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NETWORK ANALYSIS AND CORPORATE ALLIANCES

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Abstract

Reviewing existing studies on networks of alliances within industries, the paper argues that there is a need to include the analysis of alliance networks in industry analysis. It also argues that network analysis techniques can help in this task.

NETWORK ANALYSIS AND CORPORATE ALLIANCES

> «I believe that some of the fundamental ideas in microeconomics are very important in understanding strategic planning.»

This quote, taken from one of the most commonly used books on strategy (Oster, 1990), reflects what has been the main basis of industry and competitive analysis. Industry analysis has been mainly based on economic principles.

It was Michael Porter (1980) who coined the term industry analysis as the study of competitive forces in an industry, mostly based on previous microeconomic theory. The consequence of an exaggerated interpretation of Porter's argument was the idea that the only strategic decision was the choice of industry in which to compete. Some empirical studies have shown industry to be the most significant variable in explaining firm profitability (Schmalense, 1985). Cool and Henderson (1996) expand this argument by identifying the sources of this industry-derived profitability.

Hunt (1972) and Caves and Porter (1977) introduced a different level of analysis by developing the concept of strategic groups. However, the relationship between strategic groups and firm profitability is equivocal at best (Newman, 1978; Porter, 1979; Oster, 1982; Hergert, 1987). Fox et al. (1996) (1) contribute to the development of the strategic group literature by finding the concept useful for explaining firm-level profitability, taking into account the time dimension. Even though the overall results are not definite, the strategic group concept has been widely used to understand the competitive structure of an industry.

It was Rumelt (1991) who, building on previous research (Demsetz, 1973; Mancke, 1974), brought the discussion back to the industry vs. firm debate. Using longitudinal data, he found that it was mainly firm-specific assets that explained firm profitability. In a way, industry structure should therefore be understood in terms of the characteristics of each individual firm, which are, in fact, the ones that explain profitability.

As described above, three levels of analysis have been used to understand the competitive structure of an industry: that of the industry itself, that of the strategic group and that of the individual firm.

We contend that this view of industry analysis leaves out one of the most important trends in recent years: the formation of strategic linkages among firms in the same industry, broadly defined. Firms are no longer black boxes competing with one another. If they are boxes at all, they are overlapping boxes, which in some industries compete almost as much as they collaborate. Inter-firm linkages include mergers, acquisitions, equity partnerships, technology licensing and development agreements, supply agreements, manufacturing collaborations, and marketing agreements. They have been observed across a broad spectrum of industries, including automobiles, biotechnology, commercial aircraft, electronics, computers, robotics, and telecommunications, to name but a few (see Mowery, 1988, and Contractor and Lorange, 1988, for specific studies). Furthermore, we argue that these interorganizational linkages are strategic in nature (Hladik, 1985; Porter and Fuller, 1986) in that they involve commitments among major competitors that may have a crucial bearing on their competitiveness and strategic direction. These inter-firm linkages can be viewed as strategic resources that play a significant role in strategic performance (Madhavan et al., 1996).

If this is the case, then it is hard to argue that linkage networks should not be taken into account in analyzing the competitive structure of industries. Before this increase in the formation of linkages, there were already some studies that set out to assess the impact of alliance formation between firms in an industry on the level of profit in that industry. Following the market power argument, these studies focused on whether industry-level profits were affected by the intensity of alliance formation within an industry (Berg Friedman, 1980; Berg, Sanford and Friedman, 1981; Duncan, 1982). However, despite these studies addressing the issue of overall industry profitability, it is still not clear how the fact that there are networks of alliances in a given industry can be introduced into the understanding of the competitive structure of that industry.

This paper reviews the ways in which the specific studies of industry linkage networks have been carried out, and how they relate to the issue of competitive positioning within an industry.

We show how the use of network analysis techniques can throw some light on this problem. While we do not claim to have the solution to the problem, we argue that analyzing these webs of inter-firm linkages through network analysis, bringing in strategy variables, can enhance our understanding of the competitive implications of these emergent webs.

Network analysis emphasizes the relations that connect actors within a system. The organization of the network of relations becomes a central concept in analyzing the whole system. Both terms are key here: “actors” and “relations”.

