WHERE DO INTER-ORGANIZATIONAL NETWORKS COME FROM?

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This paper proposes a model for the formation of inter-organizational networks. We suggest that such networks result not only from exogenous interdependencies, but also from an endogenous embeddedness dynamic that enables organizations to identify suitable partners. In such a dynamic, organizations manage the uncertainty associated with establishing new ties by embedding them in the network that results from prior ties. The new ties in turn alter that social network for the future. Networks are thus the residual effect of past behavior and the driving force of future action. With the increasing structural differentiation of the network, the impact of endogenous embeddedness factors on ensuing tie formation is enhanced and the effect of exogenous interdependencies is mitigated. We test this model using longitudinal data from a sample of alliances among multinational firms from 1970 to 1989. The discussion closes with suggestions for its application to other areas of organizational theory.

Introduction

This paper proposes a model to explain the emergence of inter-organizational networks. Organizational sociologists have devoted considerable effort to explaining the effects of social networks on economic action (Granovetter 1985, 1992; see Swedberg 1994 and Powell and Smith-Doerr 1994 for a review). An emphasis on the effects of network structures on the behavior of organizations, however, has often led sociologists to neglect the issue of the *origin* of inter-organizational networks. Indeed, some critics see this as an important shortcoming of network analysis in general, which "has yet to provide a fully adequate explanatory model for the actual formation, reproduction, and transformation of social networks themselves" (Emirbayer and Goodwin 1994:1413).

This criticism is not without foundation. Typically, the formation of inter-organizational networks is viewed as depending on exogenous factors such as an independent structure of resource dependence that faces organizations (Pfeffer and Salancik 1978; Burt 1983; Galaskiewicz 1985). Organizations create ties to cope with resource needs that can be met by other organizations and to manage uncertain

environments. Network production is thus viewed as the consequence of exogenous interdependencies.

Such approaches provide a good account of the exogenous drivers for the creation of inter-organizational ties, but they overlook the fact that many inter-organizational contexts are rife with uncertainty (Van de Ven 1976), making if difficult to obtain information about the existence and the reliability of potential partners. A crucial problem facing organizations that seek to form new ties is imperfect information: organizations often do not know *a priori* which partners will best serve their interests. Imperfect information increases search costs and the risk of opportunistic behavior by potential partners (Williamson 1985), prompting organizations to look for indicators that may help them to manage uncertainty. Consequently, while inter-organizational ties can be a means to manage the constraints posed by an uncertain environment, there is also considerable uncertainty associated with forming such ties.

The difficulties in finding information about potential partners leads to a puzzling question. If building inter-organizational ties entails considerable uncertainty, then how do firms cope with this uncertainty and use such ties as vehicles to cope with critical resource needs?

We argue that a solution to this conundrum comes from structural sociologists, who have offered an original response to the problem of transactions subjected to uncertainty and the risk of opportunism. Although it is not primarily concerned with explaining the origin of social networks, their approach bears direct relevance to this issue. They emphasize that economic action—like any other form of social action—does not take place in a barren social context, but rather is "embedded" in networks of relationships (Granovetter 1985). In this paper, we argue that the basic theoretical propositions of the embeddedness perspective, previously used to understand the economic and behavioral consequences of social networks, can also be invoked to explain the emergence of inter-organizational networks. Applied to the inter-organizational context, this perspective suggests that organizations facing uncertainty about potential partners are likely to resort to existing networks for information that lowers search costs and alleviates the risk of opportunism. Thus, networks can be an efficient source of information on the availability, competencies, and reliability of prospective partners. This information may originate in a previous relationship with the partner, in referrals from trusted third parties, or in the reputation that results from the partner's position in a pre-existing network of cooperative ties. The different ways in which networks can provide information on possible partners results in two mechanisms through which networks may affect the formation of new ties (Granovetter 1992). Relational embeddedness stresses the role of direct and indirect cohesive ties as a mechanism for gaining fine-grain information about potential partners. Structural embeddedness emphasizes the informational value of the structural position these partners occupy in the network.

Networks, however, are not static social structures in which organizations embed new ties: they are also the evolutionary products of these ties. Specifically, we suggest that the production of inter-organizational networks is driven by a dynamic process involving both exogenous dependencies that prompt organizations to seek cooperation and an "endogenous embeddedness" dynamic in which the emerging network progressively orients the choice of partners. New ties are influenced by the social network of prior ties in which they are embedded. Yet, when observed over time, the formation of new ties in each period alters the very same network that influenced their creation, resulting in an endogenous network dynamic between embedded organizational action and the network structure that guides but is also transformed by that action. In this recursive model, networks exhibit an inherent duality: they arise from prior networks and shape their modification in the future.

