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Identification of Industrial Clusters and Complexes: a Comparison of Methods and Findings

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Summary. The paper reviews systematically studies dealing with the identification of clusters and complexes, or of groups of industries linked by flows of goods and services, or showing significant mutual locational attraction. The studies are classified according to the method used for identification, and to their spatial focus. Some 60 types of industrial groupings have been found to exist by the various students of spatial aggregation of industries but many showed only small differences in their sectoral composition. The similarity of results despite the diversity of methods used, degree of sectoral disaggregation, and areas examined was striking. A set of tables comparing the findings is presented along with a detailed analysis of methods and results.

Introduction

One of the problems most often faced by economists, planners and political decision-makers in their quest to start spatial growth processes or to invigorate a declining or depressed region, is the selection of a proper mix of industries. Among the numerous criteria they consider, the extent of multiplier effects to be expected occupies a prominent place. Multipliers generated in a regional economy by the introduction of new activities are intimately related to existing leakages or to the extent that the regional economy is closed in terms of size and character of inter-regional flows. Hence, from some points of view it might appear preferable to foster in depressed or underdeveloped regions the introduction of a cluster of related industries, instead of a scatter of heterogeneous activities.

Moreover, industrial location theory claims that spatial groupings of similar or complementary industries generate positive externalities different from those due to a simple juxtaposition of dissimilar plants (Hoover, 1948; Isard, 1956). The theory has been used extensively in order to explain differences in the industrial mix observed in such urban agglomerations as Detroit, Pittsburgh or Wilmington, and for planning regional industrialisation strategies.[1]

More recently doubts have been expressed whether the very concepts of industrial clusters and complexes are valid or usable tools of inquiry into regional economic phenomena. A pertinent question asked, in this connection, is whether existing industrial agglomerations are related to flows of goods and services, or to significant, discernible positive externalities beyond the generally accepted urbanisation economies. Several resesearch reports dealing with clustering of industries have been published in recent years, but they differ greatly, not only in definitions used and areas studied but also in objectives and methodology. None of the studies reported attacked directly the issue of external economies related to flows of goods and services, while the very heterogeneity of the industrial groupings revealed in different studies raised further questions.

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1 For a review and evaluation of some of these studies see Paelinck (1967, 1972).

The purpose of the present paper is to review the significant studies that have been published, to examine the methods of analysis employed, and above all to introduce a measure of uniformity enabling a comparison of results. We are thus concerned only with studies which try to define the composition of industrial groupings, excluding those dealing with only theoretical aspects of clustering of industries. The empirical evidence of existence of economies due to geographical proximity of industries connected by flows of goods and services is beyond the scope of our review. Fourteen studies were analysed and compared. In addition we have also reviewed three other research projects which developed a new methodology for identifying clusters or complexes, though stopping short of indicating specific groupings.[2]

Considerable confusion exists in the literature concerning the related concepts of industrial cluster, industrial complex, growth pole (introduced by Perroux (1965) and Boudeville (1972)), growth centre, and central place (due to Christaller (1966), Lösch (1954), and Beckmann (1968)). The present paper deals only with the first two notions which have been redefined and uniformly applied, sometimes at variance with the terminology of the authors whose contributions were examined. In what follows 'cluster' means a subset of industries of the economy connected by flows of goods and services stronger than those linking them to the other sectors of the national economy. The concept is thus devoid of any spatial connotation. A 'complex', on the other hand, has been defined as a group of industries connected by important flows of goods and services, and showing in addition a significant similarity in their locational patterns. Thus, complexes emphasise the spatial aspects of industrial concentration. It should be noted nonetheless that in some studies, notably those of Streit (1969) and to some extent Bergsman *et al.* (1972, 1975) the term 'complex' acquires a much narrower connotation, referring to one particular agglomeration in a specific location.

In the following section we try to classify the methodologies employed in the various studies, while in the next section an attempt is made at comparing the findings. Some tentative conclusions are presented in the final section.

Classification of Methods

The classification of the studies examined has been carried out according to two criteria, namely: (1) the mathematical tools used, and (2) the spatial focus.

Following the first criterion, five studies were found to be based on some form of multivariate analysis, three made explicit use of graph theory, two were descriptive without recourse to rigorous methods for definining the composition of existing groupings, and five were based on engineering considerations.[3, 4]

The second criterion was more involved and did not lead to a clear-cut dichotomy into two groups. All of the studies examined were concerned to varying degrees with linkages based on flows, and with spatial agglomerations. Six of the 18 studies emphasised the flows, starting with an examination of the national economy, mainly with the help of a national input–output table.[5] The aspatial groupings thus derived are here, for the sake of consistency, termed 'clusters'. The aspatial clusters were assumed to lead to the formation of spatial complexes, or to form the basis for policies aimed at promoting industrial groupings enjoying economies of spatial juxtaposition. However, only one study rigorously examined the extent to which clusters form the basis of industrial complexes.

In the eight other studies the point of departure was the existence of spatial agglomerations. Their basic contribution was the exploration of the composition of the various complexes or of the flows occurring between the sectors comprising the complexes. Yet the boundary between the two approaches was somewhat arbitrary. The study by Roepke *et al.* (1974) was classified as dealing with clusters, although its unit of observations was the Province of Ontario rather than the national economy. On the other hand, the work of Campbell (1971) was classified as dealing with complexes because of the smaller size of the region which he

2 This was done, partly because of the importance of their contribution, and partly because in all three cases the composition of the industrial complexes has been identified but omitted in published reports.

3 The study of Czamanski (1974) used both multivariate analysis and triangularisation techniques.

4 The study by Latham (1976) was not included, partly because it followed the methodology developed by Streit and partly because only one complex was presented. See Czamanski (1977).

5 The exception was the study by Roepke *et al.* (1974), who used the economy of a province rather than the national economy.

used as his frame of analysis (Washington State). The studies considered are shown grouped according to the two criteria in Table 1.

The first study listed in Table 1, that of Streit (1969), derived the sectoral composition of complexes by analysing two sets of coefficients. The first established the extent of geographic association between pairs of industries:

$$r_{ij} = \frac{\operatorname{cov}(x_{ig}, x_{jg})}{\sigma_{x_{ig}}\sigma_{x_{jg}}}$$

where x refers to employment, the subscripts i and j denote industries, and g refers to regions. The second coefficient measured the intensity of inter-industry flows:

$$L_{ij} = L_{ji} = \tfrac{1}{4}\left[O_{ij}\left(\frac{I}{\Sigma_i O_i} + \frac{I}{\Sigma_j I_j}\right) + O_{ji}\left(\frac{I}{\Sigma_j O_j} + \frac{I}{\Sigma_i I_i}\right)\right]$$

where O_{ij} and O_{ji} are sales of industry i to j, or j to i; O_i and O_j are outputs of i, or j; and I_i and I_j are total inputs of i or j.

The industrial complexes were defined as composed of pairs of industries for which r_{ij} was significant and

$$L_{ij} > \frac{1}{n}\sum_j L_{ij}, \quad \text{or} \quad L_{ji} > \frac{1}{n}\sum_i L_{ji}.$$

The method has been applied to the industrial structure of France and Germany. Thirteen complexes have been identified in Germany and 14 in France, but because of the aggregate classification used (only 26 sectors), the composition of individual complexes could not be analysed. The spatial units of analysis were, moreover, fairly large regions rather than metropolitan areas.

