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Table of Contents

METHOD FOR IDENTIFYING LOCAL AND DOMESTIC INDUSTRIAL CLUSTERS USING INTERREGIONAL COMMODITY TRADE DATA

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ABSTRACT

Defining geographic as well as industrial boundaries in industrial cluster analysis is a challenging task. The most widely used methods for identifying industrial clusters utilize data from input-output tables. Given that inter-industry linkages are not confined to political boundaries, the questions discussed in the relevant literature on input-output based approaches focus on whether to use a regional or a national input-output framework. But neither framework can capture non-local transactions, which may be of major importance for smaller study regions.

In the presented research, we expand the regional Chicago input-output framework to an interregional framework which accounts for both regional and non-local (i.e., commodity imports and exports by industry) inter-industry transactions. Applying factor analytical techniques to the data in this inter-regional framework, we are able to derive two sets of industrial clusters which we refer to as local and domestic clusters. In addition, we also identify the key sectors for each cluster based on indicators for industry backward and forward linkages. A comparison of these local and domestic clusters shows that while there are some similarities between these two types of clusters, there are also some significant differences between them. Thus, we demonstrate that it is important to include non-local inter-industry transactions as well in applied industrial cluster analysis

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INTRODUCTION

In recent years, industrial cluster analysis has received increasing attention from regional economists, economic development practitioners and policy makers alike. After decades of *first-wave* industrial attraction efforts (i.e., smokestack chasing) followed by years of *second-wave* industrial retention and expansion strategies in the 1980s, the beginning of the 1990s has seen the emergence of what might be called *third-wave* economic development strategies (Herbers 1990). These third-wave approaches are characterized by a focal shift from firm and business-level assistance to strategies that stimulate the formation of networks and clusters of industries, workers, social and political institutions, and demand markets (Fosler, 1992). Furthermore, these strategies are industrial-policy oriented, rather than project-oriented, and recognize the importance of community and business collaborations in strengthening entire and globally competitive industrial sectors (Bradshaw and Blakely, 1999).

As earlier work by Isard (1959), Czamanski (1974), and Ó hUallacháin (1984) indicates, the concept of cluster-based economic development is not a new economic development theory. Its roots can actually be traced to Marshall's (1920) ideas of agglomeration economies. But this concept gained currency only in the 1990s when it emerged as the new economic development panacea (Martin and Sunley, 2003). And much of the popularity boost of industrial clusters is attributable to Porter's (1990) widely-cited *Diamond of Advantage* in which he identifies four determinants that foster cluster development and where governments can play a proactive role.[2] But despite all the theoretical and conceptual understanding of the working mechanisms of industrial clusters, there is still no consensus in the relevant literature on the use of quantitative methods for proper cluster identification.

One important strain of cluster identification methodologies has evolved around using input-output (I-O) tables. The basic idea here is to identify inter-industry linkages based on vertical purchase-sales relationships, or group industries according to similarities in buying/selling patterns. Though widely applied, I-O based approaches for identifying regional clusters are open to a number of criticisms. One major shortcoming of these methods is that since I-O tables are aspatial by design, clusters identified using I-O based methods do not contain any information on how close firms and businesses are located to each other (Latham 1976). As suggested by Ó hUallacháin (1984), this criticism can be partially addressed by arguing that clusters identified using I-O tables do represent spatial agglomerations of industries when the region under consideration is relatively small. But even when the aspatial nature of I-O tables is not an issue, the identified regional clusters have yet another limitation, namely their inability to account for nonregional industry trade (Feser and Luger 2002). As a result, local clusters that cross regional boundaries might not necessarily be identified using these methods, a particularly relevant limitation in these times of increasing globalization.

The primary goal of this paper is to present a revised I-O-based methodological framework for identifying meaningful industrial clusters and apply it to the Chicago Metropolitan Statistical Area (MSA). The contribution of this research to the existing body of cluster literature is that our approach uses an extended regional I-O table that incorporates commodity trade between the region and the rest of the nation. This modification allows

[2] The four determinants included in Porter's *Diamond* are: firm strategy and rivalry, factor and demand conditions, and a network of related and supporting industries.

us to identify two types of clusters, which we refer to as local and domestic clusters. Following Czamanski and Ablas (1979) and Feser and Bergman (2000), we define an industrial cluster as a group of industries that are linked by significant inter-industry trade, similarities in buying/selling patterns, or similarities in markets for resources and outputs. A local industrial cluster is defined as a cluster confined to the region under consideration while a domestic cluster could be part of a supra-regional cluster with a strong presence in the local economy.

An important aspect of this research is the recognition that clusters do not represent purely local or purely national phenomena. As the focus of many cluster studies is on sub-national regions, such as metropolitan, state, or multi-state regions, non-regional trade activities are often very important for the study area. Therefore, clusters cannot be properly studied in isolation from the surrounding national economy. Focusing on selected clusters for the Chicago Metropolitan region, we will show that a comparison of local and domestic clusters can help us to understand the existing strengths of the local economy as well as provide insights for devising potential cluster-based economic development strategies.

The next section provides a brief overview of industrial cluster concepts and cluster identification methodologies based on input-out tables. The relevance of this research is outlined in section III, followed by a description of the data and study region in section IV. The next two sections present the methodology and findings of this study. And the final section presents some concluding remarks.

IMPORTANT CONCEPTS AND METHODOLIGIES IN INDUSTRIAL CLUSTER ANALYSIS

In his widely cited book *Principles of Economics*, Marshall (1920) described three agglomeration forces which explain the existence of spatial conglomerations of firms. These economies of localization are *knowledge spillovers* among firms, *labor market pooling*, and cost advantages produced by the *sharing of industry-specific non-traded inputs*. Subsequently, Hoover (1948) extended Marshall's concept of external *localization economies* by identifying two more agglomeration forces, namely, the existence of large, diverse markets (external *economies of urbanization*) and the availability of large and specialized factors of production increases (*internal returns to scale*). These theories of agglomeration economies have played a key role in shaping the definitions of industrial clusters.

Cluster concepts that focus on regional industrial specialization or the similarity among industries can trace their roots to Marshall's and Hoover's theories of agglomeration economies. Hanson (2000), for instance, emphasizes the role of localization economies in the formation of clusters and states that "the existence of localized externalities implies that firms prefer to be near large agglomerations of other firms in their own industry or related industries" (p. 4). Similarly, Hill and Brennan (2000) define a competitive industrial cluster as a "concentration of competitive firms or establishments in the same industry" (p. 67). Based on similar concepts, Munnich et al. (1998), Rex (1999), Botham et al. (2001), and Peters (2004) measure regional specialization and identify industry agglomerations through location quotients computed using industry employment data. However, as pointed out by Doeringer and Terkla (1995) and Rosenfeld (1997), location quotients are by no means sufficient to identify industrial clusters as they fail to account for the role of inter-industry trade linkages in the spatial grouping of industries.

Isard et al.'s (1959) pioneering work on industrial complex analysis is the first approach to grouping firms into clusters that do not necessarily belong to the same or similar industries. What Isard et al. loosely referred to as "combinations of industrial activities for a region" (p. 1) became the foundation for cluster analysis based on production value chain linkages derived from input-output tables. Intensive research on the use of input-output tables for identifying industrial clusters was done in the 1970's and 1980's by scholars like Czamanski (1974, 1976), Roepke (1974), and Ó hUallacháin (1984). Input-output tables continue to be widely used in industrial cluster analysis to this day. However, scholars like Feser and Bergman (1999, 2000) have raised serious concerns regarding the appropriateness of sub-national input-output tables because of the exclusion of non-local buying / selling patterns (i.e., domestic exports / imports). Furthermore, despite the long tradition of using input-output tables for cluster analysis, there is still a lack of consensus on two important issues: the choice of an appropriate method for identifying clusters and the question of whether or not these identified clusters really capture industries that are located next to each other.

One appropriate way of identifying industrial clusters using input-output tables is by means of principal components factor analysis (PCA). The goal of PCA is to reduce the number of correlated variables in the dataset to a smaller number of meaningful dimensions or factors. As a data reduction method, PCA reduces the number of industries into a smaller number of industrial clusters using the maximum common variance criteria between industries and clusters (Tinsley and Tinsley 1987). Although straightforward conceptually, there are at least three different ways of identifying clusters using this tool. The first approach involves applying PCA to the inter-industry transaction matrix to group industries based on similarities in their buying patterns (i.e., R-mode analysis). The second applies PCA to the transposed transaction table to account for similarities in selling patterns (i.e., Q-mode analysis). And the third involves applying it to a symmetric matrix of correlation coefficients derived from correlating the normalized transaction and transposed transaction matrices with each other. This last approach, which matches industry pairs where one industry's buying pattern is similar to the other industry's selling pattern, accounts to some extent for vertical value chain linkages. But regardless of which of the three methods is given preference, all I-O based PCA approaches have two important limitations. First, they cannot actually measure the extent to which the identified industries co-locate in geographic proximity. And second, grouping industries into clusters according to similarities in buying and selling patterns does not provide us with the information on which key industries policy makers should focus to get the largest return for their investment.

The issue of geographic proximity in cluster definition has repeatedly been raised in the relevant literature. For instance, Czamanski and Ablas (1979) explicitly distinguish between industrial clusters and industrial complexes based on whether or not the industry groups are spatial conglomerations. According to them, a cluster is a set of industries connected by flows of goods and services, while a complex has the additional characteristic of industrial concentration in a well defined location. Roepke et al. (1974) define an industrial cluster as: "…. a base group of industries that have similar patterns of transactions, and it also includes other industries which are major suppliers or markets for those within the group" (p. 15). Accordingly, they perform an R-mode and a Q-mode analysis on a highly aggregated (44x44) matrix of inter-industry linkages for the Province of Ontario and identify thirteen groups of industries. Using the Streit Index to evaluate the intensity of inter-industry flows within identified industry groups, Roepke et al. conclude that they have identified industrial complexes. However, Czamanski and Ablas (1979) argue that Roepke et al. identified industrial clusters rather than complexes as only *aspatial* information from a very highly aggregated input-output table was used.

While acknowledging the above distinction between clusters and complexes, Ó hUallacháin (1984) stresses that the distinction might not be as important in the regional context. More specifically, he argues that when regional input-output tables are used for regional cluster analysis, "users of regional input-output tables view functional clusters and spatial complexes as identical phenomena because the data are confined to a single region" (p. 422). As for the cluster identification approach, Ó hUallacháin (1984) uses PCA to group industry sectors according to their complementary relationships, i.e., similarities in their buying / selling patterns, and demonstrates on a (49x49) input-output table of Washington State that Chenery and Watanabe's (1958) backward and forward linkage indices, are sufficient to identify industrial complexes.

Czamanski (1974, 1976) takes a different approach to addressing concerns raised by the aspatial nature of I-O tables in the identification of industrial clusters. In his 1974 study, he focuses on detecting vertical relationships in a highly disaggregated (172x172) input-output table for the US economy by applying PCA to a symmetric intercorrelation matrix containing the largest correlation coefficients, the outcomes of correlating the normalized transaction table with the normalized transposed transaction table. Altogether, Czamanski identifies sixteen industrial clusters which he describes as *purely aspatial*. Then in his 1976 study, he uses population and employment data for 191 Standard Metropolitan Statistical Areas (SMSA) to assess whether or not the identified clusters fulfill the spatial 'geographic proximity' characteristic of industrial complexes. Regressing first employment by industry i for each region k (E_{ik}) on the region's population (P_k) and then regressing the error terms of the first regression (ε_{ik}) on employment in industry j in region k (E_{jk}), Czamanski again derives sixteen groups of industries. Spatial industrial clusters (or industrial complexes) are then identified by analyzing the similarity between these two independently derived industry groups.

The second limitation of PCA—the provision of inadequate information for identifying key sectors in the economy—can be addressed in a straightforward manner by using PCA results in conjunction with intersectoral relationship indicators derived from I-O tables. Perhaps, the simplest and most rudimentary of these linkage measures are the backward (BL) and forward (FL) linkage measures by Chenery and Watanabe (1958). Derived from the direct coefficient matrix, the Chenery and Watanabe backward and forward linkage indices measure only the direct effects of changes in the final demand for the different sectors. In other words, they only measure total intermediate purchases and total intermediate sales. It is, however, possible to account for the indirect effects as well by using partial multipliers from the

Leontief inverse matrix (i.e., the total requirements matrix) instead.

Hazari (1970), Hewings (1974), and Beyers (1976) were among the earliest to empirically identify key sectors by including both direct and indirect effects. Conceptually very similar, their approaches all focus on identifying key sectors by using two indices introduced by Rasmussen (1952), namely, the index of the power of dispersion and the index of the sensitivity of dispersion. But while Hazari (1970) and Hewings (1976) rely exclusively on the demand-driven Leontief inverse matrix to construct both indices, Beyers (1976) uses an inverse matrix derived from a supply-driven I-O model to derive the index of the sensitivity of dispersion. Beyers' inverse matrix is based on the sales coefficient matrix, where sectoral gross output relates to the primary inputs of production rather than to final demand as is done in the standard I-O model. We follow Beyer's approach in this paper.