This endogenous embeddedness dynamic, however, is constrained by the extent to which the emerging network enables organizations to effectively identify and differentiate possible partners. In the early stages of the network, few organizations are actually connected by the new ties. This makes it difficult to discriminate among partners in terms of their relationships or their position in the network. The primitive network is thus a poor source of information for organizations seeking to form partnerships. Early movers are thus less likely to build embedded cooperative ties to cope with dependency.

The initial cooperative efforts, however, transform the context for future partnerships. As the social network grows, the new ties contribute to the differentiation among organizations by their specific direct and indirect relations and by the structural positions they occupy in the emerging network. This "structural differentiation" enables organizations to discriminate among partners in terms of their particular relational and structural profiles. Although structural differentiation should typically grow with the number of ties in the network, it depends on the specific distribution of those new ties, not merely on their number. Actually, it is this distribution that creates the distinct network profiles that help organizations to distinguish among partners. The more a network is structurally differentiated, the more its members differ from each other in their network profiles and the higher the level of information available on partners.

The increased availability of information about potential partners that underlies the growing differentiation of the emerging network allows organizations to mitigate the uncertainty associated with partnerships by enabling them to embed those partnerships in the network. As the available information grows, organizations seeking to build partnerships can become less reliant on exogenous factors and instead seek to embed their ties in the network. Hence, we expect that the greater the structural differentiation of the network, the more influential the role of network embeddedness mechanisms on the formation of inter-organizational ties, and the smaller the role of exogenous factors. The tendency to build embedded partnerships

further contributes to the structural differentiation of the organizations in the network, which in turn facilitates the future formation of embedded ties.

We test our model using longitudinal data on inter-organization strategic alliances in a sample of American, European, and Japanese business organizations in three different industries over a twenty-year period. Our data satisfy several requirements that are essential to test the propositions advanced in this paper. First, the data result from the observation of an organizational field over a sufficiently long period to document the effects of an endogenous embeddedness dynamic on alliance formation. Second, the specific linkages under consideration were not widespread at the beginning of our observation period, but they experienced substantial growth during this time frame. This requisite is essential to minimize left-censoring effects and to examine the impact of increasing network development on the behavior of organizations. Third, this type of inter-organizational relationship is sufficiently important that organizations actively seek information to evaluate the reliability and adequacy of likely partners. The strategic value of inter-organizational alliances, the risks associated with them, and the uncertainty about potential partners make alliances an excellent ground to test our model (Bleeke and Ernst 1991). Furthermore, the global setting in which we observe alliance formation is rife with uncertainty about partners, given the cross-border barriers that organizations must overcome.

Explaining the Formation of Inter-organizational Networks

Interdependence

Research on the formation of inter-organizational networks has largely focused on exogenous considerations, arguing that the formation of ties can be attributed to an exogenous structure of interdependencies on critical resources (Aiken and Hage 1968; Pfeffer and Nowak 1976; Van de Ven 1976; Pfeffer and Salancik 1978; Whetten 1981; Galaskiewicz 1982; Burt 1983; Baker 1990; Mizruchi 1992).[1] Inter-organizational ties are viewed as a means by which organizations manage their dependence on specific actors controlling critical resources. Broadly defined, the sources of environmental dependence encompass two sets of organization-level considerations: resource procurement and uncertainty reduction (Galaskiewicz 1985). The emphasis on resource dependence as a driver of inter-organizational ties builds upon theories of social exchange and dates back to the early work on local human service agencies. During the 1950s and 1960s, a rich body of research explored the

[1] More recently, Oliver (1990) has reviewed the literature on exogenous drivers for inter-organizational relations and presented six broad categories of contingencies: necessity, asymmetry, reciprocity, efficiency, stability, and legitimacy. The common theme across these categories is that organizations seek out ties with partners who can assist them in resolving key contingencies they may face. These contingencies emerge from a wide array of factors whose source may be within organizations (e.g., efficiency) or in their external environment (e.g., asymmetry, reciprocity, stability, and legitimacy).

proliferation of interagency ties to address social problems such as health, welfare, and manpower. The dominant perspective on the formation of such ties was that organizations entered them to address their perceived interdependence upon other organizations. As Turk (1972:40) points out, "The need for inter-organizational relations is probably related to the awareness of organizations of interdependence with other organizations and results in attempts at coordination." Later studies incorporated such concerns as internal autonomy and constraints faced by decision makers (Whetten and Leung 1979). Still, external interdependence was viewed as the primary mechanism driving tie formation.