Network analysis has been used with very different types of actors. In most of the studies the focus of the relationships has been specific people, making the individual the actor (Crane, 1969; Laumann , 1966; Runger and Wasserman, 1980). Within the sociological tradition, however, network analysis has also been used at the firm level, focusing mainly on interlocking directorates (Sonquist and T. Koenig, 1975; Burt, 1979), or at the country level (Snuder and Kick, 1979). In the case at hand, the actors are individual firms, mostly in the same or related industries, i.e. organizational fields (Knoke and Rogers, 1979). Whereas in most previous studies dealing with inter-firm relationships the relations have been either interlocking directorates or equity holdings, the studies reviewed here focus on linkages established among firms in the same organizational field.

The paper is organized as follows. The next section describes the general approach to linkage network formation. The second section describes the different types of theoretical approach in which network analysis has been used to understand networks of alliances within industries.

The third section describes how different studies have solved the problems of using network analysis techniques. Finally, we present our conclusions and indicate avenues for further research.

A general approach to network formation

We here describe our general understanding of network formation, based on Nohria and García-Pont (1991). Firms have been competitors for quite a long period of time, and it is not until recently that there has been a surge of alliances among firms in the same industry. Looking closely at this surge in alliance formation, one can see that it occurs mainly in industries where there have been significant challenges to the competitive status quo. Pharmaceuticals, European banking, automobiles (in the 80s), microelectronics and telecommunications have all seen major changes in the way the participants compete.

These industry-wide challenges may be caused by endogenous or exogenous changes. Endogenous changes are due mainly to technological developments, such as the emergence of biotechnology in the pharmaceutical industry or the increasing level of technological sophistication in the telecommunications industry. The emergence of Japanese competitors in the automobile industry is also partly an endogenous change, given that they owed a large part of their competitiveness to their manufacturing process technology. Exogenous changes are due to external events, such as deregulation in the airline, banking or telecommunications industries.

For the firms in the industry these changes create a set of potential benefits to be derived from establishing linkages with other firms. Thus, we find an “opportunity structure” for each firm in the industry (Emerson, 1972), which basically depends on the intrinsic characteristics of the different firms. In other words, firm A has a set of potential benefits to be obtained from establishing a linkage with firm B, and a different set of benefits if it links with firm C.

In fact, the network of linkages in the industry is the result of the interactive choices of firms as they try to maximize the benefits derived from the exchange. As Blau has pointed out (Blau and Schwartz, 1984), social relations depend on opportunities for contact, which obviously exist among competitors, given that they have known each other for a while (2), but which may increase significantly when there is a challenge to established ways of competing within an industry.

The objective of the analysis

One can study industry networks from two different angles. First, one can look at the final outcome of the linkage formation process: the structure of the overall network of linkages. In this case, one is interested in elucidating the way these networks change the competitive structure of the industry. Second, one can look at the cooperative strategies of individual actors or types of actor, using network analysis techniques to describe these strategies more adequately.

Studying the overall network

Among studies of the overall network two different patterns emerge. One approach is to try to understand the network of linkages from an industry analysis perspective. These studies (Walker, 1988; Nohria and García-Pont, 1991; Ray, 1992; Lessard and García-Pont, 1992; Vanhaverbeke, 1994) focus on identifying “strategic blocks” in the industry. Strategic blocks are defined as groups of firms that are more densely linked to each other that to other firms in the industry (Nohria and García-Pont, 1991). The main argument here is that the block composition of an industry has to be taken into consideration when analysing competition in that industry, and that strategic block structure is an aspect of industry structure. If linkages allow each partner to gain access to the resources and capabilities of the other partner, each block represents a competing set of resources and capabilities. One could speak about block to block competition.

In the context of the automobile industry, Nohria and García-Pont (1991) consider the classification of strategic groups as representing similar pools of resources and capabilities. Their findings show two different types of block: “pooling“ and “complementary“. The firms that make up a pooling block have similar sets of strategic assets. Those that form complementary blocks have different sets of strategic capabilities and thus gain access to a wider variety of resources. Investigating the airline industry, Ray (1992) finds route complementarity to be the key asset; the firms in each strategic block are clearly complementary in their routes. In their study of the banking industry, Lessard and García-Pont (1992) consider size and country to be important assets to be shared. However, even though they find a large number of linkages among small and large institutions, they do not find any pan-European blocks. The key asset to be shared in the RISC (3) market is the firms’ own industry experience (microelectronics, computers or software). In three of these studies –automobiles, airlines and the RISC market– the complementarity index (Nohria and García-Pont, 1991; see appendix for a definition of the complementarity index) is used to analyze the composition of the different strategic blocks. All of them focus on the extent to which the strategic blocks found include similar or different pools of resources and capabilities within the industry.