Feser and Bergman (2000) bring to the fore another limitation of most I-O based cluster-identification approaches, namely their inability to account for the linkages of regional industries with the national economy. Defining clusters as: '…. specific constellations of linked firms' (p. 3), they argue that sub-national input-output tables are too restrictive due to the absence of non-local buying/selling patterns and use a (362x362) sector national-level input-output table to identify industrial clusters. The current study also attempts to address this limitation of I-O based approaches.

THE RATIONALE FOR PRESENTED RESEARCH

The literature reviewed above makes it clear that any sound methodology for identifying regional industrial clusters must account for the linkages among the industries, their similarities in purchase and sales patterns, and their spatial proximity to each other. In addition, and as indicated by Feser and Bergman (2000) and Feser and Luger (2002), the methodology must also recognize that while some clusters are local to a region, others can cross regional boundaries. Existing cluster identification methodologies, however, focus either on purely local clusters or identify national/supra-regional clusters that are aspatial in nature, and fail to identify supra-regional clusters that have a significant presence in the local economy. Our research attempts to address this shortcoming in the literature by proposing a methodology that identifies both local and domestic industrial clusters in the region. The main methodological innovation in this study is the integration of commodity imports and exports by industry into the regional I-O framework (in our case the I-O table for the Chicago MSA). We show that this extended I-O framework allows us to identify the two types of clusters mentioned above.

From a policy perspective, the rationale for studying both local and domestic clusters is that they provide different insights into the strengths and growth potential of the local economy. Local clusters, by grouping those industries in the region that currently exhibit significant links with each other, identify the sectors that are already in line with cluster-oriented development. They do not, however, help to identify other complementary industries that might be targeted by cluster-oriented development strategies in the future to enhance the growth of the local economy. Furthermore, since local clusters exclude industries that have especially strong non-regional trading relationships, some key local sectors could be ignored if policymakers focus exclusively on identified local clusters. Latham (1976) and Feser and Bergman (2000) suggest that we should, therefore, also examine clusters based on national I-O tables to develop economic development strategies that recognize complementary industries and existing gaps in supply-chains and product chains. More specifically, Feser and Bergmen (2000) propose using the national clusters as "templates for developing a strategic view of a regional manufacturing economy" (pp. 2). Using national clusters to identify complementary industries and gaps in chains as recommended by Latham (1976) and Feser and Bergman (2000), however, fails to account for the unique economic characteristics and competitiveness of the regional economy. Thus targeting industrial sectors on the basis of national clusters might not necessarily be an appropriate regional development strategy.

Like national clusters, the domestic clusters identified by our methodology can reveal complementary industries, supply-chain gaps and product-chain gaps that are not identified by local clusters. But since domestic clusters focus on local industries that exist as members of supra-regional clusters, they also account for the regional characteristics of these industries. Hence the identification of domestic clusters can give additional insights that could be useful for devising appropriate regional development strategies that build upon the existing competitive advantage of local industries. For example, if a set of industries is found to belong to a domestic (but not local) cluster, then we know that these industries have strong links among themselves via their import-export relationship with the national economy. Thus one potential economic development strategy in this case would be to assist them in reorienting their inter-industry purchases patterns so that input imports are progressively replaced by local purchases.

Any cluster-based development strategy must recognize that different industrial clusters have very dissimilar requirements regarding capital, labor, infrastructure, and other local factors that affect the overall business environment in which they operate. At the same time, the above discussion indicates that the spatial attributes of a region's clusters (i.e., whether they are local, domestic or national) are equally important factors in designing a policy portfolio aimed at improving the competitiveness of local clusters. The comparison of Chicago's local and domestic clusters presented in this study should give further insights into the relevance of distinguishing between these two cluster types.

STUDY REGION AND DATA

The study area, hereafter referred to as the Chicago region, includes the following eight most urbanized counties from the Chicago-Naperville-Joliet Metropolitan Statistical Area (MSA) (Census 2006): Cook, DuPage, Kane, Lake, McHenry, and Will in Illinois, and Lake and Porter in Indiana. Combined, these eight counties account for 96.6 percent of the employment and 96.2 percent of all establishments in the MSA (Bureau of Economic Analysis 2003). The main data framework is the 2001 Chicago I-O table which has been derived using the commercially available IMPLAN® economic impact modeling system (MIG 2004). The I-O framework for the Chicago region contains all the information required for performing a principal components factor analysis of inter-industry transactions. In addition, the IMPLAN dataset also includes employment and value-added data for 2001. Supplementary data on employment and establishments are taken from the Quarterly Census of Employment and Wages (QCEW) of the Bureau of Labor Statistics (BLS 2006). The industry classification in the presented framework follows the North American Industry Classification System (NAICS). To achieve a sufficient level of industry detail, we distinguish among a total of 223 individual industries in the I-O framework: eight extraction sectors (i.e., agriculture and mining), 119 manufacturing industries (including construction), and 96 service industries.

For the purpose of the presented analysis, we rely on two data sets extracted from the IMPLAN database for the Chicago MSA: i) the intra-regional inter-industry flows as captured in the use and make matrices and ii) the inter-regional flows which map commodity exports and imports by industry. The Minnesota IMPLAN Group, Inc. (MIG) relies on information from various national, state, and county level data sources to construct the regional IMPLAN database.[4] For instance county-level data on employment, employee compensation, proprietary income, population, federal and state expenditures and selected wealth data are employed for the estimation of county-level databases. These data sources, together with national I-O matrices and national tables for regional purchase coefficients (PPC), are the main ingredients for building sub-national level I-O accounts.

IMPLAN I-O tables are built top-down using a non-survey approach.[5] Thus, the national level structural matrices (i.e., use and make matrices) form the basis for the regional level use and make matrices. Adjustments are made to the national structural matrices to reflect regional differences. State level data are appropriately scaled to ensure that they sum to the national totals. Similarly, county level data within each state are adjusted so that their sums match the state totals.

Regional trade flows (commodity imports and exports) are estimated based on regional purchase coefficients (RPC) which measure the portions of total commodity demand that are supplied by regional sources. The starting point for deriving the RPCs are empirical trade flow data taken from the U.S. Department of Health and Human Services' 1977 multi-regional I-O accounts (MRIOA), a 125 sector inter-regional I-O framework for all states and the District of Columbia. Using an econometric model, the RPCs are estimated based on regional employee compensation by industry, regional employment ratios, location quotients, and area ratios. It should be pointed out that, due to data limitations, IMPLAN distributes foreign imports proportionally among all regions within the U.S. We have, therefore, excluded the foreign trade flows from our analysis.

[4] A detailed technical discussion of the data methodology employed by Minnesota IMPLAN Group can be found in MIG (2004).

[5] Ideally, we would like to use I-O tables based on data from current surveys. But building survey-based regional I-O tables is an undertaking where the amount of time and money spent does not justify the gains in accuracy.

METHODOLOGY

As indicated earlier, this paper seeks to identify two types of industrial clusters—local and domestic—based on inter-industry linkages. In both cases, the cluster identification methodologies used are similar to the principal component analysis (PCA) approaches in Czamanski (1974), Roepke et al. (1974), and Feser and Bergman (2000). Both utilize information from I-O tables for the local economy to group industries into clusters based on inter-industry purchase and sales linkages, similarities in inter-industry trade patterns, or similarities in markets for resources and outputs. And in each case, the identified clusters can be considered spatial industry agglomerations since the geographical area under consideration is relatively small. But while identification of local clusters requires data only on commodity flows across industries within the region, identification of domestic clusters requires information on inter-regional flows as well. Thus the incorporation of inter-regional inter-industry flows in the identification of domestic clusters distinguishes our methodology from others found in the literature.

Identification of local industrial clusters

The first step in identifying local industrial clusters is the construction of an I-O inter-industry transaction table for the region under consideration. We derive the inter-industry transaction table from the commodity flow tables—the make $(\mathbf{M})$ and use $(\mathbf{U})$ matrices—that are part of the I-O framework for the region. Each element m_{ij} of $\mathbf{M}$ represents the value of commodity j made by industry i, and each element u_{ij} of $\mathbf{U}$ shows the value of commodity i used by industry j. The local inter-industry transaction table $(\mathbf{T})$ is then constructed as follows:

$$\mathbf{T} = \mathbf{M}\mathbf{C}^{-1}\mathbf{U} \qquad (1)$$

where $\mathbf{C}$ is a diagonal matrix whose diagonal elements represent the total values of the different commodities produced by the industries in the region for the regional market. Each element T_{ij} of $\mathbf{T}$ denotes the quantity (in dollar terms) of industry i's output purchased by industry j for intermediate use.

The next step involves performing PCAs based on $\mathbf{T}$ to identify industries that exhibit similarities in input purchase patterns or similarities in selling patterns.[6] If we denote the total intermediate sales of industry i by $T_{i\bullet}$, we can define a local purchase coefficient $a_{ij} = \frac{T_{ij}}{T_{j\bullet}}$, and a local sales coefficient $b_{ij} = \frac{T_{ij}}{T_{i\bullet}}$. Thus each column $\mathbf{a}_j$ of the matrix $\mathbf{A} = [a_{ij}]$ shows the proportions of total inputs bought by industry j from different industries while each row $\mathbf{b}_j$ of $\mathbf{B} = [b_{ij}]$ represents the proportions of industry $j's$ sales going to different industries.

The PCA of $\mathbf{A}$ with varimax rotation gives industry clusters that are based on similarities in input purchase patterns among the industries. It is performed by treating each industry column $\mathbf{a}_j$ as a variable and deriving a smaller number of latent factors which explain observed correlations between these industries using the maximum common variance criteria between variables and a factor. The strength of the relationship between any industry and a particular factor is given by the corresponding factor loading (Feser and Bergman 2000).[7] In this paper, industries

[6] These are the R-mode and Q-mode analyses referred to in Section 2.

[7] Since the literature provides numerous examples of how to apply principal components factor analysis to

with loadings of at least 0.35 or greater on a given factor are considered members of a cluster. And while an industry can belong to more than one cluster, the industry with the highest factor loading in a particular cluster is considered the primary industry of that cluster. Industry clusters based on similarities in selling patterns are identified by performing a PCA of $\mathbf{B}$.

It is clear that the clusters identified using the above PCAs do not consider the sales and purchase linkages between industry pairs, but focus on similarities in sales and purchase patterns. One way to account for these value-chain linkages is by performing a PCA on a new matrix that captures the correlations in I-O structures between pairs of industries. The similarities in the I-O structures between industry pairs can be described by the following correlations based on $\mathbf{A}$ and $\mathbf{B}$:

$Corr(\mathbf{a}_{i,}\mathbf{a}_j)$: correlation between industries i and j in terms of purchase patterns

$Corr(\mathbf{b}_{i,}\mathbf{b}_j)$: correlation between industries i and j in terms of sales patterns

$Corr(\mathbf{a}_{i,}\mathbf{b}_j)$: correlation between the purchase pattern of i and sales pattern of j

$Corr(\mathbf{b}_{i,}\mathbf{a}_j)$: correlation between the sales pattern of i and purchase pattern of j.

Note that the last two correlations show the extent to which sectors that buy the output of one industry supply inputs to the other industry (Czamanski and Ablas 1979). In other words, they capture the indirect purchase-sales relationships between industry pairs.

In the third step, a new symmetric correlation matrix $\mathbf{S}$ is constructed by selecting the largest of the above four correlation coefficients for each industry pair, and a PCA is performed on this matrix to identify industry clusters. These clusters thus take into account indirect purchase-sales relationships between industry pairs as well as similarities in sales and purchase patterns.

Identification of domestic industrial clusters

Recall that a domestic industrial cluster is a group of linked local industries which might also belong to larger clusters that cross region boundaries. The method for identifying domestic industrial clusters is the same as the approach used for identifying local clusters except for a modification in the first step. The transaction matrix $\mathbf{T}$ now incorporates not just intra-regional inter-industry flows, but also inter-regional flows recorded in the exports matrix ($\mathbf{E}$) and the imports matrix ($\mathbf{I}$) of the I-O framework.

Each element E_{ij} of the exports matrix shows the total export of commodity j made by industry i to destinations within the US. Similarly, each element I_{ij} of the imports matrix represents the amount of commodity i imported from within the US for use as inputs to industry j. These export/import matrices are used along with the make and use matrices to derive the following domestic inter-industry transaction matrix:

$$\mathbf{T} = \left(\mathbf{M} + \mathbf{E}\right) \times \mathbf{C}^{-1} \times \left(\mathbf{U} + \mathbf{I}\right)$$

where the elements of the diagonal matrix $\mathbf{C}$ represent the total production of each commodity in the region. The domestic transaction matrix $\mathbf{T}$ given by Equation (2) thus accounts for both local and non-local

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inter-industry transaction matrices, we do not provide a more detailed description of PCA here. Instead, we refer the interested reader to Czamanski (1974), Bergman and Feser (1999), and Tinsley and Tinsley (1987).

commodity trade activities of the industries in the region. Domestic industrial clusters, which reflect the position of Chicago's industries in the larger national economy, are then identified by performing PCAs based on $\mathbf{T}$.