Exogenous approaches to inter-organizational relations consider ties—and the networks that emerge from them—to be the *dependent* variable in the analysis. According to such perspectives, organizations build ties to enable them to pursue their goals within the constraints of an exogenously determined structure of interdependencies. Organizations build ties to access resources and to maximize their control over the environment (Pfeffer and Salancik 1978; Galaskiewicz 1982; Galaskiewicz and Shatin 1981; Aldrich 1979, Baker 1990). Building on the insights of this research tradition, we expect tie formation between organizations to be a function of the intensity of the interdependence between them and arrive at our first hypothesis:

HYPOTHESIS 1. *The probability of a cooperative tie between two organizations increases with the level of interdependence between those organizations.*

By focusing on *why* organizations build ties with one another, exogenous approaches to tie formation often treat resource identification and partner selection in such decisions as unproblematic. Yet the autonomous choice of a partner may be limited by several social constraints (Baker 1990). From our standpoint, the very identification of a suitable partner may be difficult. Although resource-dependence theory recognizes an "enactment" process that mediates between environmental demands and organizational action (Pfeffer and Salancik 1978), empirical studies typically treat the adequate identification of environmental constraints and of the ties that would help organizations to cope with those constraints as unproblematic. In doing so, these studies fail to take into account a second source of uncertainty, that is, the problem of *with whom* to build cooperative ties to overcome environmental constraints.

The uncertainty associated with choosing a partner is especially salient when the advantages of the relationship cannot be properly determined before the consummation of the tie, both in terms of the resources and the integrity of the prospective partner. These conditions are pervasive in some inter-organizational contexts. In this setting, organizations face what social theorists describe as the first and second problems of order. The first problem of order dates back to Hobbes's concern with how actors can solve the dilemma of cooperation in exchange relations

where opportunistic behavior is possible. This behavioral uncertainty has a central role in Coase's (1937) theory of the firm and in the transaction-cost perspective (Williamson 1985). The emphasis of transaction-cost economics on uncertainty and asset-specificity attests to the prominence of the first problem of order in inter-organizational relations. The uncertainty associated with cooperation in exchange relations is compounded by a second problem of order, which results from the unpredictable character of social relationships. Rapid changes in the environment may lead organizations to alter their needs and orientation, thus affecting their ongoing partnerships (Elster 1989; MacIntyre 1981).

While the first problem of order makes voluntary cooperation risky, the second makes it difficult to write and to enforce contracts that may mitigate those risks (Williamson 1985). For organizations to build ties that effectively address their needs while minimizing the risks posed by the two problems of order, they must be aware of the existence of their potential partners and have an idea of their needs and requirements. Organizations also need information about the reliability of those partners, especially when success depends heavily upon the partners' behavior, as is the case with instrumental ties such as inter-organizational alliances (Bleeke and Ernst 1991).

Network Embeddedness

Structural sociologists have suggested that economic actors address the problem of order in economic transactions by embedding transactions in the social context where those transactions occur. They emphasize the fact that economic action—like any other form of social action—does not take place in a barren social context, but rather is embedded in networks of relationships. Faced with uncertainty about a partner, actors adopt a more social orientation and resort to existing networks to discover information that lowers search costs and alleviates the risk of opportunism. In an article that has become a manifesto for contemporary economic sociology, Mark Granovetter notes that "the widespread preference for transacting with individuals of known reputation implies that few are actually content to rely on either generalized morality or institutional arrangements to guard against trouble" (1985:490). In addition to identifying this socially constructed reputation, Granovetter reminds us that people also resort to "trusted informants" who have dealt with the potential partner and found him trustworthy, or, even better, to "information from one's own past dealings with that person" (1985:490).

The embeddedness approach suggests that economic exchange grows out of previous exchanges (economic or otherwise). Yet, empirical studies inspired by this approach, rather than looking at the origin of social networks, have tended to reify the notion of social networks and focused primarily on explaining the features and the consequences of economic transactions in a rich social context. Scholars stress the importance of trust, fine-grain information sharing, and joint problem solving as the

main characteristics of those exchanges, which set them apart from the stereotypical "arms-length" market transactions. Behind the multiplicity of studies, ranging from Japanese industrial groups (Lincoln, Gerlach, and Ahmadjian 1996) to the New York apparel industry (Uzzi 1996), the main theoretical concern of the embeddedness approach has been to explain economic action and outcomes in terms of the networks in which this action takes place. In only a few instances have scholars considered embeddedness to be a basis for the formation of new social ties (e.g., Baker 1990). This suggests an irony of significant theoretical importance: although social ties are viewed as crucial in influencing economic actions and outcomes of organizations, the creation of those ties is viewed as resulting from asocial, exogenous processes.

