Where Do Interorganizational Networks Come From?[1]

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Organizations enter alliances with each other to access critical resources, but they rely on information from the network of prior alliances to determine with whom to cooperate. These new alliances modify the existing network, prompting an endogenous dynamic between organizational action and network structure that drives the emergence of interorganizational networks. Testing these ideas on alliances formed in three industries over nine years, this research shows that the probability of a new alliance between specific organizations increases with their interdependence and also with their prior mutual alliances, common third parties, and joint centrality in the alliance network. The differentiation of the emerging network structure, however, mitigates the effect of interdependence and enhances the effect of joint centrality on new alliance formation.

INTRODUCTION

Sociologists have made considerable progress in explaining why organizations behave as they do in terms of their embeddedness in social networks (Granovetter 1985, 1992; Swedberg 1994; Powell and Smith-Doerr 1994), but they have seldom examined how those networks originated. With few exceptions, largely limited to the research on interlocking directorates

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(e.g., Useem 1984; Palmer, Friedland, and Singh 1986; Mizruchi and Stearns 1988) or to thick historical accounts of the development of particular interorganizational networks (e.g., Stern 1979), organizational sociologists have typically viewed network formation as driven by exogenous factors, such as the distribution of technological resources or the social structure of resource dependence (Pfeffer and Salancik 1978; Burt 1983). In this view, organizations create ties to manage uncertain environments and to satisfy their resource needs; consequently, they enter ties with other organizations that have resources and capabilities that can help them cope with these exogenous constraints.

The exogenous approach to tie formation provides a good explanation of the factors that influence the propensity of organizations to enter ties, but it overlooks the difficulty they may face in determining with whom to enter such ties. This difficulty, which results from the challenges associated with obtaining information about the competencies, needs, and reliability of potential partners (Van de Ven 1976; Stinchcombe 1990), is especially vivid in the case of interorganizational strategic alliances. Alliances are a novel form of voluntary interorganizational cooperation that involves significant exchange, sharing, or codevelopment and thus results in some form of enduring commitment between the partners. While strategic alliances can be a means to manage environmental uncertainty, there is also considerable uncertainty associated with entering those cooperative ties. Imperfect information about potential partners raises search costs and the risk of exposure to opportunistic behavior (Gulati 1995*a;* Gulati and Singh 1999). Thus, while exogenous factors may suffice to determine whether an organization should enter alliances, they may not provide enough cues to decide with whom to build those ties. Where do organizations find those cues? And how do the particular cues they use shape the formation of interorganizational networks?

These are the two questions addressed in this article. We propose that to reduce the search costs and to alleviate the risk of opportunism associated with strategic alliances, organizations tend to create stable, preferential relationships characterized by trust and rich exchange of information with specific partners (Dore 1983; Powell 1990). Over time, these "embedded" relationships (Granovetter 1985) accumulate into a network that becomes a growing repository of information on the availability, competencies, and reliability of prospective partners (Kogut, Shan, and Walker 1992; Gulati 1995*b;* Powell, Koput, and Smith-Doerr 1996). The more the emerging network internalizes information about potential partners, the more organizations resort to that network for cues on their future alliance decisions, which are thus more likely to be embedded in the emerging network. These new embedded alliances, in turn, further increase the informational value of the network, enhancing its effect on subsequent alliance formation. In this iterative process, new partnerships modify the previous alliance network, which then shapes the formation of future cooperative ties. Thus, we model the emergence of alliance networks as a dynamic process driven by exogenous interdependencies that prompt organizations to seek cooperation and by endogenous network embeddedness mechanisms that help them determine with whom to build partnerships. Interorganizational networks are thus the evolutionary products of embedded organizational action in which new alliances are increasingly embedded in the very same network that has shaped the organizational decisions to form those alliances.

We develop a model by specifying the mechanisms through which the existing alliance network enables organizations to decide with whom to build new alliances, and we discuss how the newly created ties can increase the informational content of the same alliance network, enhancing its potential to shape future partnerships. In theoretical terms, this is akin to specifying the mechanisms through which social structures shape organizational action and the mechanisms through which this action subsequently affects social structures (Wippler and Lindenberg 1987; Gargiulo 1998). We test this model using longitudinal data on interorganizational strategic alliances in a sample of American, European, and Japanese business organizations in three different industries over a 20-year period. The quantitative data collection and the empirical analysis for this study were preceded by extensive interviews with managers involved in alliance decisions at a variety of organizations. We conducted exploratory, open-ended field interviews with 153 managers actively involved in alliance decisions in 11 large multinational corporations. This fieldwork enabled us to ground our claims about the role of the existing alliance network as a source of information for organizational decision makers, as well as to identify some of the mechanisms through which they tap that information.

INTERORGANIZATIONAL STRATEGIC ALLIANCES

Strategic alliances are a vivid example of voluntary cooperation in which organizations combine resources to cope with the uncertainty created by environmental forces beyond their direct control. These alliances are organized through a variety of contractual arrangements, ranging from equity joint ventures to arm's-length contracts (Harrigan 1986; Gulati 1995*a;* Gulati and Singh 1999). Partly as a response to the growing uncertainty that characterizes the international business arena, the number of interorganizational alliances has grown at an unprecedented rate in the last 15 years, across a wide array of industries and both within and across geographical boundaries. Empirical evidence suggests that the number of interorganizational alliances prior to 1980 was very small, but there has been a virtual explosion since that time (e.g., Hergert and Morris 1988). The rapid growth of such ties provides a unique context in which to study the emergence and the evolution of an interorganizational network from the early stages of its development to the period in which alliances became a more established form of cooperation among firms (Gulati 1998).

Despite their explosive growth, strategic alliances are associated with a variety of risks and pitfalls that result in considerable uncertainty about the decision to enter such ties. This is further compounded in the global setting, with disparate firms from a wide range of national origins, in which a good number of these alliances take place (Kogut 1988; Doz 1996). This uncertainty stems from two main sources. First, organizations have difficulty in obtaining information about the competencies and needs of potential partners. This knowledge is essential to assess the adequacy of a potential partnership if both organizations are to derive benefits from the alliance. An organization that knows about the competencies and needs of a potential partner is in a better position to assess whether the alliance can simultaneously serve its own needs and its partner's needs. Yet organizational needs and capabilities are multifaceted and ambiguous. Accurate information on needs and capabilities of other organizations may be difficult to obtain before an alliance is initiated. In most cases, it may require access to confidential information that would not be revealed outside an established partnership. Such a paucity of information is even more significant between firms from different geographic origins.

The second source of uncertainty that affects strategic alliances stems from the paucity of information about the reliability of the potential partners, whose behavior is a key factor in the success of an alliance (Gulati 1995*a,* 1995*b*). Such behavioral uncertainty is intrinsic to voluntary cooperation; indeed, it plays a central role in Coase's ([1937] 1952) theory of the firm and in the transaction-cost perspective (Williamson 1985). Organizations entering alliances face considerable moral hazard concerns because of the unpredictability of the behavior of partners and the likely costs to an organization from opportunistic behavior by a partner, if it occurs (Kogut 1988; Doz, Hamel, and Prahalad 1989). A partner organization may either free ride by limiting its contributions to an alliance or may simply behave opportunistically, taking advantage of the close relationship to use resources or information in ways that may damage the partner's interests. In addition, rapid and unpredictable changes in the environment may lead to changes in an organization's needs and its orientation toward ongoing partnerships (MacIntyre 1981).

The paucity of reliable information about the capabilities, the needs, and the behavior of potential partners creates a significant informational hurdle for organizations that consider entering strategic alliances. Yet the explosive growth of strategic alliances suggests that organizations are able to overcome such hurdles and enter alliances. How do they do it? And what consequences does their behavior have for the social context in which new strategic alliances take place?

THE FORMATION OF STRATEGIC ALLIANCES

Interdependence

Interdependence is the most common explanation for the formation of interorganizational cooperative ties such as strategic alliances. A long stream of research suggests that organizations enter ties with other organizations in response to the challenges posed by the interdependencies that shape their common environment (e.g., Aiken and Hage 1968; Pfeffer and Salancik 1978; Aldrich 1979; Galaskiewicz 1982; Burt 1983). Broadly defined, environmental dependence encompasses two sets of considerations: resource procurement and uncertainty reduction (Galaskiewicz 1985). Organizations build cooperative ties to access capabilities and resources that are essential to pursue their goals but that are at least in part under the control of other organizations in their environment. Interorganizational cooperation is thus a means by which organizations manage their dependence on other organizations in their environment and attempt to mitigate the uncertainty generated by that dependence. Oliver (1990) reviewed the literature on such exogenous drivers of interorganizational relations and presented six broad categories of environmental contingencies that stimulate such ties. One of these types of contingencies—necessity—prompts ties mandated by legal or regulatory requirements, but the other categories—asymmetry, reciprocity, efficiency, stability, and legitimacy—lead to cooperative ties that organizations voluntarily initiate to address specific needs resulting from their external interdependence.

Strategic alliances are an important form of voluntary cooperative interorganizational ties. Organizations build alliances for a variety of reasons, including the need to share the costs and risks of technology development or large-scale projects, to develop existing markets or penetrate new ones, and to pursue resource specialization strategies (Mariti and Smiley 1983). Such objectives make organizations interdependent with other organizations that may have the capabilities and the resources to assist them in meeting their specific needs. Other things being equal, the higher the interdependence between two organizations, the higher their incentive to combine their resources and capabilities through an alliance. Building on the insights of this research tradition, we expect tie formation between organizations to be a function of the level of interdependence between them. Thus:

Hypothesis 1.—*The probability of a new alliance between two organizations increases with the level of interdependence between those organizations.*

Interdependence may be a necessary condition for organizations to enter alliances. In most cases, however, interdependence may not be sufficient to account for the formation of an alliance between two specific firms. Indeed, not all opportunities for cooperation between interdependent organizations actually materialize in alliances. An organization confronted with the need to build an alliance to cope with an uncertain environment faces another type of uncertainty resulting from the identification of an appropriate alliance partner. Such uncertainty stems from the paucity of information about the true capabilities, the needs, and the behavior of potential alliance partners. While interdependence may help an organization to orient the search for an adequate alliance partner, it cannot offer sufficient cues to determine with whom it should build such an alliance. This has not posed major difficulty for studies conducted at aggregate levels of analysis, which typically predict the formation of alliances across industries as a function of the intensity of the transactions between those industries (Pfeffer and Nowak 1976*a,* 1976*b;* Berg and Friedman 1980; Duncan 1982; Burt 1983). Yet, this approach masks the considerable heterogeneity of available information on prospective partners across organizations, which may influence the formation of ties between specific organizations without necessarily affecting aggregate industry trends. Although resource-dependence perspectives recognize an "enactment" process that mediates between environmental demands and organizational action (Pfeffer and Salancik 1978, p. 71), most of this research implicitly assumes that decision makers have adequately identified the sources of environmental uncertainty as well as the partners that would help their organizations to reduce that uncertainty. While this assumption is tenable at aggregate levels of analysis, it is difficult to sustain when examining alliances between specific pairs of organizations.

Interorganizational Embeddedness

If interdependence alone cannot offer sufficient cues for organizations to cooperate with one another, how do they decide with whom to build strategic alliances? Building on a growing body of research (see Powell and Smith-Doerr [1994] and Gulati [1998] for a review) and on our own fieldwork, we argue that organizations address the potential hazards associated with building alliances by relying on information provided by existing interorganizational networks. We propose that organizational decision makers that play a crucial role in the formation of new strategic alliances rely on the network of past partnerships to guide their future alliance decisions. The creation of new ties, in turn, contributes to the subsequent development of that same network, enhancing its capacity to shape subsequent alliance decisions.

Although rooted in classical sociological theory, the idea that economic action is embedded in social networks was revitalized by Granovetter (1985) in his manifesto for a new economic sociology. According to Granovetter (1985, p. 490), the microfoundations of embedded economic action rest on "the widespread preference for transacting with individuals of known reputation," for resorting to "trusted informants" who have dealt with a potential partner and found this partner trustworthy, or, even better, for relying on "information from one's own past dealings with that person." A similarly rich exchange of information occurs across organizational boundaries (Dore 1983; Eccles 1981; Powell 1990; Romo and Schwartz 1995). Personal relationships among key individuals have played a crucial role in producing trust between organizations in Japanese industrial groups (Lincoln, Gerlach, and Ahmadjian 1996) and in contractual relationships (Macaulay 1963; Bradach and Eccles 1989). Closer to our concerns, personal ties are important for the formation and success of strategic alliances (Ring and Van de Ven 1992; Doz 1996). Beneath the formalities of contractual agreements, multiple informal interpersonal relationships emerge across organizational boundaries, which facilitates the active exchange of information and the production of trust that foster interorganizational cooperation (Gulati 1995*a;* Walker, Kogut, and Shan 1997; Zaheer, McEvily, and Perrone 1998).

