WHITHER OR NOT INDUSTRIAL CLUSTER: CONCLUSIONS OR CONFUSIONS?

Rainer vom Hofe
School of Planning
University of Cincinnati
Cincinnati OH[1]

Ke Chen
Department of Geography
University of Cincinnati
Cincinnati OH

Abstract

Over the past fifteen years, regional industrial cluster development has gained popularity as a vital economic development strategy to boost competitiveness in a globalizing economy. Moreover, many policy makers and academicians see industrial cluster analysis as the ultimate policy panacea. With the mushrooming of industrial cluster studies, the relevant literature on industrial clusters offers a wide variety of definitions and methodological approaches for identifying clusters. This paper will take a closer look at past and present approaches to industrial cluster analysis from different angles. It will first systematically explore the theoretical foundations used to explain the phenomena of co-location of firms and businesses. Secondly, numerous concepts and definitions used by cluster enthusiasts are then presented in the context of their theoretical foundation. Then, using selected influential key cluster studies, various methods of identifying industrial clusters are compared and contrasted with special attention to the problem of addressing the notion of geographic proximity.

[1] Many thanks to Howard Stafford, Professor of Geography Emeritus at the University of Cincinnati, for his insightful comments in the preparation of this manuscript.

INTRODUCTION

Since the early 1990's, industrial cluster analyses have proliferated as an alternative economic development (ED) strategy. The Cluster Meta-Study by van der Linde and Porter, both associated with the Harvard Business School, collected information on 833 clusters from as many as 49 countries until 2002 for various target industries at different geographic scales. Akundi (2003) in a survey of state cluster initiatives has identified that as many as 40 states in the U.S. have engaged to a greater or lesser extent in industrial cluster analyses to promote economic development. But despite the increasing popularity of industrial cluster theory for economic development policy analyses there probably has never been more chaos, diffusion, and misinterpretation among ED practitioners and academicians alike on proper cluster definitions, appropriate cluster identification methodologies, and their translation into cluster-based economic development policies. In other words, there exists no single conceptual and analytical framework that, when correctly applied, will help identifying regional industrial clusters. On one hand it appears that the conceptual framework of cluster analysis is usually well understood. Given that all concepts of cluster definitions - the underlying principles for cluster formations - can be explained by a rich body of literature that took off with Marshall's original idea of specialized industrial location (1890), one would expect consistency in cluster theory, cluster identification, and cluster-based economic development policies. But the contrary becomes quickly apparent when reading through relevant industrial cluster literature. Overall, there appears to be little evidence in the literature on how the conceptual framework and its cluster definition(s) are translated appropriately into a methodological approach which in return allows an identification of industrial clusters useful for shaping economic development policies.

Akundi (2003), for instance, surveyed in greater detail 25 state-level cluster studies and found that 16 studies relied at least partly on the use of quantitative methodologies, of which 9 studies exclusively relied on location quotients and shift-share techniques. Doeringer and Terkla (1995) and Rosenfeld (1997) already have emphasized that these methods are by no means sufficient, either alone or in combination, to actually identify industrial clusters, suggesting some confusion and misunderstanding with respect to methodological approaches of cluster identification. Technically, location quotients measure industrial specialization and shift-share breaks down observed sectoral industry growth into three distinct growth components: a national, regional, and an industry-specific growth factor. While these economic base techniques are valid methods for evaluating regional specialization and growth by industry, they fail to account for one main argument made by many cluster enthusiasts: grouping industries according to interindustry interdependencies as expressed, for instance, by interindustry trading patterns. For instance, the car manufacturing industry in Detroit with all its complementary suppliers would be such an industrial cluster. In addition, economic base techniques contribute little to the understanding as to why firms and businesses cluster spatially, a topic that has been addressed in the recent literature (Feser, Koo, Renski, and Sweeney, 2001).

Porter's (1990) now prominent book *The Competitive Advantage of Nations* indisputably contributed significantly to the renaissance of today's cluster theory and has released an avalanche of cluster studies. Porter widened the conceptual avenue of cluster theory in his *Diamond of Advantage*, where he sees national competitive advantage as being built on four main pillars - namely, factor conditions; demand conditions; related and supporting industries; and firm strategy, structure, and rivalry. While Porter refocuses on the innovative nature of competition rather than on different aspects of cost minimization, the more traditional comparative advantage focal point of agglomeration economies, his critics, for example Martin and Sunley (2003), argue that Porter's cluster concept is rather intuitive and does not add groundbreaking new insights to cluster identification methods. Many of today's cluster enthusiasts, including Bergman and Feser (1999, 2000) still rely on statistical techniques introduced more than thirty years ago by scholars like Czamanski (1974, 1979), Roepke et al. (1974) and Ó hUallacháin (1984). More specifically, they argue that input-output tables to some extent reveal interindustry linkages and thus may be useful for industrial cluster identification.

So why is it that, unlike many other disciplines in economic development, cluster identification and therefore cluster-based economic development policies, although widely applied, are still subject to confusion? Is the confusion attributable to a misinterpretation of cluster building forces, or simply a lack of understanding as to how this methodology can help practitioners improve locational competitiveness for identified industrial clusters? Obviously, we are not the first to take a closer look at selected and influential industrial cluster publications and studies. The main goal of this paper is to provide a coherent and comprehensive review of the relevant industrial cluster literature. This review focuses primarily on cluster concepts that are grounded in pure agglomeration theory, industrial complex theory and the fusion of locational analysis with input-output analysis. Taking a regional science perspective on clusters, we try to make the connection between: i) why establishments tend to concentrate geographically – the *explanations* for industries to group in geographic proximity; ii) the various cluster definitions that can be derived from the rationale and the driving forces for geographic proximity – the *concepts*; and iii) the qualitative and quantitative methods and techniques applied to identify industrial clusters – the *methodologies*. We argue that all three main aspects must be addressed appropriately in a coherent way in order to identify meaningful industrial clusters.

This literature review is organized as follows. The next section outlines the major theories behind industrial cluster analysis—that is, why firms cluster in geographic proximity. In the third section, we explore three different cluster concepts and analytical methods: 1) clusters based on the theoretical principles of localization economies, 2) clusters accounting for interindustry relationships found in input-output analysis and 3) clusters that use a wider theoretical base, i.e., account for more than one single cluster characteristics. For each of the three identified cluster concepts, section four presents selected industrial cluster studies, the various cluster identification methodologies used, and key findings. Additionally, we highlight how, if at all, the issue of spatial proximity has been addressed in the selected studies. Finally, chapter five provides general conclusions and remarks on cluster concepts.

HISTORICAL PRECEDENTS OF TODAY'S INDUSTRIAL CLUSTER THEORIES: FINDING THE EXPLANATIONS FOR WHY FIRMS CLUSTER

There is little doubt concerning the relevance of geographic proximity of firms to one another and to large market areas, and accordingly location theory has a longstanding tradition in economic theory. Von Thünen's (1826) conceptual model of the relationship between markets, productions, and transportation can be seen as one of the earliest approaches to spatial economics. According to von Thünen's model, farmers maximize profits based on market prices net of production and transport costs. Outcome is a land use model where mono-functional land uses (i.e., different farming activities) are distributed in concentric rings around the central market place. Highly productive activities, such as gardening and dairy production, are close to the central market and less productive: for instance, livestock farming is located further away.[2] In this sense, von Thünen's model is very similar to Ricardo's classical locational analysis, where differences in the profitable cultivation of land are important. From a microeconomic perspective, von Thünen's concentric rings guarantee an upward sloping supply curve while any factor substitution or any marginality concepts are absent from the model. Launhardt (1885) and Weber (1909) conceptualized what can be seen as a second type of classical location analysis. In the Launhardt-Weber model, the focus shifted from different types of land uses to the production functions of firms. Here, cost minimizing firms face fixed input-input and fixed input-output relationships. The quantity of inputs required and the quantity of outputs produced together with transportation costs became the major issues for cost minimizing firms (McCann and Sheppard, 2003).

Weber's 1909 book on the *Theory of the Location of Industries* recognized the importance of location-specific economies of scale in manufacturing geography. However, Marshall (1890, 1920) is usually cited in the relevant literature as the first to acknowledge that the economic productivity of firms and businesses results from the location and proximity of economic agents to each other. Marshall identified three specific *sources of agglomeration economies* which foster spatial cluster formation through increasing returns to scale in the long run: *knowledge spillovers* among firms, *labor market pooling*, and cost advantages produced by the *sharing of industry-specific non-traded inputs*. Important in Marshall's localization economies is that all firms and businesses belong to the same industry sector and that proximity of firms in the same industry increases the innovation abilities of the whole industry in the locality. It was Hoover (1948) who, then, subsequently explained, partly based on Marshall's principles, that agglomeration of firms and businesses of the same or different industry is important for individual firm success. Hoover identified three *types of economic agglomeration*: economies of localization, economies of urbanization, and internal returns to scale. *Economies of localization* precisely follow Marshall's three sources of agglomeration, and as such are external to firms and business within the same industrial sector. *Economies of urbanization*, a second external factor, explains geographic proximity of establishments across different industry sectors by emphasizing the beneficial effects to firms and businesses from the existence of large, diverse markets predominant in large metropolitan areas. *Internal returns to scale*, an internal location-specific factor, accrues through the existence of large and specialized factors of production. Here, location becomes an important agglomeration force in that larger and more specialized quantities of investment and labor may lead to production cost advantages and technology improvement for establishments. However, the differences between these three economic agglomeration forces can, depending on the definitions of establishments and industry sectors, be very blurry and overlapping (McCann, 2001).