Another approach, again at the level of the structure of the overall network, explicitly sets out to sketch a first outline of the structure of the biotechnology community and its alliances. Barley, Freeman and Hybels (1992) attempt to show the evolution of the network in the biotechnology industry, using descriptive measures. What they have in common with the above-mentioned approach is that they recognize other firms as owners of resources and argue that linkages are the only way firms can engage in exchanges to gain access to the resources they need.

Studying individual actors

The second perspective in the study of industry networks focuses on the individual actors in a network. Two different approaches can be identified. The first attempts to explain the pattern of relationships of an individual firm, given certain independent variables. The second tries to explain the decision to form or not to form a linkage with a specific firm as a function both of the actual characteristics of the network and of some other industry variables.

The basic difference between the two approaches is the choice of independent variables. The first approach brings in variables that are exogenous to the network, while the second brings in variables that are endogenous to the network. Let me start with the first approach.

Freeman, Barley and Hybels (1992) use variables such as age, type of firm (dedicated biotechnology firm, investor, university, …), and region of origin to explain the network position of individual actors in terms of degrees of centrality (Freeman, 1979) and relative betweenness (Freeman, 1979) (4).

Kogut, Shan and Walker (1992) regress the number of cooperative relationships entered into by a New Biotechnology Firm in a given year on variables that are also intrinsic to the firm (size, age, product diversity, change in focus, and whether or not they have already made an IPO). They also investigate the way the behavior of individual firms changes as the network evolves by dividing the period under study into smaller sub-periods.

Powell and Brantley (1992) regress the number and types of ties and the percentage distribution of ties on variables such as employment, ownership, US region, product mix and age.

What all these studies have in common is the assumption that cooperative strategy –and thus also network position– is dependent on the characteristics of the individual firm and not on the overall evolution of the network. In this sense, I believe there is a certain contradiction between this type of approach and the use of network analysis.

The reason is that the first insight of network analysis is that any one actor is part of a social system that includes many other actors, and that these actors are important points of reference for each other in making decisions. The nature of the relationship that a given actor has with other members of the network may affect the focal actor's perspective. In fact, the view that a particular actor has of the complete system might influence that actor's positioning decision in the linkage network. Thus, in order to explain the individual cooperative actions of firms, one should take into account their social environment, which is partly defined by the cooperative actions of other firms in the network, or the overall network structure (Van der Ven, Walker and Liston, 1979).

The second approach focusing on individual actors is represented by two studies (García-Pont and Nohria, 1993; Gulatti, 1995). Both try to answer a similar question: García-Pont and Nohria investigate why two specific firms establish a linkage in a particular year, while the central question of Gulatti's study is “With whom do firms ally?”

One of the main differences between this approach and the previous one is the shift away from the individual firm and toward the dyad as the unit of analysis. Focusing on the firm assumes that firms can decide for themselves whom to link with. Focusing on the dyad takes into account the joint decision.

Both studies use the same dependent dummy variable, Y_{ijt} to represent whether firm i and firm j form a linkage in year t, or in statistical terms, the probability that a linkage between firms i and j will be established at time t.

However, the key aspect of these two studies is their choice of independent variables. García-Pont and Nohria use three basic variables: the overall density of the network at time t-1; the density of the sub-network of linkages among the firms belonging to the same strategic groups as firms i and j at time t-1; and the existence of previous linkages; as well as some other control variables which I shall not go into here for reasons of brevity. Their results suggest that the previous interactions of other firms in the network is an important factor in explaining dyad linkage decisions. According to their findings, dyads decide to establish a specific linkage on the basis of the existing network of linkages between firms with a similar degree of interdependence as themselves, i.e. firms in the same two strategic groups.

The independent variables used by Gulatti are the strategic interdependence of the firms in the dyad, the number of prior ties between the firms in the dyad, the number of other partners each firm has in common, an interaction term of the number of third party ties, and a dummy variable indicating whether a dyad has had a previous direct tie or not. Gulatti’s emphasis is on the closeness of the firms in the dyad prior to the linkage formation. According to his findings, networks grow stronger as the number of linkages increases.

