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National Industry Cluster Templates: A Framework for Applied Regional Cluster Analysis

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FESER E. J. and BERGMAN E. M. (2000) National industry cluster templates: a framework for applied regional cluster analysis, *Reg. Studies* 34, 1–19. A growing number of cities, states and regions in Europe, North America and elsewhere are designing development strategies around strategic clusters of industries. In many cases, a lack of data on local and interregional industrial linkages, shared business institutions, channels of technology and knowledge transfer, and other dimensions of the cluster concept means that relatively simple measures (location quotients, industry size) are often used to initially detect clusters in subnational regions. In this paper, we suggest a means of using available information on national interindustry linkages to identify potential clusters in subnational areas. Specifically, we derive a set of 23 US manufacturing clusters and employ them as templates in an illustrative analysis of the manufacturing sector in a single US state. The template clusters help detect gaps and specializations in extended product chains and therefore constitute a useful first step in more comprehensive examinations of local cluster patterns.

Industry clusters Input–output analysis Linkages

FESER E. J. et BERGMAN E. M. (2000) Des gabarits de grappes d'industries d'envergure nationale: un cadre pour l'analyse appliquée des grappes à l'échelon régional, *Reg. Studies* 34, 1–19. De plus en plus nombreux sont les villes, les états et les régions en Europe, en Amérique du Nord et ailleurs qui mettent au point des stratégies de développement visant des grappes d'industries clé. Dans beaucoup des cas, le manque de données sur le maillage industriel local et interrégional, le partenariat commercial, les canaux de transfert de la technologie et de l'apprentissage, et autres dimensions de la notion de grappes, signifient que des mesures relativement simples (quotient de localisation, taille de l'industrie) se voient employer souvent afin de découvrir dans un premier temps des grappes sur le plan régional. Cet article avance un moyen d'employer les données disponibles sur le maillage intersectoriel national pour identifier des grappes éventuelles sur le plan régional. Plus particulièrement, on emploie un ensemble de vingt-trois grappes industrielles aux Etats-Unis comme gabarits pour analyser à titre d'exemple le secteur industriel dans un seul état aux Etats-Unis. Les gabarits aident à découvrir les créneaux et les spécialisations des chaînes de produits élargies et constituent ainsi une première démarche dans l'examen plus approfondi de la distribution locale des grappes.

Grappes d'industries Tableau d'échanges intersectoriels Maillage

FESER E. J. und BERGMAN E. M. (2000) Schablonen für Kluster der Landesindustrie: ein Grundgerüst für angewandte Regionalklusteranalyse, *Reg. Studies* 34, 1–19. Eine wachsende Anzahl von Städten, Regionen und Staaten in Europa, Nordamerika und anderen Orten entwerfen Entwicklungsstrategien, die strategische Kluster von Industrien zum Mittelpunkt haben. In vielen Fällen führt Mangel an Information über örtliche und unterregionale Industrieverbindungen, über gemeinsam benutzte geschäftliche Institutionen, Wege der Technologie-und Wissensvermittlung sowie anderer Dimensionen des Klusterkonzepts dazu, daß relativ einfache Maßnahmen (Standortquotienten, Industriegröße) benutzt werden, um anfangs Kluster auf teilstaatlicher Ebene überhaupt zu entdecken. In diesem Aufsatz wird ein Mittel zur Nutzung vorhandener Information betreff staatlicher. Interindustrieller Verknüpfungen vorgeschlagen, um potentielle Kluster in staatlichen Teilgebieten zu identifizieren. Um präzise zu sein: es wird ein Satz von 23 Klustern der herstellenden Industrie in den Vereinigten Staaten erstellt, und als Schablone in einer illustrativen Analyse des Sektors der herstellenden Industrie in nur einem Staat der Vereinigten Staaten angewandt. Die Schablonenkluster tragen dazu bei, Lücken und Spezialisierung in erweiterten Produktketten ausfindig zu machen, und stellen deshalb einen nützlichen ersten Schritt bei der umfassenderen Untersuchung örtlicher Klustermuster dar.

Industriekluster Aufwand-Ertragsanalyse Verknüpfungen

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INTRODUCTION

The activities of firms in a given sector can affect the performance of producers in other regional sectors in the short run, through the demand for inputs and services, but also in the long run through the development and diffusion of new manufacturing technologies, the exertion of influence on producers' use of advanced production techniques and general business strategies, the informal exchange of information, and the transfer of skills and knowledge that occurs via shared labour markets. For many firms and industries, their short run supplier chain linkages form the principal conduits and circuits through which long run strategic and technological flows also course. Therefore, each producer's own success depends immediately on the quality and timely availability of its key inputs and, over time, upon mutually beneficial relationships that nurture high levels of technological sophistication, quality and flexibility from suppliers.

A growing body of research shows that firms in some industries are restructuring their relationships with suppliers to permit greater co-ordination in design and production (IMRIE and MORRIS, 1992; LAMMING, 1993; KLIER, 1994). While that is partly a response to external changes brought on by various International Standards Organization (ISO) compliance standards necessary for export production, it is also based heavily upon the supplier base consolidation and purchasing firm certification practices increasingly common to industries that face heavy global competition and that depend upon deep, fragile supply chains. Many elements of flexible manufacturing systems, such as just-in-time inventory and sourcing, require such close co-ordination between contracting parties that the potential for diffusion of information and technology across firms in the same production chain is greatly enhanced (HYUN, 1994).

The spatial implications of such dynamics are addressed in several related theories and models, including familiar concepts of agglomeration economies, technology diffusion and Marshallian industrial districts. The resurgence of industrial district concepts, in particular, represents a newly fertile area of interdisciplinary research that now combines perspectives from strategic management, industrial organization, economic geography, urban economics and sociology in an attempt to specify better formal and informal relationships between firms in specific regions (BELLANDI, 1989; HARRISON, 1992; HUMPHREY, 1995). That case-oriented literature has focused primarily on explaining the success of certain regions in Europe and North America (e.g. SIGNORINI, 1994; SAXENIAN, 1994) though applications to Third World and Asian economies are growing (MARKUSEN and PARK, 1993; CAWTHORNE, 1995; MEYER-STAMER, 1995; PARK, 1997). Externalities and technology spillovers that seem to arise from a type of co-operative competition among co-located firms are often cited as a unique means for businesses to achieve the flexibility necessary to remain competitive in a rapidly changing international marketplace. The highlighted success stories have, in turn, generated much interest among development practitioners in finding ways to replicate and promote similar synergies in lagging regions (ROSENFELD, 1995, 1996).

A specific area of application interesting to policy makers has developed from these ideas: the identification and nurturing of industry clusters. This is a concept popularized by PORTER, 1990, in his efforts to stimulate a new approach to corporate strategy that is itself based heavily on the industrial district model at the regional level. DOERINGER and TERKLA, 1995, acknowledged a half-decade later that industry clusters have become a development policy fad of the 1990s. A number of cities, states and regions in the US and Europe have begun developing cluster-based strategies, though the logic behind such initiatives is often poorly specified or simply not recognized as relevant (*ibid.*). A review of practitioner journals suggests that, at least at the local level in the US, the approach frequently involves little more than the identification of current regional specializations as targets for traditional development initiatives (see, for example, TREMBLAY, 1993; ANDERSON, 1994; MORFESSIS, 1994).[1] In such cases, a cluster strategy serves more often as a means of focusing scarce resources than as a way to build the linkages and future interindustry synergies documented so frequently in successful industrial districts.

In this paper, we suggest a method of going beyond the typical anecdotal or descriptive approach to the analysis of regional clusters. In particular, we lay out a means of using detailed information on national interindustrial linkages that help identify existing and potential clusters in US subregions. Extended buyer–supplier chains (23 in total) are first estimated for the US manufacturing economy. The chains can be shown to 'cluster' at the national level to represent the linked re-aggregations of decimalized categories in the Standard Industrial Classification (SIC) system. The linkages assemble various major final-market producing sectors with their key first, second and third-tier supplier sectors (as shown by input–output relationships).

When used in subsequent regional analyses, the national clusters serve as *templates* for developing a strategic view of a regional manufacturing economy in a manner that is wholly distinct from that revealed through typical studies and data analyses that rely upon broad SIC categories. By grouping those firms that are most likely to interact with each other, both directly and indirectly, the templates reveal relative specializations in the regional economy by exposing otherwise opaque extended product chains. They are thus a valuable analytic tool for the design of economic development strategies that seek to exploit or leverage direct and indirect interfirm linkages. Examples include buyer–supplier and import replacement strategies, as well as technology deployment, cross-firm networking and industrial park initiatives.

In the following sections, we position our approach with respect to the study of industrial clusters generally, describe our methodology and outline the derived set of national clusters. We then apply the clusters as templates to a brief analysis of the manufacturing sector in a single US state (North Carolina) while highlighting basic findings and insights derived from their use. Because space constraints preclude a detailed explication of the full set of templates, we examine one in particular as an illustrative example, that is the vehicle manufacturing cluster, one of the largest industrial clusters in the US. Vehicle manufacturing is a particularly interesting case since many studies of buyer–supplier dynamics and technology diffusion focus on this leading industry (SCHOENBERGER, 1987; HYUN, 1994; BALLEW and SCHNORBUS, 1994; HELPER, 1994). The sector has also enjoyed strong growth in North Carolina, as the geographical centre of US automaking continues to shift south from its historical base in the American Northeast and North Central regions.

UNDERSTANDING INDUSTRIAL CLUSTERS

The term 'cluster' means different things to different researchers and policy makers. Various definitions of industrial clusters as groups of related firms encompass one or more of the following dimensions: formal input–output or buyer–supplier linkages; geographic co-location; shared business-related local institutions; and evidence of informal co-operative competition. In the earlier scientific literature on this subject, clusters were defined as sectors related through formal production linkages, regardless of geographical proximity. When such clusters did exhibit a high degree of geographical concentration, they were referred to as *industrial complexes* (CZAMANSKI and ABLAS, 1979).[2] More than a decade later, PORTER, 1990, wrote of clusters as groups of related industries, regardless of geographical location. He also stressed the fact that such clusters *tend* to be localized in space. REDMAN, 1994, p. 37, denotes a cluster as 'a pronounced geographic concentration of production chains for one product or a range of similar products, as well as linked institutions that influence the competitiveness of these concentrations (e.g. education, infrastructure and research programmes)'. That is similar to, though perhaps somewhat broader, than the definition adopted by ROSENFELD, 1995, p. 12: 'A cluster is a loose, geographically bounded agglomeration of similar, related firms that together are able to achieve synergy. Firms 'self-select' into clusters based on their mutual interdependencies in order to increase economic activity and facilitate business transactions'. We use the term 'industrial cluster' in the same generic sense as Czamanski and Ablas to refer to a specific constellation of linked firms, but prefer 'regional cluster' to connote the presence of such an industrial cluster in some specific spatial context.[3]

The appropriateness of any given definition, as well as any subsequent method of cluster identification, depends on the specific policy objectives involved. Recognizing that interactions between firms occur both locally and over great distances, this study sought to first identify clusters as groups of technologically linked industries, irrespective of geographical location. Since interindustry trade occurs across regional boundaries, such a non-location based approach is the most effective means of revealing the groups of industries that are most closely related with each other, based on similarities in technological structure.