The motor behind embeddedness is the quest for information to reduce uncertainty, a quest that has often been identified as one of the main drivers of organizational action (Thompson 1967; Sinchcombe 1990). Specifically, networks can be an efficient source of information on the availability, competencies, and reliability of potential partners, thus helping organizations to cope with the problem of order that affects economic transactions under uncertainty. In these circumstances, organizations resort to existing networks to access information that lowers searching costs and alleviates the risk of opportunism, thus helping the organizations to deal with the problem of order (Granovetter 1985; Powell and Brantley 1992; Podolny 1993). The information may originate in a previous relationship with the potential partner, in referrals from trusted third parties, or in the reputation that results from the partner's position in a pre-existing network of cooperative ties (Granovetter 1992). Through these embedding mechanisms, existing inter-organizational networks can influence the formation of new ties.

Research in network analysis has identified two types of mechanisms through which a network structure can provide information about partners. The first mechanism is based on the capacity of cohesive social relations to carry fine-grain information and to promote trust, two essential features of embedded ties. The second stresses the signaling value of the position an organization occupies in the overall structure of the network. These have previously been described as relational and structural embeddedness respectively (Granovetter 1992).[2]

Relational embeddedness refers to the influence of the proximate ties of an organization. The causal force of these ties plays a prominent role in classical sociological analysis of social solidarity and cooperation (e.g., Durkheim 1933; 1951). According to the embeddedness logic, the probability that two organizations will build a partnership is a function of the intensity of the direct and indirect connections between the two members of the dyad. Indeed, these connections provide the channels through which dyad members can receive fine-grain information on each other.

[2] These two types of network influence have been variously described as cohesion and position or structural cohesion and equivalence (Burt, 1987; Marsden and Friedkin, 1993).

In network analysis, the number and the intensity of the ties between any two actors are often referred to as "cohesion" (Burt 1987; Marsden and Friedkin 1993). Prior researchers have often used cohesion as a causal force for behavioral similarity. Actors who are strongly tied to each other are expected to develop a shared understanding of the utility of certain behavior and thus to influence each other's action (Coleman, Katz, and Menzel 1966; Burt 1987; Ericksson 1988). Yet, cohesion can also be discussed as the capacity of social ties to carry information and to promote trust between actors (Granovetter 1973). A tie between two organizations is a direct channel through which each partner learns about the competencies and the reliability of the other. This closeness amplifies trust and diminishes the uncertainty associated with choosing a partner (Burt and Knez 1995; Podolny 1994). As Granovetter (1992:42) points out, "relations make behavior predictable and close off some of the fears that create difficulties among strangers." Closeness not only helps organizations learn how to cooperate fruitfully with a given partner, it may also prompt organizations to become aware of new opportunities for cooperation that would be difficult to identify outside a close relationship. 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 ties with each other.

Indirect social ties can also be a source of information about potential partners. Organizations tied to a common partner can use this partner as a reliable source of information about each other, thus accessing valuable and reliable data on a possible new partner (Baker 1990; Mizruchi 1992, 1993; Burt and Knez 1995; Gulati 1995).[3] When two organizations share common ties, it can also indicate that both are regarded as suitable and trustworthy by the same organizations. Finally, sharing common ties with a potential partner can signal that the partner can cooperate with the same kind of organizations with which the focal organization has been cooperating. All these elements are important, given the difficulties associated with inter-organizational cooperative ties (Bleeke and Ernst 1991). In addition, common third-party ties can also create a reputational lock-in whereby good behavior is ensured through a concern for reputation: any bad behavior by either partner may be reported to common partners, which in turn serves as an effective deterrent for both (Raub and Weessie 1990; Burt and Knez 1995). Consequently:

HYPOTHESIS 2. *The probability of a new cooperative tie between two organizations increases with the level of direct and indirect cohesion between those organizations.*

[3] There has been considerable debate whether indirect ties constitute a cohesion- or position-based logic (Alba and Kadushin, 1976; Alba and Moore, 1983; Friedkin, 1984). In his typology, Granovetter considered indirect social ties part of structural embeddedness. Following Marsden and Friedkin (1993), we have included indirect ties as relational and reserved the structural category for purely positional mechanisms.

Structural embeddedness captures the informational role of the position an organization occupies in the overall structure of the network. Consequently, the frame of reference