

IDENTIFYING LOCAL INDUSTRIAL COMPLEXES

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Introduction

Although the concept of an industrial complex has been recognised within regional science for a quarter of a century, there is still some debate as to the precise definition thereof. Much of the debate has focused on whether both economic and geographical criteria are appropriate. Thus Latham [13, p. 54] has argued that "the concept of an industrial complex must include information regarding both spatial or locational behaviour and interindustry relationships." In contrast with Latham, it is argued that there are three conceivable definitions of an industrial complex.

1. Complexes existing, to use Perroux's [21] term, in "economic space". These are groups of industries with close interrelationships in the production process; they have been identified mainly by examining input-output tables. Campbell [2], Czamanski [4; 5], Karaska [10; 11] and Roepke, Adams and Wiseman [24] employ this definition.

2. Complexes existing both in economic and in geographic space. In this case there must be both inter-industry linkages among the relevant industries and a spatial clustering of them. This approach is illustrated in Czamanski [6], Isard, Schooler and Vietorisz [9], Lever [15], Richter [23] and Streit [25].

3. Complexes existing in geographic space. These are groups of industries which occur in similar locations but which do not necessarily have direct production links. Because of the strong economic orientation of many of the existing studies of complexes, this definition appears to have been largely ignored, but it is the geographical equivalent of the first definition. It is exemplified by the study by Bergsman, Greenston and Healy [1], and by the extensive literature on functional typologies of cities.

These three definitions of an industrial complex all have their particular merits. For planning purposes, however, it is the second definition that is the most useful. This approach is explored in the present study, the main objective of which is to develop a methodology for identifying linked industries that occur within a single town.

Since the methodology will be briefly illustrated by the case of Ontario, the paper by Roepke, Adams and Wiseman [24] provides a useful point of departure. In essence, their technique involved using Q and R mode factor analysis to factor a transaction matrix, X, and a symmetrical aggregate flow matrix, B, where any element is the sum of the inputs from i to j and from j to i, thus $b_{ij} = b_{ji} = x_{ij} + x_{ji}$. They applied their technique to the 1965 Input-Output Table for Ontario, using the 44 x 44 interindustry submatrix, and identified thirteen interpretable factors (complexes) in the aggregate flow matrix.

It would seem appropriate to use the term regional industrial complexes to describe the results of such an approach, since the consti-

*I wish to thank Professor W.R. Latham for making some very helpful comments on an earlier draft of this paper.

tuent elements of a complex identified by this technique may be located in different parts of a region; there is nothing in the methodology that requires the immediate proximity of the constituents of a complex. Since Ontario covers over 400,000 square miles and is considerably larger, for instance, than any single country in Western Europe, it is at least conceivable that some of the complexes identified by Roepke *et al.* involve lengthy material flows from one part of the province to another.

The approach that is pursued here is rather different, since emphasis is put on identifying local industrial complexes, with the constituent elements present in a single town. From a spatial perspective, this is a much more demanding definition than that used by Roepke, and indeed by Czamanski and by Campbell. Nevertheless, it probably comes closer to Isard and Schooler's [8] original definition of a complex as "one or more activities occurring at a given location and belonging to a group of activities which are subject to important production, marketing or other interrelationships" (my emphasis).

The case to be made for identifying local industrial complexes is an empirical one. There are several instances of industrial complexes being used as a policy instrument [9; 16; 18; 22], it generally being assumed that if a specific complex exists in one place, it may be advantageous to promote a similar complex somewhere else. From a geographical viewpoint, there are grounds for arguing that this may not be a wise policy, since it presupposes that similar agglomerative forces exist in different parts of the space economy. On the contrary, studies of industrial location lead one to expect that agglomerative forces differ quite substantially from one place to another. Accordingly, four propositions concerning industrial complexes will be stated, at this stage without elaboration.

1. The incidence of complexes will vary with city size such that fewer complexes will be found in small- and medium-sized towns than in large towns.
2. Certain types of industrial complex will be found only in large towns, others will occur in towns of various size, while others may actually be attracted to smaller centres.
3. Arbitrarily dividing the space economy into a heartland which broadly coincides with the main markets and a hinterland consisting of the peripheral regions, and then holding constant the effect of city size due to the concentration of large towns in the heartland, the incidence of complexes will be higher in the heartland.
4. Although most types of complex will occur in the heartland, certain types of complex will be absent from the hinterland (again, holding constant the effect of city size).

