 'linked' and 'geographically associated'.

Of the 7310 spatial coefficients 1744 are large enough to constitute geographical associations.[1] There are 2587 negative coefficients. At the .1 significance level 731 geographical associations of industry pairs would be expected even if the industries located completely independently. Since the number of significant spatial coefficients is more than twice as high, the hypothesis that they are due to chance is rejected.

The number of backward and forward linkages is 1101; 85 industries are connected to one another by double linkages,[2] giving 1016 linked industry pairs.[3] Seven hundred and ten of the linkages are forward linkages and 391 are backward linkages.

Out of the 1101 linked industries 397 industries are also geographically associated, or 36.06 per cent.[4] However, only 1347, or 21.69 per cent, of the 6209 non-linked industry pairs are geographically associated. Clearly, linked industries are much more likely to be

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[1]At the .05 significance level there are 1438 coefficients ($r_{ij} \geq .468$) and at the .01 level there are 901 significant coefficients ($r_{ij} \geq .589$) given d.f. = 16.

[2]Two industries may be connected by as many as four linkages; this happens when industry i is linked backward and forward to industry j and industry j has a backward and forward linkage to industry i. This is the case, for example, for industries 39 Wool, Yarn & Cloth Mills and 40 Synthetic Textile Mills where $b_{3940} = .1044$, $f_{3940} = .1033$, $b_{4039} = .0114$, and $f_{4039} = .0183$.

[3]In the subsequent test of significance these double linkages will be counted separately; this does not influence the results significantly.

[4]See Table 3 for a listing of backward linkages, forward linkages, and geographical associations by industry.

TABLE 3

FREQUENCIES OF BACKWARD LINKAGES, FORWARD LINKAGES AND GEOGRAPHICAL ASSOCIATIONS FOR INPUT-OUTPUT INDUSTRIES

IOIC-L Number[a]	Backward Linkages Geogr. Associated	Backward Linkages Total	Forward Linkages Geogr. Associated	Forward Linkages Total	Geographical Associations Linked	Geographical Associations Total
12	0	1	0	0	0	26
13	1	2	0	1	1	24
14	1	3	0	1	1	5
15	0	13	0	2	0	8
16	0	3	0	3	0	1
17	3	8	0	1	3	14
18	5	10	0	0	5	29
19	1	2	0	5	1	6
20	1	6	0	1	1	10
21	1	13	0	0	1	16
22	1	12	0	0	1	9
23	0	10	0	3	0	7
24	0	4	2	8	2	6
25	2	5	2	9	4 (1)[b]	19
26	3	12	2	5	5	34
27	0	7	0	0	0	0
28	0	7	0	0	0	7
29	2	8	0	0	2	12
30	0	0	1	1	1	19
31	1	5	0	0	1	10
32	8	14	0	0	8	27
33	4	6	1	2	5	34
34	4	14	9	13	13 (1)	31
35	1	2	3	3	4	33
36	6	8	0	0	6	31
37	7	12	3	3	10 (1)	31
38	2	5	6	10	8 (2)	25
39	3	6	5	8	8 (2)	30
40	5	10	9	11	14 (4)	30
41	3	5	0	1	3	39
42	6	16	4	9	10 (2)	21
43	0	7	2	8	2	8
44	8	12	5	7	13 (4)	32
45	1	9	0	0	1	15

TABLE 3 -- Continued

IOIC-L Number[a]	Backward Linkages Geogr. Associated	Backward Linkages Total	Forward Linkages Geogr. Associated	Forward Linkages Total	Geographical Associations Linked	Geographical Associations Total
46	5	7	1	1	6(1)	38
47	4	7	0	0	4	30
48	0	1	0	4	0	2
49	1	4	1	4	2	2
50	1	6	0	1	1	2
51	1	9	5	13	6	32
52	7	18	1	1	8	32
53	10	18	0	1	10	31
54	0	5	0	3	0	0
55	1	9	0	1	1	6
56	3	6	9	23	12(2)	26
57	5	9	3	9	8(2)	27
58	0	2	0	0	0	21
59	1	5	4	16	5	13
60	0	2	0	8	0	5
61	1	7	4	8	5(1)	31
62	0	1	0	4	0	0
63	2	4	10	14	12	31
64	0	2	5	11	5	28
65	1	5	6	17	7(1)	27
66	5	10	2	4	7(2)	30
67	0	6	0	5	0	7
68	5	11	2	2	7(1)	31
69	3	6	10	18	13(1)	43
70	2	7	2	11	4	18
71	7	14	4	6	11(1)	32
72	9	16	4	9	13(2)	39
73	11	16	0	0	11	43
74	7	9	0	2	7	25
75	1	15	0	0	1	15
76	1	13	0	0	1	6
77	3	15	1	1	4(1)	8
78	0	19	0	0	0	2
79	8	20	1	3	9(2)	21
80	9	13	4	6	13(2)	41
81	10	15	5	6	15(4)	41

TABLE 3 -- Continued

IOIC-L Number[a]	Backward Linkages Geogr. Associated	Backward Linkages Total	Forward Linkages Geogr. Associated	Forward Linkages Total	Geographical Associations Linked	Geographical Associations Total
82	8	13	0	1	8	40
83	1	3	0	4	1	3
84	0	7	0	0	0	5
85	2	7	2	4	4(1)	16
86	1	8	5	14	6	23
87	3	9	0	2	3	45
88	0	2	0	2	0	3
89	0	11	0	0	0	1
90	0	2	0	0	0	5
91	2	9	6	14	8(2)	20
92	3	6	0	1	3	25
93	0	8	1	6	1	15
94	7	10	0	2	7	22
95	5	6	0	0	5	27
96	2	6	2	12	4(1)	18
97	5	14	0	2	5	41
Total	243	710	154	391	397(44)	1,744

[a] For complete industry names see Appendix 2

[b] The figures in parentheses in the column 'Geographical Associations - Linked' indicate the number of double linkages. The column total minus the number of double linked industries gives the number of linked industry pairs, i.e. 397 - 44 = 353.

geographically associated than non-linked industries. Looking at the data from the aspect of spatial association it is found that 397 of the 1744 associated industries are linked while only 704 of the 5566 non-associated industries are linked; the respective percentage figures are 22.76 per cent and 12.65 per cent, i.e. spatially associated industries are almost twice as often linked as non-associated industries. There thus appears to be a definite relationship between interindustry linkages and geographic association.

After subtracting the linked and geographically associated industry pairs from the total number of geographic associations, there remain 1347 spatially associated industry pairs that are not joined by an interindustry linkage. This figure is not too large to result if the industries located completely independently.[1] However, many of these associations may also be due to other agglomerative factors, such as ties to common markets or suppliers, attraction to a large labour market, appropriation of urban externalities, etc.[2] These locational factors will not be further investigated here.

In order to provide a more rigorous test of the relationship between the attributes 'linked' and 'geographically associated' of industry pairs, a χ^2-statistic has been computed for a test of independence. The χ^2-test as a measure of association may be appropriately applied here because it "...provides a technique for investigating

[1]See Table 4 below.

[2]See Section 2.3 above.

suspected relationships."[1] The theoretical basis for this test was developed by Karl Pearson who proposed a test criterion which approximates the χ^2-distribution.[2] These tests utilize a contingency table and have been widely used for a great variety of problems in many fields of research. Examples are as varied as: the reaction of men and women to a certain political proposal, the heritability of disease, or the relationship between defects in manufactured products and the underlying cause(s).[3] It may also be noted that these association tests are non-parametric problems[4] in which the application of the χ^2-statistic, due to its statistical properties, does not require any assumption regarding the distribution of the classifications involved.[5] The hypothesis to be tested has been formulated as

H_o: linkages and geographic associations are independent.

The χ^2-distribution is computed on the basis of a contingency table that lists the observed frequencies (O) and the expected frequencies

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[1]Alexander M. Mood, Introduction to the Theory of Statistics (New York: McGraw-Hill Book Company, Inc., 1950), p. 274.

[2]Ibid., p. 271.

[3]Ibid., p. 274.

[4]Maurice G. Kendall and Alan Stuart, The Advanced Theory of Statistics, Vol. 1: Inference and Relationship (London: Charles Griffin & Company Limited, 1967), p. 537.

[5]Taro Yamane, Statistics: An Introductory Analysis (2nd ed.; New York: Harper and Row, Publishers, 1967), p. 625.

(E, shown in parentheses)[1] for the four possible combinations of characteristics. The χ^2-statistic is computed according to the formula

$$\chi^2 = \Sigma \frac{(O - E)^2}{E},$$

the summation being over the possible combinations. It can be seen

TABLE 4

CONTINGENCY TABLE FOR TEST OF INDEPENDENCE BETWEEN INDUSTRY PAIR ATTRIBUTES

	Linked	Non-linked	Total
Geographically Associated	397 (263)	1,347 (1,481)	1,744
Non-associated	704 (838)	4,862 (4,728)	5,566
Total	1,101	6,209	7,310

that χ^2 is a measure of discrepancy between the observed and the expected frequencies.[2] If there is no discrepancy $\chi^2 = 0$; as the discrepancy increases, χ^2 becomes larger. The value obtained for the test statistic is $\chi^2 = 106.21$.[3] Given d.f. = 1,[4] for the 1 per cent

[1]The theoretical frequencies are apportioned according to row (column) total--grand total ratios. See Helen M. Walker and Joseph Lev, Statistical Inference (New York: Henry Holt and Company, 1953), p. 96. For example, $E_{11} = (O_{.1}/O_{..})(O_{1.})$.

[2]Taro Yamane, Statistics, p. 617.

[3]The χ^2 obtained by netting out double-linked associations is $\chi^2 = 82.64$. Note that the Yates continuity correction has not been applied--as is recommended when d.f. = 1--because, with the frequencies as large as in the above case, its effect would be negligible.

[4]The degrees of freedom for an r x s table is (r - 1)(s - 1).

level of significance

$$P(6.63 < \chi^2 < \infty) = .01$$

and the rejection region is $\chi^2 \geq 6.63$. Hence $\chi^2 = 106.21$ is significant and the null hypothesis that the characteristics 'linked' and 'spatially associated' are independent is rejected.

It must be pointed out that the χ^2 - test only shows whether the two attributes are independent or not. It does not measure the strength of the association nor does it indicate the direction of dependency.[1] In this case, however, the direction of dependency can only be from linkages to geographical associations. Notwithstanding the two qualifications it can then be stated that the data analyzed support the hypothesis that interindustry linkages are locational factors contributing to an agglomeration of manufacturing industries in urban areas.

4.2 Empirical Tests

In this section an attempt is made to determine the locational efficacy and impact of input-output linkages in greater detail. For this purpose six hypotheses are introduced and tested.[2] All hypotheses relate to the manufacturing sector as a whole.

4.2.1 H 1: Symmetry Hypothesis

> Backward linkages and forward linkages are equally powerful agglomerative factors.

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[1]Taro Yamane, Statistics, p. 625.

[2]These hypotheses, while formally similar to those employed by Richter, do not allow an immediate comparison with his results because of substantial changes in definitions and classifications.

There do not appear to be any a priori reasons for suspecting that either backward linkages or forward linkages are more effective in pulling industries into locational proximity to one another. It is therefore expected that the data will support the hypothesis.

For all manufacturing industries taken together there are 710 backward linkages; of these 243, or 34.22 per cent, are geographically associated. Of the 391 forward linkages 154 are geographically associated, or 39.38 per cent. As the percentage figures differ only by about 5 per cent, it appears that the hypothesis is supported. However, a firmer decision criterion is needed. The χ^2 - test may be applied to these data to ascertain whether the observed distribution of frequencies corresponds to the distribution that would be expected if the agglomerative impact of backward and forward linkages was equal. From Table 5 a χ^2 = 2.68 has been obtained with the continuity correction applied. With

$$P[\chi^2 > 2.71] = .1$$

TABLE 5

OBSERVED AND EXPECTED FREQUENCIES OF SPATIAL ASSOCIATIONS FOR BACKWARD AND FORWARD LINKAGES

	Backward Linked	Forward Linked	Total
Geographically Associated	243 (256)	154 (141)	397
Non-associated	467 (454)	237 (250)	704
Total	710	391	1,101

the χ^2 is not significant at any of the commonly accepted levels of significance and therefore the symmetry hypothesis is accepted: supply and demand linkages are equally likely to induce linked industries to locate close to one another.

4.2.2 H 2: Production Sequence Hypothesis

> Industries in the early stages of the production chain are materials-oriented; industries in the late stages of the production chain are market-oriented.

Testing of this hypothesis requires classification of manufacturing industries into 'First Stage Resource Users' (Group I), 'Second Stage Resource Users' (Group II), and 'Third Stage Resource Users' (Group III); industries are then further classified into those heavily linked to final consumption (Group A) and those not strongly linked to final consumption (Group B).[1]

This hypothesis finds its rationale in the nature of transfer costs at the various stages of production. Group I industries are the most raw material intensive and often weight losses occur at the refining or processing stages. This would tend to move Group I industries close to their suppliers. While linkages to primary industries, for reasons mentioned earlier, are not explicitly considered in this study, one would expect supply relationships to be of greater locational importance at this stage than demand side relationships. Group III industries, on the other hand, would be expected to locate close to markets in order to realize transfer agglomeration and pure agglomeration economies. These linkages through transfer economies were implied by Hoover when he stated that

[1]See Appendix 3 for details of the classification.

"... in general the earlier stages of a production sequence are unlikely to be market-oriented and the later stages are unlikely to be material-oriented while intermediate stages are generally less dependent on either procurement or distribution factors in their location."[1]

It may be surmised, however, that forward linkages are more important not only to Group III industries but also to Group II industries. Since the transportation cost savings due to weight loss occur predominantly at the initial stage of manufacturing, i.e. refining or processing, this powerful locational factor does not apply as strongly to Group II industries. Consequently the 'market pull' may be more effective.