Remarks on Principal Components Analysis (PCA)

We prefer PCA to other data reduction methods, such as factor analysis, mainly because it is the method of choice for descriptive and exploratory research where the primary focus is on summarizing data sets.[8] Furthermore, PCA allows an industry sector to be a member of more than one cluster. The goal of PCA is to transform the set of original variables to a more manageable set comprising of only a few factors.

In order to identify clusters, we use the Kaiser criterion—a criterion based on the eigenvalues of each factor. Eigenvalues in this context explain how much each factor contributes to explaining the common variance and is calculated as the sum of all squared factor loadings for a factor. More specifically, all factors with eigenvalues greater than 1.0 are initially selected as candidate clusters. If, however, a selected factor with an eigenvalue close to 1.0 is composed of seemingly unrelated industry sectors, then it is dropped from the final pool of clusters. For better interpretability of the PCA solution without changing the underlying mathematical principles, the initial factors are rotated using an orthogonal Varimax rotation.[9]

Sectors affiliated with each cluster are identified using their corresponding factor loadings, which represent the correlation of each sector with that cluster. In this paper, we use a factor loading value of 0.35 as the cut-off value for identifying cluster affiliation. Strong cluster affiliation is indicated by loadings of 0.7-1.0, median cluster affiliation by loadings of 0.5-0.7 and weak cluster affiliation by loadings of 0.35-0.5.

Though PCA is a valuable tool for identifying clusters using I-O tables, it does have a number of limitations. Most importantly, it does not use any external criterion that would allow us to test the goodness of received outcomes. For instance, in regression analysis, we can check the correlation between observed and predicted dependent variables to examine the interrelationship among a given set of variables (Tabachnick and Fidell, pp. 608). A second problem is the difficulty associated with choosing the rotation method. Though all rotations account for the same amount of variance in the final solution, the received factors may vary slightly. Third, nothing can be said about the importance of cluster members for regional economies when factor loadings are used as the sole cluster affiliation criteria. This limitation creates difficulties in making meaningful and policy-relevant interpretations of the PCA results. In other words, since factor loadings do not necessarily reflect inter-industry connectivity, industry employment and output, the ranking of sectors within a cluster based on factor loadings alone might not be meaningful from an economic perspective. Last, the ordering of derived industry clusters based on eigenvalues does not necessarily imply that clusters with higher eigenvalues are more important to regional economies. Despite the fact that higher eigenvalues usually associate with larger numbers of cluster members, nothing can be said about the position of a cluster within a regional economy. To improve the

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[8] According to Tabachnick and Fidell (2007): *Principal components analysis is an empirical approach, whereas factor analysis and structural equation modeling tend to be theoretical approaches* (pp. 25).
[9] An orthogonal rotation has been given preference as it yields independent and uncorrelated factors (Tinsley and Tinsley, 1987).

interpretation of selected clusters and cluster members, we therefore do a key industry sector identification exercise as described below.

Key industry sector identification[10]

Once we have derived the final set of industrial clusters based on the **A** and **B** matrices, the last step involves rank ordering the industry sectors following the key sector criteria proposed by Beyers (1976). As indicated earlier, Beyer's approach involves deriving the index of the power of dispersion and the index of the sensitivity of dispersion.

The index of the power of dispersion identifies the sectors that have a greater than average degree of backward connectivity with the economy. Using the Leontief inverse matrix, $(\mathbf{I}-\mathbf{A})^{-1}$, the index of dispersion for sector j (U_j) can be directly calculated as:

$$U_j = \frac{\frac{1}{m}\sum_i \alpha_{ij}}{\frac{1}{m^2}\sum_j\sum_i \alpha_{ij}} \qquad (j = 1, 2, \ldots, m) \qquad (3)$$

where α_{ij} is the $(i, j)^{th}$ element of $(\mathbf{I}-\mathbf{A})^{-1}$, and m denotes the number of rows in the matrix. Conceptually rooted in the Chenery and Watanabe (1958) linkage measures, U_j can be described as the normalized version of the average output multiplier for sector j. The numerator in Equation (3) represents what Hazari (1970) describes as the average output multiplier, while the denominator takes care of the normalization to allow for inter-industry comparisons. A sector with greater than average backward linkage is, therefore, identified by a U_j value greater than unity.

Similarly, the index of the sensitivity of dispersion for sector i (U_i) can be directly calculated from the elements β_{ij} of the forward-linkage inverse matrix $(\mathbf{I}-\mathbf{B})^{-1}$ as:

$$U_i = \frac{\frac{1}{m}\sum_j \beta_{ij}}{\frac{1}{m^2}\sum_i\sum_j \beta_{ij}} \qquad (i = 1, 2, \ldots, m)$$

Indices of the sensitivity of dispersion can be interpreted as the normalized versions of average supply multipliers.[11] As before, a cutoff value of unity is used to identify industry sectors with greater than average forward linkages.

We use the above two indices along with industry-specific employment information to rank order the component sectors of each cluster according to their economic importance.[12] The ranking involves grouping the sectors in the cluster into three categories: i) strongly linked key sectors consisting of components that have above average backward as well as forward linkages (i.e., both linkage indices are greater than 1.0), ii) moderately linked sectors which have above average links with the economy in only one direction (i.e., only one index is greater than 1.0), and iii) weakly linked sectors whose linkage indices are below average in both directions. Within each category, cluster components are

[10] This step is common to both local and domestic clusters.

[11] For example, the supply multiplier for sector i is the change in total output in the whole economy resulting from a dollar increase in the availability of value added inputs for that sector.

[12] Note that the PCA factor loadings are also used in some approaches to rank component sectors. But while the factor loading for each sector does show the extent to which the sector is correlated with the cluster, it does not convey any information regarding the economic interactions between the sector and the cluster.

additionally ranked according to employment levels.

Apart from identifying key sectors, this ranking also allows us to identify sectors that have very weak links with the cluster and are also relatively unimportant in terms of employment. Such sectors are potential candidates for exclusion from the cluster. Some of these candidate sectors are removed from the cluster by utilizing a combination of subjective a priori knowledge about the linkages in the local economy and the sector ranking information. Thus the revision of the PCA clusters using the key sector identification process enables us to address, to some extent, the problem of seemingly unrelated industry sectors within clusters. [13]

FINDINGS AND RESULTS

In this section, we present results that highlight the similarities and differences between domestic and local industrial clusters identified by the various PCAs. Starting with an overview of the list of domestic and local clusters, we proceed to discuss industrial clusters that emerged in both frameworks – the common clusters. In logical sequence we then discuss those clusters that showed up in only one of the two frameworks presented – the unique and the analogous clusters. Then, we present a detailed discussion of a few key clusters identified in the two (local and domestic) frameworks.

Overview of identified clusters

Altogether, we ran three different variants of principal components factor analysis (i.e., R-mode, Q-mode, and symmetric correlation matrix) on each of the two frameworks (local and domestic). The PCA results from these three types of analyses were used to derive the initial set of local and domestic industrial clusters. A summary of the PCA results is presented in Table 1 below.

As shown in table 1, the six individual principal components factor analyses results differ in terms of the number of identified factors. For both the local and domestic frameworks, the R-mode and Q-mode analyses have identified slightly more factors than the PCAs based on the symmetric correlation matrices. For instance, the total numbers of factors in the R-mode and Q-mode analyses are 24 and 30 respectively in the local framework, and 28 and 29 respectively in the domestic framework. On the other hand, the corresponding number of factors derived from the symmetric correlation matrix is only 16 in the local framework and 15 in the domestic framework.

While the factors identified by the PCAs represent specific industry groupings, not all such factors constitute valid industrial clusters. Hence, as a first step in the cluster identification process, we attempted to eliminate irrelevant factors by assigning the identified factors to three different groups. The first group, which we refer to as "single-industry factors", consists of factors that include three or fewer industries. As such factors contain too few industries to be considered valid clusters; they are not included in the final list of industrial clusters. The second group, labeled "undefined factors" in Table 1, includes factors that appear to be collections of a random mix of industries. Hence, these factors too are not considered valid industrial clusters. Only the remaining factors are used for deriving the final set of industrial clusters. This last group of factors is refereed to as "significant factors" in Table 1.

[13] We would like to thank an anonymous reviewer for suggesting this approach to addressing the issue of spurious cluster affiliation.

Table 1: Summary results of six variants of principal components factor analysis

Variant	Number of significant factors	Number of single-industry factors	Number of undefined factors
Local Framework			
R-Mode	18	3	3
Q-Mode	20	7	3
Sym. Correlation Matrix	13	1	2
Domestic Framework			
R-Mode	20	5	3
Q-Mode	21	4	4
Sym. Correlation Matrix	12	1	2

Source: Author's tabulation

Taking a closer look at the significant factors, we observed that some of them consisted of a distinctly large number of component industries.[14] More specifically, the PCA on the symmetric correlation matrix and the transaction matrix (R-mode) resulted in two such mega-factors: one manufacturing and one service. For instance, the PCA on the symmetric correlation matrix using the local framework results in one manufacturing factor composed of as many as 144 component industries of which 122 are manufacturing sectors and 22 are service sectors. A second mega-factor is composed of 68 component industries: 63 service sectors and five manufacturing sectors. Thus these two mega-factors combine as many as 212 of the 223 industry sectors considered in this study.[15] The same patterns hold for the R-mode analysis for both the local and domestic frameworks. Although these two identified mega-factors make perfect sense, we decided to exclude them from the final pool of relevant clusters since apart from classifying industries as manufacturing or service sectors, they do not provide much information that might be valuable for potential cluster-based economic development policies. Having decided which information, i.e., factors, to use from the original six sets of PCA outcomes, in the second step we put together two final sets of industrial clusters—one using the local framework and the other using the domestic framework. These two sets of industrial clusters are shown in Table 2. This table also shows, for each cluster, the total number of component industries identified by the PCA as well as the revisions made using the key sector identification method discussed earlier.

[14] The National Industry Cluster Template study by Feser and Bergman (2000) also highlights the fact that the number of component sectors varies a lot among the clusters; from 116 in the metalworking cluster to four in the tobacco cluster (pp. 6).

[15] These are the number of cluster components that were identified before making revisions using results from the key industry sector analysis.

Table 2: Local versus Domestic Industrial Clusters

I. Local Framework

No.	Cluster Description	Number of Original Cluster Components	Number of Revised Cluster Components	Total Revised Cluster Employment	Percent Change in Cluster Components
1	Retail	61	47	1,314,698	23.0
2	Computer-based Support	23	20	937,648	13.0
3	Construction incl. Building Servies	18	15	683,771	16.7
4	Personal Services	8	7	572,799	12.5
5	Financial Services	14	10	444,196	28.6
6	Transportation	14	14	304,841	0.0
7	Insurance	4	4	251,587	0.0
8	Metalworking	26	22	177,982	15.4
9	Telecom	6	5	142,017	16.7
10	Automotive	10	8	127,169	20.0
11	Food	26	26	112,383	0.0
12	Broadcasting-Arts-Sports	11	8	99,462	27.3
13	Electronics	11	9	70,108	18.2
14	Nonmetallic Mineral Products	12	9	62,017	25.0
15	Metal Foundries	7	7	57,486	0.0
16	Chemical-Plastic-Rubber	15	13	29,575	13.3
17	Printing	4	4	17,288	0.0
18	Textile	5	5	10,444	0.0

II. Domestic Framework

No.	Cluster Description	Number of Original Cluster Components	Number of Revised Cluster Components	Total Revised Cluster Employment	Percent Change in Cluster Components
1	Retail	78	49	1,910,307	37.2
2	Computer-based Support	33	28	1,101,432	15.2
3	Construction incl. Building Servies	23	20	748,574	13.0
4	Professional Services	10	8	483,666	20.0
5	Financial Services	12	9	439,258	25.0
6	Metalworking I	36	26	431,734	27.8
7	Travel and Sightseeing	3*	3*	338,133	0.0
8	Automotive	11	8	167,804	27.3
9	Transportation	6	6	159,042	0.0
10	Food	24	23	86,509	4.2
11	Nonmetallic Mineral Products	11	11	72,901	0.0
12	Electronics	9	9	70,369	0.0
13	Paper	11	11	69,545	0.0
14	Metalworking II	10	10	61,729	0.0
15	Plastic	12	12	61,435	0.0
16	Broadcasting-Arts-Sports	12	8	46,758	33.3
17	Wood Products	10	9	35,352	10.0
18	Chemical and Rubber	9	9	23,608	0.0
19	Utilities-Insurance	8	5	17,038	37.5
20	Textile	5	5	6,638	0.0

Note: A total of eleven clusters were common to both frameworks.