Most organizations are embedded in a variety of interorganizational networks, such as board interlocks, trade associations, and research and development ventures. Scholars have suggested that participation in such social networks can be influential in providing actors with access to timely information and referrals to other actors in the network (Burt 1992). At the interorganizational level, the network of prior alliances has been identified as one such network that is an important source of information and referrals for organizations (Kogut, Shan, and Walker 1992; Gulati 1995*b*). This insight was strongly confirmed by managers in our own fieldwork who highlighted the importance of the network of prior alliances as a source of trustworthy information about the availability, capabilities, and reliability of potential partners. In the words of one of the managers interviewed, "Our network of [prior alliance] partners is an active source of information for us about new deals [alliances]. We are in constant dialogue with many of our partners, and this allows us to find many new opportunities with them and also with other organizations out there."

The information that flows through the alliance network is not only trustworthy but is also timely. This, as another manager put it, is critical for entering strategic alliances: "In our business, timing is everything. And so, even for alliances to happen, the confluence of circumstances have to be at the right time. We and our prospective partner must know about each other's needs and identify an opportunity for an alliance together in a timely manner. . . . Our partners from past alliances are one of our most important sources of timely information about alliance opportunities out there, both with them and with other firms with whom they are acquainted."

Existing network research and insights from our own fieldwork suggest that timely, relevant information on the competencies, needs, and reliability of potential partners originates from organizations' previous direct alliances, from their indirect alliance ties through third parties, or from the reputation that results from the potential partner's position in the network of preexisting alliances. Each of these sources of information is related to specific network mechanisms that shape the creation of new embedded interorganizational ties. We refer to these mechanisms as relational, structural, and positional embeddedness, respectively.

Relational embeddedness highlights the effects of cohesive ties between social actors on subsequent cooperation between those actors. Cohesive ties play a prominent explanatory role in classical sociological analysis of social solidarity and cooperation (e.g., Durkheim [1893] 1933, [1897] 1951). Prior cohesive ties between two organizations provide channels through which each partner can learn about the competencies and the reliability of the other. Cohesiveness amplifies trust and diminishes the uncertainty associated with future partnerships (Podolny 1994; Burt and Knez 1995; Gulati 1995*a*). Cohesive ties may also prompt organizations to become aware of new opportunities for cooperation that would be difficult to identify outside of a close relationship. This facet of cohesive relationships was emphasized by one of the strategic-alliance managers we interviewed: "They [our partners] are familiar with many of our projects from their very inception, and if there is potential for an alliance we discuss it. Likewise, we learn about many of their product goals very early on, and we actively explore alliance opportunities with them." Thus, a history of cooperation can become a unique source of information about the partner's capabilities and reliability and increases the probability of the two organizations forming new alliances with each other. As a consequence:

HYPOTHESIS 2.—*The probability of a new alliance between two organizations increases with the number of prior direct alliances between those organizations.*

Structural embeddedness captures the impact of the structure of relations around actors on their tendency to cooperate with one another (Granovetter 1992). The frame of reference shifts from the dyad to the triad, while the focus of analysis shifts from direct communication between actors to indirect channels for information and reputation effects.[2] Organizations tied to a common partner can utilize reliable information about each other from that partner (Baker 1990; Gulati 1995*b*). When two organizations share common ties, it can also indicate that both are regarded as suitable and trustworthy by the same organizations. Also, sharing common ties with a potential partner may signal that the partner can cooperate with the same kind of organizations with which the focal organization has been cooperating. Finally, common third-party ties can create a reputational lock-in whereby good behavior is ensured through a concern for local reputation. Any bad behavior by either partner may be reported to common partners, which serves as an effective deterrent for both (Raub and Weessie 1990; Burt and Knez 1995).

Referrals, and their associated reputation effects, were explicitly mentioned in several of our field interviews as an important mechanism through which their organizations learned about reliable partners. In the words of one of the managers, "In some cases we realize that perhaps our skills do not really match for a project, and our partner may refer us to another organization about whom we were unaware. . . . An important aspect of this referral business is of course about vouching for the reliability of that organization. Thus, if one of our long-standing partners suggests one of their own partners as a good fit for our needs, we usually consider it very seriously." Thus:

[2] Although there is no explicit mention by Granovetter (1992), the notion of structural embeddedness is related to network models of structural equivalence, according to which two actors equally tied to the same third parties are "structurally equivalent" (Lorrain and White 1971; White, Boorman, and Breiger 1976; Burt 1976). There has been considerable debate about whether structural equivalence operates through the indirect effect of cohesive ties to common third parties (Alba and Kadushin 1976; Alba and Moore 1983; Friedkin 1984) or through "symbolic role playing" and competition between equivalent actors (Burt 1982, 1987). The essence of the debate is whether the mechanisms behind the impact of indirect ties on behavior are substantially different from those behind the effect of direct ties. Yet, as Borgatti and Everett (1994, p. 28–29) have suggested, the notion of proximity is an inseparable part of structural equivalence. In a similar vein, Mizruchi (1993, p. 280) suggested that deciding whether the effects of structural equivalence on behavior operate through the similar socializing pressures of common third parties or through symbolic role playing is practically impossible without knowing the motives that underlie the actors' behavior. It is worth noting, however, that a mechanism that stresses competition between structurally equivalent actors (e.g., Burt 1987) would predict a smaller probability of cooperation between actors tied to the same third parties, whereas a mechanism that stresses the increased trust and information between those with common third-party ties predicts a greater probability of cooperation between the actors (e.g., Coleman 1990). Our focus on the increased trust and information effects of third-party ties is congruent with our prediction that shared partners increase the probability of cooperation between organizations.

Hypothesis 3.—*The probability of a new alliance between two organizations increases with the number of prior indirect alliances between those organizations.*

Positional embeddedness captures the impact of the positions organizations occupy in the overall structure of the alliance network on their decisions about new cooperative ties. Positional embeddedness is rooted in network models of equivalence and centrality that capture the "roles" actors occupy in a system, irrespective of the specific alters involved in playing those roles (Winship and Mandel 1983; Faust 1988; Borgatti and Everett 1994). As a mechanism that influences alliance formation, positional embeddedness goes beyond proximate direct and indirect ties and highlights the informational benefits that ensue for organizations from particular positions in the network. The position an organization occupies in the emerging network can influence its ability to access fine-grained information about potential partners as well as its visibility and attractiveness for other organizations throughout the network, even if it is not directly or indirectly tied to them. The information advantages resulting from network centrality have been a recurrent theme in network analysis (see Freeman [1979] for a review). Social cognition studies also suggest that central actors have a more accurate representation of the existing network (Krackhardt 1990). Central organizations have a larger "intelligence web" through which they can learn about collaborative opportunities, hence lowering their level of uncertainty about partnerships (Gulati 1999; Powell et al. 1996). Therefore, the more central an organization's network position, the more likely it is to have better information about a larger pool of potential partners in the network.

The information advantages from centrality in networks are complemented by the higher visibility of central organizations, which enhances their attractiveness to potential partners. Because network centrality is a direct function of organizations' involvement in strategic alliances, it can also be a signal of their willingness, experience, and ability to enter such partnerships. The signaling property of network positions is particularly important in uncertain environments, because it introduces systemic reputational differences among organizations that extend beyond their immediate circle of direct and indirect ties (Podolny 1993; Han 1994; Podolny and Stuart 1995).[3] The information benefits that result from occupying a

[3] Network position often has been associated with the more traditional sociological concepts of "role" and "status" (Lorrain and White 1971; Burt 1982; Faust 1988). The notion of "role" typically evokes a relatively defined set of expected behaviors toward types of other actors, whereas "status" refers to a series of observable characteristics associated with a particular role (Linton 1936; Merton 1957; Nadel 1957). Network theory suggests that because an actor's (organization's) role and status are ultimately

prominent network position were recognized by a manager we interviewed who reflected on the attractiveness of his firm as alliance partner: "Through our vastly successful technology partnerships program, we have built ourselves a reputation in the industry for being an effective and reliable alliance partner. Today, we are pursued by other firms to enter alliances much more frequently than we pursue potential partners." If central firms have greater access to information and higher visibility than other organizations, then, other things being equal, interorganizational ties should be more common between organizations that occupy central positions in the emerging interorganizational network. Thus:

HYPOTHESIS 4.—*The probability of a new alliance between two organizations increases with the combined alliance-network centrality of those organizations.*

Organizations may seek to enhance their own visibility and attractiveness as potential partners by forming new ties with central players in the alliance network. Since the network position of an organization's partners enhances its own access to information and attractiveness to future partners, it will have a tendency to seek central partners. Central organizations, however, may not have an incentive to accept peripheral players, since they may add little to (or, worse, may damage) their own attractiveness. Furthermore, if network position is a signal of unobserved attributes that determine an organization's attractiveness as a potential alliance partner, peripheral organizations may be perceived by others to have little to offer substantively. This does not preclude the possibility that peripheral organizations may at times enter alliances with central firms. Special circumstances such as those resulting from the need to master a new technology may prompt a central organization to cooperate with a peripheral one that controls such a technology, but we expect that the probability of cooperation will increase with the similarity in alliance-network centrality between the potential partners. Therefore:

HYPOTHESIS 5.—*The probability of a new alliance between two organizations increases with the similarity in alliance-network centrality between those organizations.*

The prediction of this hypothesis corresponds to the tendency toward "structural homophily" that exist under conditions of uncertainty (Podolny 1994; Popielarz and McPherson 1995).

THE ENDOGENOUS DYNAMIC OF ALLIANCE NETWORKS

In building new alliances, organizations also contribute to the formation of the network structure that shapes future partnerships. Observed over

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based on its affiliations and patterns of interaction, they can, and should be, gauged from the position the actor occupies in the networks defining the social system.

time, this dynamic between embedded organizational action and the network structure that results from that action propels the progressive *structural differentiation* of the interorganizational network. We define structural differentiation as an emergent systemic property that captures the extent to which actors (organizations) come to occupy an identifiable set of network positions, each of them characterized by a distinctive relational profile. Because the position an organization occupies in an alliance network is a signal of its willingness, experience, and ability to enter partnerships, the higher the structural differentiation of an emerging network, the easier it is for organizations to distinguish among other organizations in terms of their relational profiles and the more the network structure acts as a repository of valuable information on potential alliance partners.

This discussion suggests a linear relationship between the level of structural differentiation of the emerging alliance network and the extent of information contained in that network. There is, however, an important caveat. While a network in which all or most organizations have a similar relational profile would offer little guidance to a decision maker, the opposite extreme, a network in which each organization has a truly unique relational profile, may be equally uninformative. This is particularly significant for the information that originates in the position an organization occupies in the structure of the alliance network. If every organization were to occupy a unique structural position, it would be impossible to infer the behavior of any particular organization from the expected behavior of other organizations that occupy that position in the system. The underlying social structure would offer little guidance to organizations seeking an alliance partner, since every potential partner would be unique from a network standpoint. As a result, the relationship between the structural differentiation of a network and the information available to the actors in that network may level off and eventually even become negative as the accumulation of new ties further increases the level of structural differentiation in the network beyond a critical level. Studies of mature social structures suggest that the structural differentiation of most real systems may not display a continuous increase over time. Instead, mature structures typically display a set of stable, self-reproducing positions occupied by actors with similar network profiles (White 1981; Burt 1988). In such structures, the level of structural differentiation remains practically constant over time. Barring exogenous shocks, the structural differentiation of alliance networks may similarly taper off as the social structure of the interorganizational network reaches a mature state.

The effects of structural differentiation are conceptually distinct from the legitimating effects typically associated with growing network density (Hannan and Freeman 1989; Scott 1995). Although structural differentiation is likely to grow with the number of ties in the network, it is distinct insofar as it depends on the specific distribution of those new ties, not merely on their number. The density of ties in a network may provide organizations with information about the pervasiveness of a new form of cooperation, thus helping them to address concerns on the legitimacy of this course of action, but it offers no guidance as to which specific organizations could be worthy partners. Thus, while network density affects the availability of information in a system (Blau 1977), it does not shed light on potential differences in effective access to that information, nor on how the pattern of ties may themselves provide information.