Both studies use two different kinds of variables: network characteristics variables and control variables to check for specific industry issues or the propensity of specific dyads or groups of firms to establish dyads among each other.

From the description of the variables in these studies, one can see that they focus on the structure of the network as a predictor of the cooperative strategy of individual firms in the industry. Their results reinforce the sociological view that there is a relationship between the decision to cooperate and the characteristics of the network of alliances at the micro level, i.e. that of the sub-network in which the firms are positioned. Their findings are important in that they confirm the usefulness of the sociological perspective for analyzing strategic cooperative decisions.

Issues in networks

Having briefly looked at the objectives of the main studies on intra-industry linkages and industry structure, this section looks at the way these studies deal with the main methodological decisions involved in network analysis techniques.

In order to apply network analysis, one has to make decisions on the following items: boundaries of the networks, attributes of the actors, definition of the relationships between the actors, the adjacency matrix, and the kind of analysis pursued. The following sections will discuss these issues in their application to intra-industry linkage networks. Exhibit 1 compares the different studies.

Exhibit 1

	Boundaries	**Attributes**	**Relationships**	**Objective of the study**	**Types of network analysis**
Walker (1988)	Aluminum industry. One industry	Strategy type	Strategic alliances	Identify cooperative strategy. Evaluate relative value of cooperative relationship.	Structural equivalence
Nohria and García-Pont (1991)	Automobiles. One industry	Strategic capabilities-Strategic groups	Strategic alliances, mergers and acquisitions	Understand industry structure.	Social circles
García-Pont and Lessard (1992)	European banking. One industry	Country of origin, size, and savings vs. public	Strategic alliances, mergers and acquisitions	Understand changes in industry structure due to EC 92.	Social circles
Vanhaverbeke (1994)	RISC field. Computers, software and microchips	Firm's industry	Strategic alliances, mergers and acquisitions	Understand the standard-setting game.	Social circles
Ray (1992)	World airline industry. Largest 29 firms	Routes	Strategic alliances, mergers and acquisitions	Explore the formation of worlwide blocks.	Social circles
Barley, Freeman and Hybels (1992)	All firms in the biotechnology field	Identity (Dedicated biotechnology firms, research institutes, ...)	Strategic alliances	Provide a prelimnary glimpse at the network structure in biotech.	Regression analysis
Kogut, Shan and Walker (1992)	Business entities specializing in biotechnology	Strategy type	Strategic alliances	Study the influence of firm and network variables in alliance formation.	Negative binomial regression
Powell and Brantley (1992)	Biotechnology. Therapeutics	Size, location in the U.S., ownership type, product orientation	Strategic alliances	Explore changing locus of innovation in biotech.	Regression analysis

Boundaries and attributes

One of the key issues in network analysis is how to define the boundaries of the network, which in practice will always depend on two contingencies: first, the problem to be studied and second, the criteria of the researcher. It is impossible to generalize about the boundaries of the network to be considered. It depends entirely on the problem at hand.

A second issue is the attributes of the actors in the network. Attributes are the characteristics of the actors that do not depend on their network position, but that can be thought of as their own identity. In the case of firms, we can think of a firm's identity as its set of strategic resources (Barney, 1991).

Let me give some examples of network boundaries and actors' attributes in different studies of this kind. As you will see, the characterization of the actors in a network basically follows from an industry analysis that identifies resources and capabilities to be exchanged in the opportunity structure that has been identified.

Walker (1988): Aluminum

In his study of the upstream joint ventures among firms in the aluminum industry, Walker limits the network to the nineteen dominant firms in the industry. With regard to attributes, he divides the firms into “majors“ and “diversifiers“, using Stuckey’s (1983) classification of strategic groups. He then argues that this classification represents what the individual firms bring into the opportunity structure mentioned above.

Nohria and García-Pont (1991): Automobiles

In this study the authors limit the network to the 35 significant producers of assembled automobiles that participate in open market economies. They argue that the sample consists of firms that may be considered to play similar roles in the economic process.