Source: Implan Pro and Bureau of Labor Statistics.

Table 3: Exclusive Clusters Comparison

I. Local Framework Cluster Description	Number of Cluster Components	Total Cluster Employment	II. Domestic Framework Cluster Description	Number of Cluster Components	Total Cluster Employment
a) Unique Clusters			a) Unique Clusters		
Personal Services	7	572,799	Professional Services	8	483,666
Telecom	5	142,017	Travel and Sightseeing	3*	338,133
Printing	4	17,288	Paper	11	69,545
			Plastic	12	61,435
			Wood Products	9	35,352
b) Analogous Clusters			b) Analogous Clusters		
Metalworking	22	177,982	Metalworking I	26	431,734
Metal Foundries	7	57,486	Metalworking II	10	61,729
Chemical-Plastic-Rubber	13	29,575	Chemical and Rubber	9	23,608
Insurance	4	251,587	Utilities-Insurance	5	17,038

Source: Implan Pro and Bureau of Labor Statistics.

Table 3 lists the Personal Services cluster as a unique local cluster with a strong focus on providing services locally only to individuals, households, and businesses. No equivalent cluster has been identified in the domestic framework. The seven components of this cluster include locally oriented sectors such as Health Care Services (621), Social Assistant including Child Care Service (624), Personal Care Services (8121) and Photographic Services (54192) [17]. Of particular regional economic importance is Health Care Services, which, apart from having the largest employment in the cluster, also has strong ties to the regional economy with above average backward linkage (U_j=1.06) and strong forward linkage (U_i=1.12). The other two local unique clusters—Telecom and Printing—too focus strongly on local business support. In addition to supporting local businesses, Telecom—which includes Computer and Telephone Manufacturing (3341-2), Telecommunications (5133), Management of Companies and Enterprises (55), Data Processing Services (5142) and Information Services (5141)—illustrates a characteristic common to many clusters with mixed manufacturing and non-manufacturing components, namely the distinctly stronger presence of manufacturing sectors among the key industries. For instance, the only Telecom sector that qualifies as a key industry is Computer and Telephone Manufacturing. None of the service sectors qualifies as a key sector. Furthermore, among the service sectors in the cluster, only Telecommunications has one above-average index (U_i=1.05); the forward and backward linkage indices for all the other sectors are smaller than l.0.

The domestic framework shows five unique industrial clusters, namely Professional Services, Travel and Sightseeing, Wood Products, Paper, and Plastic, all of which have a non-local market base. The Paper cluster, in particular, is a good example of an industrial cluster with significant cross-boundary inter-industry linkages. Its component sectors such as Forestry and Logging (113), Pulp, Paper, and Paperboard Mills (32211, 32212, 32213), and Paperboard Container Manufacturing (32221) have large

[17] North American Industry Classification System (NAICS) codes in parenthesis.

sensitivity of dispersion indices (U_i). This suggests that these sectors have great export potential since a part of the supply chain of domestic clusters is located outside the study region. Professional Services is another unique cluster that deserves special attention. With an employment level of 484 thousand, it is clearly an important cluster for the Chicago economy. Its significance to the Chicago economy is also indicated by the fact that four of its eight component industries—Real Estate (531), Legal Services (5411), Architectural and Engineering Services (5413), and Environmental and Other Technical Consulting (54162, 54169)—meet the key sector criteria.

The second group of industrial clusters in Table 3, the *analogous clusters*, can best be described as hybrid clusters in that while they do appear in both local and domestic frameworks, they nevertheless differ significantly in the two frameworks in terms of the number of cluster components and total cluster employment. Take, for example, the clusters related to the metal and steel industries. Two individual metal and steel-related clusters were identified in each framework. But although Metalworking in the local framework is somewhat similar to Metalworking I in the domestic framework in that there are 13 sectors common to both clusters, the two clusters differ significantly in other respects. Not only are the remaining cluster components and the total number of components different for the two clusters, but their employment figures are also quite dissimilar. Similar observations can be made about the other analogous clusters as well.

Of further interest to the policy analysts in this subgroup of *analogous clusters* might be the fact that the local framework merges chemical, plastic, and rubber products into one Chemical-Plastic-Rubber cluster, while the domestic framework identified two distinct clusters, namely, Chemical and Rubber and Plastic. This example shows that adding the non-regional trade data to the local input-output framework helps us to identify more clear-cut clusters, particularly when grouping industries with smaller employment numbers.

Details of specific clusters

In order to better understand the differences between the domestic and local clusters, we now present in the remainder of this section a detailed discussion of three specific clusters—Retail, Financial Services and Food Manufacturing. The Retail cluster is, by far, the largest cluster in both frameworks not only in terms of the number of components, but also when considering total cluster employment. Furthermore, unlike all other clusters, Retail includes a significant number of both service and manufacturing industries. It is, therefore, interesting to evaluate how this cluster differs in the two frameworks and what the implications for economic development purposes are. As shown in Table 2, the local Retail cluster consists of 47 industries and employs 1,314,698 people. On the other hand, the corresponding cluster in the domestic context includes 49 industries and provides employment for 1,910,307 individuals. Details on the components of this cluster are presented in Table 4.

Table 4: Retail Cluster Comparison

Local Framework

Retail	**Employment**	**Factor Loadings**	**Power of Dispersion (U_j)**	**Sensitivity of Dispersion (U_i)**
Health care services	383,916	0.383	1.06	1.12
Professional services	98,484	0.470	1.01	1.07
Food and beverage stores	86,626	0.971	1.01	1.09
Nonstore retailers	55,217	0.971	1.08	1.13
Miscellaneous store retailers	42,291	0.971	1.11	1.15
Sporting goods, hobby, book and music stores	28,172	0.971	1.06	1.08
Other Plastics Product Manufacturing	24,123	0.565	1.07	1.21
Gasoline stations	13,732	0.971	1.04	1.02
Electrical Equipment Manufacturing	11,616	0.443	1.05	1.13
Other Electrical Equipment Mfg	10,047	0.674	1.01	1.11
Commercial and Service Industry Machinery	6,059	0.480	1.06	1.08
All Other General Purpose Machinery Mfg	6,018	0.420	1.00	1.06
Cutlery and Handtool Manufacturing	4,704	0.521	1.00	1.02
Material Handling Equipment Mfg	4,434	0.394	1.05	1.09
HVAC and Commercial Refrigeration Equipment	3,839	0.764	1.00	1.04
Electric Lighting Equipment Mfg	3,495	0.638	1.06	1.02
Paint and Coating Manufacturing	3,263	0.866	1.06	1.23
Asphalt Paving, Roofing Materials and Other Petrol	2,591	0.854	1.35	1.28
Ag, Construction, and Mining Machinery Mfg	2,574	0.625	1.08	1.12
Plastics Pipe, Fittings, and Profile Shapes	2,188	0.557	1.00	1.01
Hardware Manufacturing	2,019	0.659	1.02	1.04
Other Textile Product Mills	2,005	0.384	1.03	1.06
Pulp, Paper, and Paperboard Mills	1,365	0.718	1.12	1.19
Adhesive Manufacturing	1,093	0.468	1.11	1.08
Social assistant, incl. child day care services	91,205	0.522	0.99	1.00
General merchandise stores	76,705	0.971	0.95	1.01
Clothing and clothing accessories stores	51,083	0.971	0.97	1.02
Motor vehicle and parts dealers	48,935	0.971	0.96	1.03
Furniture and home furnishings stores	20,164	0.971	0.98	1.01
All Other Fabricated Metal Products Mfg	10,971	0.596	0.99	1.08
All Other Miscellaneous Mfg	9,429	0.897	0.96	1.02
Household and Institutional Furniture Mfg	6,564	0.943	1.01	0.97
Metal Valve Manufacturing	6,423	0.846	0.96	1.03
Ornamental and Architectural Products	5,994	0.945	0.96	1.05
Machinery and equipment rental and leasing	4,995	0.362	0.97	1.00
Other Wood Product Manufacturing	3,666	0.952	0.98	1.03
Rubber Product Manufacturing	2,705	0.374	0.97	1.06
Cement and Ready-mix Concrete Mfg	2,503	0.956	0.99	1.03
Household Appliance Mfg	1,607	0.809	1.08	0.95
Lime and Gypsum Product Manufacturing	976	0.411	1.01	0.96
Abrasive Product Manufacturing	965	0.458	1.02	0.91
Clay Building Materials Manufacturing	871	0.708	1.03	0.81
Health and personal care stores	42,004	0.971	0.91	0.93
Personal care services	35,361	0.559	0.95	0.96
Warehousing and storage	33,748	0.422	0.91	0.88
Building material and garden supply stores	33,314	0.971	0.95	0.99
Electronics and appliance stores	24,640	0.971	0.87	0.85

Table 4: Retail Cluster Comparison

Domestic Framework

Retail	**Employment**	**Factor Loadings**	**Power of Dispersion (U_j)**	**Sensitivity of Dispersion (U_i)**
Wholesale trade	258,035	0.662	1.07	1.09
Management consulting services	75,299	0.401	1.02	1.21
Management of companies and enterprises	63,317	0.757	1.23	1.18
Accounting and bookkeeping services	53,558	0.437	1.21	1.20
Advertising and related services	37,501	0.592	1.29	1.21
Warehousing and storage	33,748	0.582	1.32	1.23
Business support services	30,441	0.439	1.41	1.16
Other Plastics Product Manufacturing	24,123	0.565	1.12	1.00
Other support services	18,873	0.500	1.22	1.18
Automotive equipment rental and leasing	14,313	0.515	1.07	1.17
Machinery and equipment rental and leasing	4,995	0.533	1.37	1.19
Asphalt Paving, Roofing Materials and Other Petrol	2,591	0.591	1.17	1.07
Plastics Pipe, Fittings, and Profile Shapes	2,188	0.546	1.59	1.17
Adhesive Manufacturing	1,093	0.455	1.26	1.20
Automotive repair and maintenance, except car	65,433	0.421	1.07	0.88
Drycleaning and laundry services	16,118	0.436	1.02	0.76
Electrical Equipment Manufacturing	11,616	0.468	0.86	1.08
All Other Fabricated Metal Products Mfg	10,971	0.653	0.74	1.27
Other Electrical Equipment Mfg	10,047	0.707	0.81	1.19
Metal Valve Manufacturing	6,423	0.355	0.83	1.10
Cutlery and Handtool Manufacturing	4,704	0.496	0.78	1.04
HVAC and Commercial Refrigeration Equipment	3,839	0.416	0.73	1.04
Other Wood Product Manufacturing	3,666	0.657	1.51	0.99
Pump and Compressor Manufacturing	3,594	0.722	0.75	1.14
Plate Work and Fabricated Structural Products	3,518	0.372	0.74	1.07
Paint and Coating Manufacturing	3,263	0.450	0.74	1.16
Hardware Manufacturing	2,019	0.650	0.95	1.14
Other Textile Product Mills	2,005	0.403	0.76	1.14
Doll, Toy, and Game Mfg	1,370	0.449	0.73	1.08
Lime and Gypsum Product Manufacturing	976	0.393	0.73	1.43
Clay Building Materials Manufacturing	871	0.481	0.73	1.25
Sawmills, Plywood, and Engineered Wood Mfg	584	0.727	1.58	0.96
Health care services	383,916	0.474	0.73	0.33
Professional services	98,484	0.386	0.85	0.66
Social assistant, incl. child day care services	91,205	0.475	0.73	0.32
Food and beverage stores	86,626	0.954	0.91	0.61
General merchandise stores	76,705	0.954	0.85	0.58
Nonstore retailers	55,217	0.954	0.82	0.46
Clothing and clothing accessories stores	51,083	0.954	0.82	0.50
Motor vehicle and parts dealers	48,935	0.954	0.82	0.53
Miscellaneous store retailers	42,291	0.954	0.92	0.58
Health and personal care stores	42,004	0.954	0.97	0.77
Personal care services	35,361	0.408	0.74	0.34
Building material and garden supply stores	33,314	0.954	0.99	0.74
Sporting goods, hobby, book and music stores	28,172	0.954	0.97	0.63
Electronics and appliance stores	24,640	0.954	0.93	0.84
Furniture and home furnishings stores	20,164	0.954	0.79	0.45
Gasoline stations	13,732	0.954	0.83	0.60
Office Furniture and Fixture Mfg	7,367	0.437	0.82	0.47

Source: Implan Pro and Bureau of Labor Statistics.

In terms of sectoral composition, Table 4 shows that the local Retail cluster includes 18 service sectors and 29 manufacturing industries while the domestic Retail cluster has 28 service-related industries and 21 manufacturing industries. It is also interesting to note that, in both cases, this large cluster appears to consist of a variety of seemingly unrelated industries. This finding is consistent with the observations made by Feser and Bergman (2000) in their national cluster template study, where they too identified a large cluster consisting of many unrelated components.[18] And it is not a surprising finding considering that we are using an input-output framework that includes not just the commonly used manufacturing industries but also a wide range of service industries.