Marshall and Hoover's contribution to explaining geographic proximity among establishments paved the way for regional economic development theories emerging in

[2] Von Thünen assumed: that i) the marketplace is in complete isolation from the rest of the world without any trade activities, ii) all land surrounding the market place is uniform, and iii) there exists no transport infrastructure.

the 1950's and 1960's. Perroux (1950), for instance, built upon Marshall's and Hoover's theories of auxiliary industries in industrial clusters by conceptualizing his *growth pole / development pole theories*. In post-Schumpeterian tradition, Perroux focused on innovations and investments which are the driving forces behind industrial development. Large vital and prevailing firms – the growth poles – spread positive economic effects onto other smaller firms in geographic proximity, and as such growth poles act as a catalyst of positive economic development – the spread effects. The downside of growth pole theory is that large investments may also result in augmented factor prices, leading to efficiency loss – the backwash effects. Economic space, according to Perroux, is a rather abstract and homogenous environment in which firms and businesses (or industries) buy from and sell to one another following centrifugal and centripetal forces. Later, Perroux (1988) added to his theory the notion of time in that growth poles pass through two stages: a first stage in which firms and businesses cluster, and a second stage in which growth spreads to the outside enterprise through the flow of goods, investment, and information. Myrdal's (1957) *core-periphery model* addresses spatial concentration of economic activities, and therefore sustained economic growth, by focusing on geographic dualism in economic activities. Myrdal underlined the fact that labor and capital agglomerate at locations where they can obtain the highest return in a free market. Circular and cumulative causation effects then explain why more developed regions, with a competitive advantage in factor endowments and modern sectors, are inevitably able to strengthen their competitive advantage while simultaneously disadvantaged regions with more traditional sectors fall further behind. According to the available mix of factor endowments, regions thus will show differences with respect to the composition of industry groupings and their contributions to economic development. Important with respect to the cluster concept is also the idea of path dependence which adds a *time* component to cluster theory. Self-reinforcing, cumulative processes elucidate innovations and investment decisions which in return directly form regional economic systems, industry sectors, and social and institutional structures (Britton, 2004). Thus, industrial clusters evolve according to the path dependency and can be classified as emerging, existing, or regressing industrial clusters. Vernon (1966) in his *product cycle theory* argues that the location of firms is influenced by a combination of market demand, technology change, and labor costs. As innovation activities concentrate in technically more advanced countries, more standardized production spreads to less developed areas. Vernon also added the time component to the concept of geographic proximity. According to Vernon, firms and businesses go through a series of technological and geographical transition stages. New products are developed in highly advanced and modern industrial clusters that exhibit a high level of knowledge spillovers in Marshallian tradition. Vernon further stresses that regional competitiveness depends to a large extent on demand market change, technology change, and change in production costs, all of which are subject to dynamic changes. Time becomes an important component when establishments make their choices about where to locate, and analogously industrial clusters are dynamic structures by nature. For regional economic development policies, this plays an important role as the maturity of a product – the product cycle – dictates the stage of a cluster. And each of the stages in the product cycle has different and often very specific factor requirements.

Isard et al. (1956) actually coined the expression *industrial complex.* Recognizing that one specific product can be manufactured by multiple activities, they developed the trailblazing application of using an input-output table to quantifying the cost advantage of combining a region's industrial activities characterized by intensive forward and backward input-output linkages. Isard et al. contributed the conceptual understanding of agglomeration economies in their pioneering work on the association of economic interindustry linkages with geographic proximity, a concept related to the fixed coefficient model of Launhardt-Weber. Parallel to the Isard et al. fusion of locational analysis with input-output analysis, Moses (1958) revised the classical Launhardt-Weber model by incorporating a neoclassical production function into the original classical location theory model. The outcome is a neoclassical production-location model where the technical factor relationships are now endogenous to the model and are defined by the firm's production function. A second development in classical location analysis was the introduction of models based on the fixed coefficient framework of von Thünen. Alonso (1964), Muth (1969), Mills (1970), and Evans (1973) have given much attention to integrating factor substitutability between land and a composite factor (i.e., labor and capital) into the classical von Thünen framework to develop the neoclassical land use model. But despite all conceptual revisions, none of the neoclassical location theory models adequately explain why economic activities tend to group in geographical space (McCann and Sheppard, 2003).

Chinitz (1961), based on observations from New York and Pittsburgh, conceptualized his *incubator model* which states that established older cities have the advantage of acting as an incubator that creates new firms, businesses, and economic opportunities. The level of diversification of industrial clusters provides the nourishing soil for small and new startup firms to grow by providing a wide range of production factors and input markets. The incubation of new business activities becomes a substantial ingredient for establishing a nourishing industrial atmosphere, which is essential for successful urban economic regeneration or continued development. According to Chinitz, urbanization economies have a higher prospect of successful economic development than localization economies.

The influence of scale economies onto geographic concentration is also often the focal point of urban and regional economists with a focus on the spatial organization of industries. Henderson (1974) emphasizes the agglomerative effects of *positive spillovers* between firms in geographic proximity. In a perfectly competitive environment with constant returns to scale, external sources of agglomeration in Marshallian tradition encourage regional specialization. In contrast, Krugman (1991b) departs from microeconomic location theory based on constant returns and perfect competition by assuming increasing returns to scale and a monopolistic market structure. Consumer preferences in product variety, combined with fixed production costs, lead to specialization at the firm level which explains the existence of a monopolistic-competitive market structure. After all, it is cheaper to produce one single product in large quantity rather than a variety of products in smaller quantities. With production costs fixed, transport costs become an important factor in the firm's cost minimization process. Transport costs can be minimized first by reducing the shipping costs between firms for intermediate demand within the value chain, and secondly by locating firms and businesses in proximity to large markets (i.e., urbanization economies). In Krugman's model, both internal scale economy and urbanization economies then help increase profits at the firm level.

In a more recent paper, McCann and Sheppard (2003) made a strong argument for reconsidering the microeconomic foundations of industrial location theory. More specifically, the authors argued for reconciling the methodological basis of traditional location theory models, the classical location theory models by von Thünen and Launhardt-Weber, and the neoclassical location theory models by Alonso (1964) and Moses (1958) with the recent models of industrial clusters (i.e., Porter, 1990, 1998) and new economic geography (i.e., Fujita et al., 1999). The authors view new advances in data availability and communication technologies, new academic fashions, and new international institutional arrangements as driving the need for integration. Moreover, the need is made more urgent by the absence in the new economic geography and clustering literature of consideration of certain factors important to the locational decision-making process of firms – the firm's production function, location-specific production costs, or whether transactions are external or internal to the firm. The fact that most recent cluster studies show a lack of microeconomic rigor requires a rethinking of the different theoretical assumptions underlying industrial clustering. Grounded in classical and neoclassical location theory, McCann and Sheppard propose: i) to pay specific attention to the organizational structure of the individual firm and the interrelations of co-located firms, ii) to identify the nature and behavior of the spatial transaction costs faced by modern firms, and iii) to account for changes in the interdependencies between firms and for changes in the natures of spatial transaction costs.

In the next section, we take a closer look at various industrial concepts and methodological approaches used to identify industrial clusters. Given the wide variety of methodologies, this review focuses primarily on traditional regional science concepts and methods and different approaches to measuring geographic proximity between industries.

INDUSTRIAL CLUSTER CONCEPTS AND THEIR METHODOLOGICAL IDENTIFICATION

Having discussed the theories behind firm spatial co-location, in this section we will take a closer look at how these various agglomeration theories have been translated into cluster concepts. By cluster concept we understand the way industrial clusters are being defined, described, or explained. The vast body of relevant industrial cluster literature exhibits an astonishingly large number of similar but still different cluster concepts. Generally, while all cluster concepts appear to have their roots to a more or lesser extent in agglomeration theory, the fact that there is no unique and coherent theory of agglomeration economies is also mirrored in the variety of concepts and definitions of industrial clusters. And as one might already guess, this is further evident in that the literature exhibits a tremendous number of methods to identify industrial clusters. After all, different cluster concepts and identification methods and the prospect of achieving different results gives room for practitioners and policy analysts to question which concepts and methods to use and, at least to some extent, justifies the criticism on cluster-based economic development policies. In this section, we will group 'comparable' cluster concepts together, based primarily on similarities they share when tracing back their roots to agglomeration economies, or cluster theories. Overall we distinguish between three conceptually different industrial cluster concepts (Chen, 2005):

1) Industrial clusters following the theoretical principles of *localization economies* à la Marshall and shown in the work by Rosenfeld, 1995; Schmitz and Nadvi, 1999; Swann and Prevezer, 1996 for instance.