The next two studies listed, those of Bergsman *et al.* (1972, 1975), both used multivariate analysis but each applied it in a slightly different context.

Table 1
Classification of studies

	Study area	Number of sectors	Number of types of groupings identified: Clusters	Complexes
Multivariate analysis				
1. Streit, M. E.	France (90 regions) Germany (30 regions)	26	—	13 and 14
2. Bergsman, J., Greenston, P., and Healy, R. (1972)	US (203 SMSAs)	186	—	42
3. Bergsman, J., Greenston, P., and Healy, R. (1975)	US (311 metropolitan areas)	480	—	40
4. Roepke, H., Adams, D., and Wiseman, R.	Province of Ontario	44	13	—
5. Czamanski, S.	US (191 SMSAs)	172	16	16
Triangularisation and graph theory				
1. Campbell, J.	Washington State	19	—	5
2. Fines, J. P.	4 French regions	77	6	—
3. Slater, P. B.	US	75	7	—
Descriptive studies				
1. Chardonnet, J.	The World	—	—	11
2. Kolosovskiy, N. N.	USSR	—	—	5
Composition of single complexes				
1. Isard, Walter	Puerto Rico	—	1	—
2. Karaska, G. J.	Philadelphia	—	—	1
3. Hodge, G., and Wong, C. C.	Province of Ontario	—	2	—
4. Steed, G. P. F.	Northern Ireland	—	—	1
5. Paelinck, J.		—	—	1
Methodological contributions				
1. Richter, C. E.				
2. Klaassen, L.				
3. Van Wickeren, A.				

The data base of the first study was the spatial distribution of 186 US industries among 203 SMSAs.[6] Linear zero order correlation coefficients, measuring the extent of spatial association in terms of employment, were derived for all possible pairs of industries and arranged in a symmetrical matrix. The authors then applied factor analysis to this matrix, enabling them to identify 58 factors corresponding to spatial complexes. The underlying flow phenomena were not considered at all. The resulting 42 complexes were labelled partly according to main product and partly by using other criteria.

In their second study Bergsman *et al.* used a finer industrial classification comprising 480 industries. Their data basis was moreover extended to 311 metropolitan areas covering most SMSAs and some smaller urban units. The methodology used for identifying industrial groupings was somewhat different from their earlier study. Instead of zero order correlation coefficients between all pairs of industries, rank order correlation coefficients based on employment were computed. The resulting 480×480 symmetric matrix was analysed with the help of hierarchial clustering analysis. The technique yields sets of mutually exclusive and collectively exhaustive aggregations. The algorithm starts by joining two most highly correlated industries into a group. The group is then treated as an industry and the process is iterated until in the end all industries are aggregated into groups. The levels of grouping were defined somewhat arbitrarily by setting the maximum number of subclasses formed from any one class at nine. The groups were referred to as 'clusters' but were more similar to 'complexes' according to the terminology used in this paper, except that the flow phenomena connecting the various industries were not explicitly analysed. Forty complexes were identified, composed of two-, three-, and four-digit industries.

Bergsman *et al.*, as all other students of the problem of spatial aggregation of industries, had to confront two related difficulties. The distribution of all urban phenomena, including employment, is highly skewed or J-shaped, resulting in very high but meaningless correlation coefficients. Moreover, all industries, although to varying degrees, are attracted to urban centres, because of the presence of such factors as markets, pools of trained labour, or a variety of services. Since the extent of those facilities is related to urban size, the correlation between the spatial distribution of two industries reflects not only their mutual attraction but to a certain extent at least, a common to both orientation towards larger cities. In their first study Bergsman *et al.* tried to eliminate both influences by using an employment to population ratio as an indicator of the importance of a local concentration of an industry. This procedure may be, however, insufficient since it implies that the urban pull affects all industries with equal force. In the second study rank correlation coefficients were substituted for zero order correlations but this procedure, while downgrading the importance of the largest cities, does not eliminate the problem completely since the ranking of industrial employment follows to a certain extent the ranking of population.

The study of Roepke *et al.* (1974) on the other hand, while using factor analysis, applied it to a (44×44) flow matrix of the Province of Ontario. It thus comes close to the identification of clusters rather than complexes. The authors conducted three separate factor analyses using an aggregated symmetric matrix B, each element of which was defined as $b_{ij} = b_{ji} = a_{ij} + a_{ji}$, where a_{ij} and a_{ji} are elements of a matrix of input–output technical coefficients. Two additional analyses were applied to directionally specified flow data, one using inputs (columns) and other outputs (rows).

The averaging of a_{ij} and a_{ji} coefficients without any weights appears, nonetheless, as questionable in view of their different dimensionality. In each case the derived components with eigenvalues exceeding one were rotated to a varimax solution. The final result was the identification of 13 clusters.

A different method, relying on multivariate analysis supplemented by triangularisation, has been developed by Czamanski (1974). The following four coefficients based on input–output flows describe the relative importance of the links, either for the supplying or for the receiving sector:

$$a_{ij} = \frac{x_{ij}}{\Sigma_j x_{ij}}; \quad a_{ji} = \frac{x_{ji}}{\Sigma_i x_{ji}};$$

$$b_{ij} = \frac{x_{ij}}{\Sigma_i x_{ij}}; \quad b_{ji} = \frac{x_{ji}}{\Sigma_j x_{ji}};$$

[6] For a theoretical description of this study see also Healy (1972).

where x_{ij} is the yearly flow in dollars of goods and services from industry i to industry j.

The 'a' and 'b' coefficients were next used to form a triangular E matrix, with elements (e_{ij}), where $e_{ij} = \max(a_{ij}, a_{ji}, b_{ij}, b_{ji})$ for $i>j$, and $e_{ij}=0$ for $i<j$.

The clusters were identified by making use of an e_i column vector ($i = 1, \ldots, n$) for any of the n sectors, with entries ranked by interchanging rows and columns in the triangular E matrix. The second entry in the column vector was then the strongest link that the original industry had with any other sector in the economy. This second industry was represented by the adjoining column vector. The process was repeated for the second, third, and other vectors until the mean value of the entries among the industries in the cluster (or $\Sigma_i \Sigma_j e_{ij}/m$ for $i, j = 1, \ldots, m$ where m is the number of industries in the cluster) began to decline.

In the second method of identification of clusters, the criterion for including an industry was the strength of its links with all the industries already in the cluster, rather than a single strong link.

In the third method, the criterion used for grouping industries in a cluster was similarity between their total profiles of suppliers and customers (including those outside the cluster). This method took better account of the analytically significant indirect links, since two industries, k and l, may be members of an industrial cluster in the absence of direct links.

Specifically, four coefficients of correlation describe the similarity between the input–output structure of two industries: $r(a_{ik}.a_{il})$, $r(b_{ki}.b_{li})$, $r(a_{ik}.b_{li})$, $r(b_{ki}.a_{il})$.