Hypothesis 2 is tested by calculating, for Groups I, II, and III, the proportion of employees working in the metro areas. The figures for this test are taken from Table 1. The above locational considerations would lead one to expect an increase in the employment proportions as one moves from Group I to Group III. The results shown in Table 6 bear this out. The weighted mean of the employment share in metro areas for Group I industries is 38.8 per cent; for Group II industries it is 54.3 per cent and for Group III industries the weighted mean is 63.9 per cent. These results tend to support the hypothesis. However, a firmer test of significance needs to be applied.

In order to determine whether the difference in the group means is significant an analysis of variance is performed. If the difference between the group means $\bar{x}_I$, $\bar{x}_{II}$, and $\bar{x}_{III}$ is not significant, the

[1]Edgar J. Hoover, The Location, p. 118; see also p. 35.

TABLE 6

EMPLOYMENT PROPORTIONS IN METRO AREAS BY INDUSTRY GROUP

Group	I	II	III
A	49.3	54.0	65.4
B	35.9	54.4	63.2
Weighted Mean	38.8	54.3	63.9

groups must be considered as belonging to the same population. The null hypothesis is

$$H_o : \mu_I = \mu_{II} = \mu_{III}$$

with the weighted means $\bar{x}$ as estimators for the μ. This hypothesis is tested against the one-sided alternative

$$H_1 : \mu_I < \mu_{II} < \mu_{III}.$$

This hypothesis may be tested using an F-distribution. Similar tests, applying this distribution, have been conducted in various fields of study,[1] for example the absorption of different cooking fats by doughnuts, the effect of different vitamin levels on pigs, or the influence on grades of different teaching methods.[2] Snedecor's and Cochran's remarks concerning departures from the normality assumption are relevant in this context. Of the three potential cases for non-normality mentioned by them the second, dealing "with proportions or percentages that cover a range extending nearly to zero or 100%", is of interest

[1] George W. Snedecor and William G. Cochran, Statistical Methods (6th ed.; Ames, Iowa: The Iowa State University Press, 1967), pp. 258 and 262.

[2] Taro Yamane, Statistics, p. 667.

here.[1] A check of the employment percentages of industries in metro areas reveals (Table 1) that there is no proportion below 10 per cent, with only five below 20 per cent and only two slightly above 90 per cent; this is favourable for the application of the test. It should also be noted that the magnitudes involved in the test are aggregates which tend to be normally distributed. Moreover, as Kendall and Stuart have pointed out with regard to the robustness of standard "normal theory" procedures,[2] tests on means are robust, i.e. they are rather insensitive to departures from normality of the populations.

The F-statistic is constructed as

$$F = \frac{\frac{1}{3-1}\Sigma n_i(\bar{x}_{i.} - \bar{x})^2}{\frac{\Sigma\Sigma(x_{ij} - \bar{x}_{i.})}{n-3}} = \frac{\text{estimated variance from "between"}}{\text{estimated variance from "within"}} .$$

The calculation yields a variance ratio of

$$F_o = \frac{54992.21}{364.40} = 150.93$$

The degrees of freedom are $d.f._1 = 2$ and $d.f._2 = 83$; since 83 is not given in the table as a degree of freedom for the smaller variance, the more conservative (larger) value for 80 is used. For the one per cent

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[1]George W. Snedecor and William G. Cochran, Methods, p. 276.

[2]Maurice G. Kendall and Alan Stuart, Inference, pp. 465-466. In addition separate t-tests for the difference between any two of the means were carried out; the results confirmed the conclusion of the test below. (The t-test was mentioned especially by Kendall and Stuart for robustness.)

TABLE 7

ANALYSIS OF VARIANCE TABLE FOR GROUP MEANS

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square
Between	109998.41	a - 1 = 2	54922.21
Within	30245.04	n - a = 83	364.40
Total	140243.45	n - 1 = 85	1649.92

level of significance

$$P[F > 4.88 \mid 2,80] = .01.$$

Since $F_o = 150.93 > F_2^{80} > F_2^{83}$ the null hypothesis is rejected and it is concluded that the group means are different. Group I industries are less likely to locate in major urban areas than Group III industries.

Hypothesis 2 received additional support from a comparison of the number of backward and forward linkages that are accompanied by geographical associations at the three stages of manufacturing. The locational considerations above indicated that industries in the early stages of manufacturing generally would tend to be supply-oriented; this leads one to expect that for these industries there would be relatively more backward linkages than forward linkages geographically associated.[1] The reverse would be predicted for industries in the final

[1]Henceforth, for simplicity of language, the expressions 'geographically associated linkages' or 'spatially associated linkages' will also be used. Strictly speaking it is of course the <u>industries</u> which are spatially associated.

stages of manufacturing. Intermediate stage industries, i.e. Group II, for reasons outlined above, might be expected to show a higher percentage of forward linkages to be geographically associated than of backward linkages.

TABLE 8

NUMBERS AND PERCENTAGES OF GEOGRAPHICALLY ASSOCIATED BACKWARD AND FORWARD LINKAGES BY INDUSTRY GROUP

	Backward Linkages			Forward Linkages		
	Number	Number Associated	Per Cent	Number	Number Associated	Per Cent
Group I	37	9	24.3	36	4	11.1
Group II	137	32	21.9	135	51	37.8
Group III	536	202	37.7	226	93	41.2

Examination of the percentage figures in Table 8 reveals that for industries in Group I 24.3 per cent of the backward linkages are geographically associated while only 11.1 per cent of the forward linkages are accompanied by spatial associations. For both Group II and Group III industries the proportion of geographical associations is higher among the forward than among the backward linkages; the percentages of spatially associated backward and forward linkages are, respectively, 21.9 per cent vs. 37.8 per cent for Group II and 37.7 per cent vs. 41.2 per cent for Group III industries. Thus backward linkages appear to be of greater agglomerative importance to Group I industries while forward linkages are more likely to be geographically associated for Group II and Group III industries. The combined evidence leads to an acceptance of the production sequence hypothesis.

4.2.3 H 3: Linkage Strength Hypothesis

> Strong interindustry linkages are more powerful locational factors than weak linkages.

Examination of this hypothesis required a grouping of the linkages according to their size. The first group includes linkages from the minimum value of 0.91 per cent to a value of 4.99 per cent; these are considered to be weak linkages. The group of medium linkages extends over the range of 5.00 per cent to 9.99 per cent. All linkages equal to or larger than 10.00 per cent are considered to be strong linkages. For reasons explained below, the group of strong linkages has been subdivided again into the intervals 10.00 - 49.99 per cent and 50.00 - 100.00 per cent.

TABLE 9

FREQUENCY OF LINKAGES AND GEOGRAPHICALLY ASSOCIATED LINKAGES BY LINKAGE SIZE GROUPS

Linkage Size	Number of Linkages	Number of Associated Linkages	Percentage of Associated Linkages
0.91 - 4.99	886	301	34.0
5.00 - 9.99	114	47	41.2
10.00 - 49.99	93	47	50.5
50.00 - 100.00	8	2	25.0

Table 9 shows the number of linkages, the number of geographically associated linkages, and the proportion of associated linkages by linkage size groups. The group of weak linkages has a frequency of 886 of which 301 linkages are accompanied by geographical associations; this amounts to 34.0 per cent. In the medium strength group 47 out of 114 linkages are geographically associated, or 41.2 per cent. Considering the group of strong linkages as one single group it is found that 49 out of 101 strong linkages occur with geographical associations, a percentage of 48.5. These results provide strong evidence in favour of the hypothesis and might lead to its unqualified acceptance.

However, closer scrutiny of the linkages in the highest group reveals an interesting phenomenon. If strong linkages are further subdivided as shown in Table 9, the linkage strength hypothesis fails quite definitely for the 50+ per cent group. The result for the group 10.00 - 49.99 per cent is strengthened with 50.5 per cent of the linkages associated, while only 25 per cent, or 2 out of 8, of the strongest linkages are accompanied by spatial associations.

Moreover, within the group of strongest linkages there appears to be a systematic relationship. The group contains 2 forward linkages and 6 backward linkages;[1] both the forward linkages are connected by geographical associations while none of the backward linkages are.

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[1]See Table 10.

TABLE 10

INDUSTRY DETAIL FOR THE GROUP OF STRONGEST LINKAGES

IOIC-L Number	Linkage Origin[b]	IOIC-L Number	Linkage Destination[b]	Type and Size of Linkage[a]
30	Leaf Tobacco	31	Tob. Products M.	f_{3031} = .6873*
35	Leather Tan.	36	Shoe Factories	f_{3536} = .6128*
56	Paper Box & Bag	54	Pulp & Paper Mills	k_{5456} = .6406
60	Steel Pipe & Tube	59	Iron & Steel Mills	k_{5960} = .7820
63	Aluminum R.C.E.	62	Smelt. & Ref.	k_{6263} = .7276
64	Copper R.C.E.	62	Smelt. & Ref.	k_{6264} = .8124
65	Metal R.C.E., n.e.s.	62	Smelt. & Ref.	k_{6265} = .6061
67	Fabr. Struct. Met.	59	Iron & Steel Mills	k_{5967} = .5640

[a] Linkages identified by "*" are geographically associated.

[b] See Appendix 2 for full industry names.

This result was not altogether unexpected. All the recipient industries of the backward linkages are primary manufacturing industries (Statistics Canada Classification) and likely to be heavily oriented in their location to their non-urban sources of raw materials. The large amount of weight loss occurring at the refining and processing stage would appear to be the major reason for this orientation. For reasons discussed above, the industries from which the backward linkages originate are severed locationally from their sources of supply.

Thus the linkage strength hypothesis is accepted with the proviso that the strong backward linkages from Group III industries to primary manufacturing industries of Group I (Smelting and Refining, Pulp and Paper Mills) and Group II (Iron and Steel Mills) will generally not be accompanied by spatial association of the linked industries.

4.2.4 H 4: Final Demand Impact Hypotheses

Two hypotheses are tested regarding the influence of final demand consumption sales on interindustry linkages and geographical associations.

> H 4.1: Industries heavily linked to final demand show, on average, fewer geographical associations than industries not heavily linked to final demand.

The output of any industry may either flow back into the interindustry system as intermediate inputs or it may go to final demand. If the share of output destined for the final demand sector is large only a small proportion will remain for interindustry transactions. Consequently there will be fewer interindustry linkages connecting this industry to the system. This, in turn, will result in a smaller number of spatial associations for industries strongly linked to final demand.

For the purpose of this study industries have been defined to be strongly linked to final demand if they sell at least fifty per cent of their output to final demand consumption (FDC); industries in this category are called Group A industries with the remaining industries--those not heavily linked to final demand--falling into Group B.

The hypothesis is tested by comparing the average number of geographical associations in Group A with that of Group B. Group A contains 26 industries and Group B the remaining 60. Group A industries show a total of 98 spatial associations while there are 299 in Group B. The average number of geographical associations for Group A thus is 3.77 while Group B industries average as many as 4.98. The difference of 1.21 between the two figures amounts to almost 25 per cent of the larger figure and to almost 33 per cent of the smaller one. This large difference in the number of geographical associations between Groups A and B industries points to an acceptance of the first final demand impact hypothesis.

H 4.2: The strength of the final demand link does not, on average, influence the number of linkages that are geographically associated.

While one would expect Group A industries to be tied into the inter-industry system by a smaller number of input-output linkages, there does not appear to be any reason to suspect that the linkages that do exist are systematically of a smaller size. The backward linkages are determined technologically and the forward linkages, while fewer in number, may be just as strong as those of Group B industries.

Evidence regarding this hypothesis is provided by calculating, for Group A and Group B, the proportion of linkages which are accompanied by spatial associations. For Group A there are 273 linkages and 98 geographical associations. Thus, on average, 35.89 per cent of the linkages are accompanied by spatial associations for Group A industries. For Group B industries there are 299 geographical associations for 828 backward and forward linkages; this amounts to 36.11 per cent. The difference of 0.22 between the two figures is less than 1 per cent. This difference is considered to be insignificant and leads to an acceptance of the second final demand impact hypothesis.

4.2.5 H 5: Processing Stage Impact Hypothesis

> The processing stage at which industries operate has no influence on the proportion of interindustry linkages accompanied by spatial associations.

This hypothesis expressly examines the impact the processing stage might have on the share of linkages that are also geographically associated. The hypothesis is tested for the three stages of raw material users, i.e. Group I, II, and III industries;[1] Group I industries are closely tied to the primary sector while for Group III industries raw materials are of relatively little importance.

There exists some prior information, both of a theoretical and an empirical kind, that would lead one to doubt whether the hypothesis will be confirmed. As was outlined above, location theory predicts that early raw material users will show, because of weight loss of the materials in processing, a greater affinity toward their sources of supply than toward their forward industries. Theoretical considerations

[1]See Appendix 3 for details on industry groups.

also suggest that footloose industries, i.e. those for which transportation costs are not a major locational factor, will gravitate towards a market location. The empirical clues may be derived from the tests of earlier hypotheses, especially H 2 and H 3, which indicated that there existed deviations from a strictly proportional distribution of associated linkages.

The test of the processing stage impact hypothesis is again based on the χ^2-statistic which compares the observed frequencies of the cells with the theoretical frequencies and expresses the degree of correspondence between the two. As before, a $\chi^2 = 0$ would indicate that there is no discrepancy between the observed and expected frequencies and would, in this case, confirm the hypothesis; a large χ^2 would result from a great discrepancy. Observed and expected frequencies are shown in Tables 11 and 12 respectively.

For this test the theoretical frequencies were not calculated by taking the marginal totals of the observed frequencies and calculating the proportions. The processing stage hypothesis itself specifies the distribution of cell frequencies and this a priori information was used in the calculation of the expected frequency table.[1] If the processing stage had no impact on the proportion of linkages that are also spatially associated, then the frequency of associated linkages for each industry group should be proportional to the number of industries in each group. Of the 86 manufacturing industries 14, or 16.3 per cent, fall into Group I; thus 16.3 per cent of the 353 linked and associated

[1]See G. Udny Yule and Maurice G. Kendall, An Introduction to the Theory of Statistics (London: Charles Griffin & Company, Ltd., 1946), p. 427.