In order to identify related sectors irrespective of location, 362 three- and four-digit manufacturing industries – the full range of manufacturing industries in the US – were grouped into clusters based on *national* input–output flows. The focus on manufacturing is primarily necessitated by the nature of the data and present industrial classifications. The US input–output accounts are much more detailed for the manufacturing sector, permitting a more fine-grained analysis of inter-industry linkages. The eventual replacement of the SIC system with the North American Industry Classification System (NAICS) should help rectify this, since NAICS includes a substantial number of new categories for the burgeoning non-manufacturing sector (ZEISSET and WALLACE, 1997). In addition, because key services serve such a wide range of sectors, they have the effect of skewing the analysis toward large, rather indistinct groups of industries. In preliminary tests of clustering across all US industries, similarities in sectors' relative use of services resulted in fewer, larger clusters comprised of very dissimilar industries (BERGMAN *et al.*, 1996). In that context, the meaningfulness of the cluster concept comes into question.

The types of input–output linkages between firms in different industries are complex and multidimensional. For example, the automobile assembly industry (SIC 3711) purchases inputs directly from the refrigeration and heating equipment industry (SIC 3585) and from the rubber and plastic hose and belting sector (SIC 3052). In addition to those sectors' direct links to automobile assembly, the connection between the belts and hoses sector and automobiles can also be indirect, since many firms in SIC 3052 are second-tier suppliers to producers in SIC 3711 (they are first-tier suppliers to firms in SIC 3585). Other indirect relationships may be revealed through the sharing of intermediate inputs. The household vacuum cleaners sector (SIC 3635) purchases a significant share of its total inputs from the hoses and belting (3052) and mechanical measuring devices (SIC 3823–4, 3829) industries, both important first- and second-tier suppliers to motor vehicles. If the similarities in input mix are strong enough, indirect linkages can potentially connect the fortunes of seemingly unrelated industries (autos and vacuums) to a surprising degree. An input–output based cluster methodology helps evaluate the relative strengths of those complex direct and indirect linkages, without imposing arbitrary *a priori* restrictions.

One might attempt to identify clusters in a given region by collecting or using available data on actual local input–output patterns to reveal existing buyer–supplier chains within the region. While useful for such purposes as estimating impacts triggered through regional multipliers (and assuming those rare data can be collected or are otherwise available), that approach would unnecessarily restrict the cluster analysis since it excludes any industries that do not trade locally at a significant level. Thus key sectors that may informally interact or share pools of labour with local cluster firms (by virtue of being engaged in related production) are ignored. Accordingly, the method cannot detect nor reveal gaps in supplier chains that might reveal something about local comparative advantages. That sacrifices a major advantage of the national template approach, i.e. its ability to reveal latent opportunities or strengths (or alternatively, weaknesses) in a subnational economy that are not apparent using standard SIC aggregations or local trading patterns. Indeed, we suggest below that the examination of local trading patterns most usefully comes after an analysis of the regional economy using the template interindustry chains.

METHODOLOGY

Several attempts to identify national clusters of US industries related through input–output (I/O) linkages were made in the early 1970s (Streit, 1969; Roepke *et al.*, 1974; Czamanski, 1974). Variants of those techniques were undertaken in the course of this study and the results compared. For the most part, results were similar for each methodology, with the number of derived clusters ranging from 22 to 28.[4] To our knowledge, no other I/O based, comprehensive cluster analyses of the type performed here have been attempted with recent US input–output accounts. Yet our results are strikingly consistent with earlier studies that employed much older tables. The total number of clusters is fewer in earlier studies (probably given their use of more aggregated I/O tables), but the types of clusters are quite similar to those derived here. This section describes the sequence of procedures used in the cluster analysis, including the basic measures of purchase relationships used to analyse interindustry linkages.

General approach

Earlier studies used a range of methodologies, including graph theory, triangularization and factor analysis for sorting industries into groups based on input–output linkages. For this study, measures of direct and indirect linkages computed from interindustry trade information for each sector were treated as variables in a principal components factor analysis. Data are from the detailed 1987 benchmark US input–output accounts, released by the Bureau of Economic Analysis in late 1994 (US Department of Commerce, 1994). The derived components were rotated to a varimax solution to facilitate interpretation, where the decision regarding the number of rotated components was made based on the relative proportion of variance explained by each component, the size of the associated eigenvalues and scree plots (Dillon and Goldstein, 1984; Tinsley and Tinsley, 1987). Multiple analyses were conducted using alternative assumptions regarding the number of rotated factors. The results were then compared for consistency and interpretability before a final set of clusters was selected.

The generated set of loadings effectively provide a measure of the relative strength of the linkage between a given industry and a derived factor, where the highest loading industries on a given factor are treated as members of an industrial cluster. It is standard practice in factor analysis to regard only loadings greater than 0·50 (in absolute value terms) as significant or worthy of interpretation (Tinsley and Tinsley, 1987; Roepke *et al.*, 1974). That approach, however, does not provide a means of interpreting gradations in loadings. For example, industries with loadings exceeding 0·75 on a given cluster might be regarded as closely linked to that cluster, while industries with loadings from 0·50 to 0·75 and from 0·35 to 0·50 may be viewed as only moderately and weakly linked, respectively. This interpretation appeared reasonable upon inspection of the types of industries with moderate loadings on given clusters, as well as their trading patterns within and across clusters.

In interpreting the factor analysis results to identify specific industrial clusters, we attempted to reconcile several competing objectives. Our primary objective was to derive a set of clusters based on the most significant linkages as revealed in the I/O data matrix. Accordingly, the concern was to identify the industries with the tightest linkages to each cluster (i.e. the highest loading industries for each factor) regardless of whether or not some of those industries are also tightly linked to another cluster. A secondary objective was to identify, to the degree possible, a set of mutually exclusive clusters (i.e. each sector would be assigned to only one cluster). Such a result would facilitate cross-cluster comparisons of size and growth rates. It was not known before the statistical analysis whether that objective could be reasonably met, given the first objective. A tertiary objective was to investigate the linkages both between clusters as well as between industries within each cluster. Such linkages are sometimes revealed by an examination of sectors that are only moderately or weakly related to each cluster, thus competing with the first objective.

The final set of clusters represents a compromise. Each cluster contains a set of 'primary' and 'secondary' industries. *Primary industries* for a given cluster are those sectors that achieved their highest loading on that factor *and* whose highest loading was 0·60 or higher. For example, SIC 277 (greeting cards) achieved its highest loading on the sixth factor (what we interpret below as the printing and publishing cluster) and, since the loading (0·90) is greater than or equal to 0·60, SIC 277 is classified as a primary industry for that cluster. *Secondary industries* for a given cluster are those sectors that achieved loadings on the cluster equivalent to or greater than 0·35 but generally less than 0·60. For example, SIC 3652 (prerecorded records and tapes) achieved a loading of 0·54 on the sixth factor and is thus classified as a secondary industry for printing and publishing. For some clusters, the set of secondary industries also includes industries with loadings exceeding 0·60 but that achieved their highest loading on a different cluster. While SIC 2677 (envelopes) achieved a loading of 0·68 on the sixth factor, it achieved a still higher loading on factor 1 (interpreted as the metalworking cluster). Therefore, it is classified as a primary industry in metalworking and a secondary industry in printing and publishing. As a general rule, primary industries are those that are most tightly linked to a given cluster while secondary industries are those that are less-tightly or moderately linked. Considering only primary industries yields a set of mutually exclusive industrial clusters that can be used for cross-comparison purposes.

Details

Each cell, a_{ij}, in a detailed 478 × 478 US interindustry transactions matrix, **T**, gives the dollar value of goods and services sold in 1987 by row industry *i* to column industry *j*.[5] Given, for each industry, total intermediate good purchases (*p*) and sales (*s*), the type of functional relationship between any two industries, *i* and *j*, may be expressed in terms of four coefficients (following CZAMANSKI, 1974):

$$x_{ij} = \frac{a_{ij}}{p_j}, \quad x_{ji} = \frac{a_{ji}}{p_i}, \quad y_{ij} = \frac{a_{ij}}{s_i}, \quad y_{ji} = \frac{a_{ji}}{s_j} \qquad (1)$$

Each coefficient is an indicator of dependence between *i* and *j*, in terms of relative purchasing and sales links:

x_{ij}, x_{ji}: intermediate good purchases by *j* (*i*) from *i* (*j*) as a proportion of *j*'s (*i*'s) total intermediate good purchases. A large value for x_{ij}, for example, suggests that industry *j* depends on industry *i* as a source for a large proportion of its total intermediate inputs

y_{ij}, y_{ji}: intermediate good sales from *i* (*j*) to *j* (*i*) as a proportion of *i*'s (*j*'s) total intermediate good sales. A large value for y_{ij}, for example, suggests that *i* depends on industry *j* as a market for a large proportion of its total intermediate good sales.

Correlation analysis permits the assessment of linkages between pairs of industries based on their total patterns of sales and purchases across multiple industries. Each column (**x**) in a matrix of *x*'s, **X**, gives the intermediate input purchasing pattern of the column industry. Each column (**y**) in a matrix of *y*'s, **Y**, gives the intermediate output sales pattern of the column industry. Four correlations describe the similarities in input–output structure between two industries *l* and *m*:

$r(\mathbf{x}_l \cdot \mathbf{x}_m)$ measures the degree to which industries *l* and *m* have similar input purchasing patterns

$r(\mathbf{y}_l \cdot \mathbf{y}_m)$ measures the degree to which *l* and *m* possess similar output selling patterns, i.e. the degree to which they sell goods to a similar mix of intermediate input buyers

$r(\mathbf{x}_l \cdot \mathbf{y}_m)$ measures the degree to which the buying pattern of industry *l* is similar to the selling pattern of industry *m*, i.e. the degree to which industry *l* purchases inputs from industries in which *m* supplies

$r(\mathbf{y}_l \cdot \mathbf{x}_m)$ measures the degree to which the buying pattern of industry *m* is similar to the selling pattern of industry *l*, i.e. the degree to which industry *m* purchases inputs from industries in which *l* supplies.