Examination of these propositions requires a methodology that will identify local industrial complexes consisting of activities that are both economically linked and geographically associated. The main part of this paper outlines the methodology that was developed. The results of the Ontario study are briefly summarized in the conclusion; they are discussed more fully in Norcliffe and Kotseff [20].

It might be argued that a detailed methodology is not required because an interview survey could be used to identify local complexes. While this is indeed true, the data collection task needed to identify the backward and forward linkages of each plant, and the location of each supplier and market, is comparable in magnitude to that for compiling an input-output table. It is for this reason that the methodology to be presented is based largely on published sources.

Perhaps the most straightforward measure of geographical association among industries is to use absolute employment numbers measured over a set of areal units to compute a correlation coefficient (henceforth R_a) as, for instance, was done by McCarty, Hook and Knos [17]. Some years ago, however, Richter [23] demonstrated that correlation between areal units based on raw employment data usually give rise to inflated correlations due to differences in the magnitude involved. Following Kuh and Meyer [12], he avoided this problem by expressing employment (e) in the i^{th} industry, in the j^{th} area unit as a proportion (p) of the total employment in that areal unit.¹ Thus

$$p_{ij} = e_{ij}/e_i \quad (i=1,m; j=1,n)$$

Proportional data are then used to compute correlation coefficients (henceforth R_p). Every industry is correlated with every other industry, giving rise to an $m \times n$ correlation matrix. Those pairs of industries for which the correlations are significant, at an appropriate level, are deemed to be geographically associated.

Latham [14] has reviewed measurement techniques for spatial association. He concluded that the most appropriate measure is a correlation coefficient based on raw employment data (R_a), coupled with a significance test using a non-zero null hypothesis (he suggests $H_0: \rho \leq .5$). Latham is critical of the correlation measure derived from proportional data (R_p) for three main reasons: it does not give extra weight to the influence of large outputs in large regions; proportional data may lead to a reversal of signs in some cases; and the degree of geographical association between two industries will vary with a redistribution of the base used for the proportional measure (in effect, the choice of denominator).

The contrary case can be put very briefly as follows. The weighting of areal units has been discussed in the geographical literature for some time, and is briefly set in the context of ecological correlations. Suffice it to say that small areal units are likely to filter out as much, if not more, information about the relationship between two spatially distributed variables than are large areal units. Secondly, as Chayes [3] has demonstrated, correlations using percentage (ratio) data may lead to changes of signs. As the number of categories increases, however, so this problem diminishes; typically, manufacturing employment is recorded for between 40 and 200 activities, in which case this problem is of minor importance. Finally, although choice of the denominator affects correlation coefficients based on proportional data, this is considered to be far less serious than inflated values of R_a attributable to big differences in the employment magnitudes of the areal units. Indeed the case for using R_p rests largely on the problem of inflated values of R_a which occur when there are large magnitudinal differences, such as in the case study that follows. Forty-six per cent of the sample manufacturing workforce resided in the Census Metropolitan Area of Toronto and sixty-eight per cent in the four largest manufacturing

¹Latham's [14] doubts about the value of this transformation have been questioned by Norcliffe [19] who argues that in situations where there are large magnitudinal differences in the areal units the transformation is preferable.

centres, so that values in these few centres account for the major proportion of the covariance between any pair of variables.

Lever [15] points to another problem in measuring geographical association, one which arises particularly when trying to identify local industrial complexes: not every industry is present in every areal unit. In Lever's study, the inclusion of zero-zero pairs had very little effect. Local complexes are sought in towns of various size, however, so that zero-zero pairs (and the resulting inflated correlations) occur more frequently. Accordingly we exclude zero-zero pairs from the calculation of correlation coefficients.