Following the resource-based view (Wernerfelt, 1984; Barney, 1991), they characterize the firms in terms of their strategic capabilities, which define the strategic group to which they belong. Accordingly, the firms in each strategic group can be considered as having a similar endowment of capabilities and thus a similar source of competitive advantage, which cannot easily be transferred, imitated or acquired by firms from different groups. Secondly, firms in the same strategic group are more or less equally vulnerable to changes in the environment. Thus, one can expect similar reactions in the face of the existing opportunity structure.

García-Pont and Lessard (1992): European banking

García-Pont and Lessard use two basic dimensions in classifying European retail banks. The boundaries of the network are chosen so that the firms offer similar products to the market. The authors also restrict the formal analysis to the 200 largest European banks, although when describing the results of the analysis, they do not exclude smaller institutions related to those already mentioned. These smaller institutions can play a significant role in the development of the larger banks' cooperative strategy. Following a discussion of the key issues that Europe 92 brings into the competitive arena, the selected attributes are: country, size, and whether the firms are savings banks or public banks. Country is important in that deregulation in

European banking basically opens up cross-country references, and size is important in that in most continental banking systems it is an indicator of universal vs. niche banking. And the difference between public banks and savings banks is that savings banks are subject to certain limitations to their ability to compete in terms of shareholder participation, etc.

Vanhaverbeke (1995): The RISC (Reduced Instruction Set Computer) Market

RISC microprocessors offer significant cost/performance advantages over computers based on the traditional CISC (Complex Instruction Set Computer) technology. RISC technology stresses the reduction and simplification of the instruction set in order to obtain the highest performance from available technology.

Microprocessors are only one core component of computers and are always used as part of a package or bundle of software and hardware. Therefore, in order to understand the competitive dynamics of the industry, the network must include microprocessor or integrated circuit manufacturers, workstation manufacturers, PC makers, midrange computer makers, and software developers. The basic attribute the author is interested in is which specific industry a firm belongs to - microprocessors, computers or software. Since strategic alliances with respect to RISC technology are established by companies that tend to promote a particular computer architecture as an industry standard, the network has to include all the firms that influence the standard, their main attribute being their specific business and technological expertise. In this case, the definition of boundaries and firm attributes is guided by the standard-setting competitive game.

Ray (1992): The Airline Industry

Ray defines the network as the 29 largest world airlines, arguing that their international presence was at stake when deregulation occurred. When it comes to defining the attributes of the actors, he basically argues that the key element in this opportunity structure are the routes and connections. One of the key issues in the international airline industry is airport slots. With explicit regulation, airport slots determine which routes an airline can serve. Complementarity in routes and slots allows airlines to broaden their market scope, and collaborative agreements enable them to service a broader set of potential customers.

Barley, Freeman and Hybels (1992): Biotechnology

The boundaries of the network are set by including all firms connected with the biotechnology field. In their study of strategic alliances in commercial biotechnology, the authors consider the main attribute of the different firms to be their identity, assuming that each one brings specific capabilities or resources to the opportunity structure that the emergence of biotechnology has created. They differentiate between dedicated biotechnology firms, universities, research institutes, diversified corporations, investors, government agencies, hospitals, state biotechnology centers, suppliers of goods and suppliers of services.

Kogut, Shan and Walker (1992): Biotechnology

The authors start by defining the network as consisting of independent business entities that specialize in the commercialization of biotechnology products, given that their focus is on structuring the relationships between commercial competitors. The basic attribute of the actors is whether they are focused or unfocused, although there are others (size, age and product diversity).

Powell and Brantley (1992): Biotechnology

The boundaries of the network are initially defined so that the firms are not subsidiaries of large corporations and are important enough (more than 10 employees, with a specific product focus –therapeutics) to be able to collaborate. However, the authors study all the firms related to those included in their first choice, using this as a way to characterize the cooperative strategies of the firm. The specific attributes are some measures of size, location in the U.S., ownership type and product orientation.

Mattsson, Lundgren, Ioannidis & Ottoson (1990): The Telecommunications Industry

In their study of the telecommunications industry, the authors do not establish a typology of the different players. Instead, they use individual firm attributes to explain the developments in the alliance network. Rather than choosing attributes a priori, they use them to discuss "ad hoc" the specific results of their network analysis.

Boundaries and Attributes: Conclusions

We can see that the definition of network boundaries depends on the researcher's interests. We have three studies that focus on the same industry, biotechnology, and use different network boundaries. The first focuses on the whole industry, the second on the newly created firms, and the third on newly created firms and their partners. All of them are consistent with the research question they are posing.