With respect to the economic importance of their cluster components, there are some striking differences between the local and domestic retail clusters. The local Retail cluster has 24 service and manufacturing industries—with a total employment of 800 thousand—that meet the key industry criteria based on U_i and U_j. Among these 24 key sectors, only five are retail sectors[19], while 17 are manufacturing sectors and two belong to the services category. It is interesting to note that although the remaining 23 sectors in this cluster rank low in terms of the key sector criteria, they have strong correlations (i.e., high factor loadings) with the Retail cluster. In fact, seven of these retail sectors have factor loadings of over 0.9.[20] In the local framework, the most important Retail cluster component is Health Care Services (621, 622). Not only is this sector the largest employer, but it also has strong linkages in the economy as indicated by its large U_i and U_j values. Hence, although it has a relatively low factor loading of 0.383, its membership in the Retail cluster can be explained through the value chain. Similarly, the same logic of value chain linkages and factor loading explains the cluster membership of many of the manufacturing sectors such as Other Plastic Product Manufacturing (32619) and Electrical Equipment Manufacturing (33531).

In contrast to the local Retail cluster, the domestic Retail cluster includes only 14 industries that satisfy the key industry criteria. None of these fourteen, however, is a retail sector. Also note that while Health Care services is the biggest employer in this framework as well, it no longer ranks as a key sector. Rather, the most important key industry now is Wholesale Trade (42), with a total employment of 258 thousand. Not only is this finding consistent with Chicago's role as a transshipment center of national importance, but it also makes a strong argument for the inclusion of inter-regional trade activities in applied cluster analysis to get a more complete picture of regional cluster activities.

Clearly, the full potential of the Retail cluster in strengthening Chicago's local economic base would not have been apparent if we had limited our analysis to identifying only local clusters without looking at domestic clusters. While the cluster components in the local Retail cluster gain in competitiveness by co-locating next to one another, it is the domestic cluster components including the Wholesale Trade and the Warehouse and Storage sectors that have the potential to boost Chicago's competitiveness through cross-boundary inter-industry trade.

The second cluster we focus on is Financial Services. Unlike the Retail cluster, this cluster differs only slightly in the two frameworks in terms of cluster components and employment. As shown in Table 5, the

[18] In their National Industry Cluster Templates study, Feser and Bergman identified as first cluster Metalworking which consists of as many as 116 individual cluster components.

[19] These five retail sectors are: Food and Beverage Stores (445), Nonstore Retailers (454), Miscellaneous Store Retailers (453), Sporting Goods, Hobby, Book, and Music Stores (451), and Gasoline Stations (447).

[20] These seven retail sectors are General Merchandise Stores (452), Clothing and Clothing Accessories Stores (448), Motor Vehicle and Parts Dealers (441), Furniture and Home Furnishings Stores (442), Health and Personal Care Stores (446), Building Material and Garden Supply Stores (444), and Electronics and Appliance Stores (443).

local cluster has ten components with a total cluster employment of 444 thousand. On the other hand, the domestic framework has nine component sectors and 439 thousand jobs. Funds, Trusts, and Other Financial Vehicles (525) and Other Accommodations (72119, 7212, 7213) are the only cluster components that belong exclusively to the local Financial Services cluster while All Other Miscellaneous Professional and Technical Services belongs exclusively to the domestic Financial Services cluster.

Table 5: Financial Service Clusters Comparison

Local Framework

Financial Services	**Employment**	**Factor Loadings**	**Power of Dispersion (U_j)**	**Sensitivity of Dispersion (U_i)**
Funds, trusts, and other financial vehicles	14,691	0.932	1.32	1.28
Transit and ground passenger transportation	34,501	0.378	1.03	0.97
Other accommodations	798	0.465	1.19	0.76
Securities, commodity contracts, investments	140,991	0.961	0.98	0.94
Monetary authorities and depository credit in	65,767	0.829	0.95	0.96
Legal services	58,454	0.399	0.89	0.92
Accounting and bookkeeping services	53,558	0.768	0.83	0.79
Nondepository credit intermediation and rela	33,263	0.597	0.87	0.87
Hotels and motels, including casino hotels	27,861	0.495	0.92	0.93
Automotive equipment rental and leasing	14,313	0.663	0.94	0.92
	444,196			

Domestic Framework

Financial Services	**Employment**	**Factor Loadings**	**Power of Dispersion (U_j)**	**Sensitivity of Dispersion (U_i)**
Securities, commodity contracts, investments	140,991	0.998	1.09	1.00
Legal services	58,454	0.386	1.08	1.06
Accounting and bookkeeping services	53,558	0.759	1.21	1.20
Transit and ground passenger transportation	34,501	0.371	1.04	1.04
Nondepository credit intermediation and rela	33,263	0.983	1.18	1.18
Hotels and motels, including casino hotels	27,861	0.501	1.19	1.08
Automotive equipment rental and leasing	14,313	0.644	1.07	1.17
All other miscellaneous professional and tech	10,551	0.527	1.22	1.31
Monetary authorities and depository credit in	65,767	0.980	0.85	0.90
	439,258			

Source: Implan Pro and Bureau of Labor Statistics.

The high degree of similarity between the two frameworks in the Financial Services cluster can be viewed as a local phenomena with equally important local and cross-boundary ties, a finding that highlights the important position of Chicago as a financial center in the Midwest and nationwide. Four of the ten local components are establishments directly engaged in financial transactions and/or in facilitating financial transactions. These are Funds, Trusts, and Other Financial Vehicles (525), Securities, Commodity Contracts, and Other Financial Investments and Related Activities (523), Monetary Authorities and Depository Credit Intermediation (521 and 5221), and Nondepository Credit Intermediation and Related Activities (5222 and 5223). Of these four financial sectors, only Funds, Trusts, and Other Financial Vehicles (525) is classifiable as a key industry sector in the local cluster with backward and forward linkage indices of 1.32 and 1.28 respectively. Although the remaining three financial sectors all have below average linkage measures in the local framework, two of them nevertheless stand out as important key sectors in the domestic framework.[21] Furthermore, while eight out of the nine cluster components in the domestic framework qualify as key sectors, only one of the eleven local cluster components meets the key industry criteria. The importance of the Financial Services cluster as whole is thus better captured by the domestic framework.

Our third focus cluster is the Food Manufacturing cluster shown in Table 6.[22] This is an example of a cluster where similarities as well as significant differences between local versus domestic industrial clusters are apparent.

A number of interesting observations can be made from Table 6. First, there is a high degree of similarity in the number of cluster components in the two frameworks, with 26 components in the local cluster versus 23 in the domestic cluster. Another similarity between them is that nineteen component sectors are common to both frameworks.

As for the differences between these two clusters, one interesting finding is that while the local framework shows strong linkages between food manufacturing industries and packaging plastic and paper industries, such linkages do not appear in the domestic cluster. This suggests that a substantial amount of packaging material is provided locally. Of the 26 industries in the local cluster, seven supply plastic and paper packaging materials—essential inputs to the food manufacturing industries. These are Laminated Plastics Plate, Sheet, and Shapes (32613), Plastics Packaging Materials, Film and Sheet (32611), Plastics Bottle Manufacturing (32616), Paper Bag and Coated Paper Manufacturing (32222), Other Converted Paper Manufacturing (32229), Other Plastics Product Manufacturing (32619), and Paperboard Container Manufacturing (32221). In addition, the Doll, Toy, and Game Manufacturing (33993) sector also provides some inputs to the Snack Food Manufacturing industry (31191), namely the toys included in kids meals sold by food manufacturing.

Another difference between the two frameworks is that, in contrast to the local cluster, the domestic cluster shows linkages between food manufacturing and agricultural production activities. The agricultural and fishing-related industries included in the domestic cluster are Crop Farming (111), Animal Production (112), Fishing and Hunting (114), and Animal Food Manufacturing (3111). Since agricultural activities play only a marginal role in the economy of the largely urban Chicago region, inputs such as crops and livestock need to be imported from outside the region. This could explain the existence of strong linkages between food manufacturing and agricultural production activities only in the domestic framework.

A third difference of significance relates to the economic importance of individual cluster components. As indicated in Table 6, seventeen of the 26 cluster components in the local framework qualify as key industry sectors giving the Food cluster an important place in the local economy. In the domestic framework, on the other hand, only one sector—Animal Production (112)—can be classified as a key industry sector.

[21] These two sectors are: Securities, Commodity Contracts, and Other Financial Investments and Related Activities (523) and Credit Intermediation and Related Activities (5222 and 5223).

[22] According to Porter (2003), food processing is one of three specializations in the Chicago region.

Table 6: Food Clusters Comparison

Local Framework

Food	Employment	Factor Loadings	Power of Dispersion (U_j)	Sensitivity of Dispersion (U_i)
Other Plastics Product Manufacturing	24,123	0.617	1.07	1.21
Bread and Bakery Product Manufacturing	14,925	0.987	1.02	1.14
Sugar and Confectionery Manufacturing	8,497	0.642	1.01	1.15
Beverage Manufacturing	6,897	0.919	1.10	1.17
Meat Processed from Carcasses	6,105	0.983	1.20	1.41
Fruit and Vegetable Preserving	5,878	0.983	1.08	1.23
Cookie, Cracker, and Pasta Manufacturing	4,672	0.846	1.03	1.11
Paper Bag and Coated Paper Mfg	4,263	0.884	1.06	1.20
Plastics Packaging Materials, Film and Sheet	3,308	0.916	1.05	1.18
All Other Food Manufacturing	2,706	0.636	1.08	1.19
Grain and Oilseed Milling	2,521	0.637	1.05	1.35
Dairy Product Manufacturing	1,872	0.945	1.02	1.33
Plastics Bottle Manufacturing	1,717	0.887	1.01	1.05
Seasoning and Dressing Manufacturing	1,514	0.960	1.08	1.13
Fishing and Hunting	780	0.982	1.01	1.03
Snack Food Manufacturing	692	0.927	1.10	1.16
Coffee and Tea Manufacturing	171	0.941	1.27	1.06
Paperboard Container Manufacturing	12,865	0.408	0.95	1.28
Animal, Except Poultry, Slaughtering	3,641	0.483	0.92	1.52
Other Converted Paper Manufacturing	1,486	0.875	0.99	1.03
Tortilla Manufacturing	908	0.925	1.01	0.95
Seafood Product Preparation	180	0.990	1.09	0.89
Doll, Toy, and Game Mfg	1,370	0.922	0.92	0.69
Flavoring Syrup and Concentrate Manufacturing	590	0.397	0.89	0.82
Laminated Plastics Plate, Sheet, and Shapes	364	0.933	0.95	0.57
Rendering, Meat Byproduct and Poultry Processing	336	0.977	0.90	0.99
	112,383			

Domestic Framework

Food	Employment	Factor Loadings	Power of Dispersion (U_j)	Sensitivity of Dispersion (U_i)
Animal Production	1,002	0.741	1.58	1.03
Paperboard Container Manufacturing	12,865	0.407	0.87	1.18
Crop Farming	6,175	0.706	0.83	1.22
Animal, Except Poultry, Slaughtering	3,641	0.955	1.10	0.72
Foam Product Manufacturing	3,033	0.682	1.21	0.98
Grain and Oilseed Milling	2,521	0.881	0.76	1.07
Dairy Product Manufacturing	1,872	0.946	1.08	0.72
Fishing and Hunting	780	0.983	1.11	0.87
Flavoring Syrup and Concentrate Manufacturing	590	0.398	1.41	0.96
Animal Food Manufacturing	547	0.693	0.74	1.19
Seafood Product Preparation	180	0.990	1.22	0.86
Bread and Bakery Product Manufacturing	14,925	0.987	0.88	0.63
Sugar and Confectionery Manufacturing	8,497	0.549	0.78	0.96
Beverage Manufacturing	6,897	0.929	0.76	0.63
Meat Processed from Carcasses	6,105	0.985	0.90	0.63
Fruit and Vegetable Preserving	5,878	0.945	0.74	0.88
Cookie, Cracker, and Pasta Manufacturing	4,672	0.838	0.79	0.49
All Other Food Manufacturing	2,706	0.672	0.82	0.51
Seasoning and Dressing Manufacturing	1,514	0.961	0.91	0.66
Tortilla Manufacturing	908	0.941	0.78	0.45
Snack Food Manufacturing	692	0.930	0.82	0.58
Rendering, Meat Byproduct and Poultry Processing	336	0.976	0.94	0.93
Coffee and Tea Manufacturing	171	0.942	0.99	0.64
	85,507			

Source: Implan Pro and Bureau of Labor Statistics.