2) Industrial cluster definitions which are derived mainly based on *interindustry relationships found in*

input-output tables, and seen in the work of Czamanski (1974, 1979), Ó hUallacháin (1984), Redman (1994), Roepke et al. (1974), and Bergman and Feser (1999, 2000).

3) Industrial cluster concepts which encompass the widest spectrum of arguments explaining why establishments group in geographic proximity, including *economies of localization and urbanization, internal returns to scale, value chain linkage, and technology innovation* among others, and which follow closely Porter's (1990, 1998) theoretical approach.

What we refer to above as first cluster concept relates closely to regional specialization in Marshallian tradition. In its broadest meaning, industrial clusters are conceptualized as groups of establishments belonging to the same industry sector within regional geographic boundaries. As Rosenfeld (1995, pp. 12) put it: '*A cluster is a loose, geographically bounded agglomeration of similar, related firms that together are able to achieve synergy*.' Similarly, Swann and Prevezer (1996, pp. 1139) define industrial clusters as '*groups of firms within one industry based in one geographic area'*. Hill and Brennan (2000, pp. 67) see the concentration of firms in the same industry as a necessary condition of industrial clusters by defining a competitive industrial cluster as: *'concentration of competitive firms or establishments in the same industry*.' Brenner (2004) defines a local industrial cluster as '*an industrial agglomeration that is caused by local self-augmenting processes*'. The 1970s literature on Italian industrial districts, as reviewed by Becattini (1990) and Sforzi (1990), parallels Marshall, with greater focus on the social aspects.

Though the concept of ***localization economies*** is well understood, its manifestation into a sound cluster concept and cluster identification method requires careful deliberations. A commonly used way of translating the idea of localization economies into a cluster concept is accomplished by the means of *regional industrial specialization*. Evidently, knowledge spillovers, labor market pooling, and the sharing of industry-specific non-traded inputs fosters the clustering of establishments and therefore, at least to a certain degree, should lead to regional specialization. The question on whether or not regional specialization mirrors localization economies has repeatedly been addressed in the literature. Rosenthal and Strange (2004), for instance, suggest, based on the case of Silicon Valley, that the high presence of computer-based businesses reflects regional specialization and consistency with the ideas of localization economies. Hanson (2000, pp.4) in his survey of empirical work on the geographic concentration of economic activity interprets Marshall's idea as: '*the existence of localized externalities implies that firms prefer to be near large agglomerations of other firms in their own industry or related industries. An urban hierarchy arises in which cities specialize in different industries'.* Clearly, Hanson emphasizes the conceptual connection between regional specialization and localization economies while at the same time implying that this specialization can be seen in the local emerging of industries. However, it is to be cautioned that regional industrial specialization may not necessarily imply the existence of an industrial cluster. A place that is dominated by only one super firm / industry exhibits a strong regional specialization, but one large establishment is by no means a cluster, or group of establishments. For instance, a small college town with a large research university, like Ithaca in upstate New York, will show strong evidence of local specialization in education. Nevertheless, besides Cornell

University, Ithaca College and the mandatory public school system, there will, with the exception of some copy and candy shops, be no significant groupings of educational or supporting facilities - an example which underlines the fact that the existence of one dominant establishment in a place does not necessarily meet the requirements to be called an industrial cluster. It is also possible to have a large number of linked firms in an industry but not be specialized (as, for instance, the biotech industry in New York City) while at the same time a small location quotient can occur for an area with a cluster.

If specialization is the preferred way to measure industrial clusters based on localization economies, location quotient method is then the common practice to identify regional specialization as demonstrated among others by Munnich et al. (1998), Rex (1999), Botham et al. (2001), and Peters (2004). Location quotients, which measure regional specialization by comparing local employment shares by industry to employment shares of a benchmark region (e.g., the nation), are conceptually easy to understand, straightforward to apply, require almost no time, and necessary data (such as regional employment) are readily available. While location quotients suffer from various theoretical shortcomings - such as the self-sufficiency assumption of the benchmark region, absence of cross-hauling, equal productivity, and consumption of region versus the benchmark region - a main drawback for industrial cluster identification is the fact that by no means can one argue that a 'large' location quotient is an inevitable indicator for the existence of industrial clusters. More specifically, location quotients can under no circumstances differentiate between external and internal scale economies. A large location quotient by itself cannot identify whether an industry sector consists of numerous firms and businesses of various sizes – an industrial cluster – or has only one large-scale enterprise. The former could be the result of external agglomeration sources à la Marshall, yet the latter is a case of positive internal scale economies.

Isard (1959) in his *industrial complex* concept set the stage for what we classify as a <u>second industrial cluster concept</u>. More specifically, he shows one way to expand the *within-industry* concept localization-based cluster analysis where all firms belong to the same industry by accounting for ***interindustry linkages***. Iammarino and McCann (2005, pp. 7) characterize this type of spatial cluster as '*long-term stable and predictable relations between the firms in the cluster, involving frequent transactions*' and emphasize the model's conceptual relationship to classical (Weber, 1909) and neoclassical (Moses, 1958) location-production models. We see its importance in that Isard's concept is based on input-output forward and backward linkages which allow cluster formations of establishments that are interrelated in the production value chain and do not necessarily belong to the same industry. While Isard (1959, pp. 33) loosely referred to his industrial complex as a: '*set of activities at a specific location which are linked by certain technical and production interrelations*', Roepke et al. (1974, pp. 15) described an industrial complex 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.*'

Czamanski and Ablas (1979, pp. 62) then explicitly distinguished between the interrelated concepts of industrial cluster and industrial complex: '*cluster means a subset of industries of the economy connected by flows of goods and services stronger than those linking them to the* *other sectors of the national economy. The concept is thus devoid of any spatial connotation. A complex, on the other hand, has been defined as a group of industries connected by important flows of goods and services, and showing in addition a significant similarity in their locational pattern. Thus, complexes emphasize the spatial aspect of industrial concentration.*' At the same time, the use of input-output tables for identifying industrial complexes/clusters became more and more subject to criticism. Latham III (1976), for instance, pointed out that input-output tables are purely aspatial and therefore fail to meet the locational criteria of industrial complexes, leading to the conclusion that they are unsuitable to help identifying industrial complexes. Ó hUallacháin (1984) reevaluated the use of input-output tables for industrial cluster identification. More specifically, Ó hUallacháin distinguished between vertical linkages – successive linkages in the production chain – and complementary linkages, which Ó hUallacháin refers to as the result of scale economies external to the firm but internal to the industry. As Ó hUallacháin (1984, pp. 421) put it: '*grouping sectors that are exactly or nearly homogenous in input (or output) is not unlike identifying complementary relationships.*' In this sense, he emphasized the usefulness of input-output tables for identifying complementary relationships, but at the same time acknowledged the shortcomings of principal components analysis for detection of vertical value chain linkages. More recently, input-output-based industrial cluster analysis regained popularity as seen, for instance, in the work by Bergman and Feser (1999), Doeringer and Terkla (1995) and Hill and Brennan (2000). Feser and Lugar (2002, pp. 3) also provided a *regional cluster* concept: '*concentrations of businesses that co-locate because of trading (buyer-supplier) relationships and/or to share common factor markets (including infrastructure, knowledge resources, and labor) and/or common goods markets*,' a definition which in itself reflects both relationships described by Ó hUallacháin: direct value chain linkages and complementary relationships.

All industrial cluster concepts belonging to what we see as a second cluster concept have one common denominator - namely, the use of interindustry transactions as illustrated by input-output tables. While most studies based on input-output tables define industrial clusters as spatial concentrations of industry groups based on their value chain linkages, disagreement still exists as to the appropriate method that would reveal similarity in trading patterns. Major methods applied to input-output tables can be grouped to include two major categories: direct value chain linkage analysis and trading pattern analysis.

- Direct value chain linkage analysis:

Direct value chain analysis groups industries into clusters based on vertical production chain linkages. The basic criterion is that industries with strong transaction links above a predetermined threshold value are grouped as industrial clusters (Botham et al., 2001; San Diego Association of Governments, 2001). Another important step besides direct value chain analysis is to detect co-location among industries through a separate locational analysis.

Latham III (1976) proposed the integration of locational analysis by calculating first correlation coefficients for each pair of industry employment, in his case for a total of 377 regions in the US. Co-location is present when industry pairs have correlation coefficients greater than a preset threshold value. In a second step, the author examines the input-output table to seek out the above average interindustry trade links of these pre-selected industries. Strong interindustry linkages, then, are evidence of spatial concentrations of industries with significant trading activities.

While the direct value chain method gives a full picture of interindustry linkages for a geographic region, it also suffers from severe shortcomings. First, the findings when using direct value chain method are very sensitive to preset threshold values. There is no rationale for choosing these threshold values, and since the literature fails to suggest reasonable cutoff points, the decision is up to the discretion of the policy analyst. Second, a mismatch of geographic scales for locational and interindustry linkage analyses can lead to serious misinterpretations. As Zeller (2001) found, spatial concentration does not necessarily imply a close network of input-output relationships within an industrial cluster, a problem present when matching small-scale locational analysis with large-scale interindustry transaction analysis.