On the other hand, we have the studies of the automobile, banking and airline industries, which follow similar approaches. Each has a very precise definition of its industry in line with the classical idea of firms with equivalent roles in the economic process. The study on the RISC market, however, integrates players from different industries, as the author argues that it does not make sense from a competitive point of view to separate the various industries involved in setting standards.

Regarding attributes, all of the studies we have looked at use firm-specific attributes. The biotechnology studies focus on individual firm attributes; the other studies focus on firms that are similar in that they either belong to the same strategic group (automobiles), share the same routes (airlines), or produce similar products (RISC market). All three studies focus on the key assets that the firms bring to the opportunity structure that has emerged.

While all of the studies use a similar definition of attributes, in that they determine the resources that the firms bring to the opportunity structure, the definition of the boundaries of the network depends on the specific nature of the competition in each industry and the question being addressed.

The relationships and the adjacency matrix

The next requirement of all network analysis techniques is to determine the specific relationships that link the actors in the network. Together with this issue, the researcher has to decide whether there will be one or more adjacency matrices to be studied. Typically, each matrix is binary: 1 indicating the presence of a tie, 0 indicating the absence of any tie. However, there are also cases in which the number in the cell indicates a certain measure or assessment of the strength or intensity of the linkage, as in the case of corporate interlocks (Burt, 1982: Ch. 2).

A second choice that has to be made is whether the adjacency matrix is going to be symmetric or not. One might think that it would be obvious from observing the nature of the linkage whether the matrix is going to be symmetric or not. For example, in a 50-50 joint venture, the linkage might at first be thought to be symmetric. However, if the joint venture is formed to facilitate the entrance of one of the partners into the market of the other, the matrix need not necessarily be symmetric in nature.

Let us see how different studies have dealt with this issue.

Automobiles, RISC Market, Airlines, and Banking

All these studies use the argument that in order to understand the overall web of linkages, they should work with a single adjacency matrix. They therefore collapse all the different kinds of links into one adjacency matrix.

They define a relationship as any kind of long-term agreement between two organizations in the network. This definition includes mergers, acquisitions, equity partnerships, consortia, joint ventures, technology licensing and development agreements, supply agreements, manufacturing collaborations, and marketing agreements. The basic argument for including these quite different types of linkage is that they are all answers to the opportunity structure that has emerged as a result of the changes in the industry.

The authors recognize, however, that it is difficult to justify treating all these different kinds of relationship as being the same, given that they can vary in terms of intensity and reversibility. They argue that because the relationships vary considerably in terms of resource commitment, organizational interdependence and reversibility, they have to be differentiated. They do this by weighting the relationships, adapting Contractor and Lorange’s (1988) assessment of the interorganizational interdependence created by different kinds of linkage. This weighting can only be done given the algorithm they use for the analysis (CONCOR, Breiger et al., 1975).

The adjacency matrix is considered to be symmetric in all of these cases. The argument is that the focus is on the linkage as creating an opportunity for any type of exchange, similar or complementary. As Krachardt (1990, 1991) points out in his discussion of advice networks, the opportunity for exchange provided by a tie is clearly symmetrical, even if what flows from one side to the other is not the same.

Walker (1988)

Walker also uses a single matrix of relationships, defining a relationship as any kind of linkage among the major players. However, he does not include strong irreversible linkages, mergers or acquisitions. To evaluate this decision we would need to know whether those linkages were relevant in the industry concerned.

Barley, Freeman and Hybels (1992)

In their study of the biotechnology industry, the authors conduct two parallel analyses. They study the different adjacency matrices, one for each of the different kinds of linkage. The multiplex matrix includes all the linkages of different types. Its cells, Aij, are equal to 1 if there is any type of linkage between firm i and firm j (Aij=1 if there is any Aijk =1, where i and j are the firms and k is an index for the different types of linkage) and zero in the opposite case. They report that the results were quite similar for all of the analyses they performed. Organizational alliances are coded as dyadic ties, implying a symmetric matrix; this dyadic coding allows them to compile the network data set in a relatively straightforward manner.