We calculated the four coefficients for each pair of industries using two specifications of **X** and **Y**. The first specification consisted of buying and selling patterns for 362 manufacturing industries across all other manufacturing industries (362 × 362 matrices). The second specification consisted of buying and selling patterns for 362 manufacturing industries across all other industries, both manufacturing and non-manufacturing (478 × 362 matrices). Interindustry correlations calculated using the second specification of **X** and **Y** account for similarities in manufacturing industries' sales/purchase patterns to/from non-manufacturing industries (e.g. construction, wholesaling, services).

Deriving the correlations from the first set of **X** and **Y** matrices and selecting the largest of the four between each pair of industries yielded a 362 by 362 symmetric matrix, $\mathbf{L_V}$. Each column of $\mathbf{L_V}$ describes the pattern of relative linkage between the column industry and all other manufacturing industries. Principal components factor analysis with varimax rotation identified 28 factors that together explain nearly 90% of the variation in the data matrix. A close examination of the 28 factors indicated that the approach yielded clusters based on both direct and indirect input–output patterns. Repeating the exercise for the second set of **X** and **Y** matrices generated 18 large and difficult-to-interpret clusters. When correlations were calculated

Table 1. Summary results: principal components factor analysis

Factor	Interpretation	Eigenvalue	% total variance	% common variance
1	Metalworking	90·50	25·0	28·0
2	Vehicle manufacturing	40·27	11·1	12·4
3	Chemicals and rubber	30·86	8·5	9·5
4	Electronics and computers	22·91	6·3	7·1
5	Packaged food products	18·30	5·1	5·7
6	Printing and publishing	15·96	4·4	4·9
7	Wood products	14·35	4·0	4·4
8	Knitted goods	12·49	3·4	3·9
9	Fabricated textile products	7·54	2·1	2·3
10	(Unreported)	6·05	1·7	1·9
11	Nonferrous metals	5·64	1·6	1·7
12	Canned and bottled goods	5·37	1·5	1·7
13	Leather goods	5·36	1·5	1·7
14	Aerospace	4·91	1·4	1·5
15	Feed products	4·37	1·2	1·4
16	Platemaking and typesetting	4·33	1·2	1·3
17	Aluminium	3·83	1·1	1·2
18	(Unreported)	3·77	1·0	1·2
19	Brake and wheel products	3·59	1·0	1·1
20	Concrete, cement and brick	3·53	1·0	1·1
21	Earthenware products	3·09	0·9	1·0
22	Tobacco products	2·82	0·8	0·9
23	(Unreported)	2·67	0·7	0·8
24	(Unreported)	2·47	0·7	0·8
25	Dairy products	2·37	0·7	0·7
26	Petroleum	2·32	0·6	0·7
27	Meat products	2·06	0·6	0·6
28	(Unreported)	1·90	0·5	0·6

based on non-manufacturing as well as manufacturing input–output patterns, non-manufacturing patterns tended to dominate the analysis for some manufacturing industries. This led some technologically dissimilar industries to cluster together based on similarities in non-manufacturing sales or purchases. Therefore, the template clusters reported are derived from the results of the first approach.

Although the factor analysis generated 28 distinct factors, five of the factors yielded clusters consisting of only a single primary industry and several secondary industries when we applied the loading criteria described above. Since the linkages among industries in those groupings were especially weak as indicated by the factor loadings, and since the objective of the analysis was to identify and analyse multi-industry clusters, those single-industry ‘clusters’ were ignored. The eigenvalues as well as the shares of total and common variance accounted for by each factor are reported in Table 1. Also provided is our interpretation of each factor based on an examination of the mix of industries achieving the highest loadings.

US MANUFACTURING CLUSTERS

Basic summary data on the 23 clusters identified in the US manufacturing economy are provided in Tables 2 and 3. Table 2 represents the breakdown of the clusters when both primary and secondary sectors are included in the cluster definition; the clusters in Table 3 are constituted solely of primary sectors. The clusters consist of: heavy manufacturing (e.g. metalworking, vehicle manufacturing, chemicals and rubber, nonferrous metals); light manufacturing (e.g. electronics and computers, knitted goods, fabricated textiles, wood products, leather goods, printing and publishing); five separate food-related clusters; and several clusters closely related to other major clusters (e.g. brake and wheel products and platemaking and typesetting). With the exception of the growth in importance of key high-tech clusters (electronics and computers and aerospace), the set of clusters is roughly similar to results found in earlier cluster studies conducted using input–output data from the 1960s and 1970s. Also reported in the tables is the number of three- and four-digit SIC sectors that make up each cluster (column 3 in each table), as well as the number of different two-digit SIC sectors represented (column 4).

In addition to relative size, the tables highlight two key features of the clusters. First, the number of component sectors in each cluster varies dramatically from 116 in the metalworking cluster to just 4 in the tobacco products cluster (when both primary and secondary industries are included in the cluster definitions). Clusters with the largest number of component sectors sometimes include multiple final market product chains, whereas smaller clusters (tobacco, dairy products, meat products, etc.) generally describe only a single major final market product chain. Second, most clusters are composed of sectors from a variety of two-digit level SIC industries. Sectors from 10 different two-digit SIC industries are represented in the metalworking cluster, for example; sectors from 16 different two-digit SIC categories make up the vehicle manufacturing cluster. Therefore, although the 23 clusters are similar in number to the 20 official two-digit SIC classifications, they are, in fact, very different in composition. Template clusters defined on the basis of interindustry linkages generate a unique picture of the manufacturing economy when used in subsequent economic analyses. The following subsections describe the basic make-up and characteristics of the largest of the 23 US clusters. We focus specifically on vehicle manufacturing as an illustrative example of the input–output cluster approach.

Vehicle manufacturing

In terms of 1992 value-added, vehicle manufacturing is the largest *cluster* in the US (see Table 2). It consists of 35 primary industries and 23 secondary industries. That it is comprised of three- and four-digit SIC sectors in 16 of 20 two-digit level categories illustrates the difference between input–output clusters and typical industrial classification systems. SIC 37, the

Table 2. 1992 summary statistics on US manufacturing clusters, defined in terms of primary and secondary sectors

No.	Cluster	Sectors	Two-digit SICs	Companies	Establishments	Employment (000s)	Value-added (US$ millions)
1	Metalworking	116	10	102,403	109,682	4,507·2	304,630·3
2	Vehicle manufacturing	58	16	72,459	80,747	4,052·6	323,894·4
3	Chemicals and rubber	48	14	33,897	40,721	2,390·9	293,299·7
4	Electronics and computers	38	8	42,188	46,375	3,310·2	287,121·0
5	Packaged food products	44	5	17,783	20,873	1,518·9	168,407·6
6	Printing and publishing	32	8	75,968	82,912	2,466·3	204,306·5
7	Wood products	23	6	40,286	42,172	883·7	44,962·1
8	Knitted goods	23	5	21,073	23,030	1,516·4	66,789·6
9	Fabricated textile products	22	9	27,783	29,942	1,553·5	68,244·6
10	Nonferrous metals	14	4	6,137	6,467	241·8	17,300·4
11	Canned and bottled goods	12	2	2,934	3,768	319·7	54,490·2
12	Leather goods	9	1	1,873	2,037	100·9	4,511·6
13	Aerospace	10	6	4,284	4,839	1,164·7	108,546·7
14	Feed products	10	2	3,156	4,399	318·8	70,724·1
15	Platemaking and typesetting	14	7	15,225	16,727	601·5	79,229·3
16	Aluminium	9	4	3,129	3,947	313·8	29,314·5
17	Brake and wheel products	9	4	25,980	26,534	467·3	26,673·0
18	Concrete, cement and brick	8	2	8,192	11,200	215·1	15,052·5
19	Earthenware products	8	1	1,861	2,033	54·2	3,572·8
20	Tobacco products	4	1	89	115	38·0	27,206·8
21	Dairy products	6	1	1,870	2,400	158·7	19,811·6
22	Petroleum	5	2	1,083	1,906	103·8	22,569·4
23	Meat products	5	2	3,403	3,937	465·0	24,047·6

Note: Clusters are not mutually exclusive.
Source: 1992 Census of Manufactures.

Table 3. 1992 summary statistics on US manufacturing clusters, defined in terms of primary sectors alone

No.	Cluster	Sectors	Two-digit SICs	Companies	Establishments	Employment (000s)	Value-added (US$ millions)	% all employment	% all value-added
1	Metalworking	93	9	88,345	94,078	3,507·4	234,337·3	20·7	16·4
2	Vehicle manufacturing	35	13	36,293	40,812	2,572·2	208,629·8	15·2	14·6
3	Chemicals and rubber	20	6	8,757	10,921	534·8	87,460·6	3·2	6·1
4	Electronics and computers	25	6	25,010	26,841	2,018·4	183,953·0	11·9	12·9
5	Packaged food products	21	1	7,589	8,910	602·6	66,539·6	3·6	4·7
6	Printing and publishing	21	5	61,777	67,506	1,890·1	147,086·3	11·1	10·3
7	Wood products	16	2	36,805	38,538	781·3	38,070·8	4·6	2·7
8	Knitted goods	13	3	17,724	19,221	1,115·4	42,093·6	6·6	3·0
9	Fabricated textile products	12	7	7,878	8,546	467·4	26,841·8	2·8	1·9
10	Nonferrous metals	8	3	3,869	3,983	111·2	7,799·2	0·7	0·5
11	Canned and bottled goods	6	2	1,849	2,466	254·8	35,446·3	1·5	2·5
12	Leather goods	6	1	864	972	66·7	2,820·5	0·4	0·2
13	Aerospace	5	2	1,785	2,067	712·5	65,789·2	4·2	4·6
14	Feed products	5	1	1,455	2,228	62·5	6,500·9	0·4	0·5
15	Platemaking and typesetting	4	3	4,516	4,722	84·8	5,423·4	0·5	0·4
16	Aluminium	4	3	1,429	1,802	144·5	16,325·4	0·9	1·1
17	Brake and wheel products	4	3	2,006	2,171	102·6	5,806·2	0·6	0·4
18	Concrete, cement and brick	3	1	4,257	6,543	115·8	8,522·6	0·7	0·6
19	Earthenware products	5	1	1,520	1,561	37·7	2,177·9	0·2	0·2
20	Tobacco products	4	1	89	115	38·0	27,206·8	0·2	1·9
21	Dairy products	3	1	974	1,354	101·2	10,586·4	0·6	0·7
22	Petroleum	3	2	680	1,405	89·9	20,837·1	0·5	1·5
23	Meat products	2	1	2,426	2,651	207·9	12,419·3	1·2	0·9
	Nonloading	44	15	19,426	21,521	1,347·7	162,532·5	7·9	11·4

Note: Clusters are mutually exclusive when defined in terms of primary sectors alone.
Source: 1992 Census of Manufactures.

transportation equipment *classification*, consists of industries producing similar final products; the vehicle manufacturing *cluster*, which we derive, includes many first- and second-tier transportation equipment supplier industries that manufacture significantly different products, from rubber hoses and belts (SIC 3052), storage batteries (SIC 3691) and paints (SIC 285), to carburettors (SIC 3592), carpets (SIC 227) and steel springs (SIC 349). Over 72,000 companies in the vehicle manufacturing *cluster* employed over 4 million US workers in 1992. When defined in terms of primary sectors alone, the cluster's shares of manufacturing employment and value-added are near 15% (see Table 3).