We expect that the structural differentiation of the emerging alliance network will influence new alliance formation both directly and through its interaction with some of the mechanisms that drive alliance formation. At the system level, the additional information introduced by the progressive structural differentiation of an emerging network lowers the level of systemic uncertainty faced by organizations, which directly affects the propensity of organizations to enter new ties. Thus:

Hypothesis 6.—*The probability of a new alliance between any two organizations increases with the level of structural differentiation in the interorganizational network.*

While structural differentiation focuses on system-level information, exogenous resource concerns and network embeddedness focus on the more proximate level of organizations. Given the shared focus of these factors on information availability, we expect that an increase in the extent of structural differentiation is likely to moderate the relative influence of interdependence and embeddedness factors on the creation of new ties. In early periods, when a network is relatively undifferentiated and thus likely to contain limited information about potential partners, organizations may still be prompted to cooperate by exogenous pressures that influence their interests. As a consequence, exogenous factors are likely to be the primary driver of tie formation in the early stages of a network, but the growing differentiation of a network enables it to channel increasing amounts of information about potential partners. As structural differentiation increases, exogenous factors are likely to have a diminishing influence on the formation of new ties. Thus, we expect the structural differentiation of the network to have a negative moderating effect on the influence of exogenous factors on tie formation:

Hypothesis 7.—*The effect of interdependence on the formation of new alliances between organizations decreases with the level of structural differentiation of the interorganizational network.*

We also expect the structural differentiation of the network to moderate the influence of embeddedness on tie formation, although not all embeddedness mechanisms are likely to be moderated by the growing differentiation of the network. The information organizations can obtain through previous direct dealings with other organizations (relational embeddedness) or from common third-party alliances (structural embeddedness) is readily available to a decision maker, and thus it is not necessarily dependent on the larger network in which these dyadic or triadic relations exist. Access to such information depends on the ability of proximate ties to act as conduits of fine-grained information about the competencies and cooperative behavior of other organizations, a property that is not contingent on the stage of development of the entire network. Therefore, the impact of relational- and structural-embeddedness mechanisms is not necessarily contingent on the level of structural differentiation in the overall network.[4]

While the information that results from prior ties to a prospective partner or from common third parties is immediately available to organizations, this is not the case with the information contained in the position their potential partners occupy in the emerging alliance network. The effectiveness of an organization's network position as a signal of unobservable qualities of this organization depends on the development of the overall network in which the varying involvement of organizations in partnerships becomes apparent. The relative scarcity of ties at early stages of the network makes these differences far from apparent. The increase in structural differentiation corresponds to an increase in differences in alliance involvement across organizations, which alters their relative visibility in the overall network. Thus, the informational value of the position of organizations in a social network is likely to be contingent on the level of structural differentiation of that network. We therefore expect the effect of organizations' positional embeddedness on tie formation to increase with the level of structural differentiation of the network:

HYPOTHESIS 8.—*The effect of positional embeddedness on the formation of new alliances between organizations increases with the level of structural differentiation of the interorganizational network.*

Figure 1 summarizes our dynamic model of network formation and highlights the empirically testable predictions of the model. The solid

[4] Our reluctance to suggest that the effects of relational or structural embeddedness are contingent on structural differentiation does not rule out alternative mechanisms through which the growth of the network may alter the effect of these factors and perhaps lead to an empirically observable relationship. The sheer growth in network density could enhance the legitimacy of partnerships, thus making organizations more eager to build ties. Insofar as we expect organizations to prefer embedded ties, the likelihood of entering new ties with previous partners or with common third parties may increase with the growing density of the network. Since density is a likely correlate of structural differentiation, one may still observe a growing impact of relational embeddedness as differentiation increases, but this effect is likely to be spurious from the standpoint of our model.

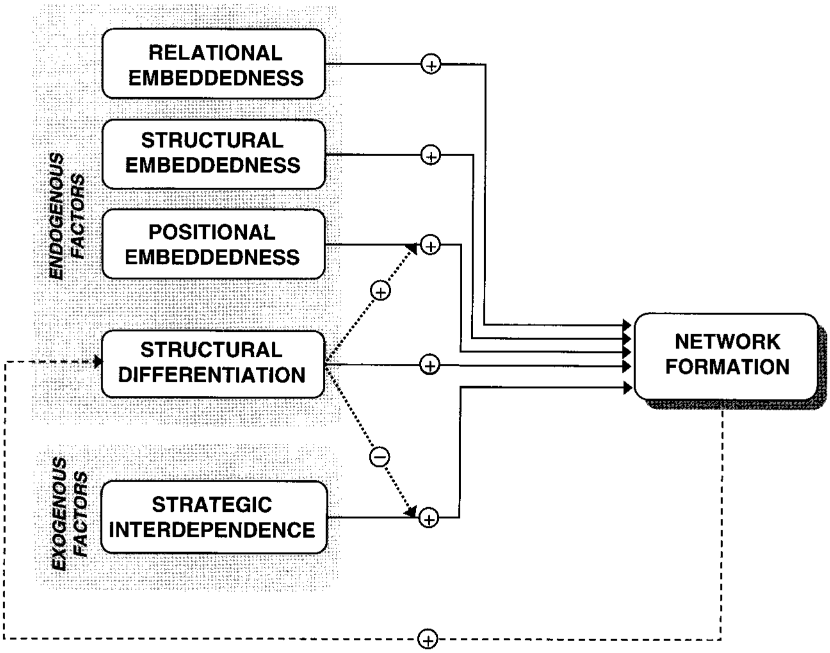

FIG. 1.—The endogenous dynamic of interorganizational networks

arrows represent the direct effects of the key variables on network formation (strategic interdependence, relational, structural, and positional embeddedness, and structural differentiation). The dotted arrows from structural differentiation to the arrows for the direct effects of interdependence and positional embeddedness capture the moderation effect of structural differentiation on the impact of those mechanisms on tie formation. The plus and minus signs indicate a strengthening or weakening of influence in the direction of the arrows. Our expectation is that the greater the structural differentiation of the emerging network, the stronger the effects of positional embeddedness and the weaker the effect of strategic interdependence. The dashed arrow from network formation to structural differentiation indicates the dynamic connection between action and structure.

METHODS

Sample

We tested our model using longitudinal data on strategic alliances in a sample of American, European, and Japanese organizations in three industries over a 20-year period. We collected data on a sample of 166 organizations in new materials, industrial automation, and automotive products. We selected a panel of 50–60 of the largest publicly traded organizations within each sector, estimating an organization's size from its sales in that sector as reported in various industry sources. We also checked with multiple industry experts to ensure that our panels included all prominent competitors in the sectors. This design led to the inclusion of 62 organizations in new materials, 52 in automotive products, and 52 in industrial automation. Of these organizations, 54 were American, 66 were Japanese, and 46 were European.

For each organization, we collected financial data for each year between 1980 and 1989 from *Worldscope,* which provides detailed information about prominent organizations in a wide range of sectors. For organizations not reported in *Worldscope,* data were obtained from *COMPUSTAT* for U.S. organizations, *Nikkei* for Japanese organizations, and *Disclosure* for European organizations. For a number of Japanese organizations, data were also obtained from *Daewoo Investor's Research Guide.*[5] We also collected information for each organization from numerous industry-specific trade journals about the subsegment of its industry within which it had expertise. To make sure that these classifications were correctly recorded, we cross-checked these with multiple experts from each of the industries.

Information on the alliances formed in the three panels of organizations was derived from a much larger and more comprehensive data set that includes information on over 2,400 alliances formed by American, European, and Japanese organizations in the three focal sectors for 1970–89. More than half the data came from the Cooperative Agreements and Technology Indicators (CATI) database collected by researchers at the University of Maastricht. We collected additional alliance data from numerous other sources, including industry reports and industry-specific ar-

[5] For a few organizations, financial data were available for only some years. The gaps typically resulted from the fact that *Worldscope* reports organization data in five-year continuous segments and omits some organizations from some volumes. One alternative for dealing with this problem would have been to use the "available-case method," including only cases with the variables of interest in the analysis. Although such an approach is straightforward, it poses a number of problems, including variability in the sample base as the variables included in models change. Furthermore, it makes little sense to exclude entire cases simply because a single variable is missing. We thus chose to estimate the missing data using a time-trend-based imputation (Little and Rubin 1987). This procedure took into account the fact that the financial outcome for an organization is the result of its own past actions as well as broad trends within its industry. We retained a dummy variable indicating imputation and later compared the results obtained with and without imputed values.

ticles reporting alliances. For the automotive industry, these included *Automotive News, Ward's Automotive Reports, U.S. Auto Industry Report, Motor Industry of Japan,* and the *Japanese Auto Manufacturers Forum;* for the industrial automation sector, *Managing Automation* (1988–89); for the new materials sector, reports from the Office of Technology Assessment and the Organization for Economic Cooperation and Development were used; and for all sectors, we used Predicast's *Funk and Scott Index of Corporate Change.* In all instances, we recorded only alliances that had actually been formed and excluded reports of probable alliances. To our knowledge, these are the most comprehensive data on alliances within each focal sector in both depth and duration of coverage.

The Structure of Interorganizational Alliance Networks

We analyzed the networks in each industry in our sample to explore the structure of the alliance networks and visually examined the emergence of structurally differentiated positions to assess the structural patterns that would clarify and illustrate the differentiation process depicted in the theoretical model. We examined the network structure resulting from the cumulative alliance activity of the organizations within each industry by conducting separate analyses of each industry network in the penultimate period of the study (1988). Each of the three networks included all interorganizational alliances announced in that industry in the previous five years (1983–88). The strength of the ties between two organizations in the network corresponded to the strongest alliance between these organizations in the period, where strength is measured on a seven-point Guttman scale (Contractor and Lorange 1988; Nohria and Garcia-Pont 1991). We used the concept of "role equivalence" to identify classes of organizations or "positions" in the network and their relationship. Role equivalence captures similarities in the organizations' pattern of involvement in alliances, even when this involvement may be with different partners. Each role-equivalent position refers to sets of actors involved in similar types of relations but not necessarily with the same "alters." While structural-equivalence models focus on relations with specific actors (Lorrain and White 1971), role-equivalence models focus on the pattern of relationships among actors and are more adequate to capture status/role sets in a network (Winship and Mandel 1983; Faust 1988; Borgatti and Everett 1994). Two actors are structurally equivalent if they have similar relationships with similar alters, while two actors are role equivalent when they are involved in similar types of relationships with others actors. For instance, two managers leading separate divisions are not structurally equivalent because they have different subordinates; however, they are role equivalent, since they have a similar type of relationship with these subordinates.[6]

To identify role-equivalent positions in the interorganizational networks, we used an approach developed by Hummel and Sodeur (1987) and by Burt (1990). Building on the triad-census idea introduced by Holland and Leinhardt (1970), this technique identifies role equivalence in terms of similarity in the actor's triad patterns. The larger the extent to which two actors are involved in similar triads, the more they are role equivalent (see Van Rossem [1996] for an example of this application).[7] Role equivalence is measured as the euclidean distance between the vectors that capture the triad pattern of each actor. Two organizations that had identical triad patterns would be separated by zero euclidean distances and would be perfectly role equivalent, regardless of the specific organizations with which they built their alliances.

We computed role-equivalence measures using the general-purpose network analysis software Structure 4.2 (Burt 1991).[8] Role-equivalent blocks were identified by cluster analysis of the matrix of euclidean distances between the organizations' triad patterns. Finally, we also performed metric multidimensional-scaling analyses of the proximity matrices of the industry networks, in which proximity was defined by the strength of the alliance between organizations.

Figure 2 presents density tables based on role-equivalent partitions of the three industry networks, along with spatial maps of each industry

[6] Several network analytical concepts—and algorithms—have been proposed to capture this abstract form of equivalence, including automorphic, regular, positional, and role equivalence. For a comprehensive reviews of these concepts, see Mizruchi (1993), Wasserman and Faust (1994), and Borgatti and Everett (1994).

[7] In a symmetric network, a focal organization, or "ego," can be involved in six different triads with two other organizations, or "alters." These triads are T1, in which all three parties are disconnected—also known as the "null triad"; T2, in which ego is connected to only one of two disconnected alters; T3, in which ego is connected to two disconnected alters; T4, in which ego faces two connected alters but has no connection to either; T5, in which ego is connected to one of two connected alters; and T6, in which all three actors are connected. T1 and T4 define an isolated role, while T3 is typical of central roles. The isolated triad (T1), however, has a disproportionately high frequency in sparse networks such as the ones analyzed here. To eliminate potential biases that stem from this dominance, we excluded the null triad from the census (Van Rossem 1996). The isolated role is thus purely defined by T2.

[8] An alternative approach would have been to use a regular equivalence algorithm, such as the one included in UCINET IV. The algorithm, however, has posed computational and interpretative difficulties when applied to symmetric networks (Doreian 1987, 1988; Borgatti 1988). The triad-census approach is computationally simpler and has an intuitive appeal; it is similar to the original Winship and Mandel's (1983) model if role equivalence is defined by direct and two-step ties only (Burt 1990).