Kogut, Shan and Walker (1992)

In this study, in contrast to others that analyze square matrices with the same firms in both axes, the authors analyze an asymmetric rectangular matrix of cooperative relationships between new biotechnology firms and their partners. It is interesting to note that this allows them to mix attributes of the firms with the network algorithms and analyze whether similar firms behave similarly or dissimilarly with respect to other groups of firms.

Powell and Brantley (1992)

The agreements considered (in this study) are bilateral relationships, implying a symmetric adjacency matrix. The matrix is also binary. The authors justify this on the grounds that they lacked data on the importance, duration or directionality of the alliance. In this study they choose symmetric matrices, focusing on the relationships that include biotech firms.

Relationships and the adjacency matrices: Conclusions

As far as the relationships between firms are concerned, the first four studies include relationships in which one of the firms ceases to exist as an independent entity, whereas the others reject this option. The first group includes such relationships because the authors believe that they are one way, among others, of establishing a linkage in response to the opportunity structure caused by changes in the industry. The downside of including these linkages is that, depending on the period under study, you run into problems when it comes to characterizing the network as a whole in terms of descriptive measures such as overall density.

Methodological issues

There are two basic approaches to the study of intra-industry linkage networks. As we have seen, the first focuses on the overall structure of the network, and the second on the actions of individual actors or dyads.

Analysis of the overall network

Walker (1988), Nohria and García-Pont (1991), García-Pont and Lessard (1992), Ray (1992) and Vanheverbeke (1994) adopt the first of these two approaches. Their basic analysis consists of applying two different clustering algorithms to the two sets of data in the study. First, a clustering algorithm is applied to the network data to find structurally equivalent actors or social circles. Second, a different clustering algorithm is used to find firms that are similar in terms of the chosen attributes.

There are two basic alternatives in analyzing the overall network. The first is to look at cohesion, and the second is to study structural equivalence.

When the criterion is social cohesion, actors are grouped together in a given position according to the degree to which they are directly connected to each other by cohesive bonds. The positions thus identified are called “cliques” if every actor is directly tied to every other actor in the position (i.e. maximum cohesion), or “social circles” if the analyst permits a more limited frequency of direct contact.

The second criterion for determining the network position of a firm is structural equivalence (Lorrain and White, 1971; White et al., 1976; Sailer, 1978). Actors are grouped into a shared position or role if they have a common set of linkages with the other actors in the system. It is not necessary for actors that are structurally equivalent to have direct ties to one another. Thus, structurally equivalent actors may or may not form a clique or a social circle, and a socially cohesive position may contain actors with very different patterns of ties to the other positions.

Which criterion is used will depend on the objectives of the researcher. If the researcher is looking for cliques or circles, he will naturally look for coalitions in the network and examine the composition of these coalitions in terms of the attributes of the actors involved.

If he is looking for structural equivalence, the researcher will try to identify firms that have similar cooperative strategies in that they are all linked to certain other firms in the network.

The difference in outcome depends both on the data base and on the method used. When the overall structure of the network can be divided into non-related dense cliques, the end result is that firms that are structurally equivalent belong to the same clique, given that they are connected with exactly the same firms in the network. However, when the density of the network is low and cliques or social circles are not easily identifiable, the results will not necessarily be similar.

Let us examine the different studies and see which method they have used and why.

Walker (1988), Nohria and García Pont (1991), García-Pont and Lessard (1992), Ray (1992) and Vanhaverbeke (1995) all use the CONCOR algorithm (Convergence Iterated Correlations, Breiger et al., 1975), a hierarchical clustering procedure that starts with a set of K observed matrices. The matrices are stacked to create a single matrix which contains linear measures of similarity (Pearson correlation among the relationships) between every pair of actors. The larger the correlation, the greater the structural equivalence of a pair. CONCOR produces following correlation matrices until convergence to values of ±1 appear in all cells of the matrix. Then it shifts the rows and columns to create a partition in the matrix. It follows on until the researcher fixes its criteria.

Walker (1988) used a second algorithm called CALCOPT, which takes as input the CONCOR ordering of the firms into blocks and reassigns the firms among the blocks according to changes in a target function (see Boorman and Levitt, 1983) (5).

For the clustering of firms using attribute data, the different studies have used either a simple classification based on the attributes (e.g., country of origin) or traditional clustering algorithms using Euclidean distance. The reason for using different approaches is that the input data for network analysis is usually quite sparse. That is, adjacency matrices have a large number of zeros in them. The CONCOR algorithm has proved useful in these settings.