TABLE 11

OBSERVED FREQUENCIES OF GEOGRAPHICALLY ASSOCIATED INTERINDUSTRY LINKAGES BY INDUSTRY GROUP

Linkage Origin	Linkage Destination: Group I	Group II	Group III	Total
Group I	6	2	5	13
Group II	3	3	23	29
Group III	7	22	282	311
Total	16	27	310	353

TABLE 12

EXPECTED FREQUENCIES OF GEOGRAPHICALLY ASSOCIATED INTERINDUSTRY LINKAGES BY INDUSTRY GROUP[a]

Linkage Origin	Linkage Destination: Group I	Group II	Group III	Total
Group I	9.3	6.0	42.1	57.4
Group II	6.0	3.9	27.1	37.0
Group III	42.1	27.1	189.4	258.6
Total	57.4	37.0	258.6	353.0

[a] Snedecor and Cochran point out that it is not necessary to combine cells if none of the theoretical frequencies is smaller than five. See George W. Snedecor and William G. Cochran, Statistical Methods (Ames, Iowa: The Iowa State University Press, 1967), p. 235.

industry pairs were entered as the marginal total for Group I in the expected frequency table. The proportions for Group II and III industries are 10.5 per cent and 73.2 per cent respectively. The marginal totals appear in Table 12; from these totals the individual cell frequencies were calculated in the usual manner.

The χ^2-test yields a χ^2 = 114.32. The critical value is

$$P[\chi^2 > 13.28] = .01$$

for d.f. = 4. The result thus shows a substantial discrepancy between the observed and the theoretical frequencies and the hypothesis is not confirmed.

A comparison of Tables 11 and 12 shows that there appear to be two major sources for the discrepancy; these conform very well with the theoretical considerations above. One source may be found within the Group III industries. Only 189.4 associated linkages were expected but 282 were observed. This large number of spatial associations between linked industry pairs of Group III may be partly due to other agglomerative factors and the greater degree of footlooseness at the later stage of production. The other source for the discrepancy lies in the number of associated linkages between Group I industries on the one hand and Group II and III industries on the other hand. For linkages emanating from Group I 6.0 were expected to be geographically associated with Group II industries but only 2 were observed; 42.1 were expected to be associated with Group III industries but only 5 were observed. For linkages emanating from Group II to Group I 6 spatial associations were expected but only 3 were observed. Between Groups III and I 42.1 were expected but only 6 were observed. In all other cases observed and theoretical frequencies correspond well. These results indicate that the processing stage does influence the proportion of linkages accompanied by spatial association of industry pairs. H 5 is therefore rejected.

4.2.6 H 6: Dispersion Hypothesis

> The proportion of the industries' final demand sales has no impact on the industries' dispersion of employment proportions.

The final hypothesis regarding all manufacturing industries to be tested is the dispersion hypothesis. Rather than being concerned with some aspect of interindustry linkages this hypothesis sets out to examine the influence of forward final demand consumption linkages on the distribution of manufacturing employment proportions in the metro areas.

Theoretical locational considerations tend to lead to the expectation of finding the employment proportions of Group A industries -- those heavily linked to final demand consumption -- more concentrated in the metro areas than the employment proportions of Group B industries. The figures for industry employment in metro areas as a percentage of total Canadian industry employment are provided in Table 1. For Group A industries a mean of 56.23 per cent is calculated. The variance for Group A is 303.19 points. Group B industries have, on the average, only 51.13 per cent of the employees in metro areas, with a variance of 537.16. Clearly, the dispersion of employment percentages in metro areas for Group B industries is much larger than that for Group A industries. The coefficient of variation,[1] a relative measure of dispersion, yields .3157 for Group A and .4571 for Group B, again a sizeable difference. However, with a ratio of the larger variance to the smaller variance of 1.77 the difference is, in a statistical sense,

[1]See Taro Yamane, Statistics, p. 76.

not very strong. Only at the 0.1 level of significance could the variances be considered different.[1] A few reasons may be advanced to explain this result. On the one hand the limit between Group A and Group B industries may have been set rather high with 50 per cent of total output destined for final demand consumption. This may have put many heavily consumption-oriented industries into Group B, thus weakening the result. On the other hand, a significant number of Group B industries may have agglomerated in metro areas, because of linkages and other reasons, resulting in similar means and variances. Overall the evidence would appear strong enough to conclude that final demand sales have some influence on the dispersion of employment proportions. The dispersion hypothesis is therefore tentatively rejected.

4.3 Summary and Evaluation of the Results

The empirical analysis has shown that interindustry linkages are important agglomerative locational factors. The result of the independence test indicated that there exists a statistically significant relationship between input-output linkages and the spatial association of industries. This result is important as it lays the foundation for further analysis and policy suggestions.

In subsequent hypotheses various aspects of the linkage/association relationship were probed. The results of these tests of hypotheses tend to confirm the predictions made on the basis of location theory. Of the interindustry linkage hypotheses both the Symmetry Hypothesis (H 1) and the Production Sequence Hypothesis (H 2) were definitively

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[1]At the 10% level of significance $F^{59}_{25} = 1.59$.

accepted; the Linkage Strength Hypothesis (H 3) was accepted with the qualification that the very strong backward linkages to primary manufacturing industries are generally not combined with spatial association of the linked industry. This result is of particular interest in the Canadian context for it indicates that there appear to exist strong forces pulling back processing and refining industries to the non-urban raw material location; these were discussed above. It also suggests, *mutatis mutandis*, that the non-urban locations would tend to find it difficult to attract the forward-linked industries into their geographical proximity. The last interindustry linkage hypothesis, the Processing Stage Impact Hypothesis (H 5) was rejected as expected.

Hypotheses 4 and 6 explored aspects of a special type of forward linkage, the final demand consumption link. Both Final Demand Impact Hypotheses (H 4.1 and 4.2) were accepted while the rejection of the Dispersion Hypothesis (H 6) was somewhat less definite than had been anticipated. Possible reasons for this result were given above.

These results provide insights into the way in which input-output linkages affect the locational patterns of the manufacturing industries as a whole. While the regions considered in the analysis are restricted to the Canadian metropolitan areas, it would appear reasonable to suggest that analogous results would be obtained for other regions delineated according to economic criteria.

5. INDUSTRY - SPECIFIC APPROACH AND INDUSTRIAL COMPLEXES

In this chapter an attempt is made to shed some light on the importance of interindustry linkages to specific manufacturing industries. The chapter also contains information on the population orientation of individual manufacturing industries. A special section deals with industrial complexes.

5.1 Affinity of Manufacturing Industries to Their Linked Industries

Correlation coefficients for each industry were computed in order to ascertain how closely associated each industry is with all of its linked industries taken together.

The correlation is over the eighteen metropolitan areas (k = 1, 2, ..., 18) between the employment proportion of an individual industry p_{ik} and the sum of the employment proportions in all of its linked industries

$$\sum_j p_{jk}$$

where j represents all the industries to which industry i is linked. The results of the correlation are shown in Table 13.

It should be noted at the outset that the specific industry coefficients cannot be expected to be very high for several reasons. Firstly, since the correlation is with a summary measure of <u>all</u> linked

TABLE 13

CORRELATION COEFFICIENTS FOR INDIVIDUAL MANUFACTURING INDUSTRIES WITH LINKED INDUSTRIES AND WITH RANDOMLY SELECTED INDUSTRIES

IOIC-L Number	Industry Title	Correlation Coefficient Linked Industries	Correlation Coefficient Random Industries
12	Slaughtering & Meat Processors	.1574	.1605
13	Poultry Processors	.2038	-.0075
14	Dairy Factories	.1459	.1015
15	Process Cheese Manufacturers	-.0866	.1289
16	Fish Products Industry	-.4161	-.1119
17	Fruit & Vegetable Canners and Preservers	.4884	.2066
18	Feed Mills	.5080	.5081
19	Flour Mills	.1485	.1861
20	Breakfast Cereal Manufacturers	.1039	-.0795
21	Biscuit Manufacturers	.1659	.6126
22	Bakeries	.1363	.2677
23	Confectionery Manufacturers	.0374	.3592
24	Sugar Refineries	.0144	-.1487
25	Vegetable Oil Mills	.6169	.2408
26	Miscellaneous Food Industries	.2753	.2687
27	Soft Drink Manufacturers	-.4648	-.1403
28	Distilleries	-.0246	.2464
29	Breweries & Wineries	.0835	-.0827
30	Leaf Tobacco Processing	.1458	.0184
31	Tobacco Products Manufacturers	.1267	.1671
32	Rubber Footwear Manufacturers	.4606	.6873
33	Tire & Tube Manufacturers	.6857	.6795
34	Other Rubber Industries	.5243	.6707
35	Leather Tanneries	.5202	.8821
36	Shoe Factories	.5334	.6518
37	Glove & Luggage Manufacturers	.5206	.0165

TABLE 13--Continued

IOIC-L Number	Industry Title	Correlation Coefficient Linked Industries	Correlation Coefficient Random Industries
38	Cotton Yarn & Cloth Mills	.6008	.0011
39	Wool Yarn & Cloth Mills	.6608	.4962
40	Synthetic Textile Mills	.6499	.2671
41	Carpet, Mat & Rug Industry	.6080	.7251
42	Linoleum & Coated Fabrics Industry	.2595	.3252
43	Textile Bags & Canvas Products Industry	.2394	.3722
44	Other Textile Industries	.7035	.3236
45	Hosiery Mills	.2653	-.0407
46	Other Knitting Mills	.8317	.2511
47	Clothing Industries	.5165	.5320
48	Sawmills	-.1964	-.2212
49	Veneer & Plywood Mills	-.1322	-.1428
50	Sash & Door and Planing Mills	.0490	.0198
51	Other Wood Industries	.7695	.0747
52	Household Furniture Industry	.7103	.9170
53	Other Furniture Industries	.7090	.2636
54	Pulp & Paper Mills	-.2007	-.2996
55	Asphalt Roofing Manufacturers	.2202	.0248
56	Paper Box & Bag Manufacturers	.4956	.4982
57	Other Paper Converters	.5149	.2730
58	Printing, Publishing & Engraving	.3557	-.0543
59	Iron & Steel Mills	.4922	.0944
60	Steel Pipe & Tube Mills	.0054	-.0982
61	Iron Foundries	.7351	.6219
62	Smelting & Refining	-.0098	-.0727
63	Aluminum Rolling, Casting and Extruding	.5288	.4891
64	Copper & Alloy Rolling, Casting and Extruding	.4181	.2955

TABLE 13--Continued

IOIC-L Number	Industry Title	Correlation Coefficient Linked Industries	Correlation Coefficient Random Industries
65	Metal Rolling, Casting and Extruding, n.e.s.	.7168	.3807
66	Boiler & Plate Works	.5830	.3739
67	Fabricated Structural Metal Industry	.2215	-.0727
68	Ornamental & Architectural Metal Industry	.5486	.3386
69	Metal Stamping, Pressing & Coating Industry	.8545	.6422
70	Wire & Wire Products Manufacturers	.8015	.6633
71	Hardware, Tool & Cutlery Manufacturers	.7386	.3460
72	Other Metal Fabricating Industries	.6656	.6744
73	Machinery & Equipment Manufacturers	.9074	.8340
74	Refrigeration, Office & Store Machinery Manufacturers	.5608	.2100
75	Aircraft & Parts Manufacturers	.0207	-.0574
76	Motor Vehicles & Trailer Manufacturers	.3369	-.1111
77	Motor Vehicle Parts Manufacturers	.4548	.0805
78	Other Transportation Equipment Industries	-.3309	-.3214
79	Manufacturers of Electrical Appliances	.7384	.2746
80	Manufacturers of Communications Equipment, including Wire	.4596	.4505
81	Manufacturers of Electrical Industrial Equipment	.6238	.4432
82	Other Electrical Products Manufacturers	.5515	.7216
83	Cement & Lime Products Manufacturers	-.3521	-.0691
84	Concrete & Gypsum Products Manufacturers	.2019	.3866

TABLE 13--Continued

IOIC-L Number	Industry Title	Correlation Coefficient Linked Industries	Correlation Coefficient Random Industries
85	Clay, Stone & Refractory Products Manufacturers	.5856	.0906
86	Glass & Glass Products Manufacturers	.7824	.3930
87	Other Non-Metal Mineral Products Industries	.7312	.5759
88	Petroleum & Coal Products Industries	-.3236	-.1503
89	Explosives & Ammunition Manufacturers	-.2542	.0016
90	Manufacturers of Mixed Fertilizers	-.0223	-.0218
91	Manufacturers of Plastic Resins	.2202	.2753
92.	Manufacturers of Pharmaceuticals and Medicines	.3995	.3507
93	Paints & Varnishes Manufacturers	.1885	.0676
94	Manufacturers of Soap and Cleaning Compounds	.6959	.7783
95	Manufacturers of Toilet Preparations	.3936	.3195
96	Industrial & Other Chemical Industries	.4673	.3614
97	Miscellaneous Manufacturing Industries	.5904	.6463

industries there may be many non-associated but linked industries which introduce disturbances. Secondly, as the foregoing analysis has shown, some of the very strong linkages are not accompanied by geographical associations and this fact will tend to depress the coefficients for a number of industries. Thirdly, while the analysis of the previous chapter has shown that strong linkages are more powerful agglomerative factors than weak ones, all employment proportions of linked industries are entered at 'face value' into the correlation. A weighting by the strength of the linkage might have produced higher coefficients. Fourthly, there exist differences among Canadian metropolitan areas in the ratio of manufacturing employment to population.[1] Moreover, the differences also extend to the employment proportions within the metro areas. This unequal distribution of employment shares will tend to reduce the correlation coefficients.

In any case, of primary importance here are not the absolute values of the correlation coefficients but a comparison of their signs and magnitudes with another series of correlation coefficients that provides a standard of comparability. This series has been obtained by correlating the employment proportion of industry i with the sum of employment proportions in randomly selected industries. For each industry the number of random industries is equal to the number of linked industries. The results of this correlation are shown in column 2 of Table 13. One would expect the correlation coefficients with random industries to be, on the average, significantly lower than the correlation coefficients with linked industries, resulting in a lower mean and

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[1]See Table 2, p. 53.

in a greater number of negative coefficients.