Automotive

Position	*1*	*2*	*3*	*4*	*Centr.*
● 1	**2.800**	2.106	.873	.000	.918
◉ 2	2.106	**1.545**	.064	.000	.652
○ 3	.873	.064	**.118**	.000	.155
□ 4	.000	.000	.000	**.000**	.000
Mean	1.020	.572	.153	.000	
N	6	11	17	18	
Rel.	99.29	90.92	95.99	100.00	

● Center ○ Periphery
◉ Semi-periphery □ Isolates

Industrial Automation

Position	*1*	*2*	*3*	*4*	*Centr.*
● 1	**2.000**	.933	.571	.000	.591
◉ 2	.933	**.448**	.157	.000	.230
○ 3	.571	.157	**.000**	.000	.067
□ 4	.000	.000	.000	**.000**	.000
Mean	.510	.221	.080	.000	
N	3	15	14	20	
Rel.	99.97	89.79	99.90	100.0	

New Materials

Position	*1*	*2*	*3*	*4*	*Centr.*
● 1	**3.300**	.866	.344	.000	.689
◉ 2	.866	**.418**	.103	.000	.308
○ 3	.344	.103	**.072**	.000	.041
□ 4	.000	.000	.000	**.000**	.000
Mean	.521	.192	.072	.000	
N	5	14	18	25	
Rel.	98.06	86.36	99.89	100.0	

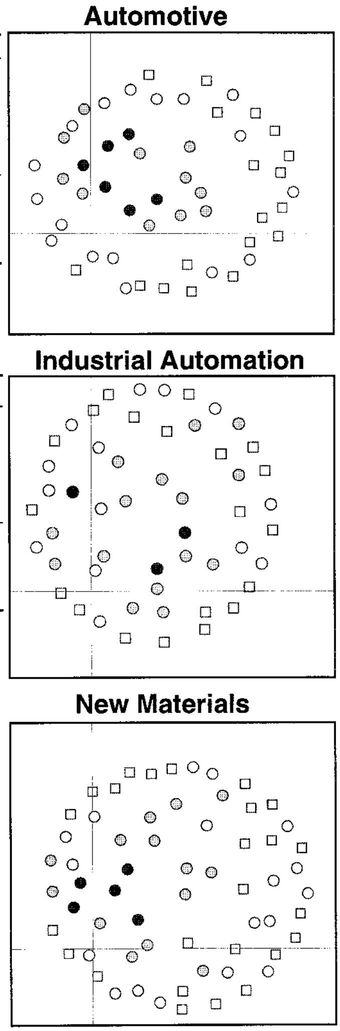

FIG. 2.—Metric MDS maps and density tables of the interorganizational network structures, 1989. Proximities in MDS maps are defined by the strength of the alliances; positions are occupied by role-equivalent organizations. Density is the mean strength of alliances between occupants of the respective position(s), measured on a seven-point Guttman scale. Mean density is the value for the whole industry network and equals .289 for automotive, .115 for industrial automation, and .106 for new materials. Centr. equals the mean eigenvector centrality within the position. Rel. equals the percentage of variance in euclidean distances explained by the first principal component of the position submatrices.

based on the first two dimensions of a metric multidimensional-scaling analysis of the observed alliance networks. For all three industries, the analysis clearly revealed four distinctive positions of role-equivalent organizations, one of which is occupied by "isolates"—organizations that did not enter any alliance in the five years prior to 1989. Figures in the main diagonal cells represent the average strength of an alliance between any two organizations occupying the same structural position; figures in off-diagonal cells represent the average strength of alliances between organizations in the respective two positions. Since we measured alliance strength on a seven-point Guttman scale, figures can vary from zero—when there is no alliance between any two organizations occupying the respective positions—to seven—if all organizations in the position(s) were tied to one another through the strongest alliances. Because alliances are symmetric ties, density tables are symmetric along the main diagonal. The tables also report average eigenvector centrality scores for the organizations in each position.[9] We tested the homogeneity of the resulting positions with a principal component analysis of the submatrices of euclidean distances between position occupants. In all but one of the cases, the first principal component explained 90% or more of the observed variance in distances within the position, which suggested that the positions were occupied by organizations that were strongly role equivalent.

An inspection of the three density tables and spatial maps revealed a similar structural pattern across the three industries. First, the same number of positions adequately described all three interorganizational structures. The homogeneity of these positions was also consistent across industries. This suggested that all three industries experienced a similar pattern of structural differentiation during our observation period and limits potential concerns associated with industry differences.

Second, the figures in the cells revealed a uniform core-periphery pattern. In all three industries, organizations in the central position or "core" (position 1, represented by the black dots in the spatial maps) built strong alliances with one another and somewhat weaker, but still significant, alliances with organizations in the "semiperiphery" (position 2, gray dots) and the "periphery" (position 3, empty dots). In addition, all structures contain a considerable number of "isolates" (position 4, empty squares). The average alliance between the core and semiperiphery was stronger than that between the core and the periphery. The mean strength of intraposition alliances for organizations in the semiperiphery and periphery—displayed in the respective cell of the main diagonal—was always smaller

[9] Centrality scores are the average eigenvector centrality (Bonacich 1987), normalized by industry to vary between 0 and 1. Central organizations are involved in alliances with partners who are in turn involved in many alliances.

than the mean strength of alliances between those organizations and the ones in the core—displayed in the first row (or column) of the tables. A similar pattern existed for the alliances between the semiperiphery and the periphery: except for the automotive industry, these alliances were stronger than the alliances between organizations in the periphery. Thus, periphery and semiperiphery organizations were more likely to build ties with organizations in the center than with organizations occupying their same positions. Core organizations, in turn, were more likely to build alliances with other core organizations than with either semiperiphery or periphery organizations. This pattern is typical of core-periphery structures (Van Rossem 1996).

Third, there was no evidence of isolated factions within the alliance networks. An inspection of the density tables and the accompanying spatial maps showed no indication of dense clusters of cohesive organizations with little interaction outside the cluster. Further, structural analysis using various clique detection routines also failed to identify isolated cohesive subgroups. Although all three networks displayed a relatively cohesive core of varying size, its occupants were also heavily involved in building alliances with organizations in the semiperiphery and—to a lesser extent—with those in the periphery.

The emergence of a core-periphery structure, such as the one revealed by our positional analysis, is consistent with the mechanisms in our endogenous embeddedness model. Organizations may originally differ in their propensity to build ties because of variability in exogenous pressures or organization-specific characteristics, yet the logic of relational and structural embeddedness amplify even a small initial variance in alliance activity, eventually creating appreciable differences among organizations. Relational embeddedness suggests that the more active organizations should have better information on potential partners, since they have access to a larger number of previously trusted partners. Structural embeddedness expands this pool to the partners' partners, which are likely to increase exponentially with the number of direct ties. Since having information on a larger pool of comparatively trustworthy potential partners increases the probability of entering new ties, the more active organizations have increasing comparative informational advantages over less active ones, which increases their likelihood of entering new partnerships (Gulati 1999). The differential involvement in partnerships eventually affects the visibility of the most active organizations beyond the circle defined by their direct and indirect ties, prompting further observable differences among organizations in the emerging network. These differences create conditions that can boost the influence of positional embeddedness on new alliance formation, because they make it easier for organizations to recognize central players in the emerging alliance network.

Variables

Alliance formation.—Our dependent variable is the formation of a new alliance between two organizations in a given observation year. Since the unit of analysis was the dyad, for each panel we listed all possible dyads within each sector, discarding reverse-ordered dyads to avoid double counting.[10] These data were then used to construct an event history for each dyad, with a record for each dyad for each year studied (1981–89). For each dyad-year record, we coded a dichotomous dependent variable that indicated whether the pair of organizations entered an alliance in the given year. The resulting data structure is best characterized as a cross-sectional time-series panel in which the units are unique dyads. Each record included the state of the dependent variable, indicating the formation of an alliance in that period, along with time-varying and time-constant covariates characterizing the dyad.

Such a broad definition of the risk set, which included all possible dyads for the sample of firms in each industry, was considered essential to uncovering unbiased results. Including many dyads that never enter an alliance can, of course, lead to its own set of biases, but we had no observable criteria to determine a priori which dyads were likely to enter alliances and which were not. To address this issue and test the robustness of the results, we conducted the analysis with two additional risk sets that were more restrictive. The first set included only dyads in which at least one member had already entered one or more alliances. The second and most restrictive definition of the risk set included dyads in which both members had entered at least one other alliance. The results obtained with different sets were comparable. The results reported here are based on the complete risk set.

Interdependence.—This variable measures the extent to which organizations may need each other to access critical resources and capabilities. Prior research (Nohria and Garcia-Pont 1991; Shan and Hamilton 1991) and our own extensive fieldwork suggest that interdependence between organizations in these industries resulted primarily from the quest for complementary capabilities and resources, but identifying and measuring this complementarity is not an easy task. Complementarity between two organizations can arise when (*a*) there is a gap between the specific capabilities controlled by each organization and those they need to pursue their strategy and (*b*) this gap can be filled at least partially by accessing the

[10] Hallinan and Sorensen (1985) used a similar dyadic approach in examining the effects of ability groups in classrooms on the patterns of student friendships formed. Fernandez (1991) examined the effects of informal and formal ties on leadership relations within organizations using such an approach. Both studies, however, used cross-sectional data.

capabilities controlled by the other organization while being able to offer something of value in return. Organizational needs and capabilities, however, are multifaceted and ambiguous; assessing them across a large number of organizations poses a formidable measurement problem. In addition, an index of complementarity for all possible pairs of organizations requires measuring the extent to which the capabilities of one organization can "complement" the capabilities of every other organization in the industry. We therefore used several approaches to assess complementary capabilities and resources that could create interdependence between organizations and conducted a statistical analysis to capture any unobserved affinity between organizations not adequately accounted for with the variables included in the analyses.

The measure of interdependence reported in this article is based on two key dimensions that drive complementarity between firms in our global setting: national origin and industry subsegment. National origin captures the geographical clustering of capabilities in the global economy. Regional contexts circumscribe important sets of unique organizational capabilities and resources, which resulted from specific historical and institutional processes (Porter 1990; Hamilton and Biggart 1988). In addition, interdependence across different geographical regions can result from the need to gain access to markets in those regions. Organizations from different regions are therefore more likely to have complementary capabilities and to benefit from strategic alliances with each other (Shan and Hamilton 1991). We captured these regional differences by grouping organizations in three categories—American, Japanese, and European—which correspond to the three major global markets, as well as to three relatively distinct historical and institutional settings.

Industry subsegment captures complementarity across different technological "niches" within an industry. Each of these niches corresponds to clusters of firms that share specific sets of capabilities and resources. Firms in different niches are more likely to have complementary capabilities that can make them interdependent and lead to alliances between them (Nohria and Garcia-Pont 1991). Building on this insight, we identified broad subsegments that define distinctive clusters of organizations within each industry. We identified two subsegments in the new materials sector (ceramics and polymer composites), four in industrial automation (discrete automation, process automation, software, and robotics), and two in the automotive sector (automobile assemblers and suppliers).

We measure interdependence between any two organizations within an industry as the normalized euclidean distance between those organizations, computed from the matrix that captures the national origin and industry subsegment of each firm and computed to capture the absence of overlap of activities. The greater the normalized euclidean distance between two organizations, the more likely they are to possess complementary capabilities and resources, and the higher their interdependence. To check the validity of this measure, we performed a cluster analysis of the euclidean-distance matrix for each industry and identified clusters of organizations with similar national and technological profile. We identified seven distinct clusters in the new materials sector and nine clusters each in the industrial automation and automotive sectors.[11] The composition of those clusters was then checked with recent studies of similar industries (Nohria and Garcia-Pont 1991), as well as with a classification of the same firms in discrete strategic clusters by a panel of industry experts. The high convergence (80%) between the groups formed by the experts and those obtained from clustering the matrix of euclidean distances between the firms validates the use of these distances as a measure of interdependence. To further assess the similarity between the groups obtained through cluster analysis and the continuous measure used in this study, we constructed a dummy variable coded "1" if the organizations in a dyad belonged to different clusters and "0" if they belonged to the same cluster. The results obtained using this variable were similar to the ones based on the continuous measure of interdependence.

We also tried to account for interdependence between organizations in our sample by considering a series of firm-specific attributes—such as size and financial performance—that capture resource availability and constraints that typically influence the propensity of organizations to enter alliances. We discuss these attributes below as control variables. Finally, we tried to capture any residual interdependence with a statistical model that controls for unobserved factors that might affect the likelihood of alliances between specific firms. Details of this follow in the next section.