A high $r(a_{ik}.a_{il})$ coefficient indicates that the two industries, k and l, have similar input structures or draw their supplies from the same producers. A high $r(b_{ki}.b_{li})$ coefficient signifies that the two industries, k and l, supply their products to a similar set of users. A high $r(a_{ik}.b_{li})$ coefficient implies that the suppliers of industry k are users of the products of l.

From sets of the four zero order correlation coefficients covering all possible pairs of industries, an $n \times n$ intercorrelation matrix was set up by selecting the highest of the four coefficients. Next, an $n \times n$ covariance matrix and an $n \times n$ intercorrelation matrix R were formed.

In order to identify the subgroup belonging to a cluster from the set of all industries, the relative strength of the links binding the industries together was assessed by employing the eigenvalues contained in the R matrix.

The ratios of the characteristic roots to the trace of the R matrix defined an Index of Association:

$$C_i = \frac{\lambda i}{\operatorname{tr} R} \times 100.$$

This provided an aggregate measure of the strength of the ties connecting the industries remaining in the R matrix, with a large C_i indicating the existence of an identifiable cluster.

The clusters derived by this method agreed on the whole with those resulting from the use of the triangularisation procedures. The three methods, using different criteria, yielded results fully consistent with one another when applied to the Washington State and US matrices.

Sixteen clusters were identified in the US economy by applying it to a 172×172 input–output table. Next, the aspatial clusters were analysed in order to determine whether or not they gave rise to spatial industrial complexes (1976). The study was carried out by examinining the 191 US SMSAs or practically all major nodal regions, with the help of regression analysis. In order to eliminate the common urban orientation of all industries, the model consisted of two equations, covering all possible pairs of industries.

$$E_{ik} = aP_r + \varepsilon_{ik}; \qquad (i = 1 \ldots 172;)$$

$$\varepsilon_{ik} = \beta_0 + \beta_1 E_{jk}; \qquad (k = 1 \ldots 191;)$$

where E_{ik} represents employment in industry i in region k, P_k the population of region k used as an index of the various urban facilities present, and ε_{ik} residual, and a, β_0, β_1 are parameters.

The regression coefficients were standardised and combined to yield a symmetric matrix. The results indicated the existence of 16 industrial complexes roughly corresponding to the clusters already identified. Most complexes were slightly smaller and comprised fewer industries than the corresponding clusters.

Studies using graph theory or network analysis address themselves primarily to the aspatial aspects of industrial aggregations, but since all were limited to a single region the notion of a complex was indirectly involved.[7] The method was first used by

[7] This group of studies was inspired directly or indirectly by the work of Chenery and Watanabe (1958) and Dacey and Nystuen (1966).

Campbell, who applied it to the study of 1963 Washington State input–output relationships. The original flow table was aggregated to 19 sectors and transformed into an adjacency matrix by inserting '1' in cells corresponding to flows exceeding $1/n$ of total sales or of total purchases of the industries involved, and '0' in others, where n represents the number of industries (19 in his case). The adjacency matrix can be represented by a digraph or directed graph with industries (rows and columns) corresponding to vertices and unit entries to edges. The connectivity of the economy was calculated by taking the ratio of all existing to potentially possible links, after the internal flows in each sector had been eliminated. The index is not, however, independent of the degree of disaggregation. Next, a distance matrix was derived by inserting in each cell the number of steps (intermediate links) necessary to establish connection between two sectors, again inserting zeros on the main diagonal. The matrix was used to derive a measure of centrality of each industry defined as a ratio of total entries in the distance matrix and the sum of entries in each industry's row.

Groups of industries (points in the digraph) forming a set of mutually reachable points were defined as strong components. These may be treated for some purposes as units leading to the identification of blocks of industries, corresponding to clusters. By analysing the digraph Campbell found five groupings in the Washington State economy.[8]

Another interesting approach was developed at the University of Aix-Marseille under the direction of Perrin, mainly by Fines (1973). This work introduced the concept of 'filière', which is close to that of a cluster or a complex, although derived in a slightly different way. The subsets of industries belonging to a 'filière' were identified on the basis of technical characteristics and with the help of the national French input–output table. Starting with a consumer-oriented industry, the sectors supplying intermediate inputs to the consumer-oriented industry were identified; next the suppliers of the suppliers, and so on. Six 'filières' were identified in the French economy.

A further refinement in the use of graph theory has been proposed by Slater (1974). Instead of arbitrarily determining in advance the threshold above which the link was given a unit value, he systematically increased the critical value by small increments, each time rerunning his model. The formation of clusters could thus be studied as a function of the threshold values.

A 75×75 submatrix of the 86×86 1967 US input–output table was derived by removing sectors of no interest such as imports, government enterprises or dummy industries, and used for the study. Next, in order to remove the effects of scale, all row and column totals were adjusted to 1000 by inserting zeros on the main diagonal and using a biproportional fitting procedure iterated 40 times. This approximated the separate use of relative flows in terms of the supplying and purchasing industries. A directed graph was constructed showing links between vertices (industries) only for values which exceeded the threshold. The links partitioned the graph into clusters of industries based on either weak or strong components. In a weak component a path of links exists between any two industries; in a strong component the path of links is a path of directed links. Seven clusters (called complexes) based on weak components were identified in the study.

The study, nonetheless, shares the weakness of all approaches making use of graph theory; it wastes a lot of information contained in the input–output table, since the flows between any two sectors are either one if they exceed a certain level, or zero otherwise. A possibly interesting improvement might be the application of network analysis.

The third group of studies includes the work of Chardonnet (1965) and Kolosovskiy (1961). Both are purely descriptive, basing their conclusions on qualitative observations, and because of this, their results cannot be compared with the others. The work of Chardonnet is significant because of its scope and careful analysis of existing industrial agglomerations. His classification of complexes is based on the main causal factors responsible for their emergence and early growth, typically ascribed to some dominant geographic feature. The industrial as well as physical structure of complexes was discussed in each case, but the former was described

[8] Lu (1974) employed an almost identical method in his study of the Rhône-Alpes region in France. His contribution consisted of an application of digraph theory to the input–output table. He explored the possibility of applying Markov chains and extending the method to an inter-regional setting.

without recourse to a standard industrial classification and without the use of any quantitative measures. Eleven types of industrial complexes were identified.

Kolosovskiy limited his study to the Soviet Union. He defined complexes on the basis of production cycles, and thus identified industries processing the same raw materials. His complexes therefore had some characteristics of 'filières' but started at the other end of the process. However, the definitions used were far from rigorous. Five types of complexes were identified.

The fourth group of studies comprises the works of Isard *et al.* (1959), Paelinck (1967), Karaska (1969), Steed (1970) and Hodge and Wong (n.d.). All of them analysed complexes which were defined on *a priori* grounds and examined them on the basis of engineering considerations. With the exception of Paelinck, none of these researchers relied heavily on statistical data. Their objectives were thus different from those of the present paper.

The pioneering work in this group of studies was carried out by Isard who analysed the possible introduction of a Petrochemical complex into Puerto Rico. His study involved a detailed examination of production processes, their levels of operation necessary for a balanced complex, and the relationship between the various processes and locational factors. Following this line Karaska examined a Paper and Paper Products complex in the Philadelphia economy, while Steed analysed a Linen complex, trying to establish multiplier effects between the industries it contained. The study by Hodge and Wong dealing with uses of Canadian ores employs a methodology which closely resembles Isard's. Paelinck's analysis of the Basse–Sambre region is slightly different. With the help of an input–output matrix, he tried to identify subsets of industries with minimum flows between groups, and to calculate the multiplier effects due to each subgroup.