Examination of Table 13 reveals that most of the manufacturing industries are locationally oriented towards their linked industries. In column 1 for linked industries 45 of 86 coefficients are significant at the 0.1 level. For random industries in column 2, there are only 25 significant coefficients. The number of negative coefficients is 13 for linked industries, or 15.1 per cent, and is 20, or 23.4 per cent, for randomly selected industries. The mean of the coefficients for linked industries is 0.3508 as opposed to 0.2585 for the set of random industries.

The t-test has been applied to the two series of data in order to determine whether the difference between the means is significant. The value of the t-statistic is $t = 1.8990$ with $n_1 + n_2 - 2 = 170$ degrees of freedom. The closest approximation in the published tables with regard to the degrees of freedom is d.f. = 120, with the table showing that

$$P(t > 1.658 \mid d.f. = 120) = .05$$

and

$$P(t > 1.980 \mid d.f. = 120) = .01$$

Thus the computed t-value is significant at the 5 per cent level and almost significant at the 1 per cent level. This evidence is considered to be strong enough to conclude that the means are different. In other words, manufacturing industries are more often geographically associated with their linked industries than with randomly selected industries.

Two reasons may be cited that explain why the difference between the means, although statistically significant, was not more pronounced. Firstly, a number of industries, especially in the textile and the metals sector, possess a relatively large number of interindustry linkages. The random selection process then picked in many cases several industries that are in fact linked. Secondly, the attraction of many manufacturing industries to centres of population results in a similarization of the correlation coefficients. In the light of these considerations the t-value obtained assumes even greater significance.

Of the industries in the food processing sector interindustry linkages are of locational importance to #17 Fruit and Vegetable Canners and Preservers and #25 Vegetable Oil Mills. In the former case the linkages are backward to suppliers such as #57 Other Paper Converters, #69 Metal Stamping, Pressing & Coating Industry, and #86 Glass and Glass Products Manufacturers; in the latter case there are supply linkages to #69 and #96 Industrial and Other Chemical Industries and forward linkages to #94 Manufacturers of Soap and Cleaning Compounds and #96, i.e. the linkage to #96 is a double linkage.

Input-output linkages appear to be of great locational importance to the textile sector. The basic textile mills, #38 Cotton Yarn & Cloth Mills, #39 Wool Yarn & Cloth Mills, and #40 Synthetic Textile Mills are closely linked and geographically associated with one another and with many of their forward textile industries, e.g. #44 Other Textile Industries, #45 Hosiery Mills, #46 Other Knitting Mills, and #47 Clothing Industries. This sector will be examined in more detail below.

In the wood sector #51 Other Wood Industries and #53 Other

Furniture Industry are particularly oriented towards their linked industries. For the former industry these are mainly forward linkages while for the latter there are a large number of exclusively backward linkages.[1] Industry #57 Other Paper Converters is also locationally tied to its linked industries, albeit it is not usually found in locational proximity to its major supplier, #54 Pulp and Paper Mills.[2]

The largest number of industries to which interindustry transactions are of locational significance may be found in the metals sector including many of the metal-using industries in that production chain. Table 13 shows that for industries #59 to #82, with only four exceptions, the locational affinity to linked industries is stronger than to random industries. For several industries, e.g. #65 Metal Rolling, Casting and Extruding, n.e.s., #71 Hardware, Tool & Cutlery Manufacturers, #73 Machinery and Equipment Manufacturers, and #79 Manufacturers of Electrical Appliances, locational proximity to their linked industries appears to be of very great importance. The metals sector will also receive further attention below.

Of the industries in the non-metal sectors the correlation coefficient with linked industries indicates a particular closeness to these linked industries for #85 Clay, Stone & Refractory Products Manufacturers, #86 Glass & Glass Products Manufacturers, and #87 Other Non-metal Mineral Products Industries. For industry #85 the

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[1]See Appendix 4 for a listing of linked and associated industries by industry.

[2]Although the backward linkage to #54 is only .4547 the reasoning of Section 4.2.3 appears to apply also in this case.

commodity flows of predominant locational importance appear to be to #59 Iron & Steel Mills, a double linkage with #81 Manufacturers of Electrical Industrial Equipment, and the inputs from #87. Industry #86 has an associated backward linkage of medium strength to #96 Industrial and Other Chemical Industries and five spatially associated forward linkages to a variety of industries.[1]

However, many manufacturing industries are not attracted into geographical proximity to their linked industries. Into this group fall especially the early refining and processing industries that seek a location--away from forward linked industries and centres of population--near their principal suppliers. #16 Fish Products Industries, #48 Sawmills, #54 Pulp & Paper Mills, #62 Smelting & Refining, and #83 Cement & Lime Products Manufacturers may serve as examples. In addition there are those industries whose distribution largely follows the distribution of population regardless of linkages, e.g. #22 Bakeries and #27 Soft Drink Manufacturers, and industries that appear to be heavily concentrated in a few centres, e.g. #41 Carpet, Mat & Rug Industry, #60 Steel Pipe and Tube Mills, #75 Aircraft & Parts Manufacturers, and #77 Other Transportation Equipment Industries.

Further discussion of the locational patterns of individual industries would require consideration of other locational factors and result in the drawing up of industry profiles of location. This is beyond the scope of the present study.

5.2 Population Attraction of Manufacturing Industries

For each industry a population correlation coefficient was

[1]See Appendix 4 for industry detail.

computed between the employment in industry i in region k and the population of region k over all regions. These coefficients indicate the extent to which the distribution of a manufacturing industry corresponds to the distribution of population.

The population correlation coefficients appear together with other industry data in Table 1.[1] They are generally high because many manufacturing industries are attracted to centres of population. It should be noted, however, that these coefficients appear to have an upward bias due to the dominating influence of the large metro regions. The overstatement of the population attraction may have been enhanced by some degree of tautology in the correlation. Since every employee is also a member of the population and to the extent that many of the employees are heads of families, there will exist a certain factor of proportionality between the two series. This would tend to raise the coefficient. Despite these reservations the population correlations would appear useful in showing relative differences in the population attraction of manufacturing industries.

5.3 Delineation of Industrial Complexes

The results obtained in the linkage analysis of location of manufacturing industries encourage further application of this approach in a more policy-oriented direction. In this section an attempt will be made to identify industrial complexes. This constitutes an extension of the bilateral aspect under which pairs of linked industries are viewed in isolation from the rest of the economic system. By

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[1]See Table 1, pp. 15-17.

taking cognizance--even if only modestly--of multilateral interdependencies and locational affinities in production chains or roundabout systems it is possible not only to show better the intricacy of a developed economy but also to suggest avenues for policy action in the area of regional development.

Isard has defined an industrial complex as

> "... a set of activities occurring at a given location and belonging to a group (subsystem) of activities which are subject to important production, marketing, or other interrelations."[1]

Without intending to stress unduly the dichotomy of production chains and roundabout systems, it may be noted that Isard implicitly stresses the former[2] while the analysis below leads to the conclusion that the latter are of prime importance.

5.3.1 Complex Criteria. The industrial complexes identified here have been delineated solely on the basis of interindustry linkage and spatial association relationships. This is, of course, a restricted view but the purpose of this investigation is to probe the agglomerative efficacy of input-output linkages rather than to present a complex analysis that takes account of a large number of locational factors.[3]

Notwithstanding the critical remarks regarding the symmetric linkage measure s_{ij} made in Chapter 3, this coefficient will be used

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[1]Walter Isard, Methods, p. 377.

[2]Ibid., pp. 377-378.

[3]See, for example, Walter Isard, Eugene W. Schooler, and Thomas Vietorisz, Industrial Complex Analysis and Regional Development (New York: John Wiley & Sons, Inc., 1959).

here in the complex analysis. Its use may be defended on two grounds: firstly, and rather pragmatically, it is convenient to employ s_{ij} because these coefficients permit the distillation of symmetric and square industrial complex submatrices from the large system matrices R and S; secondly, the more transparent linkage coefficient matrices B and F allow a constant cross-checking to ensure that interindustry flows are properly identified by the symmetric measure.

The search for industrial complexes involves then, in this context, a search for symmetric square submatrices of size 3 x 3 or larger with no or few empty cells. Fulfilment of this criterion ensures that there is substantial, often mutual, interchange of commodities among the industries of the subsystem. The complex matrices are obtained by exchanging rows (columns) of the large interindustry matrix in the appropriate manner. Each cell of the submatrix contains two numbers: the correlation coefficient measuring geographical association (top) and the linkage coefficient (bottom). The significance level of 0.1 has been retained for the spatial measure while the industry average might be suggested as a criterion for the linkage measure.[1] However, the latter criterion was not adopted and smaller s_{ij} were recorded since, as was noted above, it is possible that relatively small flows are of locational importance to certain industries. Usually the s_{ij} between associated industries of complexes are well above the average size for the industry. In some cases, especially where strong linkages are present, non-significant spatial coefficients were also entered; these are enclosed in parentheses.

[1]See Manfred E. Streit, Verbunds, p. 65. For similar criteria and approach see also ibid., Associations, p. 182.

It may be argued that the requirement for a complex industry to be in substantial exchange relationships with all other industries in the complex is too stringent. A somewhat looser and perhaps more realistic criterion might be to require an industry to be tied, technologically and locationally, to one complex industry only. While this approach may be useful for a more detailed study of one specific complex, it has not been adopted here because it detracts from the interconnected and roundabout nature of the commodity flows of the complex core. Moreover, the listing of production chains in the metals-using sector, to be further discussed below, indicates that the industries often tend to "loop back" at some stage of the sequence.[1]

5.3.2 Identification of Specific Complexes. Using the large system matrices R and S as a starting point a total of eight industrial complexes were identified. The interindustry submatrices for these complexes are presented on the following pages. For convenient reference the relevant industry titles are reproduced below each table.

Wood Complex. The wood complex (Table 14) is of the minimum required size 3 x 3. Its industries are #51 Other Wood Industries, #52 Household Furniture Industry, and #53 Other Furniture Industries. The spatial coefficients are all significant at the 1 per cent level and the linkage coefficients between the complex industries are substantially above the complex average with all manufacturing industries (.0035). All three industries are heavily backward linked to industry

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[1]See Appendix 5 for a partial list of iron- and steel-using production sequences.

TABLE 14

WOOD COMPLEX[a]

	51	52	53
51		.8454 .0109	.8198 .0058
52	.8454 .0109		.9522 .0114
53	.8198 .0058	.9522 .0114	

#51 Other Wood Industries
#52 Household Furniture Industry
#53 Other Furniture Industries

[a]Rather than showing only the entries above the principal diagonal all complex matrices are produced in full to emphasize the mutuality of the relationships involved.

48 Sawmills but none of these linkages are geographically associated. The main complex connections are backward linkages b_{5152}, b_{5153}, b_{5253}, and the forward linkage f_{5152}.

Paper Complex. The paper complex (Table 15), also of size 3 x 3, consists of #56 Paper Box & Bag Manufacturers, #57 Other Paper Converters, and #58 Printing, Publishing & Engraving. The industries in this complex are highly interconnected through double linkages (i.e. backward and forward) between #56 and #57, #57 and #56, #57 and #58, and a backward linkage of industry #56 with industry #58. All symmetric linkage coefficients are above the complex average with all manufacturing industries and all correlation coefficients are significant. As in the previous case, all complex industries possess a very strong, but non-associated, backward linkage to their principal supplier, industry #54 Pulp & Paper Mills.

Textile Complex. This complex appears to be the most closely knit of all the complexes examined (Table 16). It has been delineated as a 7 x 7 subsystem consisting of the basic textile mills #38 Cotton Yarn & Cloth Mills, #39 Wool Yarn & Cloth Mills, and #40 Synthetic Textile Mills; in addition there are #41 Carpet, Mat & Rug Industry, #44 Other Textile Industries, #46 Other Knitting Mills, and #47 Clothing Industries. The industries are connected through a large number of double and single linkages and both the linkage coefficients and the spatial coefficients are generally high. Due to the large number of geographically associated linkages not every connection will be named separately here but the bilateral linkage detail is readily obtainable from Appendix 4.

TABLE 15

PAPER COMPLEX

	56	57	58
56		.4007 .0452	.5944 .0126
57	.4007 .0452		.7523 .0082
58	.5944 .0126	.7523 .0082	

#56 Paper Box & Bag Manufacturers
#57 Other Paper Converters
#58 Printing, Publishing & Engraving

TABLE 16

TEXTILE COMPLEX

	38	39	40	41	44	46	47
38		.7437 .0152	.7282 .0828	(.3977) .0482	.6577 .0695	.6744 .0622	(.3793) .1181
39	.7437 .0152		.9729 .0369	.6197 .0392	.8223 .0733	.8339 .0438	(.2865) .1417
40	.7282 .0828	.9729 .0369		.6289 .0487	.9016 .0425	.8781 .1062	.4391 .0859
41	(.3977) .0482	.6197 .0392	.6289 .0487		.7501 .0312	.8105 .0020	.6270 .0021
44	.6577 .0695	.8223 .0733	.9016 .0425	.7501 .0312		.9537 .0198	.6903 .0724
46	.6744 .0622	.8339 .0438	.8781 .1062	.8105 .0020	.9537 .0198		.6909 .0724
47	(.3793) .1181	(.2865) .1417	.4391 .0859	.6270 .0021	.6903 .0727	.6909 .0724	

#38 Cotton Yarn & Cloth Mills
#39 Wool Yarn & Cloth Mills
#40 Synthetic Textile Mills
#41 Carpet, Mat & Rug Industry
#44 Other Textile Industries
#46 Other Knitting Mills
#47 Clothing Industries

All symmetric linkages, except for those connecting industry 41 with industries 46 and 47, are above complex average; however, these two are accompanied by very significant correlation coefficients and have therefore been recorded. It will be noted that r_{3847} is somewhat below the minimum size for significance and r_{3947} substantially so (these coefficients are enclosed in parentheses). Yet the linkage ties are extremely strong and it would appear that the industries 38, 39, and 47 would stand to gain greatly from commodity exchange in close geographical proximity. While this finding appears to have policy implications, any concrete action would of course have to rely on a more detailed study of the industries involved.