Lever also found the P_{ij} 's to have a reverse J frequency distribution as a result of the uneven distribution of manufacturing, but did not transform his data because "no simple non-grouping transformation can normalize the distribution." Neither did he use an ordinal measure of correlation, because of loss of information. Examination of various empirical data indicates that, provided zero-zero pairs are excluded, a simple logarithmic transformation typically yields an approximately normal distribution for the P_{ij} 's.

To measure economic linkage, we adopt the standard measure in input-output analysis by declaring a pair of industries in an m sector table to be linked if the flow between two sectors is greater than the mean in the respective row or column of the transactions table; that is, if $x_{ij} > x_{.j} / m$ or if $x_{ij} > x_{i.} / m$.

Defining Local Industrial Complexes

These first two steps follow accepted procedures and give rise to a subset of pairs of industries, among all possible pairs, that are both economically linked and geographically associated. The next step is to identify industrial complexes in this subset, following Campbell's [2] digraph method. A binary adjacency matrix is constructed in which a value of one indicates that a pair of industries are linked in both senses, while a zero indicates that the industries are not linked in both senses. Zeros are entered in the principal diagonal since the digraph is assumed to contain no loops. Following Harary, Norman and Cartwright [7], the adjacency matrix is raised to the n^{th} power to obtain a distance matrix indicating the topological distance (d_{ij}) between any two industries. The sum of the distances between all of the vertices and the vertices reachable from them ($\sum_i \sum_j d_{ij}$) is divided by the corresponding sum for each row (industry) ($\sum_j d_{ij}$) to obtain the index of relative

centrality for each industry. Notice that these summations apply only to reachable vertices: unreachable vertices, which are by definition infinitely distant, are not included. Industries with the highest centrality indices are those around which the greatest amount of inter-industry activity takes place. Those with a centrality index one standard deviation above the mean are designated the focal industries of complexes.

Campbell used the digraph method to identify regional industrial complexes within the state of Washington. In this study, a geographically more restricted definition of a complex is being applied, hence the methodology needs appropriate modification. For each industry with a high index of relative centrality, linked industries are sought in the binary connectivity matrix. These linked industries are added to the complex provided that each successive industry is geographically associated with all other activities in a complex. In other words the spatial

coincidence of all the members of a complex is explicitly required. In some cases this led to very small complexes with only two or three industries being identified, but this is in accordance with prior expectations.

This method proved fairly easy to apply. One problem is that "watershed" activities are sometimes encountered. These are activities with output linkages into two different kinds of subcomplex. Such complexes are split into two, and the watershed activity placed in both of the new complexes.

Identifying Geographical Patterns

Before it is possible to draw conclusions about the geographical distribution of complexes, consistent rules are needed for deciding whether a given complex is present in a particular town. For each industry, the arithmetic mean of the employment percentages is calculated. Since these percentages are typically skewed with only a few large values, well over half of the towns have a percentage less than the arithmetic mean. An industry is said to be strongly represented in a town if the employment percentage is greater than the mean for that industry.

This complete, each town is considered in turn to see whether any of the set of complexes are present. For smaller complexes, with two or three constituent industries, it is required that all of the industries be strongly represented in a town. On the other hand, for larger complexes this rule has to be modified. Generally, it is appropriate to require that the key complex-forming industry (or industries) plus half of the linked industry be strongly represented in a town.

This stage completes the technical part of the methodology, but there remains one important step; namely, empirical confirmation of the existence of particular complexes presumed to exist in particular towns. At the outset, it was stated that the identification of local complexes by purely survey methods is a massive task. Confirmation of the complexes identified using the above methodology is relatively simple; it is a matter of checking that there are indeed interindustry flows of the type assumed in a given complex within a particular town to guard against the possibility that the constituent industries of a complex are located in a town without any physical flows occurring among the various establishments. The existence of presumed complexes was confirmed in various ways; many of the complexes are described in government reports, student theses, other monographs and articles, and in municipal industrial directories. Failing these sources, interviews were required with the firms concerned, or with municipal planning or industrial officers.

In view of the hypotheses listed in the introduction identifying city size as an explanatory variable, it is important to stress that proportional and relative measures have been used through each step of the procedure. The procedure is not biased towards recognizing complexes in larger towns. On the contrary, other things being equal, a local complex is equally likely to be identified in towns of any size. Thus, if certain types of complex do occur more frequently in large towns, this cannot be attributed to the methodology.