Table 4 provides the detailed sectoral makeup of the cluster.[6] The columns labelled 'Cluster ID' provide a rough indication of some of the linkages between the vehicle manufacturing cluster and the remaining 22 clusters, though a complete analysis is possible only with primary input–output data and detailed intersectoral comparisons. The cluster in which a given sector is most tightly linked is given in column L1; L2 and L3 report additional clusters, if any, in which the sector is also moderately linked based on our criteria. (Clusters are numbered consistently as given in the first column of Table 2.)

As might be expected from the high metal content of most transportation equipment industries, 20 of 58 total primary and secondary industries in the vehicle manufacturing cluster are also members of the metalworking cluster. Other sectors are members of an additional 10 clusters, with the chemicals and rubber (including plastics), printing and publishing, fabricated textile products, and electronics and computers clusters the most significant in terms of number of cross-cluster linkages. Not surprisingly, the vehicle manufacturing cluster is also closely linked to the brake and wheel products cluster, which itself shares most of its component industries with the former as well as the metalworking cluster.

Although Table 4 gives a sense of the varied relationships between vehicle manufacturing and other clusters, the pattern of linkages within the cluster itself is more difficult to summarize. One alternative is to examine the base correlation matrices used in the factor analysis. Although this would provide the most comprehensive picture, the detail involved in summarizing relationships among 58 sectors by this means is prohibitive (there are 6,728 distinct linkages in total). Another alternative is to use the indicators of dependence defined above (x_{ij}, x_{ji}, y_{ij}, y_{ji}) to identify the major relationships tying the cluster together. Figs. 1 and 2 were developed with this approach.

Fig. 1 is a descriptive map of the intracluster purchasing linkages within vehicle manufacturing. The direction of the arrow between sectors i and j indicates that industry j purchases a 'significant' share of its inputs from industry i (x_{ij}). (Note that the length of the arrow is not related to magnitude.) In order to produce the map, we defined a significant share as one that meets or exceeds the 96th percentile (0·021 in this case). Though this cut-off is arguably somewhat arbitrary, it does reflect the skewed distribution of actual linkages; the mean and median linkages were 0·35 and 0·005%, respectively.[7] Of course, the lower the threshold, the more linkages illustrated and the more difficult to interpret the summary graphic becomes. The graphical technique with lower thresholds is more manageable when examining ties between individual sectors of interest and other industries.

Fig. 1 illustrates the centrality of several industries as basic suppliers to a wide range of sectors within the cluster. The most important of these is SIC 308, miscellaneous plastics products. The position of that industry as a core supplier within the cluster is fully consistent with the increasing plastic content of transportation equipment as manufacturers face pressures to reduce fuel consumption and emissions by reducing weight, as well as to improve safety (Fine *et al.*, 1996). Other key sectors tying the cluster together from the supplier side include hardware (SIC 3429), fabricated rubber products (SIC 306), glass and glass products (SICs 321, 3229, 323), screw machine products and bolts (SICs 3451–2), and motor vehicle parts and accessories (SIC 3714). Key multi-tier relationships are also evident. An example is the purchase by the lawn and garden equipment sector (SIC 3524) of a significant volume of inputs from screw machine products and bolts (SIC 3451–2) which, in turn, purchases goods from special dies and tools (SIC 3544–5) which itself buys a significant share of supplies from the abrasive products sector (SIC 3291), and so on.

In contrast to Fig. 1, Fig. 2 identifies a number of sectors that are central to the cluster in terms of driving demand for intermediate goods. In this case, the direction of the arrow between sectors i and j indicates that industry i sells a 'significant' share of its output to industry j (y_{ij}). Here the threshold criterion for y_{ij} is also the 96th percentile; average and median values for the cluster along that linkage dimension are 0·67 and 0·010%, respectively. Clearly, vehicle manufacturing is an apt description of the cluster; the strongest interindustry dynamic pulling sectors into the cluster is the supply requirements of SIC 3711, motor vehicle manufacturing, a $133·3 billion dollar industry in the US in 1992. Other key buying sectors in the cluster are motor vehicle parts and accessories (SIC 3714), travel trailers and campers (SIC 3792), and miscellaneous plastics products (SIC 308).

Metalworking

In terms of the number of component sectors, companies, establishments and employees, the metalworking cluster is the largest cluster in the US manufacturing economy. It is composed of 116 sectors (93 primary)

Table 4. Sectoral composition: US vehicle manufacturing cluster

SIC	Industry	Cluster ID L1	Cluster ID L2	Cluster ID L3	Loading	SIC	Industry	Cluster ID L1	Cluster ID L2	Cluster ID L3	Loading
3716	Motor homes	2			0·96	2891	Adhesives and sealants	2	3		0·68
3694	Electrical equipment, internal combustion engines	2			0·93	2512	Upholstered household furniture	2	9		0·68
301	Tyres and inner tubes	2			0·93	385	Ophthalmic goods	2			0·66
3651	Household audio and video equipment	2		4	0·91	308	Miscellaneous plastics products, n.e.c.	2		3, 4	0·65
306	Fabricated rubber products, n.e.c.	2		3	0·89	3524	Lawn and garden equipment	2		1	0·62
2952	Asphalt felts and coatings	2			0·89	3586	Measuring and dispensing pumps	2		1	0·60
302	Rubber and plastics footwear	2		9	0·88	2522[3]	Office furniture, excluding wood	1	2		0·66
3645–8	Lighting fixtures and equipment	2		1	0·88	3823[2,3]	Mechanical measuring devices	4	2		0·62
3711	Motor vehicles and passenger car bodies	2			0·87	3291[3]	Abrasive products	3		2	0·59
3519	Internal combustion engines, n.e.c.	2			0·86	3465[3]	Automotive stampings	1		2	0·59
321[1]	Glass and glass products, excluding containers	2			0·86	3493[3]	Steel springs, except wire	1		2	0·58
3635	Household vacuum cleaners	2			0·86	3843[3]	Dental equipment and supplies	10		2	0·57
2399	Fabricated textile products, n.e.c.	2		9	0·86	2541[3]	Wood partitions and fixtures	2		7	0·56
3641	Electric lamp bulbs and tubes	2			0·86	3053[3]	Gaskets, packing and sealing devices	17		2	0·51
2521	Wood office furniture	2		7	0·86	2676[3]	Sanitary paper products	6		2	0·50
3952	Lead pencils and art goods	2			0·83	2515[3]	Mattresses and bedsprings	9		2	0·50
3714	Motor vehicle parts and accessories	2		1	0·83	3544–5[3]	Special dies, tools and accessories	1		2	0·49
3585	Refrigeration and heating equipment	2		1	0·83	3429[3]	Hardware, n.e.c.	1		2	0·48
3052	Rubber, plastics hose and belting	2			0·82	3548[3]	Electric, gas welding, soldering equipment	1		2	0·48
3691	Storage batteries	2		3	0·82	274[3]	Miscellaneous publishing	6		2, 15	0·48
2396	Automotive and apparel trimmings	2		9	0·81	271[3]	Newspapers	6		2	0·48
285	Paints and allied products	2		3	0·80	224[3]	Narrow fabric mills	8		2	0·47
3715	Truck trailers	2		1	0·79	272[3]	Periodicals	6		15, 2	0·46
253	Public building and related furniture	2		1	0·79	2514[3]	Metal household furniture	1		2	0·45
3713	Truck and bus bodies	2		1	0·78	3451–2[3]	Screw machine products, bolts, etc.	1		2	0·44
3592	Carburettors, pistons, rings and valves	2		1	0·78	3792[3]	Travel trailers and campers	17		2	0·42
227	Carpets and rugs	2		8	0·74	3541[3]	Machine tools, metal cutting types	1		2	0·38
319	Leather goods, n.e.c.	2		12	0·73	3799[3]	Transportation equipment, n.e.c.	17		1, 2	0·36
3993	Signs and advertising specialties	2			0·70	3795[3]	Tanks and tank components	1		16, 2	0·36

Notes: Cluster ID: L1 reports cluster for which row sector obtained highest loading; L2 reports the cluster for which sector achieved next highest loading, for values over 0·50; L3 indicates clusters for which sector achieved loadings between 0·35 and 0·50.