Network measures.—To compute our network measures, we constructed adjacency matrices representing the relationships between the organizations in each industry for each year. We included all alliance activity among industry panel members for the previous five years. One concern with such a design is left-censoring, which is an issue because many of the sample organizations existed prior to the start of the alliance observation period in 1981. Additional alliance data were collected for the alliance activity of this sample of organizations for 11 years, dating back to 1970 to minimize left-censorship effects. These data confirm that alliance

[11] Our partitioning of industries created clusters of organizations that are akin to the concept of "strategic groups" (for reviews, see Thomas and Venkatraman 1988; Barney and Hoskisson 1990; Reger and Huff 1993). Our clusters are closest to Porter's (1979) original definition of a strategic group as a set of organizations within an industry that are similar to one another in one or more strategic dimensions, such as skills, resources, goals, and historical development.

activity was negligible until 1980, when there was an explosion of alliances (Hergert and Morris 1988).

We made a number of choices in constructing these matrices about the treatment of different types of alliances, the accumulation of multiple ties by the same partners, and the past alliances that should be included. These choices were all tested against alternatives to ensure the robustness of our findings. First, alliances were weighted by their strength, as represented by their formal governance structure, using a seven-point scale (Contractor and Lorange 1988; Nohria and Garcia-Pont 1991), and the results were checked against a simple dichotomous measure. Second, to take into account the cumulative history of alliances between organizations, we used a Guttman scale that captures the score of the strongest alliance formed by the two organizations, checking the results against simple additive scores and normalized additive scores. Third, we used a moving window of five years of prior alliances, based on research suggesting that the normal life span for most alliances is usually no more than five years (Kogut 1988). We checked the results against networks that included all previous alliances dating back to 1970 in the construction of the networks.

Relational embeddedness.—This construct indicates the extent to which a pair of organizations (dyad) had direct contact with each other in the past. For our longitudinal panel of pairs of organizations for 1981–89, we operationalized relational embeddedness as the number of alliances dyad members had entered with each other in the previous five years.

Structural embeddedness.—This construct indicates the extent to which a given pair of organizations shared common partners from past ties. For each dyad-year record, we computed the number of partners shared by the two organizations in a dyad as a result of their alliances in the previous five years. To differentiate structural embeddedness from relational embeddedness, we set common ties to zero if the members of a dyad sharing common ties had entered at least one previous direct alliance with one another (cf. Mizruchi 1992, p. 126).

Positional embeddedness.—This construct indicates the extent to which the organizations in a dyad occupy similar or different network positions. We first computed a measure for the position of each organization and then used those as inputs to compute dyadic values. We measured the position of an organization in the emerging network of alliances using the Bonacich (1987) eigenvector measure of network centrality, a choice that is consistent with prior efforts to capture the position or role of an organization in a relational network (Mizruchi 1993; Podolny 1994). Using this measure, the most central organizations are those linked to many organizations, which are in turn linked to several other organizations. We computed the eigenvector measure of the network centrality of each organization for each year and expressed the scores relative to the most central organization in the network for that particular year ($C_{max} = 1$). To capture the joint centrality of the dyad, we computed the geometric mean of the centrality scores for each member of the dyad and then normalized it by the industry maximum (Mizruchi 1993). The larger the score, the more the two organizations occupied a central role in the network. To capture the similarity in centrality in a dyad, we computed the ratio of the smaller to the larger centrality score of the two organizations. The closer this ratio was to 1.0, the more similar were the two organizations' positions in the network.

Structural differentiation.—Our indicator for this construct reflects the nature of the differentiation that characterizes the specific interorganizational systems under investigation. Our positional analysis revealed the emergence of a center-periphery structure in all the three industry networks. At the system level, the emergence of such a structure is parallel to an increase in network centralization. Thus, an indicator that captured the extent of network centralization could adequately represent the type of differentiation observed in our networks. For each observation year, we measured the structural differentiation of the network as the level of network centralization in that year. Following Wasserman and Faust (1994), we measured network centralization as the standard deviation of the eigenvector centrality scores of the organizations in the industry for that year. Because we normalized eigenvector centrality scores by the highest centrality in each industry and year, our measure captured the *relative* internal differentiation of the system for each industry and in each given observation year. The changes over time in the measure of structural differentiation captures the emergence of the center-periphery structure that characterizes the industry networks. The average standard deviation of centrality across the three industries displayed a linear monotonic increase over time, ranging from .15 in t_0 (1981) to .41 in t_8 (1989). These aggregate figures adequately represent the pattern observed in each of the three industries and further highlight the progressive centralization of the networks as alliances accumulate. We tested the hypothesized moderating influence of structural differentiation on interdependence and embeddedness with interaction terms that were constructed using the product-term approach (Jaccard, Turrisi, and Wan 1990).

Control Variables.—We included as controls a number of variables known or expected to affect the alliance activity of organizations. These are network density, time, sector, organization-level effects, and a set of financial measures capturing organizational differences in some key resources.

An alternative interpretation for the endogenous embeddedness dynamic proposed here is a density-dependence argument linking the number of previous alliances to the legitimacy of this new form of business relationship. Ecological density-dependence arguments claim that there is an initial positive impact of density on founding rates of organizations via the effect of density on the legitimacy of the new organizational form (Hannan and Freeman 1989, p. 132). Applied to this context, it would suggest that the growth in alliances may be the result of a bandwagon effect (Venkatraman, Loh, and Koh 1994). Thus, one could argue that structural differentiation might simply be capturing the progressive legitimization of alliances as a valid form of interorganizational cooperation, rather than the informational effects proposed in our model. If this were the case, the growth of alliances would be driven by the effects of density-dependent legitimization rather than by the increase in the availability of information captured by our notion of structural differentiation.

To account for this alternative explanation, we included a measure called *alliance density,* defined as the cumulative number of alliances within the industry in the previous five years, divided by the total number of possible alliances in the system. If the effect of structural differentiation is only capturing density-driven legitimacy, the inclusion of alliance density should make the effect of structural differentiation insignificant, thus bringing into question the validity of our claims. The endogenous network dynamic model, however, does not preclude a legitimization effect, because density-dependence and structural-differentiation effects need not be mutually exclusive.

To control for unobserved temporal factors that may influence alliance formation, we included dummy variables for each year. Such factors could include a progressive legitimization not accounted for by the simple accumulation of alliances—or unspecified events that may alter the likelihood of new alliances. For simplicity of presentation, we then reestimated these effects using a single variable, time, which ranges from “0” to “8” (with the default year being 1981) and assumes linearity in the effect of time. We observed no differences in the results based on the alternative controls for time. We also controlled for sector differences with two dummy variables, labeled new materials and industrial automation, using the automotive sector as the default sector.

Unobservable organization-level effects were captured by two variables indicating the prior alliance experience of each partnering organization in each dyad (Heckman and Borjas 1980). We computed a measure for each organization that captured the total number of alliances it had previously entered in the past five years. These variables, labeled alliance history, firm 1 and firm 2, capture the possibility of repetitive momentum in individual organizations’ alliance activities, as well as unobserved factors affecting each organization’s proclivity to form partnerships. It is worth noting that these measures are akin to the network analysis notion of “degree centrality,” which is defined as the number of ties in which an actor is involved (Freeman 1979).

We also included a series of financial measures to capture the differences across the organizations in a number of key dimensions. Insofar as differences in the control of financial resources may result in complementarities that lead to strategic alliances, these controls also can be discussed as an additional way of capturing possible sources of interdependence between organizations (Ghemawat, Porter, and Rawlinson 1986; Barley, Freeman, and Hybels 1992). For each such dimension, we computed a ratio of the smaller to the larger organization. In this way, we controlled for relative differences in financial resources and performance that may have influenced the likelihood of alliance formation between the two organizations. The first dimension was size, measured as total sales in the industry; the second was performance, captured as return on assets normalized to the industry mean (a common measure of performance in managerial research); the third was liquidity. Organizations frequently enter alliances to share the costs of new projects, particularly those involving large resource outlays and risks. In this context, relative liquidity, which reflects the short-term resources available to an organization, is important. We used the "quick ratio"—defined as current assets minus inventory, divided by current liabilities—to measure liquidity (Dooley 1969). Last, we examined solvency differences across the two organizations in each dyad. We used an organization's relative-debt profile within its industry, measured as the total amount of long-term debt divided by the organization's current assets.

We also examined whether each of the above financial attributes for each organization in the dyad separately influenced alliance formation. Thus, for each organization in a dyad, we introduced separate variables indicating the size, performance, liquidity, and solvency of each organization (eight variables). These variables had no effect on our main results and so, in the interest of parsimony, we omitted them from our final analysis.

Table 1 lists the variables, their summary definitions, and their predicted effect on the probability of alliance formation, while table 2 displays descriptive statistics and a correlation matrix for all the variables in the analysis.

Model

We modeled alliance formation using the following dynamic panel model, in which a variable's positive coefficients indicate that it promotes alliance formation:[12]

[12] It is important to note that this approach is distinct from that using the class of models known as network effects or endogenous feedback, which is familiar to network analysts (Marsden and Friedkin 1993). The postulated network effects here result from a lagged network of cumulative prior ties until the previous year, rather than being linked to network elements in the same period.

TABLE 1

DEFINITIONS AND PREDICTED SIGNS OF VARIABLES

Variable	Definition	Prediction
Alliance	Whether two firms formed an alliance in a given year	Dependent variable
Interdependence	Normalized euclidean distance score capturing the absence of overlap of activities between firms	+
Structural differentiation	SD of the normalized prominence scores among firms in the industry	+
Repeated ties	Number of prior alliances between the firms in prior five years	+
Common ties	Number of common partners shared by previously unconnected firms in prior five years	+
Joint centrality	Geometric mean of multiple of centrality of both firms normalized by industry maximum	+
Centrality ratio	Ratio of centrality of lesser to greater value	+
Network density	Ratio of cumulative alliances in an industry divided by the number of possible alliances	+
Time	Year value for each record, ranging from zero to eight	NP
New materials	"1" if firms are in the new materials sector (default: automotive)	NP
Industrial automation	"1" if firms are in the industrial automation sector (default: automotive)	NP
Alliance history, firm 1	Number of prior alliances entered by firm 1 in the dyad	NP
Alliance history, firm 2	Number of prior alliances entered by firm 2 in the dyad	NP
Size	Ratio of sales of smaller to larger partner	NP
Performance	Ratio of performance (ROA) of lesser to greater firm value	NP
Liquidity	Ratio of liquidity (quick ratio) of lesser to greater firm value	NP
Solvency	Ratio of solvency (long-term debt) of lesser to greater firm value	NP

NOTE.—NP = no prediction.

TABLE 2

DESCRIPTIVE STATISTICS AND CORRELATION MATRIX

Variables	Mean	SD	Low	High	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Alliance	.21	.09	0	1.00	. . .																
Interdependence	1.42	.28	0	2.47	.16																
Structural differentiation	.29	.08	.15	.41	.24	.00															
Repeated ties	.12	.40	0	5.00	.19	.10	.36														
Common ties	.56	1.21	0	9.00	.15	.03	.19	.32													
Joint centrality	.21	.32	0	1.00	.16	.07	.11	.25	.38												
Centrality ratio	.46	.21	0	1.00	.21	.01	−.02	.12	−.06	.26											
Network density	.16	.09	.06	.22	.16	−.04	.43	.30	.21	.08	.04										
Time	5.72	1.98	0	8.00	.02	.11	.38	.06	.08	.13	−.11	.49									
New materials	.44	.49	0	1.00	.00	.04	.19	−.05	−.12	−.10	.03	.21	.00								
Industrial automation	.23	.42	0	1.00	−.01	.01	−.22	−.03	−.08	−.14	−.13	.10	.00	−.24							
Alliance history, firm 1	3.00	2.79	0	16	.12	.09	.07	.21	.32	.35	.00	.03	.32	.03	−.06						
Alliance history, firm 2	3.13	2.90	0	16	.10	.13	.12	.18	.27	.42	.01	.18	.35	−.05	−.13	.14					
Size	.27	.25	.09	.94	.02	−.21	.01	.05	.06	−.03	.24	.02	.01	−.03	.00	−.01	−.05				
Peformance	.35	.29	.13	.90	.00	−.09	−.03	.00	.00	.00	.13	.11	−.01	.00	−.01	.00	.00	.00			
Liquidity	.24	.19	.07	.88	.01	−.02	.00	.02	.03	.00	.07	−.06	.04	.00	.013	.03	.00	.38	.17		
Solvency	.64	.22	.02	.80	.00	−.05	.09	.01	.03	.00	.16	.00	−.03	.05	−.05	.04	.05	.05	.00	.08	. . .

$$p_{ij}(t) = \Phi(a + bx_{ij} + cy_{ij}(t - 1) + u_{ij}),$$

where $p_{ij}(t)$ is the probability at time (t) of the announcement of an alliance between organizations *i* and *j;* x_{ij} is a time-constant vector of covariates characterizing organizations *i* and *j;* y_{ij} (t − 1) is a time-varying vector of covariates characterizing organizations *i* and *j;* u_{ij} is unobserved time-constant effects not captured by the independent variables; Φ is the normal cumulative distribution function.