The fifth, and last, group of studies is limited to those which made a significant methodological contribution, but stopped short of identification of clusters or complexes. Richter (1969) attempted to explain spatial association between pairs of industries by the existence of flows of goods and services between them. His study covered 51 industrial sectors located in 57 SMSAs. He calculated 2550 linear correlation coefficients between employment in all possible pairs of industries,[9] defined in relative terms as $P_{ij} = x_{ij}/x_i$; where x_{ij} represents the employment in industry j in region i, and x_i the total manufacturing employment in region i.

Three hundred and seventy-two coefficients were found to be significant at 0.10 level, while 2178 were not significant. Of the 372 pairs of industries showing significant similarities in their locational patterns, 117 were also linked by input–output flows, while the spatial association of the remaining 255 could not be explained. Moreover, of the 2178 pairs not related in space, 352 were linked by flows of goods and services. Next, spatial correlation coefficients were calculated between each industry and all sectors to which it was linked by flows of goods and services combined, as well as with random sectors. Twenty-three correlation coefficients between sectors linked by flows were significant at the 0.10 level, while only eight were significant between random sectors. These results provided some evidence that inter-industry flows of goods and services tend to be accompanied by similarity in locational patterns.

An important methodological contribution was made by Klaassen (1967) and further extended by van Wickeren (1972). For each industry, Klaassen defined a set of attraction coefficients measuring the pull exercised by the market and source of inputs:

$$\lambda_d = \frac{t_d}{t_d + \sum_l t_l \beta_{kl}}\,; \quad \lambda_l = \frac{t_l \beta_{kl}}{t_d + \sum_l t_l \beta_{kl}}\,; \qquad l = 1 \ldots n;$$

where λ_d is the attraction coefficient, demand, λ_l the attraction coefficient, supply, t_d the cost of friction of space (transportation, communication, etc.), t_l the cost of friction of space per unit of input l, and β_{kl} the technical coefficient of inputs of l per unit output of k.

The denominators of λ_d and λ_{lk} indicate the total costs of friction of space per unit level of operation of industry k. Since transportation costs are assumed to be unimportant as determinants of location of modern industries, the values of λs were derived by regressing

$$\Phi_{kj} = \lambda_d \delta_{kj} + \sum_l \lambda_{lk} \Phi_{lj}$$

[9] It is not obvious why he used a full, instead of a symmetric, intercorrelation matrix.

subject to

$$\lambda_d + \sum_{l=1}^{n-1} \lambda_{lk} = 1;$$

where Φ_{kj} is the share of region j in national output of k, δ_{kj} the share of region j in national demand of k, and Φ_{lj} the share of region j in national supply of l.

Obviously, if unit costs of friction of space are assumed or found to be equal to $t_d = t_l$, the coefficients are reduced to:

$$\lambda_d = \frac{1}{1+\beta_{kl}}; \quad \lambda_l = \frac{\beta_{\kappa l}}{1+\beta_{\kappa}}.$$

The attraction coefficients help to establish a regional input–output table weighted by effects of friction of space and covering both forward and backward linkages. The elements of this matrix are:

$$g_{kj} = \lambda_d d_{kj} + \sum_l \lambda_l \frac{\beta_{\kappa l}}{\beta_{l\kappa}} g_{lj};$$

where g_{kj} represents the output of industry k in region j, d_{kj} the total demand (final and intermediate) for k in region j, $\alpha_{\kappa l}$ the flow from industry l to k per unit level of operation of k, $\beta_{l\kappa}$ the flow from industry k to l per unit operation of l, and g_{lj} the output of l in region j.

With the help of this model it is possible to calculate the multiplier effects covering both forward and backward linkages.[10]

Analysis of Findings

Any comparison of results of the 17 studies reviewed has to address itself to the problem of classification, since practically all of them used a different industrial breakdown. This part of our analysis is limited only to the findings of the seven research projects which applied rigorous methods in order to identify clusters and complexes and their sectoral composition, namely those of Streit, Bergsman (1972, 1975), Roepke, Czamanski, Campbell, Fines and Slater.

An intensive analysis of the findings identified altogether 78 types of industrial groupings. This high number is, however, somewhat deceptive since many of the groupings included differed in name more than in actual sectoral composition. The types of clusters and complexes identified in the eight studies are summarised in Table 2.

The first category of clusters and complexes is related to primary, extractive industries. A Quarries complex was identified by Bergsman (1972). Roepke found an Extractive Industries cluster, while Slater identified a complex under the same name. Both Bergsman and Czamanski found groupings called Petroleum.[11]

Altogether 14 industries appeared in the five studies analysed. Of these, one was listed in four of the five studies, two appeared in three of the five studies, three appeared in two of the five studies, and eight in single studies only. Many of the industries appearing in single studies seemed to be loosely related to primary activities. The extent of agreement between the several studies has, nonetheless, to be judged as rather low.

The second category of clusters and complexes is also related to primary activities and more specifically to agriculture. Five types of groupings were identified, but these were not all distinct. Seven of the eight studies analysed found a grouping of industries called 'Food and agricultural products'. The only exception was the study of Bergsman *et al.* (1972) which claimed the existence of two complexes called 'Grain products' and 'Food canning', respectively. Bergsman (1975) identified 'Cheese', 'Farm and livestock related', 'Agricultural processing', and 'Agriculture related' complexes. The first two are categorised into 'Farm products' and the next two are categorised into 'Food and agricultural products' in Table 2. In other studies most of the industries comprising these two complexes were included in the 'Food and agricultural products' grouping. Roepke found in addition two other distinct clusters, 'Farm products' and 'Agriculture and leather industries'; but again these two groupings were composed of industries which other studies classified as forming part of 'Food and agricultural products'.[12]

Altogether 32 industries appeared in the six studies analysed. Of these, nine appared in at least four of

[10] A detailed description is contained in Boudeville, J. R. (1972); see also Ablas, L. A. (1973).

[11] A detailed analysis of the sectoral composition of the groupings is presented in the Appendix. The Appendix omits the study of Streit which used a highly aggregated industrial classification, thus preventing comparison with other results.

[12] A detailed analysis of the sectoral composition of the grouping is also presented in the Appendix, and again the study of Slater is omitted.

