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## Networks of Strategic Alliances

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The intent of this chapter is to lay out in a general way the current state and trends of research on alliance networks as well as the promising paths for future work. The emphasis is primarily on the match between theory, method, and data for both local networks—composed of firms and their partners—and for the network overall. The discussion moves from research on local relational neighborhoods to studies of larger networks defined by industry or geographical boundaries. The chapter ends with current innovations in network analysis, which are numerous and in many ways pathbreaking.

Researchers on strategic alliances frequently include the term *network* to describe the inter-firm relationships they analyze. What do they mean by this term? Generally, a network means that the firms are tied to each other just as cities are linked through road systems or people communicate through phone lines. Firms are nodes, as in a lattice, and the alliances connect them. Although many interesting and useful studies on

alliances have used the network metaphor, most of this research does not really analyze the network at all. The reason is that the properties of the network—for example, its structure or its density—are not investigated; rather, the alliances are examined not as part of a larger relational system but as if they were independent. The alliances might as well have been formed on different planets. In such studies, referencing a “network” is misleading because it creates the expectation that a network will be analyzed in the research, when in fact this is not the case. More important, if there is in fact a network of alliances among the firms and it is excluded from the analysis, the study’s results may be biased, because a large body of research has shown that the properties of a network have a significant influence on the behavior of the firms that compose it, as discussed below.

What, then, does taking a network perspective in alliance research actually mean? At a minimum, it involves analyzing alliances that are at

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least two steps away from a firm, because networks are systems of serial connections. The closest of these “indirect” ties (see Ahuja, 2000; Uzzi, 1996) connect a firm’s immediate partners to each other and to other organizations. The links between the firm and its partners together with the links between the partners themselves constitute the firm’s local relational neighborhood. The structure of this neighborhood may be relatively closed when many partners ally with each other or open when they do not. The local neighborhood’s degree of closure has been the topic of a great deal of research with broad implications for innovation, performance, and the development of the network itself.

Firms are also connected indirectly across neighborhoods through multiple chains of alliances that together form the network as a whole and whose analysis is more complex than that of local partnerships. Approaches to analyzing the network in full have been based on a variety of concepts, such as centrality and structural equivalence (see Burt, 1980a, for an early review); and studies based on these approaches have generally attempted to show how network structure and firm behavior influence each other. This line of research is rich and growing.

Studies of alliance networks have also taken either a static or dynamic approach. Research on the firm’s local neighborhood has primarily examined the network as a static system. Although some studies have looked at changes in the local networks of people (see Burt, 2002), there has been only limited research on the dynamics of local neighborhoods composed of firms. An exception to this trend is the growing research on small worlds that, in a kind of hybrid approach, takes a dynamic perspective on how local structure develops or endures in the larger network context. In contrast, research on the network macrostructure has included both static and dynamic models, and many interesting and potentially fruitful paths of inquiry are currently being followed.

Alliance network studies more generally are a small part of the currently burgeoning research

on networks of all kinds. The network literature overall has grown rapidly over the past five years with the availability of new data sources and the development of new network theory and analytical methods. A sample of the new types of network studied includes the Internet (Siganos, Faloutsos, Faloutsos, & Faloutsos, 2003), electricity grids (Watts, 1999a, chap. 5), and neuron linkages in worm brains (Watts, 1999a, chap. 5). Network theory and analysis have likewise expanded, especially with research on small worlds (Watts, 1999a), building in part on earlier work (Milgram, 1967; White, 1970), and scale-free networks (Barabasi & Albert, 1999). How these broad and numerous developments influence research on alliance networks will be discussed at the end of this chapter.

## The Network as Local Neighborhood

The vast majority of research on the structure of a firm’s local neighborhood has focused on its relative closure. A completely closed structure means that all a firm’s alliance partners are also partners of each other. A completely open network is one where the partners have no alliances among themselves. The local neighborhood structures of most firms are somewhere in between these two extremes.

*Local Closure and Structural Holes.* Two competing theories motivate research on the structure of a firm’s local neighborhood. The first is Burt’s (1992) theory of structural holes. A structural hole exists when a direct relationship is missing between two firms that are not indirectly tied by other firms in the network. When a third firm allies with both firms, the hole is filled, and network connectivity is increased. Burt’s argument is that a firm filling a structural hole benefits from acting as a broker that ties together other organizations. Based on its access to diverse resources and sources of information, a broker is able to exploit opportunities for arbitrage and to

set terms of trade that favor it over its partners. In Burt's theory, therefore, a firm gains from having an open local neighborhood with disconnected partners.

The second theory is based on the concept of social capital (Bourdieu, 1980; Coleman, 1988). Generally, *social capital* designates the benefits an individual receives from his position in the surrounding social structure, a definition that Coleman (1988) narrows by focusing on the local neighborhood. He argues, in contrast to Burt, that the more closed the network, the stronger the benefits, because in closed networks information about behavior flows faster, norms develop more quickly, and sanctions are imposed more rapidly on firms that violate their partner's expectations. Hence, for Burt, an open local network is good for the central firm because it inspires entrepreneurship and arbitrage; for Coleman, an open local network is bad for the firms that compose it because it creates the opportunity for and sustains exploitative behavior. Whether a closed or open network benefits the central firm therefore depends on whether communication and coordination within the neighborhood help or hinder the firm in achieving its goals.