Graph-theoretic analysis visualizes direct value chain linkages embedded in input-output tables. The starting point is the transformation of the input-output matrix, the transaction table, into an adjacency matrix of ones and zeros. If the cell entry in the transaction table is above a preset threshold value, then a '1' is assigned to the cell, and otherwise given a '0'. The next step graphs the identified significant interindustry linkages (i.e., the ones) of the adjacency matrix where the nodes represent industries and the connectors symbolize the industry flows. Groups of industries forming a set of mutually reachable points are then defined as strong components (Campbell, 1971). Again, the outcome of the graph-theoretic analysis depends both on the use of preset cutoff values and the simplification of interindustry transactions into binary relationships. Using low-end cutoff values may result in messy graphs complicated in their interpretation, while high cutoff points would inevitable mean loosing a lot of valuable information, as recognized by Czamanski et al. (1979).

- <u>Trading pattern analysis</u>

There are two different methods to group industries according to their similarity in terms of trading patterns: statistical cluster and discriminant analysis, and principal component factor analysis.

Statistical cluster analysis and discriminant analysis, multivariate statistical analysis techniques, group industries according to common variances in input-output tables (Hill & Brennan, 2000; Rey, 2000). The main focus is on the identification of similarities among industries in their buying / selling patterns. More specifically, statistical cluster analysis sorts industries according to statistical variances calculated between pairs of industries from the input-output tables. In a second step, discriminant analysis tests the goodness of fit of these prior cluster assignments by utilizing meaningful test statistics. Finally, using additional information such as regional specialization, multiplier effects, export activities and industry growth, a cluster-specific *driver* industry is determined (Hill and Brennan, 2000). In practice, this approach is of a rather academic value in that the derived industrial clusters are mutually exclusive, meaning that one industry can belong to one cluster only. Experience, however, shows that this might not hold in reality as, for example, service industries (such as wholesale trade or transportation and warehousing) usually serve numerous manufacturing industries simultaneously. And therefore these industries can be a major component of more than one single industrial cluster.

Principal Component Factor Analysis (PCA), a factor analytic data reduction method, is the most widely applied industrial cluster method using input-output tables. Introduced in the 1970's by widely-cited scholars like Czamanski (1974) and Roepke et al. (1974), and heavily criticized - for instance by Latham III (1976) - it presently regained wide popularity as evident in the work of Bergman and Feser (1999), Feser and Bergman (2000), Feser and Sweeney (2002), and Patton (2003). Its popularity can partly be attributed to the fact that it overcomes the mutual exclusiveness restriction of statistical cluster analysis and discriminant analysis, and therefore an industry sector can be part of several clusters simultaneously.

Generally, principal components factor analysis reduces the number of correlated variables – the column vectors in a matrix – to a smaller number of conceptually meaningful dimensions – the *factors*. The goal is to get a small number of latent factors which explain observed correlations between variables (i.e., industries) using the maximum common variance criteria between variables and a factor.[3] Applying PCA to the input-output framework means reducing the number of industries to a smaller set of industrial clusters which explain a maximum amount of variances in the input-output table. In other words, instead of recognizing interindustry transactions in a 400x400 input-output table, for instance, we now would be facing a reduced table with maybe 15 latent factors which might account for as much as 80 – 90 percent of the original interindustry correlations in the input-output table. Conceptually straightforward, it however offers several possibilities on how to employ the input-output table. Roepke et al. (1974) employed the original transaction matrix to group industries into factors according to similarities in buying patterns and called it R-mode analysis. Alternatively, the authors identified similarities in selling patterns among industries by using the transposed transaction matrix, Q-mode analysis. In either case, industries with the highest factor loadings – i.e., the highest correlation of the industry with the cluster – are identified as the *core* industries, and industries with lower loadings are the secondary industries. Czamanski (1974) proposed another variant of the PCA to account for interindustry linkages which are neglected in either R-mode or Q-mode analyses. First, both the transaction table and the transposed transaction table are normalized, achieved by dividing the cell entries by the corresponding column totals. Secondly, the normalized transaction and transposed transaction tables are correlated with each other. And lastly, a symmetric intercorrelation matrix is derived by selecting the largest correlation coefficients from the four resulting symmetric submatrices, in turn subject to the principal components factor analysis.[4] But regardless of which data matrix is used in the PCA, identifying interindustry relationships is no guarantee for geographic proximity of industries to one another, particularly when using national input-output tables. In addition, all methods using input-output tables can be subject to potential biases when using aggregated input-output tables with restricted numbers of industries.

The <u>third cluster concept</u> referenced in this review brings us back to Porter and his *Diamond of Advantage*. So far, described industrial cluster concepts were more confined to specific agglomeration economic theories, like Marshall's *localization economies* and Isard's *industrial complex*. Porter (1990, pp. 3) broadened the scope of

[3] Tinsley and Tinsley (1987)

[4] Both Czamanski (1979) and Bergman and Feser (1999) provide a detailed step-by-step description of how to derive the symmetric intercorrelation matrix.

industrial cluster concepts substantially in defining clusters as: '*geographic concentrations of inter-connected companies and institutions in a particular field. Clusters encompass an array of linked industries and other entities important to competition. They include, for example, suppliers of specialized inputs such as components, machinery, and services, and providers of specialized infrastructure. Clusters also often extend downstream to channels and customers and laterally to manufacturers of complementary products and to companies in industries related by skills, technologies or common inputs. Finally, many clusters include governmental and other institutions - such as universities, standard-setting agencies, think tanks, vocational training providers, and trade associations - that provide specialized training, education, information, research, and technical support.*' Clearly, Porter's cluster concept is more a synopsis of accepted agglomeration phenomena rather than new groundbreaking insights explaining the reasons for firms to group in space. On one side, this cluster concept reflects onto Isard's industrial complex based on interindustry transactions, i.e., the *vertical relationships*. On the other side, it also mirrors Hoover who recognized the importance of specialized factors of production, and the existence of large and diverse markets in addition to pure localization forces, i.e., the *horizontal relationships*. Furthermore, Porter's cluster concept also exhibits social network characteristics as described in more detail by McCann and Sheppard (2003). The uniqueness, however, of Porter's approach lies in his business philosophy of competition rather than locational competitiveness. As Martin and Sunley (2003) point out, Porter is successful in that he promotes competitiveness, a concept which appeals to politicians and policy makers. Rather than developing a purely theoretical framework that is difficult to translate into policy actions, Porter offers applicable business strategies aiming at promoting regional competitiveness. However, in terms of industrial cluster theory, Porter's concept is more intuitive than grounded in logic, and rather than being a modeling framework that can be rigorously applied in practice it remains, to some extent, generic and a vague way of thinking about regional economic development.

Clearly, Porter is not trying to explain a firm's decision on where to locate by leaning on location-specific comparative advantage, such as land, natural resources, or amenities. Porter suggests that spatial proximity of establishments creates a favorable economic environment of competitiveness and innovations, an environment which strengthens productivity and economic growth through the transfers of technology and information. Porter's often-cited *Diamond of Advantage* identifies four determinants where governments in a pro-active way can act as catalysts to foster competition:

i) *firm strategy, structure, and rivalry* are dynamic conditions and direct competition leads to continuous increases in productivity and innovations.
ii) creating specialized *factor conditions* including skilled labor, capital, and infrastructure.
iii) changing *demand conditions*, such as increases in product variety and cheaper, better products pressure firms to invest and innovate.
iv) geographic proximity of downstream and upstream *related and supporting industries* facilitates exchange of information, ideas, and innovations.

While this Porter-type cluster is quite fuzzy, similar cluster concepts are seen in Redman (1994, pp. 37) and Hill and Brennan (2000, pp. 67). Redman defines an industrial cluster as '*a pronounced geographic concentration of production chains for one product or a range of similar products, as well as linked institutions that influence the competitiveness of these concentrations (e.g. education, infrastructure and research programs).*' Hill and Brennan provide a cluster concept that emphasizes the relationship among the different components in a cluster: '*we define a competitive industrial cluster as a geographic concentration of competitive firms or establishments in the same industry that either have close buy-sell relationships with other industries in the region, use common technologies, or share a specialized labor pool that provides firms with a competitive advantage over the same industry in other places.*' He also used a combination of location quotients, industry-specific wages and discriminant analysis to identify the clusters. Altogether, the *all-inclusive* cluster concepts presented by Porter, Redman, and Hill and Brennan have attractive features for rethinking the promotion of economic development, but at the same time the concepts fail to offer a sound methodology that would actually enable ED practitioners to translate the concepts into action.