Metal Complex I. The first metal complex identified is of size 5 x 5 and contains industries 59 Iron & Steel Mills, 65 Metal Rolling, Casting and Extruding, n.e.s., 68 Ornamental and Architectural Metal Industry, 69 Metal Stamping, Pressing & Coating Industry, and 70 Wire and Wire Products Manufacturers (Table 17). As can be seen in the Table, several of the symmetric linkage coefficients are below or around the complex industries' average with all manufacturing industries of .0088. However, this fact should not be over-emphasized because the relatively high average is mainly due to a small number of strong linkages involving industries 59 and 62. The spatial coefficients between industries 59 and 68 and between 68 and 70 are below the minimum size. While a weakness in the subsystem matrix, the small size of a coefficient may be a virtue from an economic policy aspect especially if the correlation coefficient measuring geographic association is accompanied by a strong linkage coefficient. This is the

TABLE 17

METAL COMPLEX I

	59	65	68	69	70
59		.7840 .0049	(.2330) .0586	.5980 .1563	.8891 .1208
65	.7840 .0049		.4646 .0033	.7946 .0095	.7992 .0014
68	(.2330) .0586	.4646 .0033		.4941 .0086	(.2861) .0077
69	.5980 .1563	.7946 .0095	.4941 .0086		.7813 .0059
70	.8891 .1208	.7992 .0014	(.2861) .0077	.7813 .0059	

#59 Iron & Steel Mills
#65 Metal Rolling, Casting and Extruding, n.e.s.
#68 Ornamental & Architectural Metal Industry
#69 Metal Stamping, Pressing & Coating Industry
#70 Wire and Wire Products Manufacturers

case for r_{5968}, the linkage being a strong supply linkage of #68 Ornamental & Architectural Metal Industry with #59 Iron & Steel Mills. Most of the linkages in this complex are single linkages.[1]

Metal Complex II. The subsystem matrix of the second metal complex is of the dimensions 4 x 4 (Table 18). Contrary to the Metal Complex I the early industry here is #61 Iron Foundries which is joined by #66 Boiler & Plate Works, #69 Metal Stamping, Pressing & Coating Industry, and #72 Other Metal Fabricating Industries. The spatial coefficients are significant at the 0.1 level; indeed, except for r_{6972} which is significant at the .05 level, all other correlation coefficients meet the 1 per cent level of significance. The linkage coefficients indicate a large amount of interchange among the complex industries with only s_{6169} somewhat below the average. Industry 72 is particularly tightly connected with the complex through double linkages emanating to it from industries 61, 66, and 69. Industry 72 itself has a backward and forward linkage with industry 69; all other linkages are single linkages.

Machinery Complex I. With a subsystem matrix of size 6 x 6 the Machinery Complex I is relatively large (Table 19). Its industries are #69 Metal Stamping, Pressing & Coating Industry, #71 Hardware, Tool & Cutlery Manufacturers, #72 Other Metal Fabricating Industries, #73 Machinery and Equipment Manufacturers, #74 Refrigeration, Office & Store Machinery Manufacturers, and #81 Manufacturers of Electrical Industrial Equipment. The coefficients of the complex matrix indicate

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[1]See Appendix 4.

TABLE 18

METAL COMPLEX II

	61	66	69	72
61		.7373 .0053	.6361 .0030	.7488 .0184
66	.7373 .0053		.6191 .0093	.6279 .0368
69	.6361 .0030	.6169 .0093		.4969 .0208
72	.7488 .0184	.6279 .0368	.4969 .0208	

#61 Iron Foundries
#66 Boiler & Plate Works
#69 Metal Stamping, Pressing & Coating Industry
#72 Other Metal Fabricating Industries

TABLE 19

MACHINERY COMPLEX I

	69	71	72	73	74	81
69		.5843 .0084	.4969 .0208	.9025 .0189	.5562 .0058	.7035 .0220
71	.5843 .0084		.7641 .0220	.6078 .0091	.5185 .0043	(.3889) .0035
72	.4969 .0208	.7641 .0220		.5481 .0444	.5191 .0076	.5848 .0145
73	.9025 .0189	.6078 .0091	.5481 .0444		.4653 .0076	.6832 .0228
74	.5562 .0058	.5185 .0043	.5191 .0076	.4653 .0073		.8060 .0152
81	.7035 .0220	(.3889) .0035	.5848 .0145	.6832 .0228	.8060 .0152	

#69 Metal Stamping, Pressing & Coating Industry
#71 Hardware, Tool & Cutlery Manufacturers
#72 Other Metal Fabricating Industries
#73 Machinery and Equipment Manufacturers
#74 Refrigeration, Office & Store Machinery Manufacturers
#81 Manufacturers of Electrical Industrial Equipment

that the commodity flows among the industries are quite strong and that the degree of locational affinity is relatively high. There are two exceptions. Firstly, r_{7181}, while only slightly below the minimum size of .4000, is accompanied by a below average linkage coefficient. Since the flows are not of sufficient size to constitute a bilateral linkage, the relationship between these two industries must be described as quite loose; secondly, the entries for industries 71 and 74 show that s_{7174} is somewhat below the complex average of .0054; however, the spatial coefficient is significant at the 5 per cent level. All other coefficients are well above the critical values. The relatively large number of double linkages in this complex[1] points to a particularly high degree of roundaboutness.

Machinery Complex II. This complex also has the dimensions 6 x 6 (Table 20). Due to the great variety of products manufactured by the industries in the machinery complexes[2] four of the industries in this complex were also part of the Machinery Complex I, i.e. #69 Metal Stamping, Pressing & Coating Industry, #71 Hardware, Tool & Cutlery Manufacturers, #73 Machinery & Equipment Manufacturers, and #74 Refrigeration, Office & Store Machinery Manufacturers. New are the industries 61 Iron Foundries and 70 Wire and Wire Products Manufacturers. Apart from significant coefficients for industries 61 and 72, the relationships between the industries particular to each machinery complex are weak. This fact would tend to justify the delineation of

[1]See Appendix 4.

[2]See Canada, D.B.S., The Input-Output Structure, Vol. I, pp. 255-256.

TABLE 20

MACHINERY COMPLEX II

	61	69	70	71	73	74
61		.6361 .0032	.5911 .0023	.8929 .0027	.6423 .0258	(.3689) .0011
69	.6361 .0032		.7813 .0059	.5843 .0084	.9025 .0189	.5562 .0058
70	.5911 .0023	.7813 .0059		.5343 .0041	.9088 .0060	(.2711) .0012
71	.8929 .0027	.5843 .0084	.5343 .0041		.6078 .0091	.5185 .0043
73	.6423 .0258	.9025 .0189	.9088 .0060	.6078 .0091		.4653 .0073
74	(.3689) .0011	.5562 .0058	(.2711) .0012	.5185 .0043	.4653 .0073	

#61 Iron Foundries
#69 Metal Stamping, Pressing & Coating Industry
#70 Wire and Wire Products Manufacturers
#71 Hardware, Tool & Cutlery Manufacturers
#73 Machinery & Equipment Manufacturers
#74 Refrigeration, Office & Store Machinery Manufacturers

two separate machinery complexes. With two sets of coefficients below the required size industry 74 is not very strongly tied to the complex. It may also be observed that several of the symmetric linkage coefficients are below the complex average of .0051. This is especially so for the linkages involving industry 61. As a result the Machinery Complex II appears to be less cohesive than the other complexes identified.

Electrical Complex. The final complex delineated is the Electrical Complex of size 4 x 4 (Table 21) comprising #64 Copper & Alloy Rolling, Casting and Extruding, #80 Manufacturers of Communications Equipment, including Wire, #81 Manufacturers of Electrical Industrial Equipment, and #82 Other Electrical Products Manufacturers. The coefficients of the subsystem matrix show that this complex is tightly connected. Except for s_{6482} which is only slightly below the complex average of .0055, all other linkage coefficients are relatively large. Consultation of Appendix 4 reveals that several industries are tied to one another through both backward and forward linkages. In addition to the double linkages there are a comparatively large number of single backward and forward linkages. With the exception of r_{6482} which is significant at the .05 level, all other correlation coefficients measuring the degree of spatial association are significant at the .01 level. It may be noted that it is the weakest linkage coefficient that is accompanied by the lowest spatial association coefficient.

5.3.3 Comments. The analysis of the preceding section should be viewed as an attempt to identify, on a theoretical basis, subsystems

TABLE 21

ELECTRICAL COMPLEX

	64	80	81	82
64		.6862 .1201	.7254 .0137	.5085 .0045
80	.6862 .1201		.6219 .0534	.8421 .0899
81	.7254 .0137	.6219 .0534		.7533 .0257
82	.5085 .0045	.8421 .0899	.7533 .0257	

#64 Copper & Alloy Rolling, Casting and Extruding
#80 Manufacturers of Communications Equipment, including Wire
#81 Manufacturers of Electrical Industrial Equipment
#82 Other Electrical Products Manufacturers

whose industries are connected by relatively large commodity flows and therefore stand to benefit by locating in close proximity to one another. While quite naturally the degree of cohesiveness of the complexes varies, nearly all the industries of each complex are closely tied to one another spatially and technologically. This is especially so for the Wood Complex, the Textile Complex and the Electrical Complex. In many instances complex industries have been shown to be joined by double linkages, i.e. both industries sell to and buy from one another significant amounts, indicating the highest degree of roundaboutness. It is understood that to be operational this type of analysis would have to be complemented by a full locational study which would endeavour to take account of other economic and non-economic externalities, labour costs, actual transportation costs, and other locational factors.

The goal has been to accept as members of a subsystem only those geographically associated industries among which a high degree of mutual interchange exists. It could be argued that firmer criteria should have been imposed but one must realize that this would have probably eliminated several actual complexes from being identified. Moreover, one of the advantages of this method is that it points out directions and policy possiblities for metro and other regions.

Requiring roundaboutness is actually quite a strong demand. It might have been more realistic to specify that an industry must be tied to at least <u>one</u> industry of the subsystem. There exist usually a large number of industries that are only in a one-way relationship with the complex and it may be particularly these (satellites, services) that make a complex a dynamic force in the regional economy. However, the interest here was in the structural core relationships without which a complex cannot exist. For these it appeared appropriate, especially in the light of the production sequence findings above, to require mutual exchange of commodities.

There exist other complexes, e.g. petro-chemical complexes,[1] which have not been mentioned here. This may be due, at least in part, to the data problems; these were discussed above. It appears that at the present time in the Canadian context the choice is between many all-inclusive regions and few industries on the one hand and fewer regions with relatively great industry detail on the other hand. For this type of study the latter choice, adopted here, would appear to be much preferable, especially when it is recalled that a large volume of total manufacturing is included in the analysis. The alternative, dealing with broad industrial sectors, must leave questions regarding specific industries unanswered.[2] This problem has been avoided here.

5.4 Summary and Evaluation of the Results

In the first section of this chapter the affinity of each manufacturing industry to its linked industries was investigated. By comparing, for each industry, the correlation coefficient with employment proportions in linked industries with that in randomly selected

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[1]These have been examined in great detail by Isard et al.; see Walter Isard, Methods, p. 412 for further references.

[2]See, for example, Manfred E. Streit, Verbunds, pp. 68 ff.

industries it was determined that the majority of industries show a stronger locational affinity to their linked industries than to random industries. The means of the two series of correlation coefficients were significantly different at a level between 5 and 1 per cent. Several industries to which input-output linkages appear to be either of particularly great or of particularly little locational importance were briefly surveyed. By identifying individual manufacturing industries the results obtained in this section amplify those obtained in the previous chapter for the manufacturing sector as a whole.

The section dealing with population correlation coefficients--somewhat of a digression from the mainstream of thought--was included in this chapter in order to provide some information on the relative population attraction of manufacturing industries. Although the coefficients for early processing and refining industries are generally low, high population correlation coefficients should not necessarily be taken to mean that a large share of those industries' employees work in the metro regions. Keeping in mind the remarks about the general upward bias of the population correlation coefficients it may be stated that higher coefficients indicate that the industries' employment in metro regions varies more in unison with the variation in population of the region.

The industrial complex analysis represents an attempt to identify clusters of industries using the tools and approaches of this study. The geographical extent of the complex would be the area of the metro region. Eight complexes with subsystem matrices of a size equal to or larger than 3 x 3 were delineated. Apart from locational proximity the sole requirement for an industry to be accepted as a part of a complex was a substantial degree of interaction with all other industries of the complex. In evaluating the results of the complex analysis it must be remembered that the intent here has not been the in-depth analysis of certain industrial agglomerations and their economic feasibility; this would require consideration of all other locational factors (besides agglomerative economies from linkages), comparative cost studies, etc. The objective was to provide, on the basis of the more theoretical investigations of earlier chapters, stepping stones that could serve as starting points for detailed analyses of certain projects and locations. As such they may aid regional planners by revealing nuclei of economic activity. Policy aspects will receive some further comment in the following final chapter.

6. CONCLUSION

This final chapter consists of some concluding remarks which will summarize, in a broad outline, the main points of the study. These will be followed by a section on the potential policy content of the analysis. Finally a few words will be said about data requirements and possible avenues of future research in this area of location theory.

6.1 Summary Remarks

The two main objectives of this study were an exposition of the theoretical background regarding the locational factor involved and an investigation into the relationship between industrial linkages and the spatial association of manufacturing industries.

The theoretical discussion was undertaken in Chapters 1 and 2. The study was placed into a larger framework by sketching the role of the spatial dimension in economic theory. It was mentioned here that only belatedly did spatial phenomena in economics receive the attention they would appear to deserve. Then an attempt was made to clarify the nature of agglomeration economies by examining more closely the underlying locational factors. Transfer economies, external economies, and interindustry linkages were discussed; it was noted that linkages, while possibly indicating channels along which pure external economies might be expected to flow, would appear to derive their locational importance from the transfer costs they imply.