CONCLUSIONS AND FINAL REMARKS

The literature on analytical industrial cluster identification methodologies has paid much attention to the definition of the study region. Specifically, when using input-output tables to identify industrial clusters based on inter-industry linkages, the question of whether to give preference to a national or to a regional input-output framework has been raised repeatedly in the relevant literature. Promoters of the regional framework, for instance Ó hUallacháin (1984), argue that with data confined to a single region, identified regional clusters represent the gateway to regional economic development. Advocators of the national framework on the other hand, for instance Feser and Bergman (2000), stress the importance of using national input-output tables. Here the focus is on identifying future economic development opportunities through an understanding of missing sectors in existing or potential clusters. But since these two approaches focus either solely on local or on national inter-industry transactions, they are often not able to identify regional clusters that have strong inter-industry linkages with other regions. The domestic clusters identified using our approach overcomes this limitation. We argue that in a framework of demand-side oriented economic development policies with focus on export promotion strategies (Eisinger, 1988), the identification of 'domestic' industrial clusters provides valuable insights of the competitive position of local industries in the larger national economy.

In this research, we applied principal components analysis to two conceptually different input-output frameworks: (i) local framework based on purely regional transactions, and (ii) domestic framework utilizing combined regional and non-regional transactions. This analytical approach allowed us to identify three different groups of clusters—common, unique and analogous—for both the local and domestic frameworks. In addition, we used the backward and forward linkage indices proposed by Beyers (1976) to evaluate the economic importance of individual cluster components and refine the clusters derived from the PCA results. We used the Chicago metropolitan area as a case study to demonstrate the applicability of this approach.

The clusters *common* to both the regional and domestic frameworks include clusters such as Retail, Construction and Building Services, Computer-based Support, and Financial Services. The second group, which we refer to as *unique* clusters, contains clusters that emerged either in the local framework (e.g., Personal Services) or in the domestic framework (e.g., Professional Services), but not in both. And finally, the third group, or *analogous* clusters, includes all clusters that show some similarities between the two frameworks, but which are still too different to be labeled as *common* clusters. Altogether, we have identified eighteen clusters in the local framework and twenty clusters in the domestic framework.

Most of the identified clusters were common to both local and domestic frameworks and illustrate the integration of Chicago in the national economy. The unique local industrial clusters correspond to the regional clusters that would be obtained using purely regional data. They represent industry groups that have strong interactions amongst themselves within the region. The unique domestic clusters, on the other hand, give insights similar to those obtained from the national framework proposed by Bergman and Feser and others, while taking into account the unique features of the local economy. They represent sectors which have strong regional as well as national linkages, and which could over time be induced through appropriate policy measures to increase their vertical and horizontal relationships within the region.

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COMMUNICATION AND RELATIONSHIPS BETWEEN INDUSTRIAL DESIGN COMPANIES AND THEIR CUSTOMERS

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ABSTRACT

This paper examines the nature of relationships and communication modes between US companies in the industrial design sector and their clients. Evidence from a survey of 85 industrial design firms suggests that most of these companies have cultivated close relationships with their customers, and that trust-based relationships are an important contributor to business success. The evidence also suggests that the most successful firms are those that serve non-local markets. Services provided by the industrial design firms integrate all elements of production processes ranging from conducting research, developing existing or emerging products, making final products, to marketing the products. This small sector of the economy offers knowledge-based inputs that are critical to the business performance of both US and foreign manufacturing firms. It is argued that while modern technology rapidly changes the way companies interact with their customers, face-to-face contact between firms and their clients is necessary for relationship-building and long-term success.

Key words: U.S. industrial design sector, face-to-face contact, trust-based relationship.

INTRODUCTION

In recent years, there has been a fast growing trend among industrial firms to hire external sources of technical expertise to support new product development (Beeseley and Rothwell, 1987; Chandra and MacPherson 1994; Hagedoorn 1996, 2002; O'Connor 1996; Coffey and Drolet 1996; MacPherson 1997a). For mature industrial economies such as the United States, a focus upon excellence in product design could improve the sales prospects of import-competing firms in sectors such as apparel, children's toys, and hand-held machine tools (Chandra 1992). External design consultants, for example, were hired by Apple Corporation to develop innovative products including iPod and several other gadgets (Economist 2007). This is not a new phenomenon and has been practiced by major corporations such as Proctor & Gamble, BT, and several drugs giants, all of which have realized the power of admitting that not all good ideas start at home (Economist 2007). Effective design is fundamental to the production system because it can reduce production costs by increasing the overall efficiency of the production process (Bryson et al. 2004). Indeed, design is a complex activity that involves innovation, change, invention, and creativity. These are the fundamental elements which contribute to the development of new products or the modification of existing products (Bryson et al. 2004).

Aside from the benefits generated from using external expertise such as design services, high transaction costs associated with acquiring external technology, lack of control in the innovation process, low incentive for efficiency and effectiveness, and conflicts among partners during development as well as commercialization are some of the disadvantages of accessing external sources of innovation (Chiesa et al. 2004). It is commonly agreed that firms should not outsource core products/services that they deem to be of strategic importance. For industrial design services, the evidence is quite the opposite. Manufacturing firms are increasingly employing industrial design firms to assist them with their core products. In fact, rather than just subcontracting elements of the manufacturing process, companies are now subcontracting a substantial part of the knowledge component of their complete products to independent business service companies (Bryson et al. 2004).

Obviously, for any firm to subcontract its core services to an external firm, a close and trusting relationship must be enforced to avoid a critical mistake that could damage the survival of either firm. Trust has been viewed as beneficial to all parties involved, regardless of their exchange settings (Schurr and Ozanne 1985; Barney and Hansen 1994; Hosmer 1995; Das and Teng 1998; Sheppard and Sherman 1998). In other words, whether it is a business or personal encounter, trust positively helps shape and determine the existing and future relationship between or among the parties involved. So, how big is the U.S. industrial design industry? What kinds of relationships do industrial design firms have with their clients? What are their main communication modes and how important are they? Is locating in close physical proximity to client firms important? Is face-to-face contact important?

Little empirical research has been conducted on a firm level in the industrial design sector. Several economic geographers have drawn attention to the need for empirical work in this area (e.g. MacPherson 1997; Beyers 2003), yet this sector remains under-explored in the United States. Many studies have called for in-depth and specific research on innovation and services in terms of their linkages and relationships (Tether et al. 2001; Chiesa et al. 2004; Drejer 2004). Chiesa et al (2004) calls for in-depth studies focusing on companies that offer services for new product development, from concept definition through design, engineering, prototyping, and laboratory testing to final commercialization and marketing. Bryson et al. (2004) indicated that changes in the nature of manufactured goods affect both the internal organization of manufacturing and service companies as well as their relationships with other organizations such as suppliers and competitors. These changes may well be reflected in the formation of new and geographically different clusters of economic activity or patterns of inter-industry linkage which have hitherto been overlooked (Bryson et al. 2004). In summary, because of increasing national and international competition, the growing utilization of modern technology (e.g. e-mail and the internet), and a general lack of firm-level empirical research on the industrial design sector, this paper seeks to address the above questions by examining the results from a national survey of 85 US industrial design companies.

RESEARCH CONTEXT

The Industrial Design Society of America (IDSA) estimates that industrial design services accounted for around 15% of total US business, professional, and technical service exports in 2004. Using this estimate and the real dollar values of the total US business, professional, and technical service imports and exports provided by the U.S. Department of Commerce, exports of industrial design services accounted for $6,592 million in 1997, rising to $10,456 million in 2003. Similarly, imports of industrial design services almost doubled from $3,184 million in 1997 to $6,126 million in 2003. The primary markets for US design exports are the UK, France, Italy, Canada, Japan, and Australia (in rank order). Similarly, these nations are also the main sources of US design imports. Increasing international trade signals both growing global competition and opportunities for industrial design services. However, little is known about the firms that provide these types of services in the USA.

There are around 1,600 industrial design firms in the USA employing an average of fewer than 20 employees (US Census Bureau 2005). Industrial design firms are professional companies that create and develop concepts and specifications that optimize the function, value, and appearance of products and systems that relate most directly to human characteristics, needs, and interests (IDSA 2003, Bryson et al. 2004). The vast majority of firms in the industrial design sector have only one business location. In addition, thirty percent of all industrial design companies in the USA are one-person units that offer highly specialized services (IDSA 2005).

Geographically, industrial design firms are quite concentrated based on their service types. The cities with the highest number of industrial design establishments from 1998 to 2002 included Chicago, New York, Los Angeles, Long Beach, Detroit, and Boston (Vanchan 2006). Textile design services are commonly provided by design companies located in New York and California, whereas heavy machinery and other types of tooling design services are provided by companies located in Michigan, Ohio, Illinois, Texas, New Jersey, Pennsylvania, and Georgia (Vanchan 2006). With New York City and Los Angeles being the fashion centers, and Michigan, Ohio, Pennsylvania, and Georgia concentrating on machine tools, proximity to customers and manufacturers seems to be an obvious locational factor.

From a regional standpoint, employment in the design industry is focused in a small number of states (U.S. Census Bureau, 2006). The top ten states, according to the latest Census data in 2002, accounted for over 70% of total employment, with a notable concentration of firms in California (18.0% of total jobs), New York (9.9%), Michigan (7.2%), Florida (5.9%) and Illinois (5.2%). For the top three states, 86 new establishments were added from 1998 to 2002 (47 in California, 28 in New York, and 11 in Michigan). An implication is that the design industry contains a large number of young firms. In California alone, for instance, approximately ten new design firms have been starting business each year since the late 1990s. Although most of these new firms are small (i.e. < 5 employees), such firms can grow over time.

According to the Industrial Design Association of America (IDSA, 2003), one of the primary responsibilities of a design consultant is to create product specifications for goods that can be easily manufactured, look attractive, and work well. This means that designers typically operate across many spheres, including production-engineering, aesthetics (artistic creativity), and ergonomics (functionality). The goal is to come up with a blueprint for an item that can be easily made with respect to the tooling characteristics of the client, as well as an item that is aesthetically appealing. When a company subcontracts design services to a professional consultant, the expectation is for an output that scores highly across these types criteria. But why would any manufacturing company want to outsource design?

Many studies have explored the motivations behind the externalization of services (e.g. Coffey and Bailly 1991, Coffey and Drolet 1996, Beyers and Lindhal 1996, Standifird and Marshall 2000, Howells and Tether 2004), which can be concluded as based on both transaction costs and resource-based theories (Vanchan 2006). Specifically, the outsourcing of design services by the US industrial firms has been driven by a mixture of strategic necessity and opportunism. According to Vinodrai (2006), although three-quarters of designers whom she interviewed in Toronto (Canada) began their careers with some form of disciplinary-specific formal education at either the college or university level, a majority of them first started working for other industries and then for a number of employers before they assumed senior positions or started their own studios or businesses. Design-related employment as a percentage of total employment in the US commercial aerospace dropped from 9% to 3% between 1994 and 2004, largely because of layoffs and attrition (Pritchard and MacPherson 2007). Kalafsky (2006) notes that US producers in the machine tool industry are simply unable to attract or retain young people with design-related training. It is not surprising to find that industries that face cyclical demand are not very attractive to young graduates with design skills. Most of these people either join existing consultancies or establish their own companies. As a result, lack of internal expertise forces many manufacturing firms to outsource their design services.

From an *opportunistic* perspective, outsourcing design contributes to major cost savings. As a result, a growing number of US companies are outsourcing designs of their products to other companies (including competitors) in order to churn out products at high speed and low cost (Deutsch 2004). For example, Honeywell contracted IBM to design many of its core processors that go into its fighter jet displays (Deutsch 2004). General Motors Shanghai asked Visteon to design much of the interior of its high-end cars which now sell in China (Deutsch 2004). In outsourcing part of its Boeing 787 wing structure and fuselage, Michael J. Denton, vice president of Boeing Commercial Airplanes Engineering, stated that 'Boeing will always design the airplane's basic shape, but have realized that they don't have to design every detail' (Deutsch 2004). External contracts of industrial design services are usually performance-linked, meaning that design firms get paid very little or do not get paid until the subcontractor starts to earn profit on the project. Some of the initial start-up costs for new product or component development programs are transferred to them from the manufacturers. This is a risky business, but the long-run dividends can be substantial (Vanchan 2006).

Industrial design firms pursue an innovation strategy called 'technology brokering' by combining old ideas in new ways, developing strong social networks both within and outside their groups rather than nurturing individual geniuses, and drawing themselves extensively from the existing work of the operating divisions (Hargadon 2003). They can also be described as knowledge brokers, spanning multiple markets and technology domains. They innovate by brokering knowledge from where it is known to where it is not (Hargadon 1998). In summary, whether for new or improved products, it is apparent that industrial design firms offer a gamut of knowledge-based services that contribute to the innovation efforts of their clients.