Results for Ontario

The results presented in Norcliffe and Kotseff [20] will be summarized only briefly. Of the 1892 pairs of industries, 303 (16%) were found to be economically linked, and 314 (16.6%) were geographically associated at the .005 level of significance. As shown in Table 1, only 71 pairs of

industries (3.75%) were both economically linked and geographically associated.

Table 1
GROSS TABULATION OF ECONOMICALLY LINKED AND
GEOGRAPHICALLY ASSOCIATED INDUSTRIES IN
ONTARIO, 1965

	Linked	Not linked	Total
Associated	71	243	314
Not Associated	232	1346	1578
Total	303	1589	1892

The 71 pairs of industries linked in both senses were input into the digraph analysis, and the index of relative centrality calculated. The five industries with an index one standard deviation above the mean are listed in Table 2.

Searching for complexes based on these central activities, eleven complexes were initially indentified. Of the eleven, two were found to involve outward flows from a common supplier; after splitting of these "watershed" industries, two of the four new complexes were found to duplicate other complexes, and were omitted, leaving the eleven complexes shown in Figure 1. The towns in which these eleven complexes were located in 1965 were then identified. This done, the four propositions stated earlier could be examined.

Table 2
INDUSTRIES WITH A HIGH INDEX OF
RELATIVE CENTRALITY

Rank	Industry	Index of relative centrality
1.	Other Metal Fabricating Industries	51.02
2.	Printing and Publishing	44.22
3.5=	Metal Stamping, Pressing and Coating	41.45
3.5=	Other Chemical Industries	41.45
5.	Paints and Varnish	38.45

1. Not surprisingly, the frequency of complex was found to increase with city size. No less than five of the eleven complexes were identified in Toronto, which had a population of 1.8 million and a workforce of 3/4 million in 1961. Two other large Census Metropolitan Areas, London and Kitchener, had four and three complexes respectively. In the nineteen towns with a population exceeding 30,000, the various complexes occurred 39 times; in the twenty towns with a population under 30,000 they occurred only 13 times. This result is very much in accordance with the expectation that a large town with a diversified industrial base will support more complexes than a small town.

2. A relationship was also found between city size and the type of complex found in a city. The primary metal, motor vehicle, electrical goods, paints and varnish, and pharmaceutical complexes were found exclusively, or mainly, in large towns or in smaller towns within the commutershed of large towns. On the other hand, the two food product complexes and the furniture and paper product complexes were found in both large and small towns.

3. Ontario was split into a heartland including the Highway 401 axis from Windsor to Oshawa and the towns around that axis, and a hinterland consisting of all areas to the east and north. Complexes of all types occurred 31 times in the twenty central towns, but only 11 times in the nineteen peripheral towns. No complexes were found in ten towns in the periphery, namely Sudbury, Sault Ste. Marie, Thunder Bay, Trenton, Peterborough, Timmins, Pembroke, Kenora, Owen Sound and Barrie. In most cases these towns have a single dominant industry about which little in the way of local interindustry linkages appears to have developed.

4. Finally, all eleven types of complex are represented in the heartland region, whereas the motor vehicle, electrical goods, furniture, paper products, pharmaceutical, and paints and varnish complexes do not occur in the peripheral region.