Table 2
Types of clusters and complexes

	Streit		Bergsman *et al.*		Roepke *et al.*	Czamanski	Campbell	Fines	Slater
	Germany	France	1972	1975					
1. Quarries	—	—	1	—	—	—	—	—	—
2. Extractives industries	—	—	—	1	1	—	—	—	1
3. Petroleum	—	—	1	1	—	1	—	—	—
4. Copper, zinc, and vegetable oil	—	—	—	1	—	—	—	—	—
5. Farm products	—	—	—	2	1	—	—	—	—
6. Grain products	—	—	1	—	—	—	—	—	—
7. Food canning	—	—	1	—	—	—	—	—	—
8. Food and agricultural products	1	1	—	2	1	1	1	1	1
9. Agricultural and leather industries	—	—	—	—	1	—	—	—	—
10. Petrochemicals	—	—	1	—	—	1	—	—	—
11. Rubber products	—	—	1	—	—	—	—	—	—
12. Miscellaneous manufacturing and rubber products	—	—	—	—	1	—	—	—	—
13. Chemicals	4	2	—	—	1	—	—	1	—
14. Iron and steel	—	—	—	1	—	1	—	—	—
15. Non-ferrous metals	—	—	—	—	—	1	—	—	—
16. Aluminium	—	—	—	1	—	—	—	—	—
17. Aluminium and tobacco	—	—	—	1	—	—	—	—	—
18. Metal industries	2	1	3	1	1	—	—	1	—
19. Heavy metal industries	—	—	—	—	1	—	—	—	—
20. Motor vehicles and aircraft	—	2	—	—	1	—	—	—	—
21. Automotives	—	—	—	—	—	1	—	—	—
22. Machinery and equipment	1	—	—	—	—	—	—	—	—
23. Machinery and miscellaneous manufacturing	—	—	—	1	—	—	—	—	—
24. Machinery	—	—	1	—	—	—	—	—	—
25. Aluminium mechanical	—	—	—	—	—	—	1	—	—
26. Metal working and electrical products	—	1	—	—	—	—	—	—	—
27. Electrical products	—	2	1	—	—	—	—	—	—
28. Electrical and related products	1	—	—	—	—	—	—	—	—
29. Electrical and precision instruments	—	1	—	2	—	—	—	—	—
30. Electronics	—	—	—	—	—	—	—	—	1
31. Communication and electronics	—	—	—	—	1	1	—	—	—
32. Electrical equipment	—	—	—	1	—	—	—	—	—

Table 2—*continued*

	Streit		Bergsman *et al.*		Roepke *et al.*	Czamanski	Campbell	Fines	Slater
	Germany	France	1972	1975					
33. Electrical equipment and tertiary activities	—	—	—	1	—	—	—	—	—
34. Precision instruments	—	—	2	—	—	—	—	—	—
35. Engineering and precision products	—	1	—	—	—	—	—	—	—
36. Glass and glass products	—	1	1	—	—	—	—	—	—
37. Glass and electrical equipment	—	—	—	—	—	—	—	—	1
38. Coal, glass and ceramics	—	—	—	1	—	—	—	—	—
39. Ceramic products	—	—	—	1	—	—	—	—	—
40. Lumber	—	—	1	—	—	—	—	—	—
41. Wood and wood products	—	—	1	1	1	1	—	—	—
42. Wood and paper	1	—	—	—	—	—	—	1	—
43. Paper and printing	—	1	1	—	1	1	1	—	—
44. Paper industries	—	1	1	—	—	—	—	—	—
45. Appliances and furniture	—	—	1	—	—	—	—	—	—
46. Construction	—	—	—	—	—	1	—	—	—
47. Textiles	1	—	1	3	1	1	—	—	1
48. Textiles and leather	—	—	—	—	—	—	—	1	—
49. Tobacco/textiles	—	—	1	—	—	—	—	—	—
50. Textiles and lumber	—	—	—	1	—	—	—	—	—
51. Man-made fibre	—	—	—	1	—	—	—	—	—
52. Style goods and apparel	—	—	1	1	—	—	—	—	—
53. Leather	1	—	—	—	—	1	—	—	—
54. Shoes	—	—	1	—	—	—	—	—	—
55. Services	—	—	—	—	—	1	—	—	—
56. Medical services	—	—	—	—	—	1	—	—	1
57. Recreation	—	—	—	—	—	1	—	—	—
58. Resorts	—	—	1	—	—	—	—	—	—
59. Real estate	—	—	—	—	—	1	—	—	—
60. Market centre, business services	—	—	1	—	—	—	—	—	—
61. Market centre, consumer services	—	—	1	—	—	—	—	—	—
62. Transport and repair	—	—	1	—	—	—	—	—	—
63. Ports	—	—	1	1	—	—	—	—	—
64. Miscellaneous	—	—	8	1	—	—	1	—	1
65. Low wage	—	—	2	1	—	—	—	—	—
66. Labour intensive	—	—	2	—	—	—	—	—	—
67. Manufacturing	—	—	—	1	—	—	—	—	—
68. Manufactured specialties	—	—	—	1	—	—	—	—	—

Table 2—*continued*

	Streit		Bergsman *et al.*		Roepke *et al.*	Czamanski	Campbell	Fines	Slater
	Germany	France	1972	1975					
69. Miscellaneous specialties	—	—	—	3	—	—	—	—	—
70. Various manufactures	1	—	—	—	—	—	—	—	—
71. Miscellaneous intermediates	—	—	2	—	—	—	—	—	—
72. Assembly plant (activities for fabrication)	—	—	—	—	—	—	—	1	—
73. Old manufacturing belt and major cities	—	—	—	1	—	—	—	—	—
74. Major and old manufacturing cities	—	—	—	1	—	—	—	—	—
75. Major cities	—	—	—	3	—	—	—	—	—
76. Major and other cities	—	—	—	1	—	—	—	—	—
77. Most tertiary activities	—	—	—	1	—	—	—	—	—
78. Unspecified	—	—	—	—	—	—	1	—	—
Total	13	14	42	40	13	16	5	6	7

the seven studies. The grouping identified in Slater's study included several industries, which no other research found to have close ties with agriculture, such as Communications, except radio and television, or Hotels and lodging places; Personal and repair services, except automobile repair. Aside from Slater and Bergsman (1975), a good part of the scatter appears to be due to differences in classification or simply to different names used to describe similar activities. A substantial degree of agreement can therefore be claimed, despite the heterogeneous nature of the studies compared.

The third category of clusters and complexes is related to chemical industries. This category contains six complexes which Streit found to exist in Germany and France, two types identified by Bergsman, three by Roepke, and one each by Czamanski and Fines. The list could even be extended, since the Petroleum/Chemicals complex of Bergsman (1972) and Czamanski's Petroleum could be included here as well. Roepke's Miscellaneous manufacturing and rubber products cluster might also be included, although only one sector, Plastics and synthetic resins, would actually belong in this category.

Of the 23 industries listed in the studies of Bergsman, Roepke, Czamanski and Fines, one sector, Fibres, plastics, and rubber, appears in all four studies, two sectors appear in three of the four studies, eight in two of the four, and 12 in only a single study.[13] Again much of the apparent scatter is due to differences in classification; for example Oils and extracts, Tar and tar products, and Basic chemicals may refer partly at least to similar activities.

The fourth category of clusters and complexes is related to metal industries. Six types of groupings have been found in the various studies. Streit, Bergsman (1972). Roepke and Fines identified industrial groupings called Metal industries. In the later study, Bergsman (1975) found another three complexes: 'Iron, steel and products', 'Aluminium' and 'Aluminium and tobacco' complexes. In the study by Czamanski, Metal industries do not appear but two separate clusters identified as Iron and steel, and Non-ferrous metals, seem to include

[13] The six complexes listed by Streit could not be decomposed.

a very similar set of sectors. Roepke found an additional cluster, Heavy metal industries.