The ascertainment of a definite relationship between input-output linkages and geographical associations of manufacturing industries permitted a more detailed study of the nature of the locational impact of these interindustry linkages in Chapters 4 and 5. Since the results of the analyses were presented and summarized in those chapters it may only be pointed out here that manufacturing industries appear to be attracted to and tend to cluster in metro regions partly because of input-output linkages. That there are other--and for some industries more powerful--locational factors that attract industries to or repel them from urban centres is understood.

Several technical problems were encountered and dealt with, for example the upward bias of the correlation coefficients, differences in aggregation, or the design of the linkage coefficients. These and other topics relating to data and methodology were treated in Chapter 3.

Growing out of the study of the linkage/association relationship an interesting application suggested itself: the delineation of industrial complex cores. This topic was included in Chapter 5 as it addresses itself to specific industries rather than to the manufacturing sector as a whole. A number of complexes in various fields of activity were identified. The complex industries are characterized by generally being located in close geographical proximity to one another and by being connected through relatively large intermediate input and output flows. The use of interindustry linkages as a sole explanatory factor for complex formation suggests quite naturally that a widening of the analysis to other locational factors and different regional boundaries may modify or even alter some of the conclusions reached here. However, the limitations set for this study did not permit consideration of factors other than linkages.

Before turning to policy implications of the analysis it may be pointed out that over time there will be changes in the linkage/association relationship for certain industries. These may be due to changes in technology and transfer costs, as in the case of #22 Bakeries and the oil refineries of #88 Petroleum and Coal Products Industries for which a trend toward further concentration appears to be discernible. Other, non-structural, factors causing changes may be alterations in such industrial 'environmental' conditions as taxes, incentives, etc. However, such factors do not appear to change very drastically and would tend to take quite a long time to manifest themselves in a different geographical distribution of economic activities.

6.2 Some Policy Aspects of the Analysis

This section is not meant to suggest that regional economic policies should be based exclusively, or even principally, on interindustry linkage relationships. Indeed it appears that the fault of many past policies has been that they were based on only one or a few economic criteria or, for that matter, on <u>economic</u> criteria alone. The agglomerative tendency through input-output linkages is, of course, but one factor in a complex mosaic of locational forces; however, in the search for industries suitable for regional development or decentralization they would appear to allow a methodical rather than an ad hoc approach to the problem at hand.

The interest here is then not so much in the locational configuration which has developed historically and exists now, but in what could be or what appears feasible and advisable in the light of information about the relationship between interindustry linkages and the spatial association of industries. It may bear pointing out again at this juncture that the analysis above has been performed for metro regions only; any conclusions derived from it apply therefore, strictly speaking, only to these types of areas. It is tempting, however, and would not appear to be altogether unreasonable, to extend the policy implications to other regions. Statements concerning other regions are, however, much more tentative.

The application for policy purposes of bilateral linkages might utilize a prior survey of the existing distribution of industries in the region. If it is found that one component industry of an otherwise always linked and associated industry pair is not present in the subject region, then this particular industry may be designated as a development candidate. The set of industries thus obtained could be subjected to further study as mentioned above, i.e. market studies, comparative cost studies, etc. may be used to distill a subset of most suitable industries. Regional economic policy could foster those industries with the goal of reaching regional self-sufficiency for the outputs in question or even to make the region an exporter of those outputs while with regard to the outputs of less suitable industries the region could purposely remain an importer.

If a new industry has located in the region a linkage/association study might be used to determine not only the ensuing commodity flows of this industry to backward and forward linked industries but also to reveal whether the location of the new industry may have led to new poles and currents in the field of locational forces. This information could then be utilized by the policy authority.

Some remarks regarding the policy application of industrial complex studies as used here have already been made in Section 5.3 above. The utilization of industrial complexes as an effective policy tool would appear to require framework conditions which are less fixed by laissez faire tenets than those that exist at the present time. One might think in this context of a national industrial strategy with regional locational specifications. However, on a less ambitious level complex studies might be used as indicated above. The number of desirable complexes may be pared to the number of feasible complexes by considering the region's factor endowment (including such items as special labour skills, pollution effects, etc.), market conditions, and other relevant factors in more specific and detailed region-directed complex studies.

These remarks indicate that the utilization of the linkage/association relationship for policy purposes cannot provide more than partial assistance in the initial stages of planning. However, whether for a few industries or whole complexes, the study suggests a method of approaching a policy problem that may help to eliminate a significant amount of uncertainty. It may provide answers to some questions and pose questions that otherwise might not have been asked. In this way it may help to avoid costly mistakes.

6.3 Possibilities for Further Research

The comments of this section will be restricted to the immediate topic of the linkage/association relationship. Even within this area the possibilities for further research hinge to some extent on the availability of adequate data. The two areas of prime concern are, firstly, the provision of employment figures by place of work rather than by place of residence only and, secondly, the publication of value added data at a greater industrial and geographical detail. The former would increase the accuracy of the measurements of association. Biases of the type discussed in Subsection 3.2.2 would be eliminated. While these may not have been large for Census Metropolitan Areas they may be significant for other regions of relatively small area.[1] The value added data might be a desirable alternative to the use of employment figures because employment data will not accurately reflect the volume of industrial activity if there exist regional differences in technologies and productivity. An industrial detail of the comparable employment series (or slightly less, e.g. that of IOIC-L) would appear to be sufficient for linkage/agglomeration studies.

In order to discover intertemporal changes in the linkage/association relationship a similar study could be performed for a different point of time. Obvious choices for these points of time would be the

[1] It may be pointed out that the relevant data of the 1971 Census, not yet published, will list the number of employed also by place of work. See Canada, Statistics Canada, 1971 Census Catalogue (Ottawa: Information Canada, 1972), Cat. No. 11-506, pp. 24-25.

full census years for which new spatial data become available. New industrial information cannot be expected at the same frequency. In intertemporal comparisons a problem arises if the specification of industries has changed. Any changes would tend to detract from the degree of intertemporal comparability of the results. It would, for example, appear questionable whether the 1971 Standard Industrial Classification (used for the 1971 Census) can be reconciled with that of the 1960 S.I.C. Manual on which the 1961 Census and the 1961 Input-Output Industrial Classification are based.

An extension of the analysis to regions which cover all relatively densely settled areas of Canada might be desirable. In this endeavour problems must be expected in the Canadian context that may not exist in more compact and/or more evenly populated countries. The great areal extent of Canada makes it difficult to achieve complete coverage (even if Northern regions are excluded) with area units that can still reasonably be considered as the same location. Moreover, apart from a lack of economic boundary criteria for these regions, the degree of industrial aggregation for them would be quite high given the present state of data availability.

Further extensions might be made along three lines: Firstly, profiles of individual industries in which other locational factors are considered along with interindustry linkages. Such an analysis may provide information why, in specific cases, input-output linkages do or do not tend to be locationally effective. Secondly, a similar analysis for specific industry pairs. Thirdly, and as mentioned above, comprehensive region-directed industrial complex analyses. These types of studies would, however, appear to be more oriented towards dealing with specific problems.

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APPENDIX 1

LIST OF SYMBOLS AND DEFINITIONS[a]

b_{ij} - backward linkage of industry j with industry i; calculated as $b_{ij} = x_{ij}/U_j$

B - matrix of backward linkages

f_{jk} - forward linkage of industry j with industry k; calculated as $f_{jk} = x_{jk}/X_j$

F - matrix of forward linkages

g_{ij} - coefficient of geographical association between industries i and j

ℓ_{ik} - employment in industry i in region k (i = 1, 2, ..., 86; k = 1, 2, ..., 18)

L - matrix of absolute employment figures, classified by industry and by region

p_k - population of region k

p_{ik} - employment proportion in industry i in region k, normalized by population of region k; calculated as $p_{ik} = \ell_{ik}/p_k$

P - matrix of employment proportions, normalized by population

r_{ij} - (symmetric) correlation coefficient measuring the geographical association between industries i and j; obtained by correlating, over the metro regions, the employment proportions of industry i with the employment proportions of industry j; $r_{ij} = r_{ji}$

R - matrix of correlation coefficients measuring spatial association between pairs of industries

r'_{ij} - correlation coefficient obtained by correlating undeflated employment figures for industries i and j (not used in the analysis)

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[a]Note that the D.B.S. input-output symbols have been defined separately at the end of Appendix 1.

APPENDIX 1--Continued

s_{ij} - symmetric linkage coefficient expressing the linkages between industries i and j; calculated as $s_{ij} = 1/4(X_{ij}/U_j + X_{ji}/U_i + X_{ij}/X_i + X_{ji}/X_j)$

S - matrix of symmetric linkage coefficients

u_j - backward linkage summary measure for industry j; calculated as $u_j = \sum_i X_{ij}/X_{\cdot j}$

U_j - total use by industry j of inputs purchased from other industries

w_i - forward linkage summary measure for industry i; calculated as $w_i = \sum_j X_{ij}/Z_i$

W_i - total use by other industries of the output of industry i

X_{ij} - interindustry flow from industry i to industry j

Y_i - final demand for the output of industry i

Z_i - total supply of commodity i

D.B.S. input-output symbols[a]:

B - technology matrix containing the intermediate input coefficients of industries obtained by dividing each element in a column of matrix U by the corresponding total industry output

D - market share matrix of domestic production obtained by dividing each element in a column of the output matrix V by the corresponding total commodity output

$D^* = D(I-\hat{\mu})$ - matrix of coefficients representing the market shares of industries in the total supply of commodities classified by industry and by commodity

e - column vector containing total final demand for competing commodities classified by commodity, less competing imports classified by commodity

g - column vector of total industry outputs classified by industry

[a]For a complete list of D.B.S. symbols see Canada, D.B.S., The Input-Output Structure, Vol. 1, pp. 157 ff.

APPENDIX 1--Continued

m - column vector containing competing imports classified by commodity

$\hat{\mu}$ - diagonal matrix of coefficients representing, for each commodity, the ratio of total imports to total supply

q - column vector of total commodity outputs classified by commodity

U - matrix containing the intermediate inputs of industries classified by commodity and by industry

V - matrix containing the outputs of industries classified by industry and by commodity

APPENDIX 2

Comparison of Industrial Classifications

IOIC-L Number	Input-Output 110 Industry Aggregation Title	1961 Census CMA No.	1960 S.I.C. No.
12	Slaughtering & Meat Processors	2-1-45	101
13	Poultry Processors	2-1-46	103
14	Dairy Factories	2-1-48	105
15	Process Cheese Manufacturers	2-1-49	107
16	Fish Products Industry	2-1-50	111
17	Fruit & Vegetable Canners and Preservers	2-1-51	112
18	Feed Mills	2-1-53	123
19	Flour Mills	2-1-54	124
20	Breakfast Cereal Manufacturers	2-1-55	125
21	Biscuit Manufacturers	2-1-57	128
22	Bakeries	2-1-58	129
23	Confectionery Manufacturers	2-3-2	131
24	Sugar Refineries	2-3-3	133
25	Vegetable Oil Mills	2-3-4	135
26	Miscellaneous Food Industries	2-3-5	139
27	Soft Drink Manufacturers	2-3-7	141
28	Distilleries	2-3-8	143
29	Breweries & Wineries	2-3-9/10	145, 147
30	Leaf Tobacco Processing	2-3-12	151
31	Tobacco Products Manufacturers	2-3-13	153
32	Rubber Footwear Manufacturers	2-3-15	161
33	Tire & Tube Manufacturers	2-3-16	163
34	Other Rubber Industries	2-3-17	169
35	Leather Tanneries	2-3-19	172
36	Shoe Factories	2-3-20	174
37	Glove & Luggage Manufacturers	2-3-21/22	175, 179
38	Cotton Yarn & Cloth Mills	2-3-24	183
39	Wool Yarn & Cloth Mills	2-3-26/27	193, 197

APPENDIX 2--Continued

IOIC-L Number	Input-Output 110 Industry Aggregation Title	1961 Census CMA No.	1960 S.I.C. No.
40	Synthetic Textile Mills	2-3-28	201
41	Carpet, Mat & Rug Industry	2-3-35	216
42	Linoleum & Coated Fabrics Industry	2-3-37	219
43	Textile Bags & Canvas Products Industry	2-3-39/40	221, 223
44	Other Textile Industries	2-3-30/31/32/ 33/34/36/41	211, 212, 213, 214
45	Hosiery Mills	2-3-43	231
46	Other Knitting Mills	2-3-44	239
47	Clothing Industries	2-3-45	242, 243, 244, 245, 246, 247, 248, 249
48	Sawmills	2-3-55	251
49	Veneer & Plywood Mills	2-3-56	252
50	Sash & Door and Planing-Mills	2-3-57	254
51	Other Wood Industries	2-3-58/59/60	256, 258, 259
52	Household Furniture Industry	2-5-2	261
53	Other Furniture Industries	2-5-3/4/5	264, 266, 268
54	Pulp & Paper Mills	2-5-7	271
55	Asphalt Roofing Manufacturers	2-5-8	272
56	Paper Box & Bag Manufacturers	2-5-9	273
57	Other Paper Converters	2-5-10	274
58	Printing, Publishing & Engraving	2-5-12/13/14	286, 287, 288, 289
59	Iron & Steel Mills	2-5-16	291
60	Steel Pipe & Tube Mills	2-5-17	292
61	Iron Foundries	2-5-18	294
62	Smelting & Refining	2-5-19	295
63	Aluminum Rolling, Casting and Extruding	2-5-20	296
64	Copper & Alloy Rolling, Casting and Extruding	2-5-21	297