1. Includes SICs 321, 3229 and 323.
2. Includes SICs 3823–4 and 3829.
3. Indicates secondary industries.

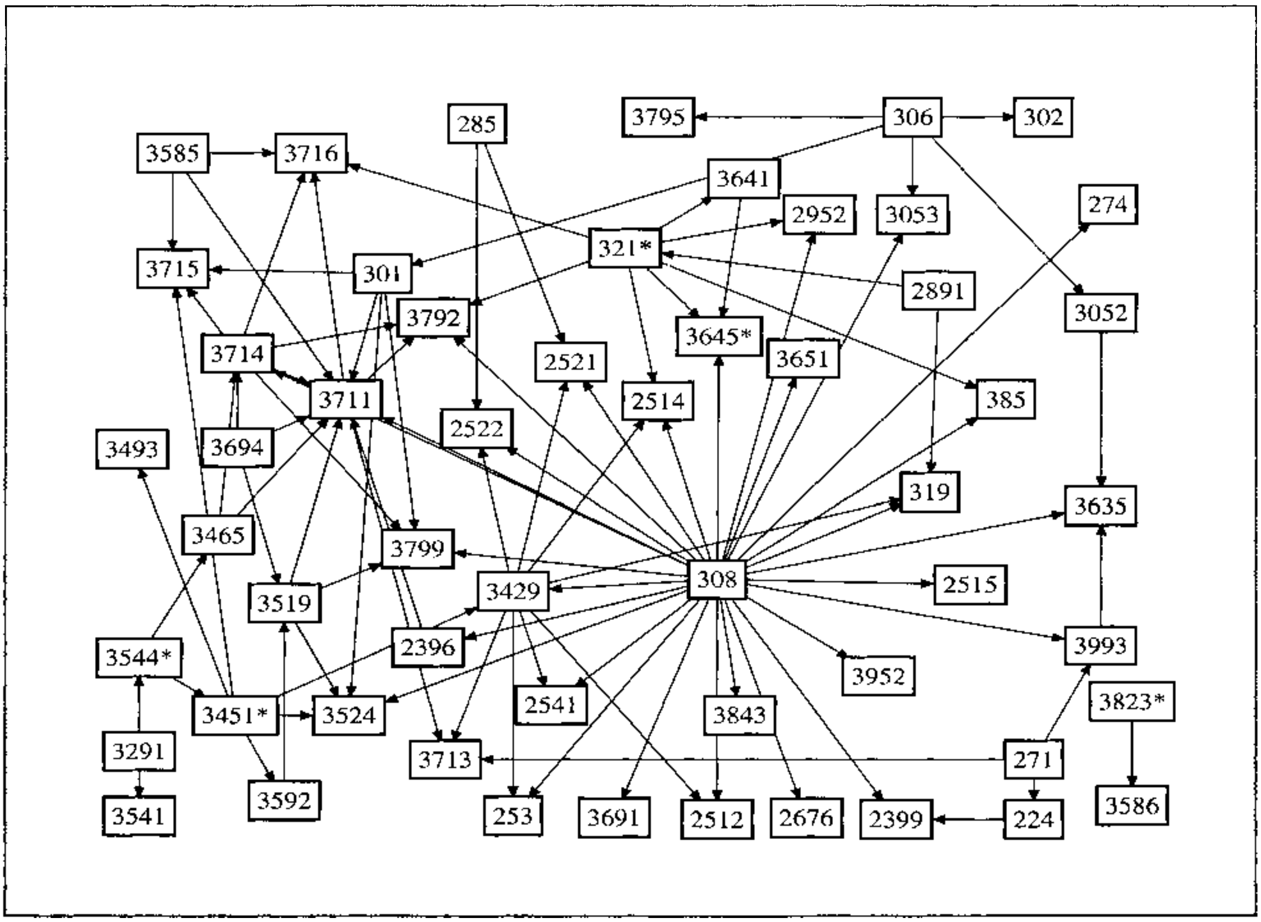

Fig. 1. Key intracluster purchasing linkages: vehicle manufacturing cluster
Note: See Table 4 for industry code titles; *indicates includes additional sectors.

that span 11 different two-digit SIC categories and employs over 4·5 million in nearly 110,000 establishments. Defined in terms of primary sectors alone, it employed one-fifth of the manufacturing workforce in 1992 while its share of value-added exceeded 16%. The cluster consists of mostly primary metal, fabricated metal and industrial machinery industries, as well as many sectors in the electronic and electrical equipment industries (SIC 36). As reflective of its key role in the manufacturing sector as a whole, the metalworking cluster shares component industries with 14 other clusters. Its primary sectors also accounted for nearly one-fifth of total US manufacturing wage payments in 1994, the highest share of any cluster.

Chemicals and rubber

The chemicals and rubber cluster, made up of 48 sectors and employing 2·4 million workers, includes industrial chemicals, tile, pesticides, synthetic rubber, soaps, brick, plastics, fertilizers and ink producers. It is one of only two clusters in which the number of component secondary sectors (28) significantly exceeds the number of primary sectors (20), suggesting that the cluster plays a limited though critical part in the manufacture of an extremely wide variety of products; in the case of chemicals and rubber, the *intra*-cluster linkages are not nearly as significant as the *inter*-cluster linkages. Put differently, chemicals are ubiquitous in the US manufacturing economy. Various chemical and rubber products components sectors are members of a total of 13 other clusters. An implication of this is that when the cluster is defined in terms of primary sectors alone, it becomes one of the smaller clusters in the manufacturing sector (3·1% of employment, 6·1% of value-added; see Table 3).

Electronics and computers

Electronics and computers, printing and publishing, packaged food products and aerospace round out the top seven US clusters in value-added and employment terms. The electronics and computers cluster includes most major high technology goods producers in SIC sectors 35, 36 and 38, including computers and peripherals, telephones and other communication equipment, x-ray, surgical and medical instruments, and laboratory instruments. Both final market and inter-

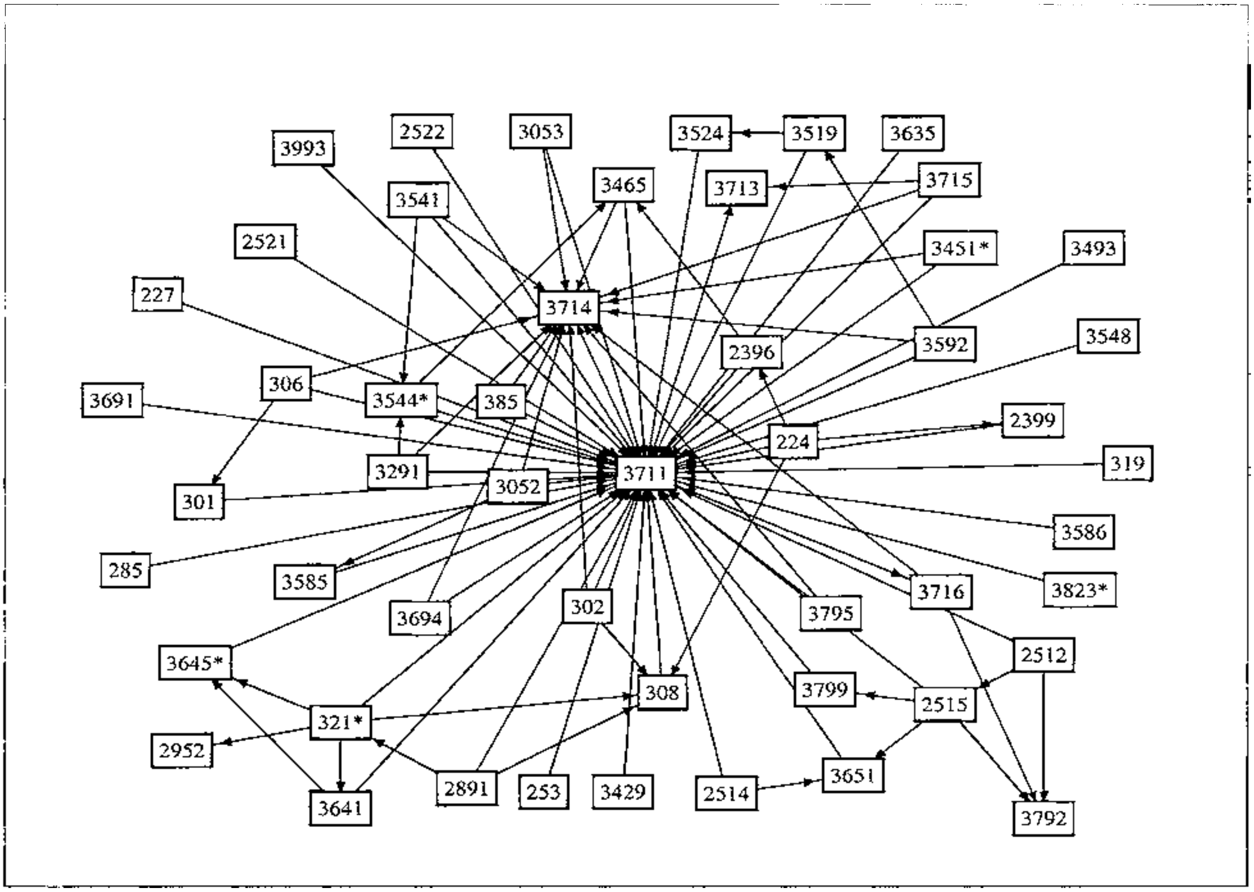

Fig. 2. Key intracluster sales linkages: vehicle manufacturing cluster
Note: See Table 4 for industry code titles; *indicates includes additional sectors.

mediate goods sectors are represented (e.g. electronic computers (SIC 3571), semiconductors (SIC 3674), electronic components (SICs 3672, 3675–9), and electrical machinery and equipment (SIC 3699)). Intercluster linkages, through component industries that also make up other clusters, extend to the high technology aerospace cluster, as well as the metalworking, printing and publishing, and vehicle manufacturing clusters.

Printing and publishing

A total of 32 three- and four-digit SIC sectors (21 primary) make up the printing and publishing cluster. They range from most of the sectors classified as printing and publishing under the SIC system (SIC 27), to paper and pulp mills (SIC 261, 262), paper industries machinery (SIC 3554), and photographic equipment and supplies (SIC 386). Key intercluster linkages extend to the wood products, chemicals and rubber, vehicle manufacturing, and platemaking and typesetting clusters. The platemaking and typesetting cluster, like the brake and wheel products cluster in the case of vehicle manufacturing, is nearly a sub-cluster of the printing and publishing cluster, though the factor analysis indicated that it possessed sufficiently strong clustering tendencies to be analysed and identified separately.

Packaged food products

The packaged food products cluster, which employs some 1·5 million workers in nearly 21,000 establishments, is made up of 44 sectors (21 primary) in only five different two-digit SIC categories (food and kindred products; stone, clay and glass products; chemicals; miscellaneous manufacturing; and paper and allied products). All of the primary sectors in the cluster are part of SIC 20, food and kindred products, although a significant volume of total cluster output originates in sectors related to packaging (e.g. glass containers and paper mills, SICs 3221 and 262–3).

Aerospace

Value-added in the US aerospace cluster exceeded $108·5 billion in 1992. The cluster is made up of 10 sectors including, aircraft and missile engines (SIC 3724, 3764), aircraft (3721), and guided missiles and space vehicles (3761), as well as non-ferrous forgings (3463), turbines (3511), and search and navigation equipment (381). A detailed review of the factor analysis results shows that the cluster has close ties with the electronics and computers, non-ferrous metals and metalworking clusters.