A detailed comparison by sectors revealed important similarities in the findings, although only four studies (those of Bergsman (1972, 1975), Roepke and Czamanski) could be analysed in detail.[14] Althgether the four studies included 30 industries, of which two appeared in all four, two in three of the four, ten in two of the three, and 16 in only one study. A careful perusal leads to the conclusion, however, that the industries missing in some studies were actually included as part of a different, usually broader sector.

The fifth category of clusters and complexes covers the important automotive and machine industries. Six types of clusters and complexes have been identified in the various studies examined, but the diversity is largely semantic due to differences in names chosen to describe the groupings. Thus Motor vehicles and Aircraft complexes found by Streit and Roepke correspond to the Automotive cluster and complex in the Czamanski study. Similarly, the Machinery and equipment complex of Streit corresponds to the Machinery complex of Bergsman. Unfortunately, no sectoral analysis could be carried out since, with the exception of the Czamanski study, all findings were at an aggregate level listing only two or three industries. Typical in this respect is the work of Roepke, whose cluster is composed of only Motor vehicles and aircraft industries, and Non-metallic mineral products.

The sixth category of clusters and complexes comprises electrical and precision instruments industries. Ten types of clusters and complexes have been identified but, again, much of this diversity is due simply to differences in terminology. A brief examination of the names employed strongly suggests that at most two distinct groups, built around electrical and precision engineering, can be identified.

A more detailed analysis of sectoral composition of Communications and Electronics clusters and complexes is presented in the Appendix. It covers the work of Bergsman (1972, 1975), Roepke, Czamanski and Slater. Of the 22 industries listed, two were listed in four of the five studies, three appeared in three of the five studies, five appeared in two, and 12 in only one study. Much of the scatter, however, is clearly due to differences in classification used and even more to differences in the level of aggregation.

The seventh category of clusters and complexes comprises those related to glass and ceramic products. Streit, Bergsman (1972), and Slater have each identified Glass and glass products complexes, and Glass and electrical equipment complexes, while Bergsman (1975) found two other complexes called Coal, glass and ceramics, and Ceramic products. No detailed analysis by sector could be carried out due to the high level of aggregation at which the findings were presented.

The eighth category of clusters and complexes covers two related groups of industries centred on wood-processing and paper and printing. The two groups could be treated separately but Streit and Fines have classified them as belonging to single complexes. Bergsman (1972) has singled out Lumber from Wood and wood products, while both Streit and Bergsman (1972) found Paper industries complexes, distinct from Paper and printing complexes. Otherwise two, or at most three types of groupings would account for the whole range.

A detailed analysis of sectoral composition of the Wood and wood products clusters and complexes presented in the Appendix covers the five studies giving a detailed breakdown (Bergsman (1972, 1975), Roepke, Czamanski and Fines). The analysis revealed that of the 18 industries listed, three appeared in four of the five studies, two appeared in three of the five studies, four were found in two of the five studies, and nine in single studies. Paper and printing clusters and complexes were found to exist by Campbell as well as in the four studies listed above. The degree of agreement in terms of sectoral composition was equally high, with five industries found in four studies, one industry found in three studies and 13 industries found only once. Most of the latter were of a type rarely associated with paper and printing activities.

The ninth category of clusters and complexes, namely Construction, was found to exist only by Czamanski. This is rather surprising since this grouping, which is huge in terms of number of industries and total output and value added, appears to be quite common in the US, and contains strong links between sectors of which it is composed.

[14] The other studies worked at too aggregate a level.

The tenth category of clusters and complexes combined textiles and leather products, which are treated here together only becauses Fines found them as forming a single complex. Eight types of clusters and complexes were identified with four focusing on textiles, two on leather and two mixed.

A detailed analysis of sectoral composition was limited to the textiles groupings and is presented in the Appendix. A similar comparative analysis of the leather industries was not possible since only the Czamanski study listed a detailed sectoral composition. Streit, who found such a complex in Germany, did not provide enough details; the Shoe complex of Bergsman (1972) lists only two related industries, namely, Footwear cut stock (soles, uppers, buckles), and Footwear, except rubber. His third industry in the group comprises textiles. Among the textiles group, the seven studies listed together 25 industries, with two industries appearing in six of the seven studies, one in five studies, one in four studies, three in three studies, seven in two of the seven studies, and 11 in single studies only. This has to be viewed as a high degree of agreement, in view of the heterogeneity of the group.

The eleventh category of clusters and complexes was composed of services. Nine types of clusters and complexes were identified by Bergsman (1972) and Czamanski, while Slater found the existence of only one. Actually all were quite dissimilar. With one exception, no sectoral comparisons were possible, and even in that case, Medical services, the sectoral composition found by Czamanski and Slater were quite different.

The twelfth and last category of clusters and complexes groups miscellaneous and unspecified groupings, for which the very criterion of classification is no longer type of products or processes, but such characteristics as Low wage, existence of Major cities, or Labour intensive processes. Most were identified by Bergsman (1972, 1975) with the help of factor analysis. An analysis of the sectoral composition of Miscellaneous clusters and complexes showed no similarity in sectoral composition.

Conclusions

Whatever generalisations can be made have to deal with the twin aspects of each study: the methodology employed and results obtained. The analysis of the eight studies which addressed themselves directly to the identification of industrial groupings revealed deep differences in both respects, but the overwhelming impression was that the heterogeneity of methods was greater than that of findings. For differences between them were not simply the result of using data pertaining to economies highly dissimilar in size and basic characteristics, but were also due to the various levels of disaggregations used and, above all, to dissimilar mathematical techniques employed.

Four of the studies used multivariate analysis, three some form of graph theory, and one combined both approaches. Except Bergsman *et al.* (1972, 1975), all studies examined used inter-industry flows, summarised in a matrix, as the basic tool of analysis. Their level of sectoral detail differed sharply, for Streit used 26 industries, Bergsman (1972) 186, Bergsman (1975) 480, Roepke 44, Czamanski 172, Campbell 19, and Slater 75. The differences in level of detail should be noted. An analysis of the results leads to the conclusion that level of disaggregation is an important issue, since few analytically interesting results concerning industrial structure can be expected from small input–output matrices. Where exactly the cut-off point lies and whether in fact even the largest matrices used in the above studies were big enough are hard to determine.

The three basic approaches used, multivariate analysis, cluster analysis, and graph theory, may be considered as complementary to one another rather than as alternatives. The multivariate analysis provides the means for a rigorous examination of a mass of information, but the insights gained into the underlying causal factors are limited. Even the consistent designation of the revealed groupings presents considerable difficulties, perhaps best exemplified in the Bergsman (1972, 1975) study, which dealt with more numerous sectors than others. This particular drawback is not shared by the various methods based on triangularisation and graph theory, but those methods are laborious and also lose some valuable information contained in the flow tables.

The relatively high degree of agreement in the findings presented, despite the variety of methods employed and data used, is rather surprising. It seems to validate, albeit only partially, the usefulness of the concepts of industrial clusters and complexes as tools of regional analysis. But some serious conceptual doubts remain.