The extant research generally supports Coleman's view. In a study of Sydney hotels, Ingram and Roberts (2000) show that the more cohesive the managerial friendship network around a hotel, the higher its economic performance, presumably because of reciprocity in sharing customer overflows and norms against price competition. Similarly, Ahuja (2000) finds that closure in the technical collaboration networks of U.S. chemical companies increases the number of patents granted to them; he attributes this result to superior cooperation among partners induced by their ability to monitor each other. Rowley, Behrens, and Krackhardt (2000) test the effect of network closure on firm performance in two industries that differ in their levels of uncertainty; the industries are steel (low uncertainty) and semiconductors (high uncertainty). The authors find that local closure

enhances firm performance (return on assets) under low uncertainty when the benefit of inter-firm cooperation should exceed the cost of greater redundancy of information and has no effect on performance under high uncertainty. Finally, in a study of alliance formation in the biotechnology industry, Walker, Kogut, and Shan (1997) find that alliances are more likely to be formed by firms located in denser regions of the overall network; they interpret this result as being consistent with Coleman's argument (see also Gulati, 1995). All four of these studies imply that normative pressure within the firm's closed local neighborhood benefits the firm.

In a study that partially supports Burt's structural hole theory, McEvily and Zaheer (1999) find that small, regional job shops whose advisors did not interact with each other were more likely to develop competitive capabilities. The argument here is that a disconnected advice network provides a broader array of information that allows the firm to produce a more robust set of practices. However, McEvily and Zaheer (1999) also find that firms with open networks of advisors are less likely to participate in acquiring knowledge from regional institutions, which in turn reduces the firms' development of capabilities. Presumably, a group of advisors that is less cohesive provides weaker access to public sources of information. In an approach similar to McEvily and Zaheer (1999), Burt (2001a) expands his theory to include both network closure and openness. He extends the frame of the analysis from alliances among the firm's immediate partners to their alliances with organizations outside the local neighborhood. These "indirect" relationships may be with a diverse or narrow set of firms that themselves may be more or less connected. The more diverse and disconnected these firms, the more likely it is that they will have different kinds of information, which leads to higher variance in the information received by the firm's local partners and therefore ultimately by the firm itself. Burt calls the degree of closure of the local neighborhood "internal constraint" and the degree of closure of the broader

neighborhood “external constraint.” He then argues that the firm achieves its highest performance when internal constraint is high, promoting cooperation within the local neighborhood, and external constraint is low, indicating diverse information sources. This theory is similar to Burt’s earlier work on structural autonomy (Burt, 1980b) and is also analogous to Granovetter’s (1973) well-known study of weak and strong ties, where high closure is analogous (but not identical) to high tie strength. As yet, Burt’s theory of internal and external constraints has not been tested using alliance data.

So far the research discussed has been on static networks and does not address how the microstructure changes over time. Unfortunately, there have been very few studies of how local networks develop. Walker et al. (1997) show that new alliances tend to increase the density of a firm’s region in the network, suggesting that firms choose partners within the local neighborhood as opposed to outside it. Burt (2000) points out that this result indicates only that closure persists but shows nothing about the benefit closure might provide.

The persistence of closure as a network develops over time has also been shown by small-worlds research. Small worlds, as discussed in greater detail below, are networks that have dense local neighborhoods and at the same time are tightly connected globally, in the sense that getting from one side of the network to the other takes only a few links. Kogut and Walker (2001), in their small-worlds study of the ownership network among German firms in 1993, demonstrate that the network had high local clustering and that a significant level of clustering remained even after extensive simulated alterations in the relationships among firms. Dense local neighborhoods therefore seem quite impervious to change.

Similarly, in a study of structural holes using data on relationships among managers, Burt (2001b) shows that relationships that span structural holes tend to disappear faster than non-bridging relationships, suggesting that clusters of relationships are more durable. However, the rate

at which bridging relationships terminate tends to be lower when the broker is a high-performing manager. Although no research has generalized Burt’s result to alliance networks, it is not inconsistent with the logic of the studies discussed above. As a whole, then, it appears that local neighborhoods that are highly clustered are likely to remain so, and brokering positions are rather fragile.

*Future Research.* Even though it seems that local closure has definitively trumped structural holes as the preferred and more stable microstructure for firms, a host of questions and important projects remain. First, Burt’s logic regarding the advantages of brokerage seems unassailable. A firm that acts as a hub connecting disconnected partners simply has more information and therefore more options. Therefore, the key questions are: How do brokers emerge to span structural holes? What forces allow unique brokerage positions to endure? And what types of decision or performance do brokerage positions contribute to most? For example, an open neighborhood may reduce effective price coordination among hotels or further alliance-building in biotechnology but may also lead to more radical innovation by the central firm (see Burt, forthcoming; contrast Ahuja, 2000).