Smaller clusters

The 16 remaining clusters each produced less than $100 billion in value-added in 1992. Five of the 16 are food products clusters of one type or another (packaged, canned and bottled, feed products, dairy and meats). Like the chemicals and rubber cluster, the number of secondary industries in the packaged foods cluster well exceeds the number of primary sectors. This is, however, largely because of the considerable sub-clustering that occurred among food products industries in the factor analysis, rather than the ubiquitous nature of food products in the manufacturing sector as a whole. Together, the sectors making up all five food products clusters span only six separate SIC two-digit categories; the vast majority fall into SIC 20.

Independent sectors

For 44 of the 362 manufacturing sectors, sectoral interdependencies are too weak to qualify them as a primary industry in any cluster. Therefore, another category of industries remains that requires attention here. The last row of Table 3 reports the total number of US companies, establishments, employees, and value-added represented by such industries in 1992. At over 11% of total manufacturing value-added, these 'independent' industries constitute a significant share of US manufacturing production. Table 5 lists the industries that failed to load as a primary industry on any cluster along with their maximum factor loading and the cluster on which this loading was achieved.[8] The most significant of the independent industries are pharmaceuticals (SIC 283), paper and paperboard mills (262–3), photographic equipment and supplies (386), and toilet preparations (2844).

CLUSTERS AS STRATEGIC TEMPLATES: THE CASE OF NORTH CAROLINA

The 23 clusters provide a unique way of characterizing the industry mix in the US manufacturing sector. Since the clusters represent distinct technological groupings of sectors or product chains, they may be used as a US framework for comparing broad patterns and proportions of sectoral representation present at various state or regional levels. That is why we term the clusters *templates*. Although the conduits of interdependence between firms extend well beyond supplier linkages, input–output flows provide the single best uniform means of identifying which firms and industries are most likely to interact through a myriad of interrelated formal and informal channels. This constitutes a marked improvement over the crude methods employed in many cluster studies in the US (e.g. anecdotal judgements or sectoral location quotients) that are typically justified on the grounds that systematic data for formal and informal linkages are unavailable. Template clusters have the added advantage of providing a means to identify potential specializations in the regional economy by revealing both relative strengths and absolute gaps in particular product chains. They also provide some insight into the technological position of a region's industries within a broader national or even global product chain. We illustrate these principles here with an application to North Carolina, a key manufacturing state in the Southeast. Again, we focus particular attention on the state's emerging vehicle manufacturing cluster.

Industry mix

Traditional analyses of the North Carolina manufacturing economy emphasize the overwhelming dominance of textiles and tobacco, followed by smaller but significant concentrations of activity in furniture, apparel and heavy industrial machinery. More recently, North Carolina's reputation as a location for high technology manufacturing – primarily in computers and pharmaceuticals – has grown due largely to the success of its Research Triangle Park. Yet textiles remains the single largest industrial employer at just under one-quarter of all manufacturing workers. Rounding out the top five manufacturing industries in employment terms are furniture, apparel, industrial machinery and electronic equipment. Although the pharmaceuticals and industrial chemicals sectors are growing rapidly, they still constitute less than 5% of total manufacturing employment. Fig. 3 illustrates the composition – using standard industrial categories – of the state's manufacturing sector in terms of value-added and employment.

Table 6 demonstrates how a very different picture of a given regional economy may be revealed when detailed sectors are re-classified using the cluster templates. Re-ordering industries into clusters and re-calculating the aggregate figures puts metalworking, chemicals and rubber, and vehicle manufacturing among the largest clusters in North Carolina, next to knitted goods and fabricated textile products. Transportation equipment, identified as SIC 37, alone appears quite inconsequential since it accounts for only 2·5–3% of manufacturing value-added and employment (see Fig. 3). Only by considering the many industries that typically supply transportation equipment to manufacturers does the potential significance of the vehicle industry for the state's economy become apparent. When primary cluster industries alone are considered, sectors linked within the vehicle manufacturing input–output chain account for 15% of total North

Table 5. Semi-independent manufacturing sectors (maximum loadings do not exceed 0·60)

SIC	Description	Maximum loading	Cluster ID L1	Cluster ID L3	Value-added (US$ millions)
283	Pharmaceuticals	0·47	3	14	48,545·7
262–3	Paper and paperboard mills	0·44	5	6, 3, 15	23,043·0
386	Photographic equipment and supplies	0·58	15	4, 6	14,885·4
2844	Toilet preparations	0·55	5	3	13,167·2
2015	Poultry slaughtering and processing	0·51	23	5	6,656·5
2087	Flavouring extracts, flavouring syrups, n.e.c.	0·49	11	5, 3, 15	5,269·7
2035	Pickles, sauces and salad dressings	0·57	5	21	3,749·2
2047	Dog and cat food	0·56	14	11, 5	3,729·9
2046	Wet corn milling	0·50	5	11	3,257·5
3442	Metal doors, sash, frames, molding, trim	0·58	1		3,221·2
3221	Glass containers	0·59	5		3,038·4
3944	Games, toys and children's vehicles	0·42	5	3, 6	2,389·8
2092	Prepared, frozen fish and seafoods	0·43	5		2,325·1
2084	Wines, brandy and brandy spirits	0·55	15	11	2,088·7
3291	Abrasive products	0·59	3		2,030·6
3732	Boat building and repairing	0·43	1		1,991·4
2085	Distilled and blended liquors	0·35	11	11	1,945·6
2541	Wood partitions and fixtures	0·56	2	7	1,747·4
3546	Power-driven handtools	0·48	1		1,506·8
3432	Plumbing fixture fittings and trim	0·27	10		1,358·5
3671	Electron tubes	0·49	4		1,280·4
2297	Nonwoven fabrics	0·48	3	8	1,217·5
3652	Prerecorded records and tapes	0·54	6	4	1,181·6
3295	Minerals, ground or treated	0·56	1	18, 19	1,081·2
2068	Salted, roasted nuts and seeds	0·48	5		1,028·0
3996	Hard surface floor coverings, n.e.c.	0·49	3		902·7
311	Leather tanning and finishing	0·57	23		895·9
3961	Costume jewellery	0·53	10	15	874·5
3399	Primary metal products, n.e.c.	0·48	10	4, 3	871·4
2892	Explosives	0·49	3		851·7
3792	Travel trailers and campers	0·48	17	2	774·9
3991	Brooms and brushes	0·57	9		745·4
3951	Pens, mechanical pencils and parts	0·57	5	15	657·7
328	Cut stone and stone products	0·34	18		607·4
393	Musical instruments	0·59	4	7	588·4
3463	Non-ferrous forgings	0·59	13	16, 1	588·3
387	Watches, clocks, watchcases and parts	0·17	4		423·5
3543	Industrial patterns	0·45	1		416·3
2296	Tyre cord and fabrics	0·51	8		402·6
2298	Cordage and twine	0·52	8		350·1
3915	Jewellers' materials and lapidary work	0·45	10	3	335·3
2097	Manufactured ice	0·35	5		255·1
2519	Household furniture, n.e.c.	0·47	3		193·0
2429	Special product sawmills, n.e.c.	0·51	7		62·0

Notes: Cluster ID: L1 gives cluster for which the row sector obtained its highest loading; L3 reports additional clusters for which the row sector achieved loadings between 0·35 and 0·50.

Source: Value-added data are from *1992 Census of Manufactures*.

Carolina manufacturing employment in 1994. Together, manufacturers associated with the vehicle manufacturing and knitted goods clusters account for 37% of statewide manufacturing employment in 1994.

Though it is not known to what degree local firms in the vehicle manufacturing cluster produce goods related directly to automaking (or the production of trucks and buses), there is nevertheless potential in the state for the further development of a real vehicle manufacturing chain. Indeed, North Carolina appears poised to take advantage of the continuing southward shift in the geographical centre of vehicle production in the US. Although there are no automotive assembly plants in the state, the recent location of production facilities of several major automakers to the south and west, including BMW in South Carolina, General Motors (Saturn) in Tennessee and Mercedes in Alabama constitute potential markets for suppliers based in North Carolina. Consistent with these trends, the vehicle manufacturing cluster within the state is shifting westward. Fig. 4 plots the location of establishments in the cluster.[9] Much activity is concentrated in the Piedmont and Carolinas development planning regions. Fig. 5 illustrates the relative shares in each region as

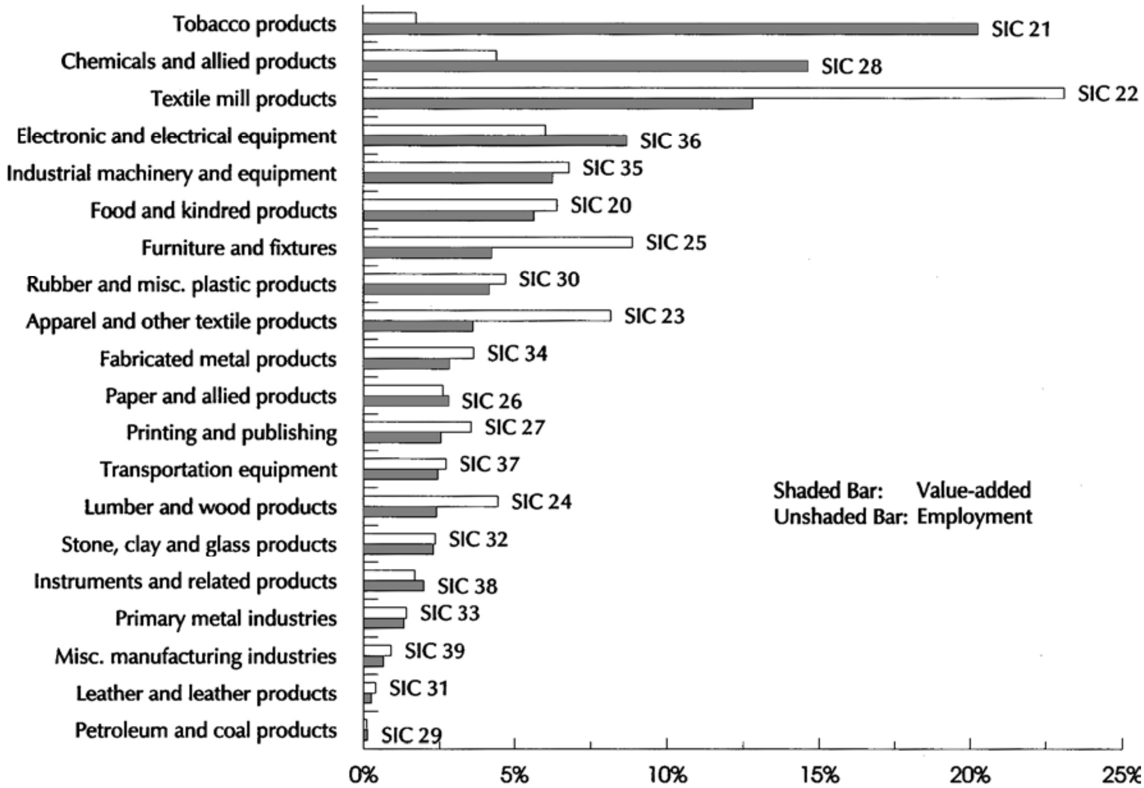

Fig. 3. Industry shares of total North Carolina value-added and employment in manufacturing, 1992
Source: Census of Manufactures.