Although beyond the scope of this literature review, this paper would be incomplete without at least referring to the works of Gordon and McCann (2000) and McCann and Sheppard (2003), two cluster studies which identify three different cluster types. One cluster type, labeled *pure agglomeration,* is best represented by Marshall's model of agglomeration and through later work by Krugman and Fujita. A second cluster type is the *industrial complex* model which is conceptually grounded in the classical (Weber, 1909) and neoclassical (Moses, 1958) location-production models and analytically carried out through the use of input-output analysis. So far, their definition is coherent with the cluster classification used in this review. A third cluster type, *social network*, goes back to the work by Granovetter (1973) and Williamson (1975) where *mutual trust relations between key decision-making agents in different organizations* lead to reduced inter-firm transaction costs in the absence of opportunism (McCann and Sheppard, pp. 657). Here, the co-location of firms fosters a positive business environment of mutual trust, risk-taking and cooperation. Using the London region as an example, the study by Gordon and McCann concludes that *the data cannot provide clear measures of the comparative fit of the three ideal-typical models to the pattern of specialization in the London economy*. In other words, none of the concepts by itself can explain the existence of all observable clusters, and elements of each of the three cluster types may co-exist in certain industries and / or regions. For cluster analysts this means more confusion when interpreting the analytical cluster results or translating the results into cluster-based economic development policies.

SELECTED INDUSTRIAL CLUSTER STUDIES

Bearing the concepts and methodologies of industrial cluster theory in mind, in this section we will review some selected, influential cluster studies which serve practitioners as well as academicians as blueprints for regional cluster studies. It also became apparent that while most studies were able to address the industrial cluster criteria appropriately, not all studies were able to specify whether or not identified clusters can be labeled industrial complexes. Altogether, many of the surveyed cluster studies in this review have utilized location quotients to identify advantageous industries and / or utilized interindustry connectivity exhibited in input-output tables. Furthermore, relatively few industrial cluster studies have appropriately addressed the spatial criterion necessary to label a group of industries an industrial complex. In other words, not all studies explicitly accounted for whether or not firms are actually co-located next to one another.

Utilizing location quotients as the main tool to identify regional specialization in the Marshallian tradition (i.e., our first cluster concept) is a common and widely used approach for identifying industrial clusters – either by themselves or in combination with other qualitative and / or quantitative methods. Rex (1999), for instance, in his cluster analysis for thirteen counties in Arizona, relies on location quotients as the main method to find county-level industrial clusters that in turn serve as economic bases. However, there is no further discussion of how these clusters have formed, nor is their implication for policy suggestions provided. Bergman and Feser (1999) see location quotients as efficient when the focus is on identifying regional specialization, but reinforce the critiques of both Doeringer and Terkla (1995) and Rosenfeld (1997) by emphasizing that location quotients reveal no information on interindustry relationships, and therefore need to be supplemented by more sophisticated techniques - for instance, input-output analysis. Munnich et al. (1998) started their industrial cluster study covering eighteen counties in Southwest Minnesota and identifying regional specialization by applying location quotients. Subsequently, industries with high location quotients have been diagnosed qualitatively following Porter's four cornerstones described in his *Diamond of Competitive Advantage*. However, no evidence is found to support Porter's cluster argument and presented policy suggestions are more based on qualitative studies.

Recognizing the economic base as first step for a more elaborate and detailed industrial cluster analysis and as suggested by the relevant cluster literature, many studies supplemented location quotients analysis with information on interindustry linkages as found in input-output tables. For instance, Hill and Brennan (2000) used location quotients and changes in the region's share of national employment in the industry to sort out *driver* industries that build the economic base of the region. Then a regional based input-output table using 3 digit SIC codes has been analyzed through statistical and discriminant cluster analysis to find out the industries that are similar to the driver industries in terms of the trading patterns. Though the regional input-output table combines their suppliers and customer industries with driver industries to form industrial clusters, the input-output table does not provide proof of comparative advantage from these suppliers or buyers to the driver industries. In similar fashion, Botham et al. (2001) identified export-oriented industries at the national level in the United Kingdom using location quotients. Using the input-output table, industries which have strong direct and indirect ties to these exporting industries are grouped into clusters. Another study by Peters (2004) also relies on the use of output and employment location quotients to identify target industries in Missouri. Common in all these studies is the reliance on location quotients for identifying local driver industries within the target region. At the same time, supplementary use of input-output tables addresses the problem of using location quotients as the sole methodological cluster identification.

Cluster methodologies that clearly go along with the second group of cluster concepts are mainly based on the concept of interindustry linkages, supplemented by spatial statistics to measure the spatial concentration of the grouped industries, as demonstrated in Feser et al's (2001) G* statistics and locational coefficient in Harvard Business School's cluster mapping project. While input-output tables have traditionally been used in more descriptive ways to supplement localization-based cluster studies, they also provide the means for industrial cluster studies which group industries based on interindustry linkages as mapped by input-output tables. To address the aspatial nature of input-output tables and to be able to classify identified industry groups as industrial complexes following Isard and Czamanski, many cluster studies incorporated an additional approach with a focus on measuring geographic proximity of industries within industrial clusters. In this section, we will pay particular attention to how these two issues, i.e., interindustry linkages and geographic proximity, have been addressed.

Roepke et al. (1974) applied three principal component factor analyses to a highly aggregated (44x44) matrix of interindustry linkages for the Province of Ontario: i) a nondirectional aggregated transaction matrix with combined flows between industries[5], ii) the transaction matrix (i.e., R-mode), and iii) the transposed transaction matrix (i.e., Q-mode). Roepke et al. found remarkable similarities between the outcomes of these three PCAs, namely thirteen dimensions which account for approximately 85 percent of the variance found in the data. Based on these resemblances, they argued for the existence of clearly defined industrial complexes.[6] However, small differences occurred in the makeup of individual components. Since PCA groups industries according to similarities in buying / selling patterns but falls short of actually capturing interindustry transactions, the authors followed Streit's (1969) suggestion of additionally testing the intensity of interindustry flows within identified industrial complexes. They calculated all interindustry linkage values between all industries within one industrial complex with factor loadings of above 0.65. In a next step, a relative mean linkage value, derived from these linkage values, is used as evidence of interdependence among industries within one complex. The authors conclude that they have identified meaningful groupings of industries and the use of the Streit Index provided enough validity to call them industrial complexes. Subsequently, and according to the authors, this provides evidence that input-output tables are usable in both spatial and aspatial analysis.

Another approach to applying principal components analysis to input-out data is demonstrated by Czamanski (1974, 1976) by using a symmetric intercorrelation matrix containing the highest correlation coefficients from a set of four zero order coefficients. Using a (172x172) input-output table of the U.S. economy, Czamanski identified sixteen clusters, which as pointed out by Czamanski are purely aspatial by character. In a subsequent study (Czamanski, 1976) using population and employment data for 191 Standard Metropolitan Statistical Areas (SMSA), Czamanski identified whether or not identified clusters fulfill the spatial 'geographic proximity' characteristic of industrial complexes. To account for the *urban influence,* the author first regressed employment by industry i for each region k (E_{ik}) on the region's population (P_k). The urban influence implies that all regional employment is distributed unevenly as businesses, and thus employment is attracted to inner cities which in return depend on the size of the metropolitan

[5] With a_{ij} denoting the dollar value of goods purchased by industry j (input) from industry i (output), the aggregated transaction matrix with combined flows between industries is derived as: $b_{ij} = a_{ij} + a_{ji}$.

[6] Contrarily, Czamanski and Ablas (1979) argue that Roepke et al. have identified industrial clusters rather than complexes.

region. In a subsequent regression, the error terms of the first regression (ε_{ik}) are regressed on employment in industry j in region k (E_{jk}). Using standardized regression coefficients, setting up a symmetric matrix, and analyzing them again resulted in 16 industrial complexes. Overall, these industrial complexes were roughly similar to previously identified industrial clusters, with fewer industries per complex as in the corresponding cluster.

Latham (1976) recognized in his study the importance of a spatial component and criticized the studies by Roepke et al. and Czamanski as inadequate to address the spatial factor due to the large size of each economy, namely the U.S. and Ontario economy respectively. In addition, Latham argued that neither the study by Roepke et al. nor the study by Czamanski is useful for cluster-based economic development strategies as the level of industrial aggregation shrouds existing interindustry linkages, and significant and necessary information is lost to the policy analysts. Hence, Latham proposed a simpler method to address both the locational and the interindustry linkage requirements of industrial complexes. Location is measured by calculating correlation coefficients between each pair of employments by industry across 377 regions in the U.S. Secondly, Latham neglected to do a detailed multivariate analysis on the input-output table and gave preference to calculating a linkage coefficient similar to the Streit Index. More specifically, the linkage index is the sum of all possible four normalized input-output flows, for the supplying and for the receiving sector.[7] Again, the effect of urbanization economies is accounted for through supplementary regression analysis. Locational relationships exist for pairs of industries which indicate significant geographic association in addition to significant interindustry transactions. Interdependent complexes are identified by tracing all included industries. Of a total of 199 industries included, Latham demonstrated his method using the electronic components complex as an example, but failed to take the additional step of showing how this information of the electronic components complex can help to develop cluster-based economic development strategies.