Second, alliance research on the network microstructure has typically obscured asymmetries of power and dependence in the partnerships. Differences between partners in their control over resources and information in the alliance can be salient, because power in a relationship may overwhelm any benefits provided by the firm’s position in the network structure (see Cook, Emerson, & Gillmore, 1983). Detailing how asymmetries in interfirm relationships interact with local network structure is an important task.

Third, Burt’s (2001) hybrid model, which embeds the local neighborhood in the larger network, may be generalized to alliance networks by identifying both the degree of local closure and the structure of the relationships among all firms in the network. This has not yet been done (Burt, Guilarte, Raider, & Yasuda, 2002).

Fourth, the dynamics of network closure are not well understood. Industry factors—for example, the degree of market uncertainty and shifts in the level of demand—may affect how much value normative constraint contributes to the firms in the network. One possibility is that as uncertainty increases and demand decreases, firms may become more conservative in their partners, increasing the degree of local closure. But when the industry enters a period of expansion, neighborhoods may open up. Exploring this potential dynamic could be useful in future research.

Finally, there has been little study of differences between the neighborhoods of entrants and incumbents over the history of the industry (see Walker et al., 1997). Compared to entrants, incumbents obviously have greater experience of the partnering capabilities of other firms, and this experience may substitute for or complement the structural benefit of a closed neighborhood. Likewise, older firms may have a more stable set of partners. Much new research remains to be accomplished in this area as well.

## The Network as Macrostructure

Studies of the total network, comprising all local neighborhoods and the cross-neighborhood connections of firms, are best discussed in terms of how they conceptualize the network macrostructure. Here we identify five current approaches: (1) indirect ties, (2) the centrality of both firms and the overall network, (3) structural and stochastic equivalence, (4) network density and components, and (5) small worlds. These widely differing concepts of the network macrostructure cover almost all of the existing empirical research on this topic. With relatively few exceptions, each provides a unique window onto how characteristics of the network outside the local neighborhood affect firm alliance behavior and outcomes.

*Indirect Ties.* The most obvious and succinct way to assess the importance of alliances outside the

local neighborhood is to measure a firm's number of indirect ties—the firm's relationships with partners two or more steps away in the network. Uzzi (1996), in his seminal study of embeddedness, concludes that the structure of indirect ties has a significant, albeit nonlinear (U-shaped), influence on a firm's chances of failing. He argues that organizations whose suppliers are neither strongly nor weakly connected to their own suppliers will have lower rates of failure, where strong connections are highly concentrated in one or a few partners. A broader concept of indirect ties is developed by Ahuja (2000). His construct includes all the organizations a firm is connected to outside its local neighborhood, not just two steps out as in Uzzi's (1996) study. Ahuja's research shows that the scope of a firm's indirect ties increases its rate of innovation, but this effect is dampened when the local neighborhood is large. His conclusion is that local ties and indirect ties are therefore partly substitutable. It is noteworthy that the way Ahuja measures indirect ties conforms to studies of network components, which are discrete groups of firms that are connected to each other. This topic is discussed later in this chapter.

*Firm Centrality.* The centrality of network members or of the network overall has long been a focus of network research (see Freeman, 1979, for a classic review). Because this chapter discusses network studies that include indirect relationships only, it will focus only on research that conceptualizes centrality as networkwide and not on those studies that examine "degree centrality," which is the firm's number of alliances. (For research on the determinants and effects of degree centrality, see Gulati & Gargiulo, 1999; Gulati, 1999; Powell, Koput, & Smith-Doerr, 1996; Powell, White, Koput, & Owen-Smith, forthcoming; Walker et al., 1997).

An important measure of firm centrality discussed by Freeman (1979) is "betweenness," which is roughly based on how many geodesics the firm lies on (a geodesic is the shortest path between a pair of firms in the network). Another

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measure of centrality has been developed by Bonacich (1987). His measure, called "eigenvector centrality" or the eponymous "Bonacich centrality," identifies central firms as those that have relationships with other firms that are themselves central. Finally, Freeman (1979) describes a measure, called "closeness," that can be thought of as the inverse of centrality in general; closeness is defined by the sum of the shortest paths between a firm and other firms in the network. Clearly, the larger this sum, the further the firm is from other firms, and so the lower its centrality.

The meanings of these three centrality measures are based on the common themes of brokerage and information availability. Betweenness characterizes the kind of brokering role Burt ascribes to firms that fill structural holes. Closeness has a slightly different meaning; a higher degree of closeness in the network implies that a firm can reach or be reached by other firms more quickly or more efficiently, in terms of the number of links taken. Finally, the Bonacich measure has elements of both brokering and reachability.

Studies of network centrality have used all three measures. In a study of corporate restructuring in 1990s Germany, Kogut and Walker (2003) construct a network of firm owners based on their overlapping holdings and find that the firms whose owners were more central in the network, in the sense of betweenness, engaged in more merger and acquisition events. Firms with central owners apparently had better access to information and opportunities related to restructuring. Research on centrality as closeness follows the same general logic as betweenness. Powell et al. (1996) predict and show that firms that have higher centrality in terms of shorter path-length connections with other members of the network tend to form more alliances. Gulati's (1999) analysis produced the same result. Gulati (1995) also finds that the shorter the path length between two firms in the network, the more likely they were to form an alliance.