Table 6. Summary statistics on North Carolina manufacturing clusters, 1994

		Primary and secondary		Primary industries only		
No.	Cluster	Establishments	Employment	Establishments	Employment	% all employment
1	Metalworking	2,613	132,755	2,183	91,451	10·6
2	Vehicle manufacturing	2,283	168,744	1,356	129,607	15·0
3	Chemicals and rubber	1,017	106,831	332	32,658	3·8
4	Electronics and computers	905	97,287	509	66,972	7·7
5	Packaged foods	433	61,372	120	12,381	1·4
6	Printing and publishing	2,229	72,591	1,668	47,730	5·5
7	Wood products	2,144	85,520	2,025	77,607	9·0
8	Knitted goods	1,998	279,728	1,485	187,341	21·6
9	Fabricated textile products	1,751	211,858	606	82,288	9·5
10	Nonferrous metals	94	11,825	42	1,327	0·2
11	Canned and bottled goods	85	8,463	70	8,043	0·9
12	Leather goods	50	2,680	22	1,555	0·2
13	Aerospace	71	8,929	27	2,551	0·3
14	Feed products	159	22,378	84	2,232	0·3
15	Platemaking and typesetting	342	15,512	94	1,576	0·2
16	Aluminium	87	7,788	46	2,901	0·3
17	Brake and wheel products	605	9,353	46	1,932	0·2
18	Concrete, cement and brick	322	7,489	173	3,735	0·4
19	Earthenware products	68	1,955	53	974	0·1
20	Tobacco products	26	19,015	26	19,015	2·2
21	Dairy products	33	2,920	14	1,238	0·1
22	Petroleum	19	409	10	53	0·0
23	Meat products	149	29,309	101	7,788	0·9
	Nonloading	N/A	N/A	533	82,498	9·5

Source: North Carolina ES-202 files, NC Employment Security Commission.

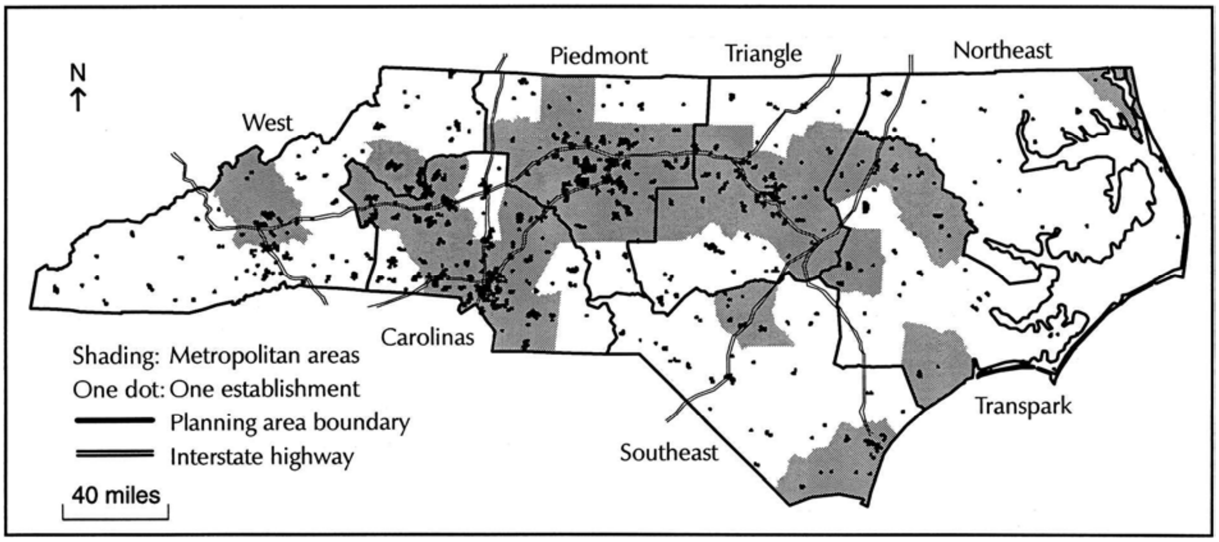

Fig. 4. Distribution of North Carolina vehicle manufacturing cluster establishments, 1994
Source: NC ES-202 files.

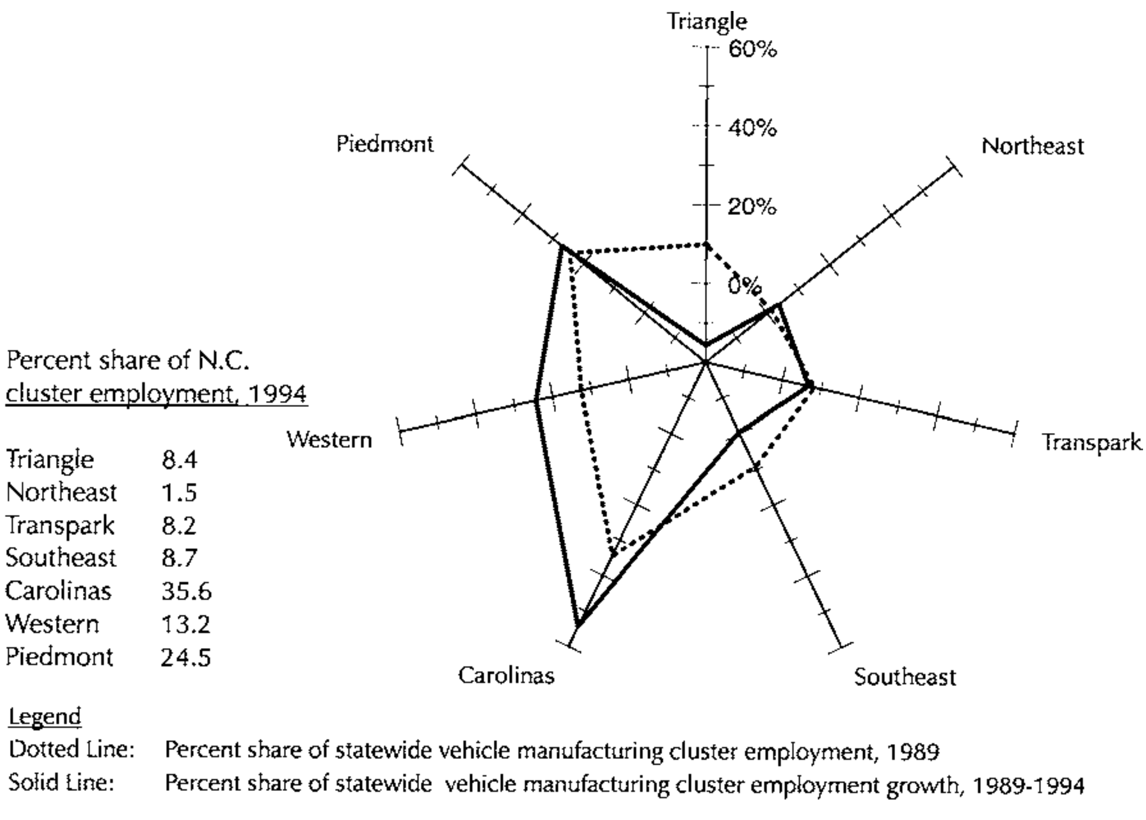

Fig. 5. Regional distribution of North Carolina vehicle manufacturing cluster employment
Source: NC ES-202 files; North Carolina Employment Security Commission.

well as the regional distribution of employment growth in the cluster between 1989 and 1994. Employment in the state's vehicle manufacturing cluster grew by 4·5% over the period. Fig. 5 reveals most of this growth occurred in the West, Carolinas and Piedmont regions. Points in these regions are also excellent locations for suppliers serving vehicle producers in Ohio and elsewhere to the north, given the proximity of a major north–south transportation corridor (Interstate 77).

Intracluster specializations

While the geographical distribution of manufacturing activity of firms belonging to aggregate clusters is revealing, the greater utility of the approach lies in its rich, underlying sectoral detail. In order to truly understand the relative presence and significance of a given cluster in North Carolina, it is necessary to examine the cluster's detailed industrial mix to identify local industry specializations and gaps in the product chain. Explaining the origin of these gaps and specializations can then lead to a better understanding of the prospects for growth (or potential for decline) in the cluster. Regional endowments, market conditions and technological requirements may preclude some regions from seeking or developing particular pieces of a given chain, a point noted in many early studies of industrial complexes by regional scientists. Understanding such constraints and requirements is a precursor to the design of development strategies and policy portfolios targeted to a given region's specific comparative advantages. In this sense, cluster analysis of the type described here is merely a first but significant step in a more comprehensive analysis of a region's economic strengths and weaknesses.

To illustrate these ideas, Fig. 6 charts the distribution of value-added in the vehicle manufacturing cluster both nationally and in North Carolina.[10] The chart highlights the unique specializations in North Carolina *vis-à-vis* the US, as well as notable gaps in activity. Also indicated in the chart is the classification of sectors as high, medium or low value-added according to national value-added to worker ratios.[11] The classification helps detect the higher productivity industries in the chain, as well as the sectors that tend to pay higher wages. In North Carolina, the vehicle manufacturing cluster is dominated by miscellaneous plastics products (SIC 308), motor vehicle parts and accessories (SIC 3714), upholstered household furniture (SIC 2512), tyres and inner tubes (SIC 301), and glass products other than containers (SICs 321, 3229, 323). As noted above, there is comparatively little activity in the motor vehicle assembly industry (SIC 3711). Other industries with little presence in the state include automotive stampings (SIC 3465) and screw machine products and bolts (SIC 3451–2).