Ó hUallacháin (1984) in his cluster study of the Washington State economy specifically addressed contemporary criticisms towards principal components analysis and strongly reinstated its usefulness for industrial cluster analysis when using input-output tables. While Ó hUallacháin declared principal components analysis as unsuitable for detecting vertical relationships (i.e., co-location of successive stages of production to avoid, for instance, transportation costs), he stated at the same time that PCA is an appropriate method when the focus is on grouping industries' sectors in accordance to similiarities in their buying / selling patterns which he refers to as *complementary relationships*, and which result from external scale economies combined with industry internal agglomeration forces. In addition, Ó hUallacháin (1984, pp. 422) made a strong argument for the use of regional input-output tables in the context of 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'*. He did R-mode and Q-mode principal components analyses on a (49x49) input-output table of Washington State, supplemented by intra-group interindustry linkage indices; i.e., Chenery and Watanabe's (1958) forward and backward linkage indices (L_F, L_B). Altogether, Ó

[7] These normalized coefficients are technically identical to the coefficients used by Czamanski as starting point for calculating the (nxn) intercorrelation matrix.

hUallacháin derived fifteen components from R-mode and Q-mode analyses explaining 83.0 percent and 84.1 percent of the total variance respectively.

Almost twenty years later, and despite the fact that cluster-based economic development analysis made it into the methods toolboxes of economic development strategists in the U.S. as well as in Europe, Feser and Bergman (2000) recognized one major obstacle to contemporaneous industrial cluster analysis, namely (and as mentioned earlier in this paper) the fact that many cluster-based strategies are poorly specified to begin with and that applied industrial cluster analysis often boils down to little more than identifying regional specialization. The bottom line for practitioners is that industrial cluster analysis still remains, at least to some extent, an indecipherable alternative for identifying economic development strategies difficult in its application. To overcome this obstruction, the authors derived *cluster templates* by applying principal component factor analysis to the detailed 1987 benchmark US input-output accounts of 362 manufacturing industries. The outcome is a total of 23 industrial clusters, which according to the authors are usable as templates for regional, manufacturing-based economic development strategies aiming at enhancing direct and indirect interfirm linkages - such as buyer-supplier and import replacement strategies, technological development, cross-firm networking and industrial park initiatives. Feser and Bergman give preference to national templates rather than choosing regional input-output tables and declare sub-national input-output tables as being too restrictive due to the absence of non-local buying / selling patterns (i.e., domestic exports). According to the authors, the cluster templates allow measuring of regional economic specialization through identification of regional strengths and gaps in particular product chains when comparing regions to the nation. Applying the cluster templates to North Carolina, Feser and Bergman re-classified regional employment and establishment data accordingly. An improved understanding of regional constraints and requirements for economic growth then leads to cluster-based economic development strategies and policy portfolios aiming at increasing regional comparative advantage, an approach demonstrated by the authors by means of North Carolina's vehicle manufacturing cluster.

The question of whether or not identified clusters fulfill the spatial 'geographic proximity' characteristic of industrial complexes has regained strong interest among scholars in recent years. Feser, Koo, Renski, and Sweeney (2001), for instance, incorporated spatial analysis in a cluster study by means of spatial statistical analysis of employment patterns, the Getis and Ord G* statistics. In a first step, the industrial value chain clusters have been identified through a principal component analysis on the national input-output table. In a subsequent step, the geographic concentration of establishments is tested using the G*statistics. Like location quotients, the Ellison and Glaeser index of localization, or the spatial Gini coefficient, the G* statistics is a simple spatial autocorrelation coefficient to measure geographic concentration. Calculated for each individual county in 49 U.S. states using cluster employment levels for the county itself and all neighboring counties, the G* statistics indicates cluster activities across county boundaries. While the location quotient is a widely accepted regional specialization indicator, it falls short of capturing cross-boundary cluster activities. According to the authors, using the G* statistics to measure geographic concentration thus represents an improvement over the more conventional location quotient method. Feser and

Sweeney (2002) redefined the point data approach, the G* statistics, in a cross-metropolitan comparison of 14 MSAs of selected manufacturing clusters. Using chemical manufacturing activity in the U.S., they derive the local G* statistics using different variants of employment data, including chemical employment as a share of county employment and natural log employment of the chemical value chain, the authors emphasize the dependence of derived results on the population distribution across the country. Stimulated by Czamanski's (1976) handling of this *urban settlement influence*, Feser and Sweeney fine-tuned the G* statistics by using the residuals of a regression of chemicals value chain employment on population. The outcome is a more discriminating pattern of localized chemical activity in the U.S. In addition, they present an approach for representing intraurban and intrametropolitan clustering by means of Diggle and Chetwynd's (1991) *D* function which tests for clustering in the presence of environmental heterogeneity.[8] The importance of analyzing industrial clusters as spatial phenomena rather than a sole operating economic grouping of industries is also emphasized in the work by Feser and Luger (2002). Further, they point out that cluster analysis is best viewed as a general mode of inquiry rather than a narrow technical methodology in regional economic analysis with the specific cluster definition and methodology depending on the particular policy concerns. Industrial clusters must be studied twofold: i) in spatial isolation which sheds light on regional businesses and institutional interdependencies, and as such lays the foundation for understanding the complexity of regional economies, and ii) in spatial context together with a larger economic unit (i.e., state or nation) of which the region is part.

An innovative approach of measuring spatial proximity is demonstrated by Lee, Liu, and Stafford (2000). Using firm-level survey data, the authors try to identify industrial districts in the Cincinnati metropolitan region through measuring local linkages, or *local-ness*. Conceptually, the authors define industrial districts following closely Wheat (1973). To be called an industrial district, four criteria must be met by firms in the Cincinnati metropolitan region: i) evidence of high degrees of spatial proximity (SP) among firms, ii) existence of vertical linkages (VL), iii) existence of horizontal linkages (HL), and iv) indication of strong local labor force linkages (LL). For each criterion, a local-ness index number ranging from 0 – 1 is calculated. Zero indicates no *local-ness* and one indicates perfect *local-ness*. Subsequently, the authors computed a composite Industrial District Index (IDI) from these four local-ness indices.[9] Based on survey data from 71 individual manufacturing plants, the authors found patterns of highly spatially-clustered manufacturing industries (SP = 0.9) in Cincinnati. Confirming prior expectations, they also found that horizontal linkages (HL = 0.31) are more important to firms than vertical linkages (VL = 0.16). However, very interesting is the author's finding that, despite a high spatial proximity index, the relatively low local-ness indices of vertical and horizontal linkages do not support the argument for the existence of industrial districts in Cincinnati. Based on these findings, the authors conclude that the industrial district concept is questionable at the metropolitan level and below. Defining the region is of major importance in applied industrial district analysis and *there is no one spatial scale that fits all circumstances*.

Among the sample studies that fall into the third cluster concept, undoubtedly the most

[8] For a detailed description of the *D* function approach, please see Feser and Sweeney (2002).

[9] For a detailed discussion on the methodology, please see Lee, Liu, and Stafford (2000).

elaborate applied industrial cluster work is the *Cluster Mapping Project* by the Harvard Business School, carried out for all state / metropolitan areas across the U.S. Following the principle that industries group together spatially because of external economies, the project analogously focuses on these cluster-forming externalities. The Harvard Business School's mapping project uses multiple geographic scales, including states, metropolitan statistical areas (MSA), consolidated metropolitan statistical areas (CMSA), and primary metropolitan statistical areas (PMSA). Accordingly, geographic proximities are calculated for each geographic level. More specifically, every single pair of industries is correlated with one another using 3-digit SIC County Business Pattern employment data. Industries that indicate strong correlations with a predetermined and prominent *core* industry form the extent of this specific industrial cluster around the core industry. Supplementary information on national value-chain linkages are taken from input-output tables and specific industry knowledge, like expert opinions. As such, the Harvard Business School mapping project methodological approach resembles at least to some degree earlier work by Czamanski (1974, 1976) and Latham III (1976).

Other scholars have applied Porter's (1998) cluster diamond framework to identify comparative advantages for the exporting industries. Munnich et al. (1998) utilized location quotients to find industry clusters in 18 counties in Southwest Minnesota. After identifying industries that have high location quotients, Porter's (1998) four components in the cluster diamond are diagnosed for each of the advantageous industries. Comparing these results with studies by Munnich et al. (1996, 2001) in Southeast, South Central and Northeast Minnesota indicate that all four components do not have to be located within geographic proximity to make feedback mechanisms among firms work effectively. Demand does not have to be *home demand*, and related and supporting industries do not have to be in proximity to offer effective supplies and services. Companies can keep in touch with customers via fax, communicate complex machinery specifications to suppliers over the internet, and deliver goods just-in-time using overnight express services. According to Munnich et al., linkages among an industry's firms are still important, but those feedback mechanisms have evolved into a different form since Porter's research. Further, they maybe never have been that important to begin with.