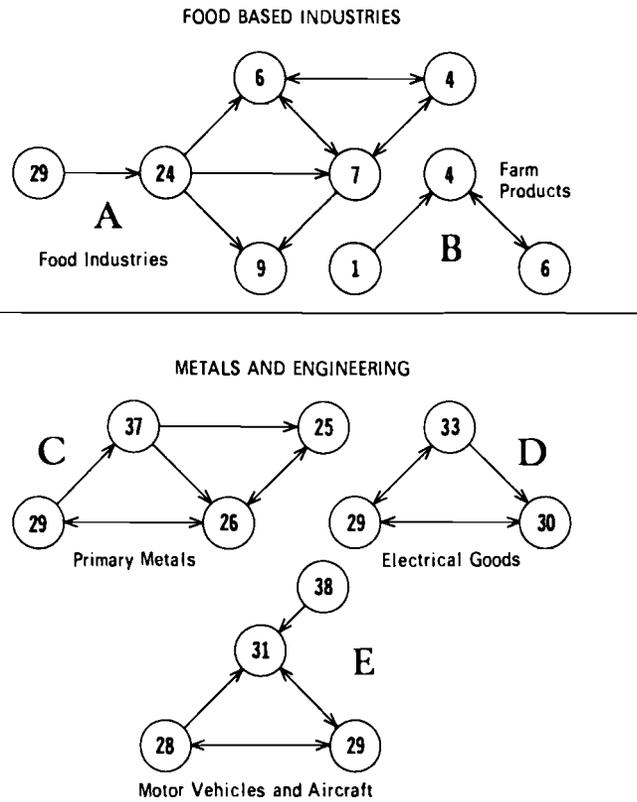
Discussion

There would seem to be some parallels between the history of growth poles and of industrial complexes. Perroux originally proposed the concept of a growth pole as a description of how towns grew, empirically. Before the mechanics of this empirically observed phenomenon were fully understood, planners were designating growth poles as a policy instrument, only to discover that in many instances their expectations were not fulfilled. Likewise, there seems to be an over-willingness on the part of planners to use industrial complexes as a policy instrument before the workings of actual industrial complexes are properly understood.

We are not aware of any previous study that has attempted systematically to identify the geographical characteristics of industrial complexes. Despite using an imperfect methodology, we have produced evidence which suggests that both the frequency and type of complex vary with city size and also with market accessibility. That being the case, complexes as a policy instrument should be used with great care.

The methodology outlined in the foregoing discussion is by no means perfect. Four interesting methodological issues are raised.

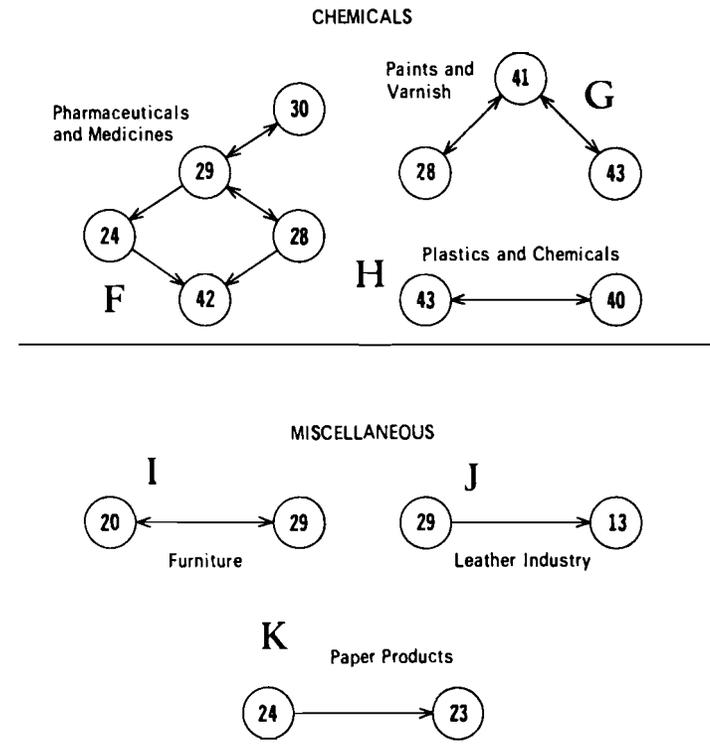
First, the choice of input-output table needs considering. Latham [13, p. 49] has cautioned against the use of inappropriate input-output tables, stating that "for the purpose of regional industrial development through industry attraction, it is inappropriate to use an input-output table of the economy of the region in question Rather, one should examine an input-output table for an entire country to discover through less limited interrelationships what industry might be most complementary to those already present." Latham's line of argument concerns the use of industrial complexes for prescriptive purposes, whereas our objective is to make empirical statements about the geographical distribution of the local complexes. The main thrust is descriptive and empirical, which makes the input-output table for the study region in question the most appropriate one. In the case study of Ontario, certain geographical regularities were found in the location of local industrial complexes. There are good grounds for arguing that there will also be interregional differences in the type and structure of industrial complexes, since every region has a different resource en-