Much of North Carolina's production and employment relative to the nation in the vehicle manufacturing cluster falls into medium to low value-added industries. That is true with most of its other major industrial clusters as well. The ratio of high value-added employment to total employment in North Carolina falls short of the same ratio for the US as a whole in eight of the state's nine largest clusters (see Fig. 7). North Carolina's strengths *vis-à-vis* other US regions in terms of recruiting and developing new industry have traditionally been a ready supply of low-cost, non-unionized labour, reasonably priced land, and a comparatively less-

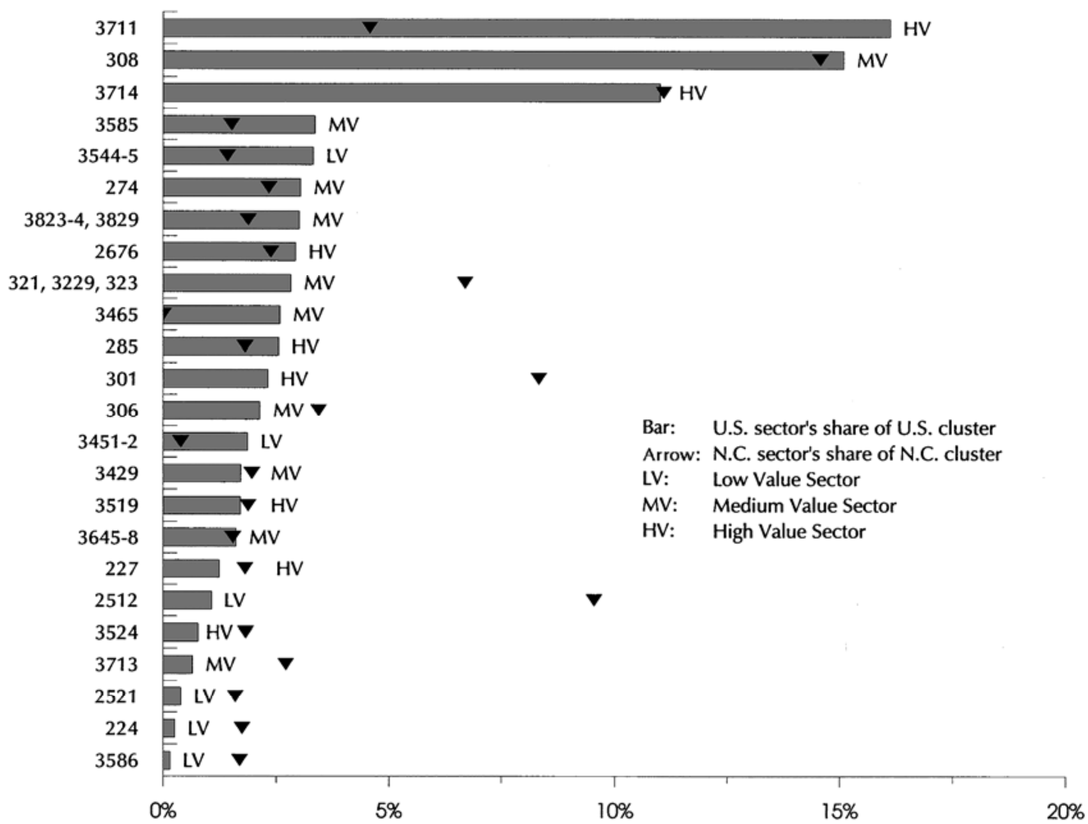

Fig. 6. Member industry shares of total value-added in vehicle manufacturing cluster: US and North Carolina, 1992
Note: Only sectors accounting for at least 1·5% of US or North Carolina cluster value-added are shown.
Source: Census of Manufactures.

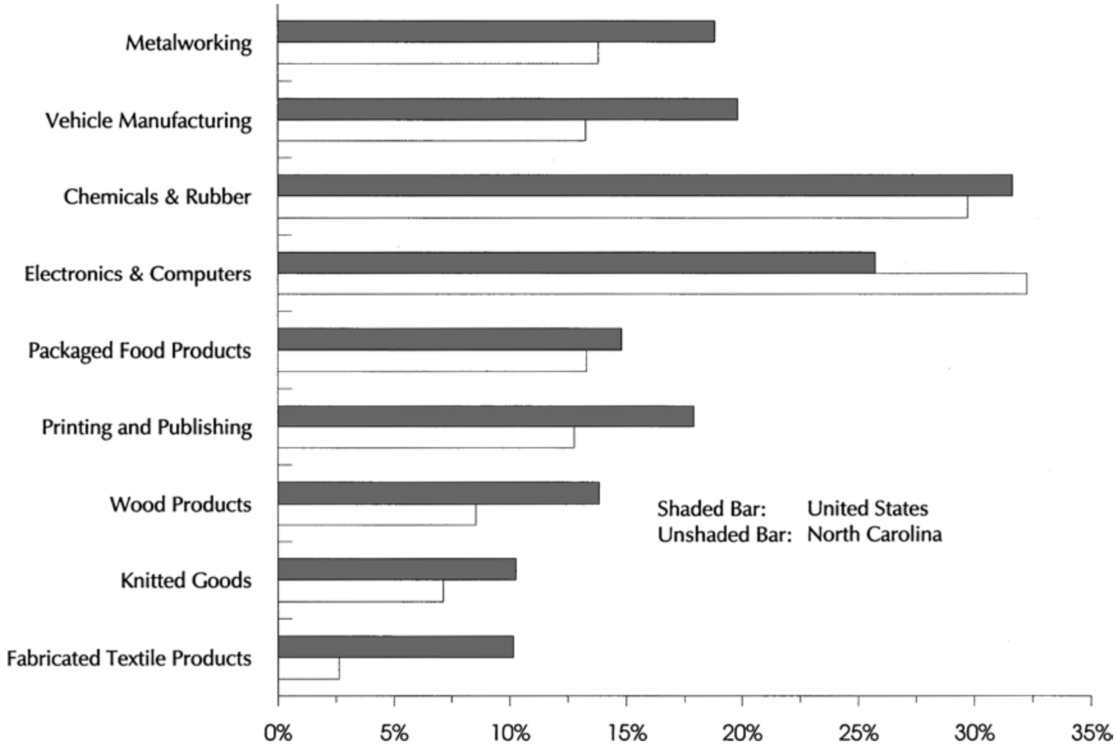

Fig. 7. Percentage share of US and North Carolina cluster employment in high value sectors: 1994, nine largest clusters
Source: US Bureau of Labor Statistics; North Carolina Employment Security Commission; and *Census of Manufactures.*

rigid regulatory structure. Historically, such advantages served as an effective lure for branch plant relocations from the Northeast and Midwest in industries such as textiles and apparel. Therefore, it is not surprising that lower value-added, lower technology industries that depend on low cost locations still dominate the clusters.

SUMMARY

The analysis of industry clusters has become a popular focus in local and regional development practice. Such analyses are accumulating in many journals and for many regions, but their findings are typically so uniquely derived and depicted that little can be usefully generalized about the structure of key industrial clusters. In the US, cluster analysis at the regional level often involves little more than the identification of core regional industries through the use of simple measures of specialization (e.g. location quotients). In this paper, we develop a *national* set of benchmark or template technological clusters that effectively represent strategically important alignments of underlying detailed sectors. We then apply the templates to data for the manufacturing sector in North Carolina, one of the top 10 manufacturing states, illustrating the process by examining vehicle manufacturing in detail.

Cluster analysis of the type described here is perhaps the first best step in the development of regional development strategies that attempt to foster and leverage interindustry synergies. The clusters represent a good first approximation in terms of grouping firms that are most likely to interact with each other either formally or informally. But they can only form the basis for more in depth analyses that look at actual trading patterns, regional institutions and mechanisms that foster interindustry networking, the exchange of information or diffusion of technology, and possible market and technological barriers to the development of specific pieces of key product chains. The national templates do not constitute a definitive 'vision' of the industry mix that could or even should develop in a region, but rather a baseline picture of the regional industry mix across broad supplier chains. Examining the local distribution of activity in such chains is a valuable first analytical step to more in-depth cluster studies.

NOTES

1. This approach yields the same thin evidence delivered by location quotients to economic base analysts who rely upon measured degrees of regional specialization to proxy existing regional export potential.
2. 'Industrial complex' was a convenient shorthand term used then in the context of growth pole theory and of the growth centre, one of its policy equivalents. An industrial complex often implied an I/O-based supplier chain that was both functionally and spatially dependent on some large, capital-intensive industrial investment, which in current parlance would surely be termed 'Fordist' in nature.

3. We do not distinguish further among types of relationships and forms of co-operation within regional clusters of the US (or elsewhere), although other scholars have made many useful suggestions along those lines (PARK and MARKUSEN, 1994; MARKUSEN, 1996; PARK, 1997).
4. A full, detailed discussion of the different clustering methodologies tested is provided in BERGMAN *et al.* 1996. All variants involved factor analysis; they differed primarily in the specification of the measure of linkage.
5. The transactions matrix was derived from the commodity by industry US use and make matrices using the industry-based technology assumption, which assumes that the total output of a given commodity is provided by industries in fixed proportions (MILLER and BLAIR, 1985). Note that the Bureau of Economic Analysis I/O accounts use two classifications systems, one for industries and another for commodities. Although the I/O industry classification system is based on the SIC system, the concordance is imperfect due to adjustments made to the SIC system by the BEA. The adjustments involved are relatively minor in volume of output terms and the vast majority of manufacturing industries are not affected at all. Concordance issues are described in more detail in BERGMAN *et al.*, 1996.
6. A complete table with the sectoral makeup of all 23 clusters is available in BERGMAN *et al.*, 1996.
7. Figs. 2 and 3 were produced with KrackPlot 3·0, graph layout software for social network analysis (KRACKHARDT, LUNDBERG, and O'ROURKE, 1993; KRACKHARDT, BLYTHE, and MCGRATH, 1994).
8. Note that all of the independent sectors are classified as secondary industries in one or more clusters.
9. Establishments are geocoded to zip code centroids and slightly randomly dispersed to improve interpretability.
10. Because of data suppression for confidentiality purposes in the *Census of Manufactures*, value-added for some industries in the North Carolina vehicle manufacturing cluster is estimated using national ratios of value-added per employee and state employment data.
11. High value-added sectors are those in the upper 75th percentile of industries in the cluster based on national value-added to worker ratios. Medium value-added sectors are those in the 25th to 75th percentile; low value-added sectors are those in the bottom 25th percentile.

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