APPENDIX 2--Continued

IOIC-L Number	Input-Output 110 Industry Aggregation Title	1961 Census CMA No.	1960 S.I.C. No.
65	Metal Rolling, Casting and Extruding, n.e.s.	2-5-22	298
66	Boiler & Plate Works	2-5-24	301
67	Fabricated Structural Metal Industry	2-5-25	302
68	Ornamental & Architectural Metal Industry	2-5-26	303
69	Metal Stamping, Pressing & Coating Industry	2-5-27	304
70	Wire & Wire Products Manufacturers	2-5-28	305
71	Hardware, Tool & Cutlery Manufacturers	2-5-29	306
72	Other Metal Fabricating Industries	2-5-30/31/32	308
73	Machinery & Equipment Manufacturers	2-5-34/35	311, 315
74	Refrigeration, Office & Store Machinery Manufacturers	2-5-36/37	316, 318
75	Aircraft & Parts Manufacturers	2-5-39	321
76	Motor Vehicles & Trailer Manufacturers	2-5-40/41	323, 324
77	Motor Vehicle Parts Manufacturers	2-5-42	325
78	Other Transportation Equipment Industries	2-5-43/44/45/46	326, 327, 328, 329
79	Manufacturers of Electrical Appliances	2-5-48/49	331, 332
80	Manufacturers of Communications Equipment, including Wire	2-5-51/54	335, 338
81	Manufacturers of Electrical Industrial Equipment	2-5-52	336
82	Other Electrical Products Manufacturers	2-5-50/53/55	334, 337, 339
83	Cement & Lime Products Manufacturers	2-7-2/3	341, 343
84	Concrete & Gypsum Products Manufacturers	2-7-4/5/6	345, 347, 348
85	Clay, Stone & Refractory Products Manufacturers	2-7-7/8/9	351, 352, 353

APPENDIX 2--Continued

IOIC-L Number	Input-Output 110 Industry Aggregation Title	1961 Census CMA No.	1960 S.I.C. No.
86	Glass & Glass Products Manufacturers	2-7-12	356
87	Other Non-Metal Mineral Products Industries	2-7-10/11/13/14	354, 355, 357, 359
88	Petroleum & Coal Products Industries	2-7-16/17	365, 369
89	Explosives & Ammunition Manufacturers	2-7-19	371
90	Manufacturers of Mixed Fertilizers	2-7-20	372
91	Manufacturers of Plastic Resins	2-7-21	373
92	Manufacturers of Pharmaceuticals and Medicines	2-7-22	374
93	Paints & Varnishes Manufacturers	2-7-23	375
94	Manufacturers of Soap and Cleaning Compounds	2-7-24	376
95	Manufacturers of Toilet Preparations	2-7-25	377
96	Industrial & Other Chemical Industries	2-7-26/27	378, 379
97	Miscellaneous Manufacturing Industries	2-7-28	381, 382, 383, 384, 385, 393, 395, 397, 399

APPENDIX 3

FORMATION OF INDUSTRY GROUPS

Several of the tests of hypotheses require a further division of the manufacturing industries into more homogeneous groups. A glance at the industries contained in the manufacturing sector makes it clear that they are of a very different nature: some of them receive the major share of their inputs from the primary sector while others have no connection with primary industries at all; some industries sell a large proportion of their output to final demand while the output of others is largely destined for other industrial customers as intermediate inputs. A dual classification is employed, the criteria being, firstly, the relative size of material inputs received from the primary sector, i.e., for IOIC-L, the inputs from industries 1 to 11 as a percentage of the inputs from industries 1 to 97; and, secondly, the share of total output going to private consumption.

Group I industries, or 'First Stage Resource Users', receive at least 50 per cent of the value of their material inputs from the primary sector. Group II industries, or 'Second Stage Resource Users', receive 25 per cent or more of the value of their material inputs from primary industries. Industries whose inputs from the primary sector amount to less than 25 per cent of the value of their material inputs are furthest removed from resource extractors and fall into the Group III of 'Third Stage Resource Users'.[1]

[1]A somewhat similar classification was employed by Perloff *et al.* although there are substantial differences in the definitions. See Harvey S. Perloff, *et al.*, Regions, Resources, and Economic Growth (Baltimore: Johns Hopkins Press, 1960), p. 380; see also their Appendix Table L, pp. 677 ff.

APPENDIX 3--Continued

This classification is formally similar, at least in part, to the one suggested by Statistics Canada for classifying manufacturing industries into primary and secondary manufacturing industries.[1] Group I largely corresponds to primary manufacturing industries and Groups II and III would make up the secondary manufacturing industries. However, due to different data bases the correspondence is not complete. While the industry data of this study are based on the 1961 interindustry tables, the value of inputs in the Statistics Canada classification is that reported to the Census of Manufactures. As a result the number of industries in Group I is slightly smaller than the number of primary manufacturing industries. It should also be noted that a few of the Statistics Canada industry designations are somewhat arbitrary.[2]

Industries were then further classified according to the strength of their final demand (FDC)[3] linkage into "heavily linked to final demand" and "not heavily linked to final demand". The former group designated Group A is comprised of industries selling at least 50 per cent of their output to final demand (FDC). All other industries are in Group B.

The industry groupings are provided in the following table.

[1]Canada, Statistics Canada, "Primary and Secondary Manufacturing in Canada", (unpublished discussion paper, n.p., n.d.), p. 3.

[2]Canada, Statistics Canada, "Primary and Secondary Manufacturing in Canada", p. 12.

[3]FDC - final demand private consumption.

APPENDIX 3--Continued

INDUSTRY GROUPINGS ACCORDING TO INTENSITY OF RAW MATERIAL USE AND FINAL DEMAND SALES

IOIC-L Number	Industry Name[a]	Industry Group	Percentage of Material Inputs from Primary Sector	Percentage of Output to FDC[b]	Percentage of Output to FDX[c]
12	Slaught.	I - A	76.0	63.3	5.3
13	Poultry	I - A	75.3	72.1	0.0
14	Dairy	I - A	83.0	71.3	2.7
15	Cheese	III - A	2.4	73.3	1.3
16	Fish	I - B	80.1	17.2	65.8
17	Fruit	II - A	25.1	72.5	2.8
18	Feed	I - B	55.9	4.5	2.0
19	Flour	I - B	91.5	18.1	28.0
20	Breakf.	II - A	42.7	78.0	2.7
21	Biscuit	III - A	1.1	80.1	2.5
22	Bakeries	III - A	2.1	80.6	0.0
23	Confect.	III - A	2.5	84.7	0.0
24	Sugar	I - B	57.0	39.6	0.0
25	Oil	II - B	36.0	1.9	24.2
26	Misc. Food	II - A	29.0	56.3	5.5
27	Soft D.	III - A	0.0	74.8	0.0
28	Distil.	II - B	29.1	35.5	47.2
29	Brew.	III - A	14.0	90.3	2.0
30	Leaf Tob.	I - B	97.5	0.0	26.7
31	Tob. Prod.	III - A	15.2	98.4	0.0
32	Rubber	III - A	0.0	92.7	1.3
33	Tire	III - B	1.4	24.7	2.9
34	Other R.	III - B	1.5	16.9	4.1
35	Leather	III - B	5.6	0.0	19.2
36	Shoe	III - A	0.2	95.1	1.8
37	Glove	III - A	0.0	68.0	2.3
38	Cotton	III - B	0.7	11.6	4.5
39	Wool	III - B	13.0	16.8	27.8
40	Synth.	III - B	0.1	9.0	7.7
41	Carpet	III - A	0.0	62.1	7.3

APPENDIX 3--Continued

IOIC-L Number	Industry Name	Industry Group	Percentage of Material Inputs from Primary Sector	Percentage of Output to FDC	Percentage of Output to FDX
42	Linol.	III - B	0.9	4.1	2.3
43	Bags	III - B	0.0	20.1	1.2
44	Other T.	III - A	0.4	28.3	4.7
45	Hosiery	III - A	0.0	90.0	0.0
46	Oth. Knit.	III - A	0.2	73.7	1.1
47	Clothing	III - A	3.1	89.6	1.0
48	Sawmills	I - B	81.4	1.8	51.9
49	Veneer	I - B	77.4	0.0	20.9
50	Sash	III - B	2.4	3.1	10.3
51	Oth. Wood	II - B	27.7	5.4	10.7
52	Hh. Furn.	III - A	0.6	74.7	0.0
53	Oth. Furn.	III - B	1.0	45.9	1.2
54	Pulp & Pap.	I - B	65.2	2.2	67.4
55	Asphalt	III - B	7.7	2.0	1.0
56	Pap. Box	III - B	0.1	6.3	1.0
57	Oth. Pap.	III - B	0.3	21.5	3.2
58	Printing	III - B	0.1	20.4	1.9
59	Iron & Steel	II - B	33.7	0.0	14.0
60	Steel Pipe	III - B	0.1	0.0	3.3
61	Iron F.	III - B	2.7	1.0	3.6
62	Smelting	II - B	62.1	0.0	60.3
63	Al RCE	III - B	0.2	1.3	32.9
64	Cu RCE	III - B	0.3	0.0	18.2
65	Metal RCE	III - B	0.7	1.5	24.4
66	Boiler	III - B	0.0	0.0	3.2
67	Struct. M.	III - B	0.0	0.0	3.5
68	Orn. & Arch.	III - B	0.0	1.8	2.2
69	Met. Stamp.	III - B	0.2	6.5	2.5
70	Wire	III - B	0.2	2.5	2.7
71	Tool	III - B	0.0	1.5	8.1
72	Oth. Metal	III - B	0.5	3.0	5.6
73	Machinery	III - B	[illegible].4	3.9	19.4
74	Refrig.	III - B	0.0	6.4	13.7
75	Aircraft	III - B	0.2	2.1	26.3
76	Motor Veh.	III - A	0.2	63.6	3.0

APPENDIX 3--Continued

IOIC-L Number	Industry Name	Industry Group	Percentage of Material Inputs from Primary Sector	Percentage of Output to FDC	Percentage of Output to FDX
77	Veh. Parts	III - B	0.6	9.4	5.4
78	Oth. Transp.	III - B	0.3	6.6	8.3
79	El. Appl.	III - A	0.3	59.2	3.8
80	Communic.	III - B	0.1	3.0	8.9
81	El. Indust.	III - B	0.2	2.6	6.6
82	Oth. El.	III - B	0.2	39.2	3.2
83	Cement	II - B	31.1	0.0	3.6
84	Concrete	III - B	17.0	0.0	0.0
85	Clay	II - B	32.6	13.3	7.1
86	Glass	III - B	6.0	12.0	1.4
87	Oth.Non-Met.	II - B	42.2	3.8	24.3
88	Petrol.	I - B	87.0	37.5	4.5
89	Explos.	III - B	2.6	8.6	6.9
90	Fertil.	III - B	8.5	2.0	6.3
91	Resins	III - B	0.9	2.2	20.4
92	Pharm.	III - B	1.5	43.4	4.9
93	Paints	III - B	1.5	7.3	1.4
94	Soap	III - A	0.8	56.1	1.7
95	Toilet P.	III - A	0.7	79.0	1.5
96	Oth. Chem.	III - B	12.3	6.6	24.6
97	Misc. Manuf.	III - B	1.4	31.9	8.1

[a]For full industry titles see Appendix 2.

[b]The Final Demand Matrix was also made available by Statistics Canada in November, 1971. FDC - Final Demand Consumption.

[c]FDX - Final Demand Net Exports.

APPENDIX 4

GEOGRAPHICALLY ASSOCIATED INTERINDUSTRY LINKAGES AND FINAL DEMAND LINKAGES BY INDUSTRY

IOIC-L Number	Backward Linkages: IOIC-L Number	Backward Linkages: Linkage Size	Backward Linkages: Correlation Coefficient	Forward Linkages: IOIC-L Number	Forward Linkages: Linkage Size	Forward Linkages: Correlation Coefficient
12				FDC	.6327	
13	12	.0236	.7503	FDC	.7211	
14	88	.0101	.4317	FDC	.7126	
15				FDC	.7325	
16				FDC	.1717	
17	57	.0137	.5707	FDC	.7254	
	69	.2183	.6340			
	86	.0287	.8647			
18	12	.0392	.5813	FDC	.0449	
	24	.0137	.4788			
	26	.0289	.6090			
	56	.0097	.4839			
	69	.0123	.4364			
19	43	.0254	.7368	FDC	.1812	
20	56	.1354	.7402	FDC	.7797	
21	56	.1517	.7150	FDC	.8011	
22	56	.0589	.4854	FDC	.8060	
23				FDC	.8473	
24				18	.0250	.4788
				26	.0564	.5180
				FDC	.3961	
25	69	.0182	.7702	94	.1043	.9[illegible]26
	96	.0248	.5535	96	.0319	.5535
				FDC	.0187	
26	24	.0305	.5180	18	.0159	.6090
	56	.0761	.4806	29	.0387	
	69	.0264	.4033	FDC	.5632	
27				FDC	.7483	
28				FDC	.3546	
29	26	.1367	.4020			
	56	.1030	.5544	FDC	.9034	
30				31	.6873	.6415
31	30	.4665	.6415	FDC	.9838	
32	34	.0382	.5616	FDC	.9272	
	35	.0385	.7019			
	37	.1284	.8570			
	38	.0453	.7047			
	39	.0597	.9903			
	40	.0314	.9811			
	44	.0237	.8178			
	91	.0092	.5677			

APPENDIX 4--Continued

IOIC-L Number	Backward Linkages: IOIC-L Number	Backward Linkages: Linkage Size	Backward Linkages: Correlation Coefficient	Forward Linkages: IOIC-L Number	Forward Linkages: Linkage Size	Forward Linkages: Correlation Coefficient
33	34	.0443	.5095	73	.0115	.7564
	38	.2125	.8122	FDC	.2467	
	70	.0330	.6339			
	91	.0169	.4800			
34	39	.0191	.5513	33	.0232	.5095
	40	.0214	.5750	36	.0503	.6382
	44	.0227	.5049	44	.0109	.5049
	56	.0313	.6744	52	.0276	.5298
				53	.0117	.5199
				73	.0160	.4745
				79	.0121	.4015
				80	.0261	.7713
				82	.0329	.7996
				FDC	.1687	
35	12	.3275	.6156			
				36	.6128	.8248
				37	.1142	.6729
				97	.0181	.4006
36	34	.0735	.6382	FDC	.9508	
	35	.4207	.8248			
	37	.0848	.9295			
	38	.0270	.8626			
	44	.0095	.7866			
	97	.0246	.4061			
37	35	.2039	.6729	32	.0255	.8570
	38	.0310	.7859	36	.1162	.9295
	39	.0194	.8499	97	.0094	.5550
	46	.0113	.8641	FDC	.6799	
	51	.0149	.7305			
	71	.0209	.5187			
	97	.0941	.5550			
38	40	.2186	.7282	33	.0585	.8122
	44	.0508	.6577	36	.0097	.8626
				40	.0144	.7282
				44	.0565	.6577
				46	.0607	.6744
				53	.0093	.6575
				FDC	.1156	
39	38	.0439	.7437	34	.0092	.5513
	40	.1044	.9729	40	.0133	.9729
	44	.2023	.8223	41	.0212	.6197
				46	.0752	.8339
				FDC	.1683	