Classical location theory, with its heavy emphasis on transport costs, inter-regional differences in labour costs, and economies of scale, devoted scant attention to spatial groupings of similar and complementary industrial activities. The great progress in transportation technology during the past decades has greatly weakened the basic assumptions on which the theory rests and further limited its explanatory power. Studies focusing on the observed phenomenon of urban-industrial agglomerations revealed some interesting persistent patterns and led to a classification of industries, on the basis of their main locational preferences, into geographically oriented, complementary, and urban oriented (Czamanski, 1964). These attempts failed, however, to explain the underlying mechanism and the forces responsible for the mutual spatial attraction of activities and for the sectoral specialisation of centres.

Most of the studies here reviewed, rest on two implied assumptions, namely: (1) that transportation costs are not of overwhelming importance in explaining the spatial distribution of industries, and (2) that any spatial economic phenomena must find their expression in flows of goods and services, ultimately translated into money flows. Hence, input–output tables have been generally used as the basic format for the organisation of data. The serious drawback of input–output in this connection is that some important links such as those existing between wholesalers, commodity brokers and agents, and their suppliers and/or customers are given insufficient weight. Furthermore, the mutual attraction of financial and other service sectors may be due to crucial information flows revealed only indirectly by an input–output table. More generally, the importance of flows of goods and services as determinants of location need not be proportional to the absolute or relative value of flows. Some ways of weighting flows before using them in locational studies ought to be considered, perhaps along the lines suggested by Klaassen. A more recent contribution of Alperovich *et al.* (1975) proposed, although with other objectives in mind, the use of exponentially-decaying functions of distance to weight the 'attractions' exercised by customers. Such studies currently under way may yield a better understanding of the process of formation of industrial complexes.

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Appendix

Sectoral composition of clusters and complexes

I. *Extractive industries and petroleum**

	Bergsman *et al.*		Roepke *et al.*	Czamanski		Slater[a]
	1972	1975		Clusters	Complexes	
Industrial organic and inorganic chemicals	x	x^2	—	—	—	—
Petroleum refining[a]	x	x^2	—	x	x	x
Miscellaneous petroleum and coal products (lubrication oils, fuel briquettes)	x	—	—	—	—	—
Petroleum refineries and coal products	—	—	x	—	—	—
Clay, lime, and cement	—	—	x	—	—	—
Mining (includes coal mining)	—	x^1	x	—	—	x
Crude petroleum and natural gas	—	x^2	—	x	x	x
Oil and gas field services	—	—	—	x	—	—
Paving and roofing materials	—	—	—	x	x	—
Local passenger transportation	—	—	—	x	—	—
Air transportation	—	—	—	x	—	—
Real estate	—	—	—	x	—	—
Construction, mining, oil field machinery and equipment	—	x^2	—	—	—	x
Electric, gas, water and sanitary services	—	—	—	—	—	x

* The table combines two types of groupings. Roepke and Slater identified Extractive industries groupings, while Bergsman and Czamanski identified Petroleum groups. Bergsman *et al.* (1975) worked with 420 sectors. These were grouped by us into essentially three-digit categories to enable comparisons.

[a] Slater includes related industries. x^1 = Mining; x^2 = Petroleum.

II. *Food and agricultural products*

	Bergsman *et al.*		Roepke *et al.*	Czamanski		Campbell	Fines	Slater
	1972	1975		Clusters	Complexes			
Agriculture, agricultural and related services	x[2]	—	x	x	x	x	x	x
Forestry, hunting, trapping, fisheries	x[2]	—	x	x	x	x	—	x
Sugar	x	x[4]	x	x	—	—	x	—
Meat products	—	—	x	x	x	x	x	—
Dairy products	—	x[3]	x	x	—	x	x	—
Canned and frozen foods	x[2]	x[4]	—	x	x	x	x	—
Grain mill products	x[1]	x[3]	x	x	x	x	x	—
Bakery products	—	—	x	x	x	—	x	—
Soft drinks	—	—	x	x	—	x	x	—
Distilleries, breweries and wineries	—	x[4]	x	x	—	x	x	—
Miscellaneous food preparations	x[1]	—	x	x	x	—	—	—
Tobacco manufactures	—	—	—	x	—	—	—	x
Wooden containers	—	—	—	x	x	—	—	x
Agricultural chemicals	—	—	—	x	—	—	—	—
Leather goods n.e.c.	—	—	—	x	—	—	—	x
Metal cans (light metals products)	—	x[4]	—	x	x	x	—	—
Farm machinery and equipments	—	x[3]	—	x	—	—	—	—
Medical, dental labs; health services n.e.c.	—	—	—	x	x	—	—	—
Livestock and livestock products	—	—	—	—	—	x	x	x
Non-ferrous metals, except aluminium	—	—	—	—	—	x	—	—
Shipbuilding and repairing	—	—	—	—	—	x	—	—
Paper products	—	x[4]	x	—	—	—	—	—
Noodles	—	—	—	—	—	—	x	—
Seasonings and spices	—	x[4]	—	—	—	—	x	—
Communications, except radio and television	—	—	—	—	—	—	—	x
Hotels and lodging places, personal and repair services, except automobile repairs	—	—	—	—	—	—	—	x
Lumber and wood products, except containers	—	x[4]	—	—	—	—	—	x
Wood and kindred products	—	x[4]	—	—	—	—	—	x
Other agricultural products	—	x[4]	—	—	—	—	—	x
Miscellaneous manufacturing	—	—	—	—	—	—	—	x
Wholesale and retail trade	—	x[3]	—	—	—	—	—	x
Real estate and rental	—	—	—	—	—	—	—	x

[1] Cluster grain products. [2] Cluster food canning. [3] Farm products. [4] Food and agricultural products.

III. *Petrochemicals*

	Bergsman *et al.*	Roepke *et al.*	Czamanski		Fines
			Clusters	Complexes	
Chemical and fertiliser mineral mining	—	—	x	—	—
Basic chemicals	—	—	x	x	x
Fibres, plastics, rubbers	x[1]	x	x	x	x
Paints, varnishes and allied products	—	x	x	x	x
Gum and wood chemicals	x[1]	—	x	—	—
Agricultural chemicals	—	—	x	x	—
Miscellaneous chemical products	—	—	x	x	—
Tyres and inner tubes	x[2]	—	x	x	—
Rubber footwear	—	—	x	x	—
Reclaimed rubber	x[2]	—	x	x	—
Fabricated rubber products n.e.c.	x[2]	—	x	x	x
Miscellaneous plastic products	—	—	x	x	x
Special industry machinery except metal working	—	—	x	—	—
Photographic equipment and supplies	—	—	x	—	x
Pharmaceuticals and medicines	—	x	—	—	x
Other chemical industries	—	x	—	—	—
Detergents	—	—	—	—	x
Oils and extracts	—	—	—	—	x
Fertilisers	—	—	—	—	x
Explosives	—	—	—	—	x
Electro-chemicals	—	—	—	—	x
Compressed gas	—	—	—	—	x
Tar and tar products	—	—	—	—	x

[1] Chemicals. [2] Rubber products.