Analysis of the overall network: Conclusions

There are two basic criteria: looking for cliques or social circles, and looking for structural equivalence. The first criterion is basically aimed at finding groups of firms that are densely linked to one another; in terms of alliances, it implies that they have tied their strategic positions. The second criterion is basically aimed at identifying firms that could, in fact, be competing for the same kinds of resources with third firms, given that they are tied to exactly the same third firms. However, in densely linked subnetworks the output difference is not significant.

Analysis of individual actors

As mentioned above, the second type of study has focused on the actions of individual actors. The techniques have been twofold. The first uses network analysis and the second statistics.

Researchers have looked mainly at individual firms' network parameters: degree of centrality, relative betweenness (Barley, Freeman and Hybels, 1992); number of a firm's relationships (Kogut, Shan and Walker (1992); number and types of ties (Powell and Brantley, 1992).

Subsequently, these studies have used statistical techniques to explain the network behavior of individual firms through the firm's attributes. The methodologies have varied depending on the issue at hand, ranging from regression analysis to Manova or negative binomial regression. As these are traditional statistical methods, I will not describe them here.

The dyad-based studies (García-Pont and Nohria, 1992; Gulatti, 1995) differ in that they include network variables as independent variables, as noted above.

García-Pont and Nohria (1992) use a logistic regression. Gulatti (1995) uses a dynamic panel model that accounts for unobserved heterogeneity using a random-effects approach (Butler and Moffit, 1982).

Conclusion

This paper has described the main uses of network analysis techniques in analyzing the network of linkages within industries. The basic argument has been that strategy needs a way of bringing these webs of alliances into industry analysis, and that network analysis can help. There is a danger of believing that network analysis is a theory in itself, whereas, in my view at least, it is merely a tool that can help us study certain aspects of reality in greater detail. The analysis, as usual, can only be as good as the theory behind it.

One feature that the various studies reviewed here have in common is that they view linkage networks as the outcome of a potential exchange network among firms facing competitive challenges. Either by looking at the resulting competitive structure of the industry in both network and resource terms, or by looking at the actions of individual actors in forming the network, all the studies focus on the structure of the network. However, the initial argument of this paper was built on the different sources of profitability. None of the studies has assessed the effect of these network structures on individual firm profitability. I believe that if we want to improve our understanding of the way linkage networks affect the competitive characteristics of an industry, more research should be carried out in this direction.

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(1) This document is to be published in (Ghertman et al., 1997).

(2) Except in cases where there are a large number of new competitors in the industry.

(3) Reduced Instruction Set Computer, as opposed to CISC, Complex Instruction Set Computer.

(4) See Appendix for definitions of degree centrality and relative betweenness.

(5) There are other methods of computing structural equivalence. One of them is based on similiarities of Euclidean distances among actors (Burt, 1976; Burt, 1980). A second method based on graph theory assesses the positional similarity between two actors by comparing their relations to other actors on measures such as local dependency, the number of geodesics or geodesic distance. The measure of association is the coefficient of identity (Zegers and Berge, 1985).

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Appendix 1

NETWORK ANALYSIS AND CORPORATE ALLIANCES

Definitions

Degree of centrality

The integer count or number of other actors with which a given actor has direct contact (Knoke and Kuklinski, 1982).

Density

A characteristic of the entire network, density is a proportion that is calculated as the number of all ties occurring in the matrix divided by the number of all possible ties (N2-N, if self-directed relations are not permissible).

Relative Betweenness

The relative betweenness of an actor is a ratio that measures the extent to which a point in a network approaches the betweenness score of a star (Freeman, 1979). An actor's relative betweenness can lie between zero, when it lies in no geodesics, and a maximum of one, when the actor is at the center of a star.

Geodesics

The shortest path between two actors in the network.

Complementarity index

The complementarity index measures the degree to which a block is "pooling" or "complementary". In other words, whether the actors in a strategic block (set of actors closely linked among them) belong to similar or different previously defined strategic groups. It has been used to study differences of strategic group membership between members of the same block. The complementarity index is equal to 1 if all the firms belong to different previously defined strategic groups, and 0 if all the firms in a block belong to the same previously defined groups. It is used to bring into network analysis the previous cluster of the actors based on their attributes (Nohria and García-Pont, 1991).

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