APPENDIX 4--Continued

IOIC-L Number	Backward Linkages: IOIC-L Number	Linkage Size	Correlation Coefficient	Forward Linkages: IOIC-L Number	Linkage Size	Correlation Coefficient
40	38	.0306	.7282	38	.0676	.7282
	39	.0115	.9729	39	.0183	.9729
	44	.0163	.9016	41	.0112	.6289
	47	.0211	.4391	44	.0378	.9016
	91	.0180	.6136	46	.0987	.8781
				47	.1903	.4391
				52	.0185	.8797
				53	.0149	.9469
				97	.0096	.4490
				FDC	.0904	
41	39	.1327	.6197	FDC	.6208	
	40	.1833	.6289			
	44	.1070	.9016			
42	44	.0861	.4966	44	.0647	.4966
	46	.0266	.4407	47	.0770	.7989
	57	.0142	.4223	58	.0113	.4139
	93	.0116	.5910	97	.0162	.4407
	96	.1867	.4797	FDC	.0408	
	97	.0333	.4407			
43				19	.1256	.7368
				47	.0097	.4704
				FDC	.2014	
44	34	.0152	.5049	38	.0211	.6577
	38	.1496	.6577	39	.0476	.8223
	39	.0225	.8223	40	.0097	.9016
	40	.1064	.9016	46	.0203	.9537
	42	.0271	.4966	47	.1025	.6903
	47	.0148	.6903	FDC	.2826	
	51	.0140	.6851			
	97	.0177	.6191			
45	56	.0340	.8098	FDC	.9001	
46	38	.1870	.6744	47	.1776	.6906
	39	.0938	.8339	FDC	.7369	
	40	.3231	.8781			
	44	.0495	.9537			
	47	.0388	.6906			
47	40	.1294	.4391	FDC	.8962	
	44	.0520	.6903			
	46	.0697	.6906			
	97	.0524	.5221			
48						
49	48	.0112	.9642	50	.0519	.4403
50	49	.0825	.4403	FDC	.0307	

APPENDIX 4--Continued

IOIC-L Number	Backward Linkages: IOIC-L Number	Linkage Size	Correlation Coefficient	Forward Linkages: IOIC-L Number	Linkage Size	Correlation Coefficient
51	71	.0148	.6083	13	.0097	.7809
				44	.0135	.6851
				52	.0184	.8454
				69	.0137	.5578
				97	.0487	.4409
				FDC	.0538	
52	34	.0363	.5298			
	38	.0199	.6081	82	.0302	.8629
	40	.0491	.8797	FDC	.7473	
	44	.0125	.8729			
	51	.0180	.8454			
	71	.0153	.5629			
	97	.0410	.5856			
53	34	.0206	.5199	FDC	.4590	
	38	.0311	.6575			
	40	.0529	.9469			
	44	.0237	.8961			
	51	.0114	.8198			
	52	.0248	.9522			
	69	.0092	.6308			
	71	.0206	.6111			
	82	.0176	.8468			
	97	.0283	.5319			
54				FDC	.0223	
55	59	.0273	.4197	FDC	.0202	
56	57	.0620	.4007	20	.0096	.7402
	58	.0298	.5944	21	.0204	.7150
	97	.0270	.4600	22	.0326	.4854
				26	.0533	.4806
				29	.0370	.5544
				57	.0118	.4007
				79	.0123	.5397
				94	.0243	.4257
				95	.0099	.4468
				97	.0196	.4600
				FDC	.0632	
57	56	.0388	.4007	17	.0144	.5707
	58	.0095	.7523	56	.0680	.4007
	63	.0349	.8633	58	.0144	.7523
	96	.0326	.5887	FDC	.2151	
	97	.0093	.7436			

IOIC-L Number	Backward Linkages: IOIC-L Number	Linkage Size	Correlation Coefficient	Forward Linkages: IOIC-L Number	Linkage Size	Correlation Coefficient
58				FDC	.2038	
59	85	.0214	.7722	69	.1320	.5980
				70	.0600	.8891
				73	.0471	.7325
				79	.0240	.8779
60						
61	72	.0175	.7488	72	.0356	.7488
				73	.0714	.6423
				76	.0208	.4778
				77	.0491	.6246
				FDC	.0103	
62						
63	65	.0164	.5472	57	.0327	.8633
	96	.0095	.5628	68	.1038	.8065
				69	.0720	.5687
				72	.0275	.4629
				73	.0314	.5312
				79	.0224	.4404
				80	.1008	.5665
				81	.0152	.9278
				82	.0147	.5721
				97	.0398	.7879
				FDC	.0132	
64				72	.0605	.5392
				80	.2928	.6862
				81	.0237	.7254
				82	.0095	.5085
				97	.0532	.5763
65	69	.0095	.7946	59	.0143	.7840
				63	.0180	.5472
				69	.0211	.7946
				73	.0184	.8016
				79	.0182	.7314
				97	.0229	.5872
				FDC	.0154	
66	61	.0144	.7373	72	.0295	.6279
	69	.0241	.6191	73	.0526	.5782
	72	.0976	.6279			
	73	.0271	.5782			
	81	.0130	.4960			
67						
68	63	.1767	.8065	72	.0093	.4097
	69	.0237	.4941	73	.0135	.4690
	72	.0313	.4097	FDC	.0181	
	86	.0249	.6504			
	97	.0135	.5869			

APPENDIX 4--Continued

	Backward Linkages			Forward Linkages		
IOIC-L Number	IOIC-L Number	Linkage Size	Correlation Coefficient	IOIC-L Number	Linkage Size	Correlation Coefficient
69	59	.4899	.5980	12	.0127	.5281
	63	.0384	.5687	17	.1060	.6340
	72	.0242	.4969	26	.0159	.4033
				72	.0142	.4969
				73	.0256	.9025
				79	.0211	.6401
				80	.0102	.4709
				81	.0160	.7035
				96	.0187	.4525
				97	.0236	.6736
				FDC	.0653	
70	59	.4174	.8891	33	.0096	.6339
	69	.0108	.7813	73	.0111	.9088
				FDC	.0247	
71	51	.0093	.6083	52	.0123	.5629
	69	.0241	.5843	53	.0123	.6111
	70	.0110	.5343	73	.0108	.6078
	72	.0736	.7641	76	.0126	.6838
	73	.0187	.6078	FDC	.1505	
	87	.0103	.4222			
	97	.0169	.5071			
72	61	.0185	.7488	69	.0134	.4969
	63	.0171	.4629	71	.0100	.7641
	64	.0406	.5392	73	.0628	.5481
	66	.0112	.6279	77	.0251	.5898
	69	.0314	.4969	FDC	.0301	
	73	.0148	.5481			
	80	.0094	.6343			
	81	.0113	.5848			
	97	.0107	.6520			
73	59	.1471	.7325	FDC	.0396	
	61	.0269	.6423			
	63	.0141	.5312			
	66	.0145	.5782			
	69	.0412	.9025			
	70	.0098	.9088			
	72	.[illegible]3	.5481			
	79	.0116	.8590			
	80	.0206	.4700			
	81	.0368	.6832			
	97	.0156	.5785			

APPENDIX 4--Continued

IOIC-L Number	Backward Linkages IOIC-L Number	Linkage Size	Correlation Coefficient	Forward Linkages IOIC-L Number	Linkage Size	Correlation Coefficient
74	58	.0232	.7370	FDC	.0642	
	64	.0169	.5770			
	69	.0165	.5562			
	72	.0192	.5191			
	73	.0128	.4653			
	81	.0412	.8060			
	97	.0094	.8385			
75	80	.0459	.5566	FDC	.0214	
76	77	.3860	.9655	FDC	.6361	
77	61	.0298	.6246	76	.4664	.9655
	72	.0613	.5898	FDC	.0939	
	76	.0148	.9655			
78				FDC	.0659	
79	34	.0105	.4015	73	.0106	.8590
	56	.0300	.5397	81	.0125	.5083
	59	.1315	.8779	FDC	.5925	
	63	.0176	.4404			
	69	.0596	.4289			
	70	.0124	.6401			
	73	.0363	.8590			
	81	.0626	.5083			
80	34	.0169	.7713	73	.0111	.4700
	63	.0594	.5665	75	.0128	.5566
	64	.1868	.6862	81	.0238	.6219
	69	.0216	.4709	82	.0828	.7533
	72	.0100	.6343	FDC	.0298	
	81	.0388	.6219			
	82	.0146	.7533			
	91	.0263	.4341			
	97	.0140	.6024			
81	63	.0182	.9278	73	.0407	.6832
	64	.0307	.7254	74	.0111	.8060
	69	.0684	.7035	79	.0394	.5083
	72	.0303	.5848	80	.0327	.6219
	73	.0119	.6832	82	.0320	.7533
	79	.0365	.5083	FDC	.0260	
	80	.1182	.6219			
	82	.0178	.7533			
	85	.0113	.4436			
	97	.0141	.8402			
82	34	.0267	.7994	FDC	.3915	
	52	.0409	.8629			
	56	.0182	.4726			
	63	.0109	.5721			

#82 continued

APPENDIX 4--Continued

IOIC-L Number	Backward Linkages: IOIC-L Number	Backward Linkages: Linkage Size	Backward Linkages: Correlation Coefficient	Forward Linkages: IOIC-L Number	Forward Linkages: Linkage Size	Forward Linkages: Correlation Coefficient
	80	.2533	.8421			
	81	.0476	.7533			
	91	.0173	.4929			
	97	.0175	.7218			
83	88	.0412	.7191			
84						
85	81	.0178	.4436	59	.0742	.7722
	87	.0127	.7005	81	.0125	.4436
				FDC	.1334	
86	96	.0873	.5762	17	.0480	.8647
				68	.0141	.6504
				92	.0353	.4175
				94	.0102	.8581
				95	.0210	.4210
				FDC	.1197	
87	56	.0277	.4123	FDC	.0385	
	70	.0116	.7330			
	96	.0282	.5072			
88				FDC	.3750	
89				FDC	.0861	
90				FDC	.0201	
91	40	.0275	.6136	12	.0137	.7467
	96	.3060	.5245	33	.0093	.4800
				40	.0169	.6136
				80	.0426	.4341
				82	.0223	.4929
				96	.0364	.5245
				FDC	.0222	
92	57	.0137	.4703	FDC	.4341	
	86	.0477	.4175			
	97	.0320	.6307			
93				97	.0145	.5355
				FDC	.0731	
94	25	.0694	.9826	FDC	.5606	
	56	.0883	.4257			
	57	.0117	.8354			
	69	.0157	.7197			
	86	.0125	.8581			
	96	.1616	.5854			
	97	.0336	.5420			
95	56	.0844	.4468	FDC	.7903	
	57	.0141	.7215			
	69	.0393	.4827			
	86	.0605	.4210			
	97	.0422	.7941			

APPENDIX 4--Continued

IOIC-L Number	Backward Linkages IOIC-L Number	Linkage Size	Correlation Coefficient	Forward Linkages IOIC-L Number	Linkage Size	Correlation Coefficient
96	69	.0283	.4525	91	.0231	.5245
	91	.0161	.5245	94	.0228	.5854
				FDC	.0665	
97	51	.0166	.4409	FDC	.3194	
	56	.0253	.4600			
	63	.0166	.7879			
	64	.0241	.5763			
	69	.0352	.6736			

APPENDIX 5

PARTIAL LIST OF IRON- AND STEEL-USING PRODUCTION SEQUENCES

The production sequences are established on the basis of forward linkages only. Industries designated with an asterisk are spatially associated with their forward linked industries.[a]

1. 4[b] → 59* → 69* → 17 → FD[c]
2. 4 → 59* → 69* → 73 → FD
3. 4 → 59* → 69* → 79* → 73 → FD
4. 4 → 59* → 69* → 79* → 81* → 82 → FD
5. 4 → 59* → 69* → 79* → 81* → 73 → FD
6. 4 → 59* → 69* → 79* → 81* → 80* → 82 → FD
7. 4 → 59* → 69* → 79* → 81* → 79* → 73 → FD
8. 4 → 59* → 69* → 79* → 81* → 80* → 73 → FD
9. 4 → 59* → 69* → 79* → 81* → 79* → 81 ...
10. 4 → 59* → 69* → 79* → 81* → 80* → 81* → 73* → FD
11. 4 → 59* → 69* → 79* → 81* → 80* → 81* → 80* → 81 → FD
12. 4 → 59 → 69 → 79 → 81 → 80 → 81 → 80 → 82 → FD

13. 4 → 59 → 60 → 72 → 69 ...
14. 4 → 59 → 60 → 66* → 73 → FD
15. 4 → 59 → 60 → 72* → 73 → FD
16. 4 → 59 → 60 → 66* → 72* → 73 → FD
17. 4 → 59 → 60 → 72* → 71* → 73 → FD
18. 4 → 59 → 60 → 66* → 72* → 71* → 73 → FD
19. 4 → 59 → 60 → 66* → 72* → 69 ...

20. 4 → 59 → 61* → 73 → FD
21. 4 → 59 → 61* → 72* → 69 ...
22. 4 → 59 → 61* → 72* → 73 → FD

APPENDIX 5--Continued

23. 4 → 59 → 61* → 72* → 71* → 73 → FD

[a] For industry titles see Appendix 2

[b] Industry 4 Iron Mines

[c] Final Demand