CONCLUSIONS AND FINAL REMARKS

The field of industrial cluster analysis has come a long way since Isard conceptualized the idea of an industrial district. A large body of literature on various aspects of industrial cluster concepts, definitions of industrial clusters, and numerous quantitative and qualitative approaches to identify them contribute to today's understanding of industrial clusters. Among the most single influential contributions to understanding the underlying causes for firms and businesses to co-locate in geographic proximity is the work of Marshall, Hoover, and lately Porter. With little to no disagreement on the scholarly contributions explaining why industrial clusters appear in the first place, cluster concepts as well as subsequent methods of cluster identification vary widely among academicians and practitioners. As Doeringer and Terkla (1995) put it, there simply exists no single correct definition of an industrial cluster. However, most (if not all) cluster concepts share a common denominator: industrial clusters refer to groups of firms, businesses, and institutions that co-locate geographically in a specific region and that enjoy economic advantages through this co-location. Deviations from these commonalities appear when focusing on the interdependencies of these firms, businesses, and institutions. Narrower by definition are *vertically-integrated clusters* where the focus is on the buyer and seller relationships among enterprises. Unsurprisingly, input-output tables are a preferred tool for identifying these interindustry relationships. A second and more comprehensive type of industrial clusters is the *horizontally-integrated cluster* where industries might share one or more factor input conditions, such as a trained labor force, specialized physical or information infrastructure, and/or other similar resources. In addition, regional demand conditions as seen in common markets for intermediate and final products, firm strategies, and the local business environment are recognized cluster suppositions. All these aspects are summarized in Porter's now famous *Competitive Diamond* metaphor. Additionally, the literature classifies industrial clusters according to the type of product and / or service they provide, the stage of development they have achieved, and the locational dynamics they are subject to (Ketels, 2003).

Usually, industrial clusters are identified through the use of analytical techniques. Popular, but also very limited, are location quotients. Location quotients prove very effective when the focus is on identifying regional specialization as a form of localization economies. In contrast, when industrial clusters are defined on interindustry linkages, a large body of quantitative methods evolved around input-output tables. Here, two conceptually different strains are well documented in the literature: i) direct value chain linkage analysis with focus on production chain linkages, and ii) trading pattern analysis where attention is paid to similarities in buying and selling behavior of industries. The distinction between clusters and industrial complexes plays an important role, as only industrial complexes are defined as groups of industries connected in one way or another and showing significant similarity in their locational pattern - and as such emphasize the spatial aspect of industrial concentration. Proposed methods to measure spatial proximity include regression and correlation analysis, often based on employment and population data. Besides sophisticated analytical methods, qualitative techniques - such as surveys, interviews, or focus groups - are suitable and often applied to detect additional information on interindustry relationships that are not enclosable by means of quantitative techniques. In addition, valuable information on social capital entrepreneurial climate, education and physical infrastructure, and quality of life (to name just few factors that influence a local business climate) can be gained through qualitative analysis techniques.

Moreover, qualitative analysis techniques are a suggestive supplement to quantitative statistical analysis methods for designing region- and industry-specific cluster-based economic development strategies. Industrial clusters do not evolve and mature solely around interindustry relationships, i.e., buying and selling between industries. Rather, they are a product of a large spectrum of locational business factors as illustrated in Porter's *Diamond of Competitive Advantage.* Identifying industrial clusters and putting them into context with respect to the prevailing regional business climates will help provide an understanding as to how the cluster is embedded into the local economy. It will give the policy-interested analysts and politician a better understanding of how the local economy is structured. And, most importantly, it is a necessary and inevitable step to translate knowledge on industrial clusters into cluster-based economic development policies.

The fact that no consensus has emerged regarding a single coherent cluster definition and / or cluster methodology adds much to the confusion surrounding contemporary cluster analysis. Instead, cluster analysis appears to be a broad umbrella for a wide variety of similar, but nevertheless different concepts and methodologies. Unfortunately, as pointed out by Brenner (2004), when focusing on the reasons why industries clusters emerge, exist or decline, local industrial clusters have only little in common. A deeper understanding of how firms benefit from co-locating is necessary to avoid confusion, formulate a meaningful cluster concept, and select the appropriate cluster methodology. But even a sound and theoretically grounded cluster concept may still admit confusion because, and as noted by Gordon and McCann, no single cluster concept is able to explain the emergence, existence or decline of all industrial clusters. Based on an empirical analysis, the authors suggest fine-tuning of existing cluster approaches. For instance, pure agglomeration with its diffuse, unstable and unrecognized linkages needs to add a spatial externality measure using aggregate production functions. Industrial complex analysis with its focus on production links can improve its local embeddedness by accounting explicitly for factor inputs. It appears that no single cluster concept is uniquely applicable for any cluster study. In addition, the purpose of any study – whether it is a general regional cluster study trying to identify all available clusters or a study of the nature of one pre-selected single cluster – will play a key role for determining the appropriate cluster concept and methodological approach.

REFERENCES

Alonso, W. 1964 *Location and Land Use*. Cambridge M.A.: Harvard University Press.

Akundi, K. 2003 Cluster-based Economic Development, Part 1: A Survey of State Initiatives. Texas Economic Development, Business and Industry Data Center, www.bidc.state.tx.us.

Barkley, D. L. and Henry, M. S. 2001 Advantages and Disadvantages of Targeting Industry Clusters. *REDRL Research Report 09-2001-01*. Regional Economic Development Research Laboratory, Clemson University, Clemson, SC.

Becattini, G. 1990 The Marshallian Industrial District as a Socio-economic Notion. In *Industrial Districts and Inter-firm Co-operation in Italy,* edited by Pyke, F., Becattini, G. and Sengenberger, W. Geneva: International Institute for Labour Studies, pp. 37-51.

Bergman, E. M. and Feser, E. J. 1999 *Industrial and Regional Clusters: Concept and Comparative Applications.* Web Book *in Regional Science*, Regional Research Institute, West Virginia University, http://www.rri.wvu.edu/WebBook/Bergman-Feser/contents.htm.

Botham, R., Gibson, H., Martin R. and Moore, B. 2001 Business Clusters in the U.K – A First Assessment. *A Report for the Department of Trade and Industry,* A Consortium led by Trends Business Research.

Brenner, T. 2004 *Local Industrial Clusters: Existence, Emergence, and Evolution*. London: Routledge.

Britton, J. 2004 The Path Dependence of Multimedia: Explaining Toronto's Cluster. Working Paper, Presented at the 6th. Annual ISRN National Meeting, Toronto.

Campbell, J. 1972 A Structural Approach to Growth Pole Theory. In *Problems of Slow Growth and Stagnant Areas in Developed Countries*, edited by Micklewright M.A. and Villeneuve P.Y. pp. 59-68.

Chen, K. 2005 Biotechnology Industry Cluster Analysis across Metropolitan Areas in the U.S. Dissertation: University of Cincinnati.

Chenery and Watanabe 1958 International Comparisons of the Structure of Production. *Econometrica* 26: 487.

Chinitz, B. 1961 Contrast in Agglomeration: New York and Pittsburgh. *American Economic Review* 51: 279-89.

Czamanski, S. 1974 *Study of Clustering of Industries*. Halifax, Nova Scotia, Canada: Institute of Public Affairs, Dalhousie University.

Czamanski, S. 1976 *Study of Spatial Industrial Complexes*. Halifax, Nova Scotia, Canada: Institute of Public Affairs, Dalhousie University.

Czamanski and L. A. de Q. Ablas 1979 Identification of Industrial Clusters and Complexes: A Comparison of Methods and Findings. *Urban Studies* 16: 61-80.

Diggle and Chetwynd. 1991 Second-order Analysis of Spatial Clustering for Inhomogeneous populations. *Biometrics* pp. 1155-63.

Doeringer, P.B. and Terkla, D.G. 1995 Business Strategy and Cross-industry Clusters. *Economic Development Quarterly* 9: 225-37.

Feser, E. J. 2003 What Regions Do Rather than Make: A Proposed Set of Knowledge-based Occupation Clusters. *Urban Studies* 40: 1937-1958.

Evans, A. W. 1973. *The Economics of Residential Location.* London: Macmillan.

Feser, E. J. and Luger, M. 2002 Cluster Analysis as a Mode of Inquiry: It's Use in Science and Technology Policymaking in North Carolina. *European Planning Studies* 11.1: 1-14.

Feser, E. J. and Sweeney, S. H. 2002 Theory Methods and a Cross-metropolitan Comparison of Business Clustering. In *Industrial Location Economics*, edited by McCann, P. Cheltenham: Edward Elgar.

Feser, E. J., Koo, K., Renski, and Sweeney, S. H. 2001 Incorporating Spatial Analysis in Applied Industry Cluster Studies. Manuscript, www.planning.unc.edu.

Feser, E. J. 2000 A Flexible Test for Agglomeration Economies in Two U.S. Manufacturing Industries. Working Paper, Department of City and Regional Planning, University of North Carolina at Chapel Hill.

Feser, E. J. and E. M. Bergman 2000 National Industry Templates: A Framework for Applied Regional Cluster Analysis. *Regional Studies* 34.1: 1-19.