- KEY**
- | | |
|---------------------------------------|---|
| 1. Agriculture, forestry, and fishing | 28. Metal stamping, pressing, and coating |
| 4. Dairy products | 29. Other metal fabricating industries |
| 6. Biscuits and bakeries | 30. Miscellaneous machinery |
| 7. Sugar and confections | 31. Motor vehicles and aircraft |
| 9. Soft drinks | 33. Electrical appliances |
| 24. Printing and publishing | 37. Clay, lime and cement |
| 25. Iron and steel mills | 38. Other non-metallic mineral products |
| 26. Other primary metals | |

Figure 1

LOCAL INDUSTRIAL COMPLEXES IDENTIFIED IN ONTARIO, 1965



- KEY**
- | | |
|--|-----------------------------------|
| 13. Leather and leather products | 30. Miscellaneous machinery |
| 20. Furniture and fixtures | 40. Plastics and synthetic resins |
| 23. Paper products | 41. Paint and varnish |
| 24. Printing and publishing | 42. Pharmaceuticals and medicines |
| 28. Metal stamping, pressing and coating | 43. Other chemical industries |
| 29. Other metal fabricating industries | |

Figure 1 (continued)

dowment and factors are available in different proportions in each region. These differences necessitate caution in trying to create in a region industrial complexes identified in some other input-output table.

The second issue, which has been raised by Latham [13, p. 50], by Czamanski [4, p. 150], and by Roepke *et al.* [24, p. 27], is that the aggregate form of most input-output tables conceals many interesting detailed relationships. The Ontario table used to illustrate the methodology is highly aggregated, and hence makes our results far less useful than they might be if a finer industrial disaggregation were used. One can only hope that by drawing attention to the planning possibilities and pitfalls, the relevant government agency may be spurred to construct more disaggregated tables.

Third, the digraph approach, although it appears to model inter-industry relations better than the multivariate approach, has an important weakness. When a small group of industries form a submatrix with strong internal linkages but weak external linkages, members of that group of industries usually have relatively low centrality indices. For instance, in the case study of Ontario, food-related industries form a submatrix and "Agriculture, Forestry and Fishing", which is the industry with the highest centrality score in this group, ranks only sixteenth overall. Thus Complex A was identified because it happened to include links with "central" industries 29 and 24. More generally, the centrality measure is not necessarily the best identifier of the core industry of a complex. In the case study, "Other Metal Fabricating" has the highest centrality index, but it is not the sort of industry around which complexes are formed. On the contrary, it tends to fulfill a service role, which is why it has numerous links with other industries and is locationally widely dispersed. Indeed the same point could be argued for each of the five industries scoring highest on the centrality index. In other words, this kind of industry tends to be complex serving more than complex forming. Nevertheless, in the present study the central industries did serve to identify most of the complexes. Our conclusion, however, is that there is a need to develop a better method of identifying complex-forming industries, a method which should take into account the ability of an industry to generate agglomeration economies.

The fourth problem concerns the possibility that we have omitted some local linkages that take place between an establishment located inside a municipal or C.M.A. boundary and a plant located just outside that boundary, or within some arbitrary distance such as ten miles. No doubt this does occur in some instances, but given the nature of the published data it is impossible to guard against such a possibility. Nor is it possible to aggregate the data into some larger over-bounded definition of an urban centre. Moreover, given that the thirty-nine urban centres accounted for almost exactly 80 per cent of Ontario's manufacturing employment, it is clear that only a small proportion of the province's manufacturing activity is located outside the urban network. It follows that we have omitted, at most, only a few complex-type linkages involving plants located just outside municipal boundaries.

In the last few years there has been a revival of interest in industrial complexes, particularly as an instrument for regional development. As the concept has been refined, so it has become apparent that the concept can be applied at different spatial scales. Much of the research has dealt with regional industrial complexes; it is argued here that local industrial complexes are an equally valid focus for study. In this paper, a methodology has been presented for identifying local industrial complexes. The insights gained from applying this methodology suggest that, like growth poles, industrial complexes have a crucial geographical dimension and should not, therefore, be viewed as a universal panacea for development problems.

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