We employed a random-effects panel probit model that accounts for unobserved heterogeneity and was implemented here using LIMDEP 6.0 (Butler and Moffitt 1982). Details about our choice of model and the necessity for accounting for unobserved heterogeneity are provided in the appendix.

One concern with analyzing dyadic data is possible interdependence across observations (Lincoln 1984; Mizruchi 1989). To ensure the robustness of our results, we employed a procedure similar to the Multivariate Regression Quadratic Assignment Procedure (MRQAP), routinely used by researchers studying dyads (Krackardt 1987, 1988; Manley 1992; Mizruchi 1992). The percentage of frequency with which the results in the random-sample simulations exceeded the original estimates was far less than 5% in all instances, which attests to the robustness of our probit estimates. Details of these tests are reported in the appendix.

RESULTS

Table 3 presents probit estimates for the effects of factors influencing the formation of new ties between organizations. The coefficients indicate how a change in an independent variable in the previous year affects the probability of two organizations forming a new alliance during the current year.

Model 1 presents a baseline containing an array of control variables. These include the density of alliances in the sector, time, dummy variables for industrial sectors, and controls for each organization's previous alliance experience (labeled alliance history) as well as their similarity in a series of financial indicators. The density of alliances in the prior time period has a positive impact on new alliance formation, which suggests possible legitimization effects. The introduction of alliance density in the model makes the effect of time nonsignificant, suggesting that most linear time-related factors are captured by cumulative industry density. There was a significant improvement in the chi-square statistic once we introduced alliance density, which further suggests that the density of the network may mediate the influence of time on alliance formation. In separate

TABLE 3

Random-Effects Panel Probit Estimates

Variable	1	2	3	4	5	6	7	8	9	10
Constant	1.33*	1.09*	.58	.52	.50	.52	.52	.43	.37	.39
	(.24)	(.21)	(.49)	(.48)	(.48)	(.47)	(.47)	(.34)	(.35)	(.37)
Interdependence	. . .	1.15*	.91*	.69*	.66*	.59*	.57*	.52*	.56*	.58*
		(.39)	(.30)	(.21)	(.20)	(.17)	(.17)	(.16)	(.17)	(.18)
Structural differentiation			3.78*	3.51*	3.03*	2.93*	2.88*	2.46*	2.39*	2.08*
			(1.02)	(1.01)	(.91)	(.88)	(.89)	(.74)	(.70)	(.63)
Repeated ties				1.38*	.73*	.61*	.60*	.43*	.48*	.44*
				(.20)	(.15)	(.14)	(.14)	(.12)	(.13)	(.12)
Common ties					1.26*	1.18*	1.03*	.64*	.94*	.98*
					(.14)	(.20)	(.21)	(.18)	(.20)	(.22)
Joint centrality						.69*	.48*	.42*	.29*	.38*
						(.10)	(.13)	(.13)	(.07)	(.13)
Centrality ratio							.08	.06	.07	.18
							(.05)	(.05)	(.05)	(.10)
Structural differentiation × interdependence								−1.79*	. . .	
								(.40)		
Structural differentiation × joint centrality									1.38*	. . .
									(.22)	
Structural differentiation × centrality ratio									. . .	1.08*
										(.20)

Network density	.16*	.15*	.11	.10	.11	.11	.10	.09	.12	.12
	(.03)	(.03)	(.06)	(.06)	(.06)	(.07)	(.07)	(.07)	(.07)	(.08)
Time	.07	.06	.03	.03	.03	.00	.00	.01	.01	.03
	(.05)	(.05)	(.05)	(.04)	(.04)	(.04)	(.05)	(.03)	(.03)	(.02)
New materials	−.23	−.23	−.20	−.21	−.19	−.16	−.15	−.16	−.15	−.17
	(.15)	(.14)	(.14)	(.14)	(.14)	(.11)	(.12)	(.10)	(.10)	(.12)
Industrial automation	.03	.06	.05	.05	.04	.02	.06	.06	.02	.04
	(.02)	(.05)	(.04)	(.05)	(.05)	(.05)	(.05)	(.04)	(.04)	(.06)
Alliance history, firm 1	.42	.31	.29	.23	.18	.15	.10	.10	.12	.08
	(.27)	(.23)	(.23)	(.21)	(.20)	(.21)	(.16)	(.16)	(.15)	(.14)
Alliance history, firm 2	.11	.24	.19	.18	.17	.14	.17	.16	.15	.16
	(.07)	(.15)	(.14)	(.16)	(.16)	(.16)	(.16)	(.16)	(.16)	(.15)
Size	−.52*	−.47*	−.39*	−.35*	−.32*	−.31*	−.25*	−.20*	−.18*	−.23*
	(.12)	(.12)	(.11)	(.11)	(.10)	(.10)	(.05)	(.05)	(.05)	(.06)
Performance	−.15*	−.09	−.05	−.03	−.03	−.00	−.02	−.02	−.03	−.05
	(.03)	(.05)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)
Liquidity	−.34	−.30	−.27	−.26	−.20	−.18	−.17	−.21	−.19	−.16
	(.19)	(.18)	(.19)	(.18)	(.14)	(.13)	(.11)	(.10)	(.10)	(.12)
Solvency	.10	.08	.07	.06	.05	.06	.05	.05	.06	.05
	(.12)	(.11)	(.10)	(.11)	(.11)	(.11)	(.10)	(.10)	(.10)	(.10)
Rho	.44	.43	.36	.35	.32	.30	.29	.24	.21	.23
	(.13)	(.13)	(.10)	(.10)	(.09)	(.09)	(.09)	(.07)	(.07)	(.07)
N	7266	7266	7266	7266	7266	7266	7266	7266	7266	7266
Chi square	45.73*	49.34*	58.47*	65.62*	69.76*	74.57*	76.71*	83.42*	87.11*	85.04*

NOTE.—SDs are in parentheses.
* $P < .05$.

analyses, we also introduced a variable capturing the number of alliances announced in the industry in the previous year, but this variable was not significant once we controlled for industry density and thus was not included in the models.

The variables for alliance history of each organization were insignificant across all models, indicating that the individual prior experience with alliances of each organization within a dyad did not make an alliance between them more likely. Model 1 also included ratios measuring the similarity between pairs of organizations in size, performance, liquidity, and solvency. Except for size, similarity of financial indicators did not have a significant impact on the probability of alliance formation. Alliances are more likely to occur between organizations of different size. While these ratios are introduced as controls, they also capture any residual effects of interdependence not accounted for by our measure of interdependence. We also examined whether the above financial attributes introduced separately for each organization in the dyad influenced alliance formation, but these variables had no impact on our main results and were omitted from our final analysis in the interest of parsimony.

Model 2 introduced our measure of interdependence between the members of the dyad. As predicted in hypothesis 1, organizations separated by a larger normalized euclidean distance in the matrix that captures interorganizational interdependence were more likely to enter alliances. This result is congruent with research on the role of interdependence in alliance formation and also helps enhance the construct validity of our indicator. Our alternative measure for interdependence, using membership in the clusters corroborated by industry experts, yielded similar results.

We introduced structural differentiation in model 3. As predicted by hypothesis 6, structural differentiation has a strong positive effect on alliance formation. Introducing this measure also leads to a significant improvement in the fit of the model, as measured by the chi-square statistics. Moreover, the effect of density became nonsignificant at the .05 level once we introduced structural differentiation into this model. This suggests that the systemic effects on tie formation captured by density may actually be mediated by the structural differentiation of the network. Although hypothesis 6 was not formulated as an alternative for a density-dependent legitimization process, the statistical insignificance of the density effect in model 3 suggests that the increase in the probability of alliance formation is perhaps best explained by the growing differentiation of the network structure. Thus, the upward-sloping rate of alliance formation during the 1980s may be prompted by the emergence of a differentiated social structure that made it easier for organizations to identify suitable partners in an uncertain environment, rather than a consequence of a legitimization effect driven by the mere accumulation of ties over time.[13]

Models 4–7 test the effect of the various embeddedness mechanisms on alliance formation, as predicted by hypotheses 2–5. Models 4 and 5 confirm the expected influence of both relational and structural embeddedness on subsequent alliance formation, as proposed in hypotheses 2 and 3. In model 4, the positive and significant coefficient of repeated ties indicates that the presence of prior ties between organizations in the previous five years positively influences the likelihood of their forming a new alliance. In model 5, the positive and significant effect of common ties indicates that shared third-party ties between previously unconnected organizations increases their probability of entering an alliance. The effects of both direct and indirect ties on alliance formation remain significant across all the models.[14]

Models 6 and 7 examine the role of the position of organizations in the emergent structure of interorganizational ties on their alliance behavior. Model 6 shows that the probability of two organizations forming a new alliance increases with the joint centrality of the potential partners, as predicted by hypothesis 4. The evidence for hypothesis 5, which predicts an increase in the probability of an alliance between organizations with similar centrality, is less conclusive. The results indicate that the difference in centrality scores does not have a statistically significant influence on the likelihood of an alliance between two organizations. In separate

[13] We also assessed the impact of diversity-dependent legitimation on alliance formation by modeling the effects of the diversity of alliances formed within industries. Diversity was conceptualized in terms of the kinds of governance structure organizations used to formalize their alliances. We assessed diversity with two sets of measures. First, we computed the reciprocal of the Herfindahl index for governance structure of prior alliances. Second, we used a specification akin to Blau's index of heterogeneity (Blau 1977; Powell et al. 1996). We computed the proportion of organization *i*'s ties of type *j* until year *t*, out of the total number of ties the organization had entered until that year, denoted as $P_{it,j}$. We defined six types of governance structures. We computed the index of diversity Y_{it} by subtracting the summation over all *j* of the square of $P_{it,j}$ that is, $Y_{it} = 1 - \sum_j (P_{it,j})^2$ and $(1 \leq j \leq 6)$. The results were insignificant for both measures of diversity across all models and were thus not included with the final analyses.

[14] We also tested polynomial transformations of the two cohesion variables to account for nonlinear effects. The results suggest that the relationship between previous alliances and future alliances within the dyads is best described as an inverted U-shaped relationship, captured by a second-order polynomial function. The effect, however, is exponential for shared common ties between unconnected organizations. As the number of common ties between organizations increases, the likelihood of their allying with each other increases disproportionately. The inclusion of the polynomial transformations does not affect the results obtained with the linear forms. We report the results of the linear model for the sake of parsimony.

estimations, however, we found that the ratio of centrality was positive and significant if joint centrality was excluded from the model. To interpret this result, it is worth noting that the ratio of centrality approaches 1.0 for any two organizations that have similar centrality scores, regardless of their absolute level of centrality. In other words, while two "central" organizations are similar, so are two "peripheral" ones. Yet our positional analysis of the networks has shown that peripheral organizations are much less likely to enter alliances. If they do, they are likely to do so with central organizations, not with other peripheral ones. Central organizations form ties with other central organizations and, to a lesser extent, with less central organizations. Thus, the homophily tendency implicit in hypothesis 5 only applies to central organizations. Once the joint centrality of the dyad is controlled for, the effect of homophily is no longer significant. Viewed in this light, these results are consistent with the distinction introduced by Mizruchi (1993) between "central" and "peripheral" role equivalence, which suggests that there are significant differences in the behavior of these two types of actors that cannot be easily captured by a single sociological construct.

Models 8, 9, and 10 assess the moderating influence of structural differentiation on both endogenous and exogenous drivers of alliance formation. We had predicted that structural differentiation in the system would moderate the influence of positional embeddedness on alliance formation (hypothesis 8). This prediction should translate into a significant and positive coefficient for the interaction between structural differentiation and both joint centrality and similarity in centrality. But we also predicted that the effect of exogenous interdependence on alliance formation would diminish with structural differentiation (hypothesis 7). This effect should yield a significant and negative coefficient for the interaction between interdependence and structural differentiation. We tested these models separately because of concerns of multicollinearity across the interaction terms.