IV. *Iron and steel*

	Bergsman *et al.*		Roepke *et al.*	Czamanski	
	1972	1975		Clusters	Complexes
Iron and ferro-alloy ores	—	—	—	x	x
Anthracite, lignite and bituminous coal mining	—	—	x[2]	x	x
Oil and gas field services	—	—	—	x	—
Office furniture	x[4]	—	—	x	—
Partitions and fixtures	x[4, 5]	—	—	x	x
Steel rolling and finishing	—	—	—	x	x
Iron and steel foundries	x[4]	x	x[1, 2]	x	x
Primary metal industries n.e.c.	x[5]	x	x[2]	x	x
Metal cans	—	—	—	x	x
Cutlery, hand-tools, hardware	x[5]	—	—	x	—
Fabricated structural metal products	—	—	x[1]	x	x
Screw machine products and bolts	x[5]	x	—	x	x
Metal stampings	—	—	x[1]	x	x
Coating, plating, polishing and engraving	—	—	x[2]	x	—
Fabricated wire products n.e.c.	x[4]	—	—	x	x
Fabricated metal products n.e.c.	—	x	x[1, 2]	x	x
Ship and boat building and repairing	—	—	—	x	—
Railroad equipment	—	—	x[1, 2]	x	x
Water transportation	—	—	—	x	—
Electric, gas, and sanitary services	—	—	x[1]	x	x
Electrical industrial equipment	—	—	x[1]	—	—
Miscellaneous manufacturing	—	—	x[2]	—	—
Motor vehicles and aircraft	—	—	x[2]	—	—
Clay, lime and cement	x[5]	—	x[2]	—	—
Industrial leather belting	x[5]	—	—	—	—
Metal working machinery	x[5]	x	—	—	—
General industries machinery	x[5]	—	—	—	—
Engines and turbines	x[4]	—	—	—	—
Miscellaneous non-electrical machinery	x[4]	—	—	—	—
Toys and sporting goods	x[4]	—	—	—	—

[1] Metal-using industries. [2] Heavy motors industries. [3] Metal products I. [4] Metal products II. [5] Metal products III.

V. *Communications and electronics*

	Bergsman *et al.*		Roepke *et al.*	Czamanski		Slater
	1972	1975		Clusters	Complexes	
Complete guided missiles; ammunition n.e.c.	—	—	—	x	—	—
Sighting and fire control equipment	—	—	—	x	—	—
Household furniture	—	—	—	x	—	—
Public building and related furniture	—	—	—	x	—	—
Machinery (except electrical) n.e.c.	—	—	—	x	x	—
Radio and TV receiving equipment	—	x	—	x	x	x
Communication equipment	x	x	x	x	x	—
Electronic components	x	x	—	x	x	x
Aircraft and parts	—	—	—	x	x	—
Scientific equipment	—	—	—	x	x	—
Optical instruments and lenses	x	—	—	x	—	—
Photographic equipment and supplies	x	x	—	x	—	—
Other electrical products	—	—	x	—	—	—
Electrical industrial equipment	—	x	x	—	—	—
Other primary metals	—	—	x	—	—	—
Non-ferrous foundries	x	—	—	—	—	—
Miscellaneous electrical equipment	x	x	—	—	—	—
Mechanical measuring and control devices	x	x	—	—	—	—
Medical instruments and supplies	x	—	—	—	—	—
Ophthalmic goods	x	—	—	—	—	—
Office machines and computers	x	x	—	—	—	x
Electric test and distributing equipment	x	x	—	—	—	—

VI. *Wood and wood products*

	Bergsman *et al.*		Roepke *et al.*	Czamaanski		Fines
	1972	1975		Clusters	Complexes	
Forestry, hunting, trapping, fisheries	—	—	—	x	—	—
Contract construction	x	—	—	x	—	—
Small arms	—	—	—	x	—	—
Small arms ammunition	—	—	—	x	—	—
Logging camps and contractors	x	—	—	x	x	—
Sawmills	x	—	x	x	x	x
Planing mills	x	—	x	x	x	x
Mill-work and related products	x	x	—	x	x	—
Wooden containers	x	x	—	x	x	—
Miscellaneous wood products and wood finishing	x	x	—	x	x	x
Paper board containers and boxes	—	—	—	x	—	x
Pulp mills	—	—	—	x	—	—
Paperboard mills	—	—	—	x	—	—
Other wood industries	—	—	x	—	—	—
Furniture and fixtures	—	x	x	—	—	—
Other metal fabricating	—	—	x	—	—	—
Building paper and board mills	x	—	—	—	—	—
Heavy wood products	—	—	—	—	x	—

VII. *Paper and printing*

	Bergsman *et al.* 1972	Roepke *et al.*	Czamanski Clusters	Czamanski Complexes	Campbell	Fines
Commercial printing	—	—	x	x	—	—
Pulp mills	x	x	x	—	x	—
Paper mills	x	x	x	x	x	—
Paper and paperboard products	x	x	x	x	—	x
Newspapers	—	—	x	x	—	—
Periodicals	—	x	x	x	x	x
Book publishing and printing	—	x	x	x	x	x
Miscellaneous publishing	—	x	x	x	x	x
Minifold business forms	—	—	x	x	—	—
Printing trades services	—	—	x	x	—	—
Office supplies	—	—	x	x	—	—
Government enterprises	—	—	x	—	—	—
Other foods	—	—	—	—	x	—
Wholesale retail trade	—	—	—	—	x	—
Gas, water, sanitary services	—	—	—	—	x	—
Business services	—	—	—	—	x	—
Insurance	—	—	—	—	x	—
Real state	—	—	—	—	x	—
Other industries (7 industries)	—	—	—	—	x	—

VIII. *Textiles*

	Bergsman *et al.* 1972	Bergsman *et al.* 1975	Roepke *et al.*	Czamanski Clusters	Czamanski Complexes	Fines	Steed	Slater
Floor-covering mills	x	x	—	x	x	—	—	—
Apparel (except fur goods)	—	—	x	x	x	—	—	x
Fabric and yarn mills, textile finishing	x	x	—	x	x	x	x	x
Narrow fabric mills	—	x	—	x	x	x	—	—
Knitting mills	—	x	x	x	x	x	—	—
Textile goods n.e.c.	—	—	—	x	x	—	—	x
Fabricated textiles n.e.c.	—	—	—	x	x	—	—	x
Fibres, plastics, rubbers	—	—	—	x	x	—	—	x
Rubber footwear	—	—	—	x	—	—	—	—
Motor vehicles and equipment	—	—	—	x	—	—	—	—
Costume jewellery and notions	—	—	—	x	x	—	—	—
Weaving mills, cotton	x	x	x	—	—	x	x	—
Weaving mills, synthetics	x	x	x	—	—	x	x	x
Men's and boys' furnishings	x	—	—	—	—	—	—	—
Other textiles	—	x	x	—	—	—	—	—
Spinning	—	—	—	—	—	—	x	—
Threadmaking	—	—	—	—	—	x	x	—
Making-up	—	—	—	—	—	x	x	—
Trade home-stitching	—	—	—	—	—	—	x	—
Intermediate textile products	—	x	—	—	—	x	—	—
Hats and caps	—	—	—	—	—	x	—	—
Garments	—	—	—	—	—	x	—	—
Textile printing	—	—	—	—	—	—	x	—
Chemicals and fertiliser mineral mining	—	—	—	—	—	—	—	x
Chemicals and selected chemical products	—	—	—	—	—	—	—	x