With many plausible outcomes from outsourcing of services, there are serious risks associated with outsourcing strategic functions such as design (Hoecht and Trott 2006). Outsourcing design services means that firms are subcontracting a substantial part of the knowledge component of their complete products to independent business service companies (Bryson et al. 2004), which involves a transfer of both codified and tacit knowledge to the outside supplier (Vanchan 2006). Tacit knowledge is an internal asset that most firms want to keep secret. Why would any firm want an external organization to access this knowledge? There are two possible answers to this question. The first reason lies in the repeat-business nature of design services. For example, Vinodrai (2006) found that design careers in Toronto are characterized by repeated collaboration and joint career paths. Moreover, the career paths of designers are intricately interwoven with one another, building a repertoire of shared experience and institutional common ground (Vinodrai 2006). The second reason that explains the outsourcing of core design rests on the basis of trust-based relationships between industrial design firms and their clients. Designers also build long-term relationships with other designers whom they collaborated or worked with throughout their careers (Vinodrai 2006). These relationships often lead to employment and additional work for the designers (Vinodrai 2006). The advantage is likely to be sustainable if a firm can generate competitive advantage through cooperative buyer-supplier relations (Mudambi and Helper 1998). Moreover, trust, in any sort of exchange, is a source of advantage (Schurr and Ozanne 1985; Barney and Hansen 1994; Hosmer 1995; Das and Teng 1998; Mudambi and Helper 1998; Sheppard and Sherman 1998).

Goe et al. (2000) suggest that more advanced services, such as industrial design services, exhibit lower levels of contact sensitivity because of their long duration and high cost. In addition, the need for face-to-face interaction varies directly with the technological intensity of the client sector, in terms of service delivery modes (Goe et al. 2000). On the other hand, many scholars suggest that face-to-face contact is key to advanced service provision despite the potentially moderating influence of new information technology and the internet (Gertler 1995; Bennett and Robson 1999; Byers 2003; Chiesa et al. 2004; Storper and Venables 2004).

Based on the above discussion and studies, it is evident that outsourcing of industrial design services has increased nationally and internationally. As noted earlier, this outsourcing trend is driven by a mixture of strategic necessity and opportunism. The geographic proximity between firms and their clients appears to be the rational location choice. Is this true for the US firms in the industrial design industry? What are their main client sectors? Where are their clients located? On the other hand, although many studies agree that communication is a key to any successful business relationship, they do not necessarily agree on the modes of communication between firms and their clients. Does the need for face-to-face contact in the design business vary directly with the technological intensity of the client sector? The following sections describe the results of a firm-level survey which was conducted to supply answers to the questions set forth above.

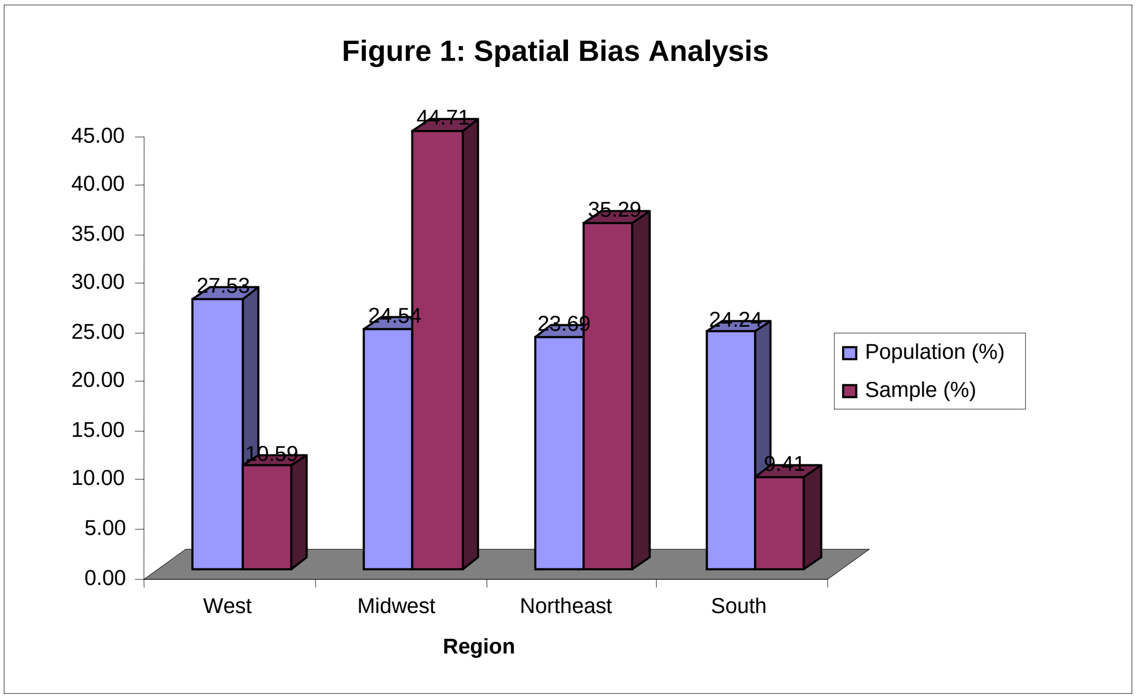
SURVEY METHODOLOGY

A list of industrial design companies was extracted from Reference USA (www.referenceusa.com), which is a databank organized by North American Industry Classification System (NAICS) codes. Industrial design has 54142 or 541420 as its NAICS codes. The official NAICS definition of the industrial design sector is 'an industry that comprises establishments primarily engaged in creating and developing designs and specifications that optimize the use, value, and appearance of products' (NAICS, Executive Office of the President Office of Management and Budget 2002). However, serious limitations come with the use of NAICS codes for industry identification. For example, firms that specialize in contract R&D may also offer design services. Similarly, large firms that mainly sell management consulting services may also have design divisions. Therefore, from this perspective, the task of identifying the design industry is far from straightforward.

A total of 759 companies with either NAICS code was listed in Reference USA database in 2005. This number is smaller than the Census Bureau's 2005 estimate of 1,600 companies because firms are under no obligation to register with Reference USA. All 759 companies were contacted by phone to encourage participation in the survey. These initial contacts screened out a total of 74 companies that were wrongly coded by Reference USA (i.e. most of these companies were graphic and/or interior design units). Of the remaining 685 companies in the database, 389 agreed to participate in the study. Thus, three-hundred and eighty-nine questionnaires were mailed to the participants. A total of 85 companies completed the survey, resulting in a 21% response rate.

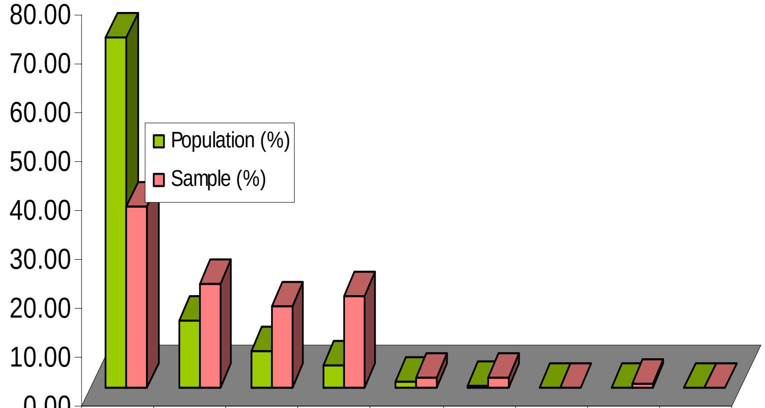
The survey instrument was designed to obtain basic data on firm-level attributes (e.g. employment size, age, occupational structure); the nature of their relationships with customers; competitive and market attributes (e.g. sectors served, sales territories, export activity); recent growth performance in terms of employment, sales, and profitability; and a variety of innovation measures including investment in new technology and worker training.

The response rate of 21% was quite disappointing even though response rates of 20% or lower are prevalent in surveys of small companies (Bartholomew and Smith 2006; Dennis 2003). It was not possible to probe for non-response bias because the sampling frame contained insufficient data to compare respondents with non-respondents. The alternative technique was to compare early versus late respondents (the assumption is that the latter more closely resemble non-respondents). Unfortunately, this approach was not possible either, as around 90% of the surveys were received within ten days of the initial mailing. One source of bias in the sample concerns surveyed firms' locations. The sample appeared to over-represent firms in Rustbelt locations, and under-represent firms in the South and West (see Figure 1). On the other hand, the sample is representative of the broader population in terms of the size distribution of firms as reported by the US Census Bureau in 2005 (see Figure 2).



Source: Figure created by the author in Vanchan (2006) with data from the survey and the U.S. Census Bureau of the industrial design establishments in 2002

Figure 2: Size-Class Bias Analysis



	1-4	5-9	10-19	20-49	50-99	100-249	250-499	500-999	1000 or more
Population (%)	71.32	13.82	7.61	4.87	1.46	0.73	0.06	0.06	0.06
Sample (%)	36.90	21.43	16.67	19.05	2.38	2.38	0.00	1.19	0.00

Total Number of Employees

Source: Figure created by the author in Vanchan (2006) with data from the survey and the U.S. Census Bureau of the industrial design employment in 2002

SURVEY RESULTS

Table 1 gives a synopsis of the basic characteristics of the surveyed firms. The youngest firm in the sample was three years old at the time of the survey, whereas the oldest was established 67 years ago (the modal age was around 17 years). Although the average size of employment is 22.5 workers, the typical design company is a single-person unit (mode = 1 employee). This average reflects a rather abnormal distribution because one firm employs around 600 people. In terms of the employees' skills, the surveyed firms employ, on average, around four professional designers, two engineers, and two specialists in related fields. Moreover, the majority of firms (87.1%) have only one-business location.

Table 1: Basic characteristics of responding firms

	Mean	Median	Mode	Minimum	Maximum
Age (years)	1982.7 ≈ 1983	1986	1989	1939	2003
Size (total number of employees)	22.43 ≈ 22	7	1	1	600
Number of Designers	3.66 ≈4	2	1	0	23
Number of Engineers	2.06 ≈ 2	0	0	0	50
Number of other Professionals	2.10 ≈ 2	0	0	0	80
Multi-branch organization	Yes	No			
	11 (12.9%)	74 (87.1%)			

Source: Vanchan (2006)

Table 2 summarizes the types of assistance provided by the surveyed firms. A majority of firms (90.1%) assist their customers in developing new designs or products. Increasing clients' revenues (83.75%) comes in second, followed by improving clients' product quality (80.3%), improving clients' products' styles and aesthetics (79%), easing clients' manufacturing performance (77.8%), reducing clients' product defect rates (72.8%), improving clients' technological performance (70.4%), conducting research (70.4%), and improving clients' ergonomics (64.2%). In summary, the data indicate a positive contribution in all categories among the majority of respondents.

Face-to-face linkages and the nature of relationships

The results indicated that firms rated similarly on the importance of modes of communication and delivery of products/services based on 5-point Likert scales (see Table 3). From a communication perspective, face-to-face communication ranks first (72.9%) as the most important mode of communication, followed by e-mail or internet (65.9%), telephone (51.2%), fax (16.5%), and mail (10%). From a service delivery perspective, a face-to-face method still holds the first position (63%), followed by e-mail or internet (60%), telephone (38%), mail (17.5%), and fax (10.1%) (Table 3). Moreover, a chi-square test revealed no statistically significant variations between the need for face-to-face contact and the technological intensity of client sector (P = 0.774). In other words, a majority of the surveyed firms indicated that face-to-face meetings with clients are critically important across all phases of project development, regardless of the technological intensity of their client sectors. Typically, most design contracts start and finish with face-to-face discussions with clients. The front end of a contract usually begins with face-to-face conversations to establish design parameters, payment conditions, timelines, and other aspects of the business relationship (e.g. the identification of project liaison teams). The rear end of a contract usually requires site visits by the consultant to showcase the nature of the output, which can include anything from helping the client with tooling setup to explaining the technical attributes of the final outputs.

Table 2: The types of assistance provided to client firms

Type of Assistance	Yes	No
Conducting Research	57 (70.4%)	24 (29.6%)
Developing New Designs or Products	73 (90.1%)	8 (9.9%)
Reducing Clients' Product Defect Rates	59 (72.8%)	22 (27.2%)
Easing Clients' Manufacturing Performance	63 (77.8%)	18 (22.2%)
Increasing Clients' Revenues	67 (83.75%)	13 (16.25%)
Improving Clients' Product Quality	65 (80.2%)	16 (19.8%)
Improving Clients' Ergonomics	52 (64.2%)	29 (35.8 %)
Improving Clients' Products' Styles and Aesthetics	64 (79%)	17 (21%)
Improving Clients' Technological Performance	57 (70.4%)	24 (29.6%)

Source: Vanchan (2006)

Table 3: Importance ratings of modes of communication and delivery of products/services

Importance of communication and delivery modes	Zero		Low		Medium		High	
	Comm.	Delivery	Comm.	Delivery	Comm.	Delivery	Comm.	Delivery
Face-to-Face	2 (2.4%)	5 (6.2%)	3 (3.5%)	6 (7.4%)	18 (21.2%)	19 (23.5%)	62 (72.9%)	51 (63%)
Telephone	4 (4.8%)	14 (17.7%)	4 (4.8%)	15 (19%)	33 (39.3%)	20 (25.3%)	43 (51.2%)	30 (38%)
Fax	22 (25.9%)	31 (39.2%)	22 (25.9%)	27 (34.2%)	27 (31.8%)	13 (16.5%)	14 (16.5%)	8 (10.1%)
Mail	31 (38.8%)	29 (36.3%)	28 (35%)	30 (37.5%)	13 (16.3%)	7 (8.8%)	8 (10%)	14 (17.5%)
E-Mail/Internet	5 (6.1%)	6 (7.5%)	9 (11%)	8 (10%)	14 (17.1%)	18 (22.5%)	54 (65.9%)	48 (60%)
Other	0 0%)	0 (0%)	0 (0%)	1 (10%)	3 (75%)	0 (0%)	1 (25%)	9 (90%)

Source: Vanchan (2006)

Most firms indicated in writing that electronic modes (internet-based) of interaction have not reduced the need for face-to-face interactions, even though such modes have become quite important for exchanging design drafts and large files. Moreover, face-to-face meetings, according to most firms, help to build trust-based relationships with clients. Over half of all the firms' sale revenues over the last five years come from existing customers (see Table 4). Existing customers account for an average of 73.39% of the firms' sales over the last five years (Table 4). This underscores the importance of existing customers to the firms within the industrial design industry and the fact that customer retention is a top priority. Having an existing relationship with clients was also found to be one of the top five factors that contribute to firms' success (see Vanchan 2006). Eighty percent of the respondents view their existing relationship with their customers as the most successful marketing approach for their businesses. Moreover, seventy- three percent of the respondents consider word-of-mouth as their most successful marketing approach (see Vanchan, 2006).