Gordon, I. R. and McCann, P. 2000 Industrial Clusters: Complexes, Agglomeration and/or Social Networks? *Urban Studies* 37:3: 513-532.

Hanson, G. H. 2000 Scale Economies and the Geographic Concentration of Industry. Working Paper 8013, National Bureau of Economic Research. Cambridge: Massachusetts.

Henderson, J.V. 1974 The Sizes and Types of Cities. *American Economic Review* 64: 640-56.

Higgins, B. and Savoie, D.J. 1997 *Regional Development Theories and Their Application.* New Brunswick: Transaction Publisher.

Hill, E.W. 1998 Principles for Rethinking the Federal Government Role in Economic Development. *Economic Development Quarterly* Vol. 12, 4: 299-312.

Hill E. W., Brennan, J. F. and Wolman, L. 1998 What is a Central City in the United States? Applying a Statistical Technique for Developing Taxonomies. *Urban Studies* 35(11): 1935-1969.

Hill, E. W. and Brennan, J.F. 2000 A Methodology for Identifying the Drivers of Industrial Clusters: The Foundation of Regional Competitive Advantage. *Economic Development Quarterly* 14: 67-96.

Hoover, E. M. 1948 *The Location of Economic Activity*. New York: McGraw-Hill.

Hoover, E. M. and F. Giarratani 1999 *An Introduction to Regional Economics (3rd edition).* The Web Book of Regional Science, Regional Research Institute, West Virginia University.

Iammarino, S. and McCann, P. 2005 Firm Location and Technology: Stylized Constructs and Illusory Policies? Presented at the 4th European Meeting on Applied Evolutionary Economics (EMAEE), Utrecht, Netherlands.

Isard W. 1956 *Location and Space-Economy*. New York: Technology Press of Massachusetts Institute of Technology and John Wiley.

Isard, W., Schooler, E.W. and Vietorisz, T. 1959 *Industrial Complex Analysis and Regional Development: A Case Study of Refinery-Petrochemical-synthetic-Fiber Complexes and Puerto Rico.* Cambridge: Technology Press of the Massachusetts Institute of Technology.

Ketels, C. H. M. 2003 The Development of the Cluster Concept – Present Experiences and Further Developments. Presented at the NRW Conference on Clusters, Duisburg, Germany

Krugman. P. 1991a *Geography and Trade*. Cambridge, Massachusetts: MIT Press.

Krugman. P. 1991b Increasing Returns and Economic Geography. *Journal of Political Economy* 99: 483-99.

Latham W.R. III 1976 Needless Complexity in the Identification of Industrial Complexes. *Journal of Regional Science* 16.1: 45-55.

Launhardt, W. 1885 *Mathematische Begründung der Volkwirtschaftslehre.* Leipzig: B.G. Teubner.

Lee, B., Liu, L. and Stafford, H. A. 2000 Industrial Districts: Measuring Local Linkages In *Industrial Networks and Proximity,* edited by Green, M. B. and McNaughton, R. B. Aldershot: Ashgate.

Marshall, A. 1890 *Principles of Economics*. London: Macmillan.

Martin, R. and Sunley, P. 2003 Deconstructing Clusters: Chaotic Concept or Policy Panacea? *Journal of Economic Geography* 3: 5-35.

McCann, P. 2001 *Urban and Regional Economics*. Oxford: Oxford University Press.

McCann, P. and Sheppard, S. 2003 The Rise, Fall and Rise Again of Industrial Location Theory. *Regional Studies* 37.6,7: 649-663.

Mills, E. S. 1970. *Urban Economics*. Glenview, IL: Scott Foresman.

Moses, L.N. 1958 Location and the Theory of Production. *Quarterly Journal of Economics* p.259.

Munnich, L. W., Bau, M. M., Clark, J. J., Young, N. J. and Patel, A. M. 1998 *Southwest Minnesota Industry Cluster Study.* Humphrey Institute of Public Affairs and Minnesota Extension Service of the University of Minnesota.

Muth, R. F. 1969. *Cities and Housing*. Chicago: University of Chicago Press.

Myrdal, G. 1957 *Economic Theory and Under-developed Regions*. London: Duckworth.

Ó hUallacháin, B. 1984 The Identification of Industrial Complexes. *Annals of the Association of American Geographers* 73.3: 420-436.

Patton, O. M. and Reweta, W. S. J. 2003 Industry Clusters for the State of Colorado. *Workforce Research and Analysis, Labor Market Information,* Colorado Department of Labor and Employment,

Perroux, F. 1950 Economic Space: Theory and Applications. *Quarterly Journal of Economics* 64: 89-104.

Perroux, F. 1988 Growth Pole Theory and Strategy Reconsidered: Domination, Linkages and Distribution. *Economic Development Essays* in Honour of Francois Perroux

Peters, D. 2004 Revisiting Industry Cluster Theory and Method for Use in Public Policy: An Example Identifying Supplier-based Clusters in Missouri. Presented at the Mid-Continent Regional Science Association, 35th. Annual Meeting, Madison, Wisconsin.

Porter, M. E. 1990 *The Competitive Advantage of Nations.* New York: Free Press.

Porter, M. E. 1998a Clusters and the New Economics of Competition. *Harvard Business Review* 76.6: 77-90.

Porter, M. E. 1998b Clusters and Competition: New Agendas for Companies, Governments, and Institutions. In *On Competition*, Boston: Harvard Business School Press.

Porter, M. E. 2000 Location, Competition, and Economic Development: Local Clusters in a Global Economy. *Economic Development Quarterly* 14.1: 15-34.

Porter, M. E., Ketels, C.H.M., Miller. K, AND Bryden, R.T. 2004 Competitiveness in Rural U.S. Regions: Learning and Research Agenda. Institute for Strategy and Competitiveness, Harvard Business School: http://www.eda.gov/ImageCache/EDAPublic/documents/pdfdocs/eda_5frural_5fregions_5ffinal_2epdf/v1/eda_5frural_5fregions_5ffinal.pdf.

Rey, S. J. and Mattheis, D. J. 2000 Identifying Regional Industrial Clusters in California. *Volume II: Methods Handbook Technical Report.* California Employment Development Department, Sacramento.

Redman, J. 1994 Understanding State Economics through Industries Studies. Washington DC: Council of Governor's Policy Advisors.

Rex, T. 1999 Prominent Industry Clusters Vary by County. *Arizona Business* 46.6: 6-8.

Roepke H. D., Adams, D. and Wiseman, R. 1974 A New Approach to the Identification of Industrial Complexes Using Input-Output Data. *Journal of Regional Science* 14.1: 15-29.

Rosenfeld, Stuart A. 1995 Industrial Strength Strategies: Regional Business Cluster and Public Policy. Washington, DC. The Aspen Institute.

Rosenfeld, Stuart A. 1997 Bringing Business Clusters into the Mainstream of Economic Development. *European Planning Studies* Vol. 5 No. 1.

Rosenfeld, Stuart A. 2001 Backing into Clusters: Retrofitting Public Policies. Presented at the John F. Kennedy School Symposium, Harvard University.

Rosenthal, S. and Strange, W. C. 2004 The Micro-Empirics of Agglomeration Economies. In *Companion to Urban Economics,* edited by R. Arnott, Oxford: Blackwell Publisher.

San Diego Association of Governments 2001 San Diego Regional Employment Clusters: Engines of the Modern Economy. *INFO SANDAG / SourcePoint*, No. 1, http://www.sandag.org.

Schumpeter, J. A. 1934 *The Theory of Economic Development*. Cambridge: Harvard University Press.

Sforzi, F. 1990 The Quantitative Importance of Marshallian Industrial Districts in the Italian Economy. In *Industrial Districts and Inter-firm Co-operation in Italy,* edited by Pyke, F., Becattini, G. and Sengenberger, W. Geneva: International Institute for Labour Studies, pp. 75-107.

Streit, M. E. 1969 Spatial Associations and Economic Linkages between Industries. *Journal of Regional Science* 9:177.

Swann, P. and Prevezer, M. 1996 A Comparison of the Dynamics of Industrial Clustering in Computing and Biotechnology. *Research Policy* 25: 1139-1157.

Van der Linde, C. 2002 The Cluster Meta Study – List of Clusters and Bibliography. Institute for Strategy and Competitiveness, Harvard Business School, http://www.isc.hbs.edu/MetaStudy2002Bib.pdf.

Vernon, R. 1966 International Investment and International Trade in the Product Cycle. *Quarterly Journal of Economics* 80: 190-207.

Von Thünen, J. H. 1826 Der isolierte Staat in Beziehung auf Landwirtschaft und Nationalökonomie, Teil 1, Hamburg: Friedrich Perthes.

Weber, A. 1909 *Über den Standort der Industrien*. Tübingen, Germany: Mohr Verlag.

Wheat, L.1973 *Regional Growth of Industrial Location*. D.C. Health and Co, Lexington, MA.

Zeller, C. 2001 Clustering in Biotech: A Recipe for Success? Spatial Patterns for Growth of Biotechnology in Munich, Rhineland and Hamburg. *Small Business Economics* 17(1/2): 123-141.