Model 8 introduces an interaction term between interdependence and structural differentiation. The negative coefficient for the interaction term supports hypothesis 7 and suggests that the explanatory power of interdependence diminishes with the growing differentiation of the social structure of interorganizational ties, but interdependence on its own has a positive impact on alliance formation across all models. Thus, while exogenous factors do influence the creation of new ties, the increasing structural differentiation of the network enables organizations to use this network as a source of information for their future partnerships, which mitigates the effects of exogenous interdependence on the formation of new alliances.

Models 9 and 10 introduce the interactions between structural differentiation and the two indicators of positional embeddedness. Model 9 tests the interaction between structural differentiation and joint-dyad centrality, and model 10 adds the interaction between structural differentiation and the similarity in centrality within the dyad. Together, these two models test the contingent influence of positional embeddedness on alliance formation (hypothesis 8). Both models show significant positive effects for the interaction between positional embeddedness and structural differentiation. The impact of both joint centrality and similarity in centrality increases with the level of structural differentiation of the emerging network. This suggests that the effect of positional embeddedness on alliance formation increases with the level of structural differentiation of the emerging network. As predicted by our framework, the effective impact of positional-embeddedness mechanisms on subsequent tie formation is thus contingent upon the level of structural differentiation of the network.

Although similarity in centrality was not a significant predictor of alliance formation, the interaction between this variable and structural differentiation is statistically significant. This suggests that, with the growth of structural differentiation, organizations may become increasingly aware of differences in centrality when choosing a partner, although this tendency is not strong enough to make the difference in centrality statistically significant during the period of observation. The more the respective positions of organizations in the network become apparent, the more difficult it may become for a peripheral organization to build alliances with a central one. Although this does not mean that such alliances will not occur, it does suggest that peripheral organizations may need to possess some unique attributes that can enhance their attractiveness as alliance partners with central organizations.

DISCUSSION

The central message of this research is that the formation of a new interorganizational network structure results from a longitudinal dynamic in which action and structure are closely intertwined. Our model portrays the social structure of interorganizational relations as a "macro" phenomenon emerging out of the "micro" decisions of organizations seeking to gain access to resources and to minimize the uncertainty associated with choosing alliance partners. The network structure that results from the accumulation of those ties increasingly becomes a repository of information on potential partners, helping organizations decide with whom to form new alliances. The emerging alliance network consequently increasingly influences organizational action. In this model, the dialectic between macro and micro is thus translated into the dialectic between structure and action.

The results show that both interdependence and network embeddedness factors have a significant impact on new alliance formation. Consistent with prior research, organizations build ties with other organizations that have complementary resources and capabilities, but they also take into consideration the position the potential partners have in the emerging social structure of the network. The influence of interdependence and network factors is contingent on the level of structural differentiation of the social system. The role of positional embeddedness in alliance formation increases with the growing structural differentiation of the emerging interorganizational network, while the impact of exogenous factors declines. These findings support our claim that the increasing differentiation of social structure reflects a process by which the network becomes a repository of information about potential partners. The higher the structural differentiation of the emerging network, the more organizational decisions about new partnerships are guided by endogenous network considerations and the less by exogenous factors.

As we interpret the results, the emerging alliance network progressively internalizes relevant information about competencies, needs, and reliability of potential partners. The embeddedness mechanisms enable organizations to identify complementary and reliable partners, reducing the hazards of cooperation. This interpretation implicitly assumes that there is no tension between instrumental and social drivers of alliance formation, yet our results do not preclude the possibility of such a tension. The emergence of a network structure increases the information available to organizations, but it may also limit the effective range of potential partners organizations are likely to consider. The possibility that instrumental rationality could be subordinated to embedded action has been emphasized often in neoclassical economics. Yet sociologists have also suggested that in some situations, social structures may actually hinder, rather than help, the pursuit of economic interest. Studies of ethnic entrepreneurs (Portes and Sensenbrenner 1993) and middle managers (Gargiulo and Benassi 1998) suggest that the same social mechanisms that facilitate instrumental cooperation may also have a "dark side" that can damage an actor's ability to pursue instrumental goals (Gulati and Westphal 1999). One of the themes in these studies is that membership in cohesive clusters hinders the actor's ability to build cooperative ties with actors not connected to that cluster. A similar risk is implicit in our structural-embeddedness mechanism and could equally limit the formation of ties within a cohesive "core" of central organizations.

By relying on an evolving social structure, boundedly rational organizations effectively diminish the uncertainty associated with picking partners, but gains in partner reliability may be offset by the limitations on the choice of potential partners. Some features of strategic alliances suggest that this trade-off may be more than a theoretical possibility. The hazards of interorganizational cooperation, coupled with the difficulty of assessing complementary capabilities and the often ambiguous link between alliances and organizational performance, may prompt organizations to enter "secure" partnerships that could fail to realize the full potential of strategic alliances they could have entered. Future research in this field should investigate a possible trade-off between the reduction of uncertainty attained through embedded partnerships and pursuit of the instrumental logic that promotes interorganizational cooperation. If such a trade-off exists, the search for an alliance partner could result in a path-dependent process (Arthur 1989), in which instrumental rationality is at times subordinated to considerations of embeddedness. While available evidence suggests that organizations usually avoid the perils of excessive involvement with the same partner (Gulati and Lawrence 1999), they may still be victims of subtler forms of "overembeddedness" that could limit their search for partners, depriving them of the full benefits of strategic alliances. Consistent with Gargiulo and Benassi's (1998) work on managerial networks, we could expect that organizations tied to a cohesive cluster of alliance partners might run a higher risk of falling into a path-dependent process that effectively limits their range of potential partners.

Our analysis of the structure of alliance networks uncovered the emergence of core-periphery structures in the automotive, new materials, and—to a lesser extent—industrial automation industries. The structural-differentiation process that is at the core of our model of network formation, however, can be compatible also with alternative structural configurations. In some circumstances, structural differentiation may result in a structure with two or more blocs of organizations (or "factions") with relatively few ties across blocs. Such structures typically arise when there are strong exogenous barriers to the formation of ties between organizations from different blocs, like those between defense firms belonging to the Soviet and the western blocs during the cold war. It is worth noting that core-periphery structures are compatible with polarization, a clear example of which is the world system before the collapse of the former Soviet Union (see Van Rossem [1996] for analysis and discussion). In such structures, the process of structural differentiation leading to core-periphery structures may still operate within clusters, while exogenous forces restrict the formation of ties across clusters. The increasing globalization of the economy, however, makes it imperative for most large business organizations to have access to all major markets and to all possible sources of innovation. Insofar as strategic alliances are a crucial tool to attain these goals, faction-type interorganizational structures should be less likely to occur, except when geographical distance, competitive network dynamics, or geopolitical considerations restrict access to other organizations that may have complementary capabilities.

While our model proposes that the emergence of network structures is driven by the endogenous differentiation of this structure, emerging interorganizational networks may not always evolve into a definite structural pattern. This could occur in certain new, extremely dynamic, innovation-driven industries, where all players could benefit from alliances with almost any other player. In the absence of players that can establish their dominance through their superior command of financial or other resources, like Microsoft in the software industry and the large pharmaceutical companies in biotechnology, the evolution of the emerging network may not reveal any definite pattern. According to our theory, organizations in such industries would face extremely high levels of uncertainty at the time of building cooperative partnerships because they would lack the guidance of embeddedness mechanisms. In those cases, however, it is conceivable that other networks—such as those resulting from the circulation of engineers between firms in Silicon Valley or from the relationships between university researchers and industry researchers as in biotechnology—may provide an alternative to the network of prior alliances as a source of information tapped by organizations. While this may result in an interorganizational network structure that partially mirrors the pattern of the networks that provided information to organizational decision makers, this may not necessarily occur since such alternative networks may have resulted from exchange processes that differ from the ones that drive strategic alliances.

Another important issue raised by the results pertains to the relationship between structural differentiation and information, on one hand, and alliance formation, on the other. Although our model implicitly assumed a linear relationship between the amount of information internalized in the network structure and the differentiation of this structure, we have also acknowledged that further increases of structural differentiation beyond a certain critical level could actually *decrease* the level of information in the system, which in turn would have a negative effect on the formation of new alliances. This outcome would be consistent with the logic underlying our theory but not with the monotonic relationship between structural differentiation and alliance formation predicted by our hypotheses. Yet the monotonic relationship in the hypotheses is a simplification warranted by our data, which cover only a segment in the development of the observed interorganizational networks. A more extended observation period would have allowed us to explore the relationship between structural differentiation and alliance formation in more detail.

From a theoretical standpoint, the relationship between structural differentiation and alliance formation could take two different forms. Each of these forms corresponds to alternative effects of new ties on the differentiation process in the network structure. First, new ties may prompt a continuous increase in the differentiation of the emerging social structure. This continuous increase would eventually result in lower levels of information, which should reduce the probability of new alliances. The relationship between structural differentiation and new tie formation would then correspond to an inverse U-shape. Second, the emerging social structure may reach a state where the creation of new ties simply reproduces a stable pattern of distinct positions occupied by organizations with similar relational profiles, without further increasing the differentiation of the network. Such an evolution would result in stable levels of structural differentiation over time, which would effectively turn it into a constant in our dynamic models. This is consistent with existing research showing that mature interorganizational structures typically evolve into stable positions occupied by actors with similar network profiles (White 1981; Burt 1988). It is unfortunate that we could not test these alternatives with our data, since alliance networks were far from stabilizing at the end of our observation period. The evolution of structural differentiation in emerging networks may also be specific to the system—or type of system—under consideration. In this case, future research should investigate the factors that might affect the growth of structural differentiation as well as those that might influence its stabilization in some mature structures.

While this article has focused on the effects of structural differentiation on alliance formation, our construct may be important also in other areas of research on the effects of social structures on behavior. The central tenet of network research is that the pattern of social ties among actors is the main driving force behind those actors' attitudes and behaviors (Wellman 1988). Network scholars have shown how this approach can provide new insights into a varied set of social phenomena, including diffusion of innovations (Burt 1988; Westphal, Gulati, and Shortell 1997), social influence (Galaskiewicz and Burt 1991), political contributions (Mizruchi 1989, 1992), control strategies (Gargiulo 1993), and organizational performance in competitive situations (Burt 1992). Most network research, however, assumes a relatively stable structure that creates constraints and opportunities for individual behavior. Our research suggests that the effects of network structures on behavior may be contingent on the level of structural differentiation of that network. Future longitudinal studies on network effects on the behavior of organizations should take into consideration not only the mechanisms through which the network structure affects behavior but also how the level of structural differentiation of this network moderates the effective impact of those mechanisms on organizational action.

Our focus on the origin and evolution of networks complements recent efforts to develop mathematical models of longitudinal network data, in which the dynamics of social networks are similarly modeled as a function of exogenous factors and endogenous network parameters (e.g., Iacobucci and Wasermann 1988; Carley 1990, 1991; Zeggelink 1994; Leenders 1995, 1996; Snijders 1996). These models often include specific network mechanisms such as reciprocity and transitivity to spell out how previous ties pattern the formation of future ties (e.g., Leenders 1995), which are akin to our relational- and structural-embeddedness mechanisms. In most cases, however, the main goal of this work has been the development of mathematical models to analyze longitudinal network data, rather than to develop specific theory on the factors driving the dynamics of networks. Our research contributes to these attempts by showing empirically how the formation of cooperative interorganizational networks results from a dynamic process in which networks are both a driving force and a product of this process.

Although this article has focused on the emergence of cooperative interorganizational ties that take transactions out of the market logic, it nevertheless has implications that are pertinent for the development of the economic sociology of markets. Sociologists have demonstrated that under conditions of uncertainty and imperfect information, market players use the network of interorganizational relationships to guide their action. The reliance on existing networks leads to a self-reproducing market schedule (White 1981; Leifer and White 1988). Our results suggest that the social mechanisms that sustain a mature market structure might also play an important role during the formation of that structure. There may be an important difference in network dynamics between the formative and mature stages of a market structure that does not originate from differences in the nature of the mechanisms that guide the behavior of organizations but results from differences in the effective impact of these mechanisms on organizational action. If the emergence of market structures follows a pattern similar to the one we uncovered in alliance networks, the information content of the social structure of the market is likely to be scant in the early stages of the market formation process. This primitive market structure would provide little guidance to market players, who should face considerable levels of uncertainty. In a mature market, the informational content of this network stabilizes, resulting in the markets that White (1981, p. 518) described as "self-reproducing social structures" among organizations that evolve different roles by observing each other's behavior. In such markets, organizations may come and go, but the overall structure of market transactions remains stable, as Burt (1988) has demonstrated in his longitudinal analysis of American markets.