Table 4: The nature and change of the relationship between responding firms and their customers

<table>
<tr><th>% of sales over the last five years</th><th>Existing customers</th><th colspan="3">New customers</th></tr>
<tr><td>Mean</td><td>73.39%</td><td colspan="3">26.61%</td></tr>
<tr><td>Median</td><td>80%</td><td colspan="3">20%</td></tr>
<tr><td>Mode</td><td>80%</td><td colspan="3">20%</td></tr>
<tr><td>Minimum</td><td>0%</td><td colspan="3">0%</td></tr>
<tr><td>Maximum</td><td>100%</td><td colspan="3">100%</td></tr>
<tr><td rowspan="2">Relationship with customers</td><td>Not close at all</td><td>Medium or somewhat close</td><td colspan="2">Very close</td></tr>
<tr><td>1 (1.2%)</td><td>24 (28.6%)</td><td colspan="2">59 (70.2%)</td></tr>
<tr><td rowspan="2">Changes in relationship with customers compared to 3 years ago</td><td>Remained unchanged</td><td>Have changed but only slightly</td><td>Have changed to a significant extent</td><td>Have changed completely</td></tr>
<tr><td>44 (53%)</td><td>25 (30.1%)</td><td>13 (15.7%)</td><td>1 (1.2%)</td></tr>
</table>

Source: Vanchan (2006)

An overwhelming majority of the surveyed firms (98.8%) described their relationship with customers as somewhat close or very close (see Table 4). When asked to identify changes compared to three years ago, not much change was found in the firms' relationships with customers as more than half of the surveyed firms (53%) indicated that their relationship with customers has remained the same or unchanged compared to three years ago. Most importantly, those changes were positive rather than negative. For example, some firms indicated that they were more driven by clients needs and improved technology. Some were calling, visiting clients more often, and spending more time at customers' locations. For changes in the relationships with other businesses, some firms indicated that they had established a larger vendor base and more networking.

In summary, face-to-face contact was found to be strategically important for all participating firms and did not vary with the technological intensity of client firms. Most firms had a close relationship with their clients and relied more on existing customers than new customers. If there were any changes in their relationship, they were only positive rather than negative changes.

Geographic location and proximity issues

Thirty-one percent of respondents are automotive component or sub-assembly designers, followed by textiles (26.2%), machinery (21.4%), household goods (13.1%), and aerospace designers (8.3%) (see Table 5). Around forty-four percent of the surveyed firms are located in the Midwest, followed by the Northeast (35%), West (11%), and South (9%) (see Figure 1). According to the latest data from the US Census Bureau, 27.53% of all industrial design firms are located in the Western region, followed by 24.54% in the Midwestern region, 24.24% in the Southern region, and 23.69% in the Northeastern region (Figure 1). Therefore, the sample over-represents firms in Rustbelt locations, and under-represents firms in the southern and western regions of the United States. Even so, cross-tabulation results indicated statistically significant differences between customer segments and the regional location of the survey firms (Chi-Square = 0.001). This evidence suggests that the design skills of the responding firms reflect the nature of industrial demand in their home regions. In other words, there is a distinct geography of industrial design firms based on their specialization in that most firms exhibit a client focus that reflects the nature of nearby production. For example, firms that cater to the aerospace sector locate in aircraft producing states such as Washington and California; whereas those that cater to the machine tool builders are clustered in Ohio and Illinois.

Respondents were asked to identify their client locations and to rate the importance of locating in close proximity to these buyers in order to address the geographical proximity issues between industrial design firms and their customers. A majority of them (55 or 64.8%) indicated that it is either important or very important to locate in close physical proximity to their customers (see Table 5). Again, industrial design firms are highly specialized; thus, their location decision reflects their specialization, customer focus, and the structure of nearby production. A single firm may have customers in multiple locations ranging from local to international. Customers could locate within a firm's local area and region, across the country, or outside of the country (across the world). A local area is an area within 30 miles or 50 kilometers radius of each firm's main business location. This metric is used in conformity with a standard metric that was used in the European Union's project in studying design and innovation a few years ago (Howells and Tether 2004). A region is defined by the Census Bureau's regional divisions. Each primary customer location is determined by the percentage of sales from which that location generates compared to other locations. For instance, firms having primary local and regional markets are those that have the highest percentage of sales coming from customers located within the same metropolitan region; firms having national markets are those that have the highest percentage of sales coming from customers across the country; and firms having global markets are those that have the highest percentage of sales coming from foreign customers. Table 5 summarizes the main customer locations (current, five years ago, and next five years) corresponding to all three location categories described above, the importance ratings of locating in close physical proximity to client firms, and the relationship between the customers' locations and growth.

Table 5: Main client sectors, main customers' locations, characteristics, and relationship with growth

Main client sector served	Automotive	Aerospace	Machinery	Household goods	Textiles /Apparel	
Current	25 (31%)	7 (8.3%)	18 (21.4%)	11 (13.1%)	22 (26.2%)	
Main customer's location	**Local and Regional**		**National**		**Global**	
Current	55 (64.7%)		26 (30.6%)		4 (4.7%)	
Five years ago	48 (64%)		23 (30.7%)		4 (5.3%)	
Next 5 years	41 (61.2%)		23 (34.3%)		3 (4.5%)	
Importance of locating in close physical proximity to customers	**Zero**		**Low**		**Medium**	**High**
	14 (16.5%)		16 (18.8%)		36 (42.4%)	19 (22.4%)
Growth			**Local/Regional**		**Non-Local**	**P Value**
Employment	Zero		56.5%		20.7%	.004*
	Negative		26.1%		31%	
	Positive		17.4%		48.3%	
Sales	Zero		47.7%		28.6%	.139
	Negative		27.3%		25%	
	Positive		25%		46.4%	
Profits	Zero		31.8%		25.9%	.276
	Negative		38.6%		25.9%	
	Positive		29.5%		48.1%	
Exports	Zero		47.8%		25%	.354
	Negative		8.7%		12.5%	
	Positive		43.5%		62.5%	

*= Statistical significance (P<0.05)

Source: Vanchan (2006)

From a sales perspective, 55 (64.7%) identified their current customers to be mainly located within their local and regional areas; 26 (30.6%) to be located across the country; and four (4.7%) to be located across the world (see Table 5). In other words, the majority of firms are local/regional in focus, followed by nationally and globally oriented firms. The distribution of sales generating from all customers' locations has not changed over the last five years, and is expected to remain unchanged in the next five years. Over half of all respondents (64.8%) indicated that locating in close physical proximity to their customers is an important factor. Around nineteen percent (18.8%) of the respondents considered this as of low importance, while 16.5% considered this to be unimportant. These data indicate no change in the locational patterns of survey firms' main customers over the last five years and in the next five years.

A cross-tabulation analysis was conducted in order to explore the relationship between firm-level growth and the existence of non-local markets. Two main customers' markets (i.e., local/regional market and non-local market) were constructed based on their corresponding sales. The local/regional market was defined based on the percentage of sales generated from local and regional areas (i.e. > 50% of sales come from local and regional customers). On the other hand, the non-local market was defined as having more than half of sales generated outside of the local and regional areas (> 50% from national and global customers).

Firms serving non-local customers experienced more growth in all areas: employment, sales, profits, and exports (see Table 5). For example, 62.5% of firms serving non-local customers experienced positive growth in their exports over the last five years, whereas only 43.5% of firms serving local or regional customers experienced growth in their exports. Similarly, around forty-eight percent of firms serving non-local markets experienced positive growth in their profits over the last five years, compared to 29.5% of those serving local markets. Only twenty-five percent of firms serving local markets/customers experienced growth in their sales over the last five years, while almost half of firms serving non-local markets/customers experienced sale growth. Around eighty-three percent of firms serving local customers experienced no growth and a deficit in their employment over the last five years, compared to 51.7% among those serving non-local customers. In summary, the rates of company growth have been fastest for industrial design firms that have been developing non-local markets.

SUMMARY AND CONCLUSIONS

Increasing employment of industrial design services to assist core product development, manufacturing, and to some extent product marketing, highlights the significance of the industrial design services and intimacy of the relationship between the industrial design firms and their clients. It is apparent that the types of assistance provided by the industrial design firms are characterized by high levels of scientific and/or artistic intensity (Windrum and Tomlison 1999, Miles 2000, Muller and Zenker 2001, Chiesa et al. 2004), and are known to support the creative needs of users (e.g. Rothwell 1977, MacPherson 1997b, Gemser and Leenders 2001, Bryson et al. 2005). As a result, firms in the industrial design sector provide knowledge-based inputs that spur innovation, which is increasingly vital to the survival and success of modern industrial firms, including major corporations such as Boeing, Caterpillar, General Motors, and Ford (Reina and Tulacz 2001, Hoecht and Trott 2006).

The survey results suggest that the industrial design business is mainly built upon repeat contracts and an existing customer base. This finding supports Vinodrai (2006) on the importance of reputation-building, shared career paths, and repeated collaborations in the design business. With the sensitive nature of exchanged services involving a transfer of codified and tacit knowledge, close and trust-based relationships have been viewed as important factors for long-term relationship building as well as strategic imperatives for the business survival of both design firms and their clients. The intimacy of the relationship in this paper, however, is voiced from a vendor perspective (i.e. the industrial design firms, not the manufacturing firms). Therefore, future studies are needed to shed more light on this interwoven relationship from the client perspective.

With rapidly growing modern modes of communication such as e-mail and the world-wide-web, the results indicated that face-to-face communication is still of strategic and operational necessity to the design businesses; from generating the first impression and hammering out plans, to demonstrating the nature of the output and assisting clients with all relevant issues. In other words, while acknowledging the rising use and popularity of electronic modes of communication across many different horizons, the findings suggest that a conventional form of communication (i.e. face-to-face interaction) is not expected to become obsolete in the foreseeable future.

A concentration of design firms' locations based on their service types is evident as regional specializations were found among the surveyed firms. However, the results indicated that while locating in close physical proximity to customers is important, the most successful firms were those that serve non-local markets. Furthermore, firms that export and operate with foreign customers tend to exhibit faster growth rates than firms that cater to the domestic market alone. By expanding their target markets, firms are able to attract more customers. As globalization continues, it is crucial for firms in the design sector to deviate from their local-market focus by searching for additional market opportunities if long-term growth is their goal.

In summary, face-to-face communication between industrial design firms and their clients is necessary for relationship-building and long-term success. Trust-based relationships and market diversification are also the critical determinants of their success. Detailed qualitative work is needed in future research, including case studies at the firm-level with regard to the relationship-building and related processes that allow for the development of long-term partnerships between industrial design firms and their clients. As discussed earlier in this paper, outsourcing of design services has been criticized as risky because both tacit and codified knowledge must be transferred to the outside supplier which might give potential competitors access to this knowledge. The risks, however, appear to be neutralized or reduced by the development of trust-based relationships between industrial design firms and clients. These relationships typically breed repeat business. But how are these relationships built in the first instance? Do they start with low-risk or simple projects, and then move to more sophisticated or higher-risk projects? How are new clients found? How have relationships between design firms and their clients evolved over time? The author is currently pursuing follow-up case studies in order to shed light on these questions. For example, early results suggest that very small firms are able to offer a comprehensive array of product development services because they network collaboratively with other design companies.

On a final note, this paper helps offer key results to shed light on a sector that has been overlooked and little studied, especially among economic geographers in the United States. Although my results are still preliminary and a more qualitative study of the industrial design firms and their clients is still needed, the results are important in understanding the contribution of this sector to the overall U.S. economy and its relationship with the U.S. manufacturing sector.

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