Finally, Bonacich's (1987) measure of centrality has been used primarily to measure what

Podolny (1993, 2001) has called "status": the primacy or hegemony of some firms over others. Differences among firms in status, using Bonacich's measure, have been used to predict firm growth (Podolny, Stuart, & Hannan, 1996) and the successful diversification of firms into related markets (Jensen, 2003). Sorenson and Stuart (2001) use Bonacich's measure to indicate superior information-gathering by venture-capital firms. Finally, in their research on alliance formation, Gulati and Gargiulo (1999) argue and find that firms with high Bonacich centrality tend to form alliances with each other, a kind of assortativity that is often found in social networks (Newman, 2002).

A last study that examines the effect of centrality on firm behavior is research by Kogut, Walker, and Kim (1995) on technology-based alliances in the semiconductor industry. Their theory relies on an interpretation of betweenness as brokerage, but with a twist. They studied how the centrality of the network as a whole (see Freeman, 1979) affected entry into the industry.

The empirical results for firm and network centrality are hence rather robust and encourage future research. The assumption of superior information brokerage or access commonly underlying the theories in these studies seems reasonable given the outcomes they predict. Yet work remains to be done on how relevant information is distributed throughout the network and how this distribution maps onto the firm-level incentives to share or expose the data the firms need to make decisions. We address this issue in greater depth below in our discussion of small worlds.

*Network Stratification: Structural Equivalence.* A second approach to the network macrostructure is based on the principle of structural equivalence. Structurally equivalent firms have the same (or about the same) set of partners (Lorrain & White, 1971; see also Batagelj, 1997; Nowicki & Snijders, 2001). Firms in a network are typically grouped according to the equivalence of their partner sets, and the groups of structurally equivalent firms are the basis of what

White, Boorman, and Breiger (1976) call a *blockmodel*, a homomorphic reduction of the network in which relationships among the groups (sometimes called positions) indicate the relationships among their member firms.

Blockmodel studies of alliance networks have been motivated by a range of research questions. Several early studies (Knoke & Rogers, 1979; Van de Ven, Walker, & Liston, 1979) found that a blockmodel analysis showed how different types of partnership were distributed across the network and how they affected firm performance. Using a blockmodel analysis of joint ventures among firms in the global aluminum industry, Walker (1988) demonstrates that a search for economies of scale is likely to be the most important factor driving the formation of alliances. Nohria and Garcia-Pont (1991), in an analysis of alliances in the global automobile industry, argue that the structure of partnerships should reflect the structure of competition. In support of their argument, Nohria and Garcia-Pont find that the groups in the blockmodel are centered either on powerful global firms or on collections of regional competitors and are generally highly inbred, meaning that they form alliances more within the group than outside it.

In two papers on the network of alliances in the early years of the biotechnology industry, Walker et al. construct a blockmodel to test two distinct theories. In their first paper (Shan, Walker, & Kogut, 1994), they propose, and the results show, that because firms in different blockmodel groups are likely to give and receive different resources and capabilities, they should have different propensities to form new alliances. The second paper (Walker et al., 1997) shows that firms with alliances in denser regions of the blockmodel tend to have more partnerships.

In addition, Walker et al. (1997) analyze how the network structure in the biotechnology industry develops over time. The blockmodel includes biotechnology start-ups as one dimension and their established firm partners as the second dimension, so that there are both start-up groups and established firm groups. Moreover,

as the network evolves, new firms of both types enter the network. Walker et al. (1997) find that membership in start-up groups over time is much more stable than in groups of established firms, primarily because of the latter's higher rate of entry. Furthermore, the trend towards stability in network position becomes more pronounced as the network develops.

Studies of network structure using blockmodels have demonstrated a potential that has yet to be explored fully. Although technical challenges remain in identifying structurally equivalent firms (see Nowicki & Snijders, 2001), these are minor compared to the important questions blockmodeling can address, especially regarding industry evolution. For example, the notion of structural equivalence underlies a major rationale for research on alliances: Firms that share a common set of partners have similar capabilities. How alliances and capabilities in an industry develop over time is therefore a rich area of research that is particularly suited for blockmodel analysis. Further, the structure of intergroup relationships measures differences in organizational status, and the evolution of this structure, as represented by blockmodels of alliances over time, may be a key indicator of status change, an important dimension of firm performance.

*Network Components and Density.* A fourth perspective on the macrostructure of the alliance network has been the analysis of network density. Denser networks are, almost by definition, more cohesive, which means that in theory, information and resources can move from one side of the network to the other faster and with fewer intermediaries. In an interesting study of cohesiveness in networks over time, Marquis (2003) argues that cohesiveness could be imprinted. He shows that a dense network of firms that are geographically proximate before the advent of extensive air travel to the region tends to remain tightly connected after air travel arrived, suggesting that cohesiveness endures in the face of pressures to break it down. Whether this trend is due to the lasting benefits of cohesiveness, a kind of

network externality, or unproductive inertia remains an open question.

A concept related to network density is the partition of the network into discrete, cohesive components. A component is a set of firms that have partnerships only with each other; there are no cross-component alliances. Many networks have a "main" component composed of most of the firms in the network and a number of satellite components containing a few firms each. In their ongoing research on biotechnology alliances, Powell et al. (forthcoming) argue and show that pairs of firms that are in the same component and whose component is highly cohesive are more likely to form an alliance. The two plausible premises behind this finding are, first, that two firms in a cohesive component have lower search costs and so can find each other faster, and second, that cohesiveness induces normative pressure to cooperate, which facilitates alliance-building. This logic is virtually identical to the arguments motivating research on closed and open local neighborhoods discussed above.

*Small Worlds.* Research on small worlds is a rapidly emerging area of research on alliance networks—in fact, on networks of all kinds. The small-world metaphor was first made popular by Milgram's (1967) search experiments and formalized by White (1970) (see also Kochen, 1989, for a review). Recent research by Watts and his colleagues (Watts, 1999a, 1999b; Newman, Strogatz, & Watts, 2001) has formally refined the small-world concept and led to a rapid increase in empirical studies using interfirm relationships (Baum, Shipilov, & Rowley, 2002; Corrado & Zollo, 2004; Davis, Yoo, & Baker, 2003; Kogut & Walker, 2001). The quickened pace of research over the past four years has introduced such a wealth of approaches to network structure and dynamics that small-world models that were recently seen as standard are now being seriously questioned (Watts, 2004).

In Watt's (1999a, 1999b) model, a small-world network has both dense local neighborhoods and

a low average number of paths between any two firms. Watts tests for the existence of a small world through two simple ratios: the first for clustering, and the second for the path length. The clustering ratio has in the numerator the empirical network's average clustering coefficient. In the denominator is the clustering coefficient for a hypothetical network, constructed by randomly assigning ties between firms. The random network has the same number of firms,  $n$ , and the same average number of alliances per firm,  $k$ , as the empirical network. The clustering coefficient for the random network is  $k/n$ . For the network to be a small world, the clustering coefficient of the empirical network should be substantially greater than that of the random network. The ratio for the average path length is constructed similarly. The numerator is the empirical network's value for the average path length, and the denominator is the value for a hypothetical, randomly constructed network of the same size and average outdegree. Watts calculates the denominator as  $\log(k)/\log(n)$ . Since the average path length in a small world is short, the path-length ratio of empirical to random network values should be around one.

The small world has many similarities with the types of micro- and macrostructure discussed above. There is an obvious correspondence with Burt's (2001) extension of his structural hole theory to include both local clustering and relationships with firms outside the neighborhood. In a small world, firms may experience normative pressure imposed by a closed neighborhood and at the same time benefit from efficient search throughout the network due to its high level of connectivity. Also, the small-world model includes a parameter that is analogous to centrality. To become a small world, a network must contain alliances called shortcuts that tie together otherwise disconnected firms and thus shorten the average distance from one firm to another (Watts, 1999a, p. 71). Shortcuts are therefore similar (but not identical) to geodesics, and firms that are on many shortcuts are likely to be highly central in the network.



In addition, the small-world model as a whole resembles Granovetter's (1973) well-known theory of weak ties, in which "strong" ties (within a firm's local neighborhood) enforce norms and "weak" ties (with nonlocal firms) are important for information acquisition.

The small-world model applies primarily to networks that are low-density or sparse, as is typical of those composed of alliances. This is important because sparse networks have often been viewed as lacking a meaningful structure. Small-world studies of alliance networks show that they do indeed have structure in spite of their low densities (Baum et al. 2002; Corrado & Zollo, 2004; Davis et al., 2003; Kogut & Walker, 2001). One may say, then, that although an alliance network need not be a small world, recent evidence suggests that it probably is.

The small-world model opens up three clear avenues of research on alliances. First, it raises important questions about network evolution: How does a network become a small world? What factors determine the emergence of firms that are more central, in the sense of lying on numerous shortcuts? How do the local neighborhoods of these firms evolve over time? Second, the small-world model provides a window onto the evolution of empirical networks in specific institutional environments. For example, Corrado and Zollo (2004) examine the network of inter-firm ownership in Italy in the 1990s and show that in spite of major national reforms during this period, the small-world structure of the network remained remarkably stable (see also Davis et al., 2003, for similar findings regarding the stability of the U.S. corporate network of board interlocks). Third, the small-world model indicates how one might compare two or more alliance networks, either at one point in time or over multiple time periods. Regional or national networks of partnerships, either within or across industry, are ripe for this kind of analysis.

*Problems With the Small-World Model.* Although the small-world model shows promise for examining alliance networks, it has several problems

(see Watts, 2004). These are created primarily by questions about the behavioral origins of the small-world structure and questions about the identification of the small world in the special case of bipartite networks. The first of these concerns is important not only for clarifying how small worlds evolve but for understanding what the structure implies for the behavior of firms in the network. The second raises the significant issue of how the scope and content of alliances affects network development.

One of the common assumptions about small worlds is that they are created as firms search for and find partners outside the local neighborhood. These cross-neighborhood ties decrease the average path length in the network without reducing the degree of local clustering, thus creating the small world. This assumption need not be true, however. Walker and Kogut (2004) show that the syndication network of venture-capital firms in the United States develops in the opposite way: it is highly integrated with a low average path length first and develops distinct clusters second.

A second important assumption in research on small worlds is that partners are chosen with equal probability (Watt, 1999a). Kleinberg (2000) shows, however, that if the mechanism underlying the creation of a small world is a search process, this assumption is very rarely true. He demonstrates that for a network to be searchable, the likelihood of forming a link with a nonlocal partner must decline exponentially with its distance from the firm, and the exponent must be equal to the number of dimensions used in the search process. This means that the probability distribution of potential partners cannot be uniform.

Therefore, a fundamental tenet of the creation of small worlds—that they emerge through a process of finding partners—is highly dependent on how potential partners are arrayed around each firm. Building on Kleinberg's result, Watts, Dodds, and Newman (2002) show how searchability is affected by the number of dimensions firms use to find partners and how close the firm

is to these partners. Like Kleinberg (2000), Watts et al. (2002) find that not all networks can be searched efficiently and so cannot evolve into small worlds, at least through a search mechanism.

A second problem with the small-world model involves how relationships are defined. Many networks, especially those composed of alliances, are bipartite (Borgatti & Everett, 1997; Wasserman & Faust, 1994, chap. 8), which means they are constructed from the joint participation of firms in associations, consortiums, syndicates, or some other form of common affiliation. Firms become allied through shared membership, as, for example, venture-capital firms are tied through their participation in syndications of start-ups. The problem with the bipartite structure as a means for forming small worlds is that the network's local clustering and global connectivity parameters are influenced by the number of members in the partnership.

For example, Newman et al. (2001) show that the clustering coefficient of the small world of interfirm board interlocks in the United States (Davis et al., 2003) is completely due to the sizes of the boards. Hence, to manipulate the degree of local clustering in the network one need only change the distribution of board sizes. Other sources of interlocks, such as reciprocity, social class, or the hegemony of financial firms, can be ignored completely. Small-world research on alliances using bipartite data should therefore be sensitive to characteristics of the affiliations (associations, syndicates) used to build the network. Microstudies of local neighborhoods should obviously be sensitive to this problem as well.

## Some Final Issues

Over the past five years, alliance network research has become a kind of hotbed of new questions and problems:

1. Network evolution: Kogut (2000) has argued that networks develop as firms follow

generative rules, such as reciprocity and transitivity, that spring from economic, cultural, and institutional constraints. This line of research has tremendous promise for developing testable hypotheses regarding network dynamics. For example, one rule, preferential attachment, has been proposed as the central determinant of network structures that follow a power law distribution (Barabasi & Albert, 1999; Newman, 2001). Another important topic is how adherence to rules changes over time; for example, transitivity may rise and fall with shifts in market uncertainty. Finally, networks evolve as incumbent firms persist and new firms enter. How network structure persists with entry and how entrants gain access to that structure, if at all, are important questions, especially because the rules governing exchange must be learned (Kogut, Urso, & Walker, 2005; Walker et al, 1997; Walker & Madsen, 2004).

2. Bipartite networks: The recent rise in research on bipartite networks suggests a range of questions regarding alliance formation. For example, the investment project that motivates a partnership is almost always ignored as a factor in alliance studies. Yet in any industry the opportunities stimulating joint investment—for example, emerging technology platforms or growing geographical regions—commonly follow a life cycle that is separate from the partnerships formed to exploit them. How these life cycles intersect with the evolution of the alliance network remains an open question.

3. Models of diffusion and catalysis: A traditional and continuously interesting problem in network analysis is diffusion (for a recent study on diffusion through alliances, see Westphal, Gulati, & Shortell, 1997). As Watts (2004) points out, there has been insufficient study of the structure of the network through which diffusion occurs (see Burt, 1987, for a classic study). In this regard, the parameters of network structure in a small world, particularly the number of shortcuts, can clearly affect the rate at which an innovation is adopted (Moore & Newman,

2000). Moreover, in addition to facilitating the diffusion of organizational practices (e.g., Davis, 1991), the network may serve as a conduit for new types of investment projects, which themselves involve further partnering. For example, as a system for funding start-up firms, the existing network structure of syndications may determine the diffusion rate of investment in a new industry; and as investments in the new industry grow, the venture-capital syndication network is rejuvenated. In this way, the speedy rise of e-commerce firms in the 1990s may have been enabled by the existing syndication networks for investment in related industries, such as software.

## Conclusion

Research on alliance networks has achieved some robust results, especially regarding the effects of local closure and global centrality. But recent approaches to network structure and analysis present challenges to these conclusions and have opened many avenues of inquiry that are enormously promising. How alliance networks are formed and how they are refreshed with new investment opportunities are key questions that motivate a broad range of study. As new data become available and older data sets yield new insights, alliance network research has an interesting and productive future.

## References

- Ahuja, G. (2000). Collaboration networks, structural holes and innovation: A longitudinal study. *Administrative Science Quarterly*, 45, 425–455.
- Barabasi, A.-L., & Albert, R. (1999). The emergence of scaling in random networks. *Science*, 286, 509–512.
- Batagelj, V. (1997). Notes on blockmodeling. *Social Networks*, 19, 143–155.
- Baum, J., Shipilov, A., & Rowley, T. (2002). Where do small worlds come from? *Industrial and Corporate Change*, 12, 597–725.
- Bonacich, P. (1987). Power and centrality: A family of measures. *American Journal of Sociology*, 92, 1170–1182.
- Borgatti, S. P., & Everett, M. G. (1997). Network analysis of 2-mode data. *Social Networks*, 19(3), 243–269.
- Bourdieu, P. (1980). Le capital social. *Actes Recherches Sciences Sociales*, 31, 2–3.
- Burt, R. (1980a). Models of network structure. *Annual Review of Sociology*, Neil Smelser (Ed.), 6, 79–141.
- Burt, R. (1980b). Autonomy in a social topology. *American Journal of Sociology*, 85, 892–925.
- Burt, R. (1987). Social contagion and innovation: Cohesion versus structural equivalence. *American Journal of Sociology*, 92, 1287–1335.
- Burt, R. (1992). *Structural holes: The social structure of competition*. Cambridge, MA: Harvard University Press.
- Burt, R. (2000). The network structure of social capital. In R. I. Sutton & B. M. Staw (Eds.), *Research in organizational behavior* (Vol. 22). New York: Elsevier Science.
- Burt, R. (2001a). Structural holes versus network closure as social capital. In N. Lin, K. S. Cook, & R. S. Burt (Eds.), *Social capital: Theory and research*. New York: Aldine de Gruyter.
- Burt, R. (2001b). Bridge decay. *Social Networks*, 24, 333–363.
- Burt, R. (forthcoming). Structural holes and good ideas. *American Journal of Sociology*.
- Burt, R., Guilarte, M., Raider, H. J., & Yasuda, Y. (2002). Competition, contingency, and the external structure of markets. In P. Ingram & B. Silverman (Eds.), *Advances in strategic management*. New York: Elsevier.
- Coleman, J. (1988). Social capital in the creation of human capital. *American Journal of Sociology*, 94, S105–S120.
- Cook, K. S., Emerson, R. M., & Gillmore, M. R. (1983). The distribution of power in exchange networks: Theory and experimental results. *American Journal of Sociology*, 89, 275–305.
- Corrado, R., & Zollo, M. (2004). *Small worlds evolving: Governance reforms, privatizations and ownership networks in Italy*. Working Paper, INSEAD, Fontainebleau, France.
- Davis, G. (1991). Agents without principles? The spread of the poison pill through the intercorporate network. *Administrative Science Quarterly*, 36, 583–613.

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- Davis, G., Yoo, M., & Baker, W. (2003). The small world of the American corporate elite, 1982–2001. *Strategic Organization*, 1, 301–326.
- Freeman, L. (1979). Centrality in social networks: Conceptual clarification. *Social Networks*, 1, 215–239.
- Granovetter, M. (1973). The strength of weak ties. *American Journal of Sociology*, 78, 1360–1380.
- Gulati, R. (1995). Social structure and alliance formation: A longitudinal analysis. *Administrative Science Quarterly*, 40, 619–652.
- Gulati, R. (1999). Network location and learning: The influence of network resources and firm capabilities on alliance formation. *Strategic Management Journal*, 20, 397–420.
- Gulati, R., & Gargiulo, M. (1999). Where do interorganizational networks come from? *American Journal of Sociology*, 4, 1439–1493.
- Ingram, P., & Roberts, P. (2000). Friendships among competitors in the Sydney hotel industry. *American Journal of Sociology*, 106, 387–423.
- Jensen, M. (2003). The role of network resources in market entry: Commercial banks' entry into investment banking, 1991–1997. *Administrative Science Quarterly*, 48, 466–498.
- Kleinberg, J. (2000). Navigation in a small world. *Nature*, 406, 845.
- Knoke, D., & Rogers, D. (1979). A blockmodel analysis of interorganizational networks. *Sociology and Social Research*, 64, 28–52.
- Kochen, M. (Ed.). (1989). *The small world*. Norwood, MA: Ablex.
- Kogut, B. (2000). The network as knowledge: Generative rules and the emergence of structure. *Strategic Management Journal*, 21, 405–425.
- Kogut, B., Urso, P., & Walker, G. (2005). *Generating rules and the emergence of network structure*. Working Paper.
- Kogut, B., & Walker, G. (2001). The small world of Germany and the durability of national networks. *American Sociological Review*, 66, 317–335.
- Kogut, B., & Walker, G. (2003). *Restructuring or disintegration of the German corporate network: Globalization as a fifth column*. William Davidson Institute Working Papers Series, 2003-591.
- Kogut, B., Walker, G., & Kim, D.-J. (1995). Cooperation and entry induction as an extension of technological rivalry. *Research Policy*, 24, 77–95.
- Lorrain, F., & White, H. (1971). The structural equivalence of individuals in social networks. *Journal of Mathematical Sociology*, 1, 49–80.
- Marquis, C. (2003). The pressure of the past: Network imprinting in intercorporate communities. *Administrative Science Quarterly*, 48, 655–690.
- McEvily, B., & Zaheer, A. (1999). Bridging ties: A source of firm heterogeneity in competitive capabilities. *Strategic Management Journal*, 20, 1133–1156.
- Milgram, S. (1967). The small world problem. *Psychology Today*, 2, 60–67.
- Moore, C., & Newman, M. E. J. (2000). Epidemics and percolation in small-world networks. *Physical Review E*, 61, 5678–5682.
- Newman, M. (2001). Clustering and preferential attachment in growing networks. *Physical Review E*, 64, 025102.
- Newman, M. (2002). Assortative mixing in networks. *Physics Review Letters*, 89, 208701.
- Newman, M., Strogatz, S., & Watts, D. (2001). Random graphs with arbitrary degree distributions and their applications. *Physical Review E*, 64, 026118.
- Nohria, N., & Garcia-Pont, C. (1991). Global strategic linkages and industry structure. *Strategic Management Journal*, 12, 105–124.
- Nowicki, K., & Snijders, T. A. B. (2001). Estimation and prediction for stochastic blockstructures. *Journal of the American Statistical Association*, 96, 1077–1087.
- Podolny, J. (1993). A status-based model of market competition. *American Journal of Sociology*, 98, 829–872.
- Podolny, J. (2001). Networks as the pipes and prisms of the market. *American Journal of Sociology*, 107, 33–60.
- Podolny, J., Stuart, T., & Hannan, M. (1996). Networks, knowledge and niches: Competition in the worldwide semiconductor industry, 1984–1991. *American Journal of Sociology*, 102, 659–689.
- Powell, W., Koput, K., & Smith-Doerr, L. (1996). Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology. *Administrative Science Quarterly*, 41, 116–145.
- Powell, W., White, D., Koput, K., & Owen-Smith, J. (forthcoming). Network dynamics and field evolution: The growth of interorganizational collaboration in the life sciences. *American Journal of Sociology*.
- Rowley, T., Behrens, D., & Krackhardt, D. (2000). Redundant governance structures: An analysis

- of structural and relational embeddedness in the steel and semiconductor industries. *Strategic Management Journal*, 21, 369–386.
- Shan, W.-J., Walker, G., & Kogut, B. (1994). Interfirm cooperation and startup innovation in the biotechnology industry. *Strategic Management Journal*, 15(5), 387–394.
- Siganos, G., Faloutsos, M., Faloutsos, P., & Faloutsos, C. (2003). Power laws and the AS-level Internet topology. *IEEE/ACM Transactions on Networking*, 11(4), 514–524.
- Sorenson, O., & Stuart, T. (2001). Syndication networks and the spatial distribution of venture capital investments. *American Journal of Sociology*, 106, 1546–1588.
- Uzzi, B. (1996). The sources and consequences of embeddedness for the economic performance of organizations: The network effect. *American Sociological Review*, 61, 674–698.
- Van de Ven, A., Walker, G., & Liston, J. (1979). Coordination patterns within an interorganizational network. *Human Relations*, 32, 19–36.
- Walker, G. (1988). Network analysis for cooperative interfirm relationships. In F. Contractor & P. Lorange (Eds.), *Cooperative strategies in international business*. Lexington, MA: Lexington Books.
- Walker, G., & Kogut, B. (2004). The early small world of venture capital in the United States. Working Paper presented at the Utah Strategy Conference, Park City, Utah.
- Walker, G., Kogut, B., & Shan, W. (1997). Social capital, structural holes and the formation of an industry network. *Organization Science*, 8, 109–125.
- Walker, G., & Madsen, T. (2004). *Incumbent stratification, interfirm mobility and organizational growth in the foreign exchange market, 1973–1993*. Paper presented at the Annual Meeting of the Academy of Management, New Orleans.
- Wasserman, S., & Faust, K. (1994). *Social network analysis*. New York: Cambridge University Press.
- Watts, D. (1999a). *Small worlds*. Princeton, NJ: Princeton University Press.
- Watts, D., (1999b). Networks, dynamics, and the small-world phenomenon. *American Journal of Sociology*, 105, 493–527.
- Watts, D. (2004). The “new” science of networks. *Annual Review of Sociology*, 30, 243–270.
- Watts, D., Dodds, P. S., & Newman, M. (2002). Identity and search in social networks. *Science*, 296, 1302–1305.
- Westphal, J., Gulati, R., & Shortell, S. (1997). Customization or conformity? An institutional and network perspective on the content and consequences of TQM adoption. *Administrative Science Quarterly*, 42, 366–394.
- White, H. C. (1970). Search parameters for the small world problem. *Social Forces*, 49, 259–264.
- White, H., Boorman, S., & Breiger, R. (1976) Social structure from multiple networks. I. Blockmodels of roles and positions. *American Journal of Sociology*, 81, 730–780.