Our focus on the coevolution of organizational actions and of macrostructures resulting from the cumulated networks complements recent attempts to understand the coevolution of organizations and institutions (e.g., Davis, Diekmann, and Tinsley 1994; Haveman and Rao 1997; Davis and Greve 1997). While we have focused on interorganizational networks of cooperation, our approach could be extended to consider the potential role of other types of interorganizational networks in enabling the creation of new ties and in facilitating the production of institutions that may ultimately regulate the subsequent production of such ties (e.g., Stern 1979). Thus, the development of coevolutionary accounts of embedded organizational action and of the macrostructures that result from that action remains an important line of inquiry that could benefit from attention to the endogenous network factors described in this article.

This study opens several important avenues for future research. First, scholars could examine the relative importance of endogenous embeddedness dynamics across a wider array of industries. Since endogenous embeddedness is a way to cope with the hazards of cooperation, its role on alliance formation may be affected by industry-specific factors such as the level of technological uncertainty and the rate of change. In a preliminary examination of this question, we found that structural differentiation played a more significant role in the high-uncertainty new materials sector than in the more certain automotive sector. Additional research in this direction may shed light on the contingent effects of structural differentiation across industries.

Second, since structural differentiation facilitates the selection of adequate alliance partners, embedded alliances formed in more differentiated social structures should have comparatively higher levels of success. Testing this proposition, however, would require detailed survey data on the quality, duration, and relative performance of the cooperation within the alliances (Zaheer, McEvily, and Perrone 1998). Third, since different types of alliances entail different levels of risk, future studies could examine the role of network embeddedness across various types of alliances.

Finally, the domain of inquiry could be expanded beyond the formation of alliances and consider additional organizational activities such as mergers and acquisitions, which also may be influenced by endogenous embeddedness. While each of these possibilities opens important avenues for future research, examining them would require significant additional data. We hope that this study will stimulate scholars to collect such data and expand our understanding of the dynamics associated with various types of interorganizational networks.

This article proposed a model in which the formation of interorganizational networks is the evolutionary outcome of socially embedded organizational action. Our model provides a systematic link between the social structure of an organizational field—understood in network terms—and the behavior of organizations within the field. This link is bidirectional. On the one hand, the emerging social structure progressively shapes organizational decisions about whether and with whom to create new ties. On the other hand, this social structure is produced by the (structurally shaped) decisions of individual organizations to establish relations with one another. Seeking an answer to the question in our title, we have shown that interorganizational networks result not only from exogenous drivers such as interdependence but also from an endogenous evolutionary dynamic triggered by the very way in which organizations select potential partners. In this model, actors not only react to conditions of their own making but in the process reproduce and change those very conditions. The endogenous embeddedness model opens the way to more detailed studies of network-formation processes that go beyond the role of exogenous factors and consider the dialectic between action and structure that is at the core of many social processes.

APPENDIX

Interdependence of Observations

We conducted a number of additional tests to address concerns of interdependence across observations resulting from our dyadic approach, which led to the presence of the same organization across multiple dyads. We employed a procedure similar to the Multivariate Regression Quadratic Assignment Procedure (MRQAP), routinely used by researchers studying dyads (Krackardt 1987, 1988; Manley 1992). Our approach differs from MRQAP in that we used the random-effects probit model instead of ordinary least squares regression for each iteration of the simulation. As a result, we randomized the key network variables for each time period for each industry. We ran 500 iterations of a completely specified random-effects model with a new randomized independent network variable obtained by random permutations of the rows and columns in each alliance matrix for each industry and year. The coefficients obtained were compared with those obtained in the original formulation. The percentage of frequency with which the independent variables exceeded their original values divided by the number of permutations plus 1 (in this case, we used 501) indicates the statistical reliability (pseudo *t*-test) of the original results.[15] This test can be interpreted like conventional tests of significance: a result of less than 5% (or, even better, 1%) provides evidence that the original estimates are indeed accurate. The benefit of a randomization procedure is that obtaining satisfactory results does not require an assumption of independent observations, a random sample, or a specified

[15] A more complete specification of this test would have entailed randomly extracting the 500 permutations from all possible ones for each industry (Mizruchi 1992), which was not feasible here due to the extremely large number of permutations that would be necessary for each industry and for each year.

distribution function. This procedure allowed us to assess the efficiency of our results, a primary concern resulting from any dyadic interdependence.

The manner in which we specified our network-embeddedness effects makes our model akin to the P^* logit models recently proposed by Wasserman and Pattison (1996). Building on the pioneering work by Holland and Leinhardt (1970) and on Strauss and Ikeda (1990), P^* models produce pseudo–maximum-likelihood estimators of the probability of observing a binary tie x_{ij}, conditional on the rest of the data, without having to make the implausible assumption that the observations (dyads) are independent. Specifically, these models build into a logistic regression parameters that capture possible sources of interdependence of the observed dyads—such as reciprocity, transitivity, in and out degree of each dyad member, and network density—and obtain estimators of the effect of these parameters on the conditional probability of $\{x_{ij} = 1\}$. Our models include network parameters that are similar to the ones of a typical P^* model—transitive triads, the degree of each dyad member, and network density—but we measured these parameters on the network at $(t - 1)$, while a strict pseudolikelihood estimation requires parameters measured on the same network that contains the predicted tie. Since the inclusion of the $(t - 1)$ parameters cannot be considered an adequate safeguard against the potential effects of nonindependent observations, we used the abovementioned MRQAP-like procedure to test the robustness of the results and limit concerns of interdependence. The percentage of frequency with which the results in the random-sample simulations exceeded the original estimates was far less than 5% in all instances. Thus, we can say with some confidence that for these data reasonable coefficients were obtained.

The problem of cross-sectional dyadic interdependence can also be understood as one of model misspecification (Lincoln 1984). If a statistical model incorporated all essential nodal (organization-level) characteristics that influence alliance formation, no unobserved effects resulting from common nodes would remain. To capture any organization-level effects across dyads sharing the same organization, we controlled for each organization's cumulative history of alliances. Organization history is an important factor that captures any residual organizational propensities to engage in alliances (Heckman and Borjas 1980; Black, Moffitt, and Warner 1990). As noted earlier, we also ran separate estimations in which we included a host of financial attributes of each of the organizations in the dyad, including its size, performance, liquidity, and solvency. In addition to these controls, the models used here account for unobserved heterogeneity and adjust for such systematic biases resulting from missing variables. We expected the unobserved heterogeneity term (ρ) to capture any residual dyad-level effects not included in the model.

Unobserved Heterogeneity

An issue that arises when analyzing data on a time series of cross-sections, or panel data, is the possibility of unobserved time-invariant effects known as "unobserved heterogeneity." This is of particular concern for this study with respect to the claim that the prior history of alliances between two organizations affects the future likelihood of their entering an alliance. There are two distinct explanations for this empirical regularity, if it occurs (Heckman 1981*a,* 1981*b*). One explanation is that a genuine behavioral effect exists, whereby, because of the prior alliances it has experienced, a dyad's preferences are altered in the future. In econometric terms, such a behavioral effect is called "state dependence"—the likelihood of an event is a function of the state of the unit.

If state dependence alone encapsulated the empirical reality, there would be no problem; however, there is another possibility that, if not accounted for, could lead to spurious results: dyads may differ in their propensity to enter alliances because of unobserved factors. In this instance, such unobservable effects could result from permanent differences between dyads in their preferences for alliances, such as geographical proximity, not captured by the independent variables. If this noise were systematic for the same unit over time, it could lead to a serial correlation among the error terms for those observations, which would yield consistent but inefficient coefficients, rendering any statistical testing inaccurate. Furthermore, prior alliance experience may appear to be a determinant of future alliance formation solely because it is a proxy for temporally persistent unobservable factors that determine alliance formation and nonformation. Improper treatment can lead to spurious effects appearing with attempts to assess the influence of past experience on current decisions; this phenomenon is also termed "spurious state dependence" (Black et al. 1990; Heckman 1981*a,* 1981*b;* Hsiao 1986).

In a statistical sense, the problem of unobserved heterogeneity relates to model specification (Peterson and Koput 1991). If a model is completely specified, no such problem occurs, but most statistical models suffer from some degree of omitted variable bias. Another way to confront this problem is to refine the risk set studied. In the current design, we include all possible dyads within each industry for each year as the set of dyads at risk of entering an alliance. It is quite likely that some of these dyads are in fact not at risk of entering an alliance in some or even all observation periods, while other dyads have a higher propensity to ally. This suggests the possibility of misspecification of the risk set unless adequate allowances are made for such unobserved differences in propensity. One way to deal with such a bias is to clean up the risk set by eliminating records unlikely to experience the event, a process analogous to removing men from pregnancy studies. The difference in propensity is frequently a result of unobservable factors, however, making it impossible a priori to weed out records from the sample on reasonable grounds without biasing the sample.

Two approaches frequently used to address problems of unobserved heterogeneity are fixed- and random-effects models. Fixed-effects models treat the unobserved individual effect as a constant over time and compute it for each unit (dyad). The method entails estimating a constant term for each distinct unit and including dummy variables for each and is similar to least squares with dummy variables (LSDV) regression models (Hannan and Young 1977; Mizruchi 1989). Random-effects models treat the heterogeneity that varies across units as randomly drawn from some underlying probability distribution. Both types of models have shortcomings. Both assume that the unobserved effects are time invariant. Fixed-effects models are applicable only to repeatable events (Yamaguchi 1991), do not allow the inclusion of time-independent covariates (Judge et al. 1985; Reader 1993), and involve estimating a large number of parameters, which grows with sample size (Chamberlain 1985). This approach can be problematic when there are many groups but only a few observations in each group (Chamberlain 1985). Random-effects models are more tractable but also assume that the unobserved effect is not correlated with any of the exogenous variables in the system (Chintagunta, Jain, and Vilcassim 1991; Hausman and McFaden 1984).

To address concerns of heterogeneity, we employed a random-effects panel probit model, developed by Butler and Moffitt (1982), for the statistical analysis.[16] Our decision to employ a random-effects model was based on the following. First, estimates computed using fixed-effects models can be biased for panels over short periods (Chintagunta et al. 1991; Heckman 1981*a,* 1981*b;* Hsiao 1986). This is not a problem with random-effects models. As all the dyads in our sample were present for only nine years, random effects was clearly the favored approach. Second, fixed-effects models cannot include time-independent covariates, a limitation that would have meant excluding several variables, and an analysis without some of these variables would have been severely limited. The computa-

[16] In random-effects models, numerous alternatives are possible, depending on the choice of form for the distribution of unobservables. Although Butler and Moffitt (1982) specified a normal distribution, other functional forms are also possible. Recent efforts have moved away from functional specification of heterogeneity toward semiparametric random-effects approaches that estimate the probability distribution directly from the data (cf. Chintagunta et al. 1991).

tion of random-effects models is relatively straightforward for continuous dependent variables but more problematic for qualitative choice variables and was implemented here using LIMDEP 6.0.

We also tried to address concerns of heterogeneity by conducting the analysis using three increasingly restrictive definitions of the risk set. The first set included all dyads in the sample, the second set included only dyads in which at least one member had prior alliance experience, and the third set included dyads in which both members had entered into at least one alliance. The results obtained with different sets were convergent, and we report those based on the complete set.

Comparative Analyses

The primary theoretical contention underlying our use of network measures is that the ties formed in an industry are not random but are driven by the structure of relationships formed in prior years. The models that include network variables were expected to be powerful predictors of alliance formation to the extent that (*a*) alliance formation among organizations arises from the flow of information underlying the networks of preexisting relationships and (*b*) the specific structural models used to reflect these information flows cluster organizations that are densely connected by such informational links (Friedkin 1984).

To verify our claims of systematic interorganizational alliances, we compared the results for this study's sample against results obtained with a sample in which the formation of alliances was assigned randomly. The implicit null hypothesis here is that an observed pattern in the data is due purely to chance. Such a comparative analysis serves as a valuable baseline (cf. Zajac 1988). Finding no differences in the predictive power of the independent variables for the actual and random dependent variables, or greater predictive power for the random dependent variable, would suggest that the postulated independent effects could have predicted the random occurrence of alliances just as well or better. As a result, our claims for systematic patterning of alliances would be moot.

We tested the predictive ability of each model specified in table 3 against random assignments on the dependent variable on the basis of its original distribution. The results indicated that none of the hypothesized effects are better predictors of randomly assigned alliances than those in table 3. Not a single independent variable is significant in all the models. This finding allows us to reject the implicit null hypothesis and suggests that the postulated independent effects are not at all good predictors of the random occurrence of alliances. The exogenous interdependence and endogenous embeddedness effects explain the systematic pattern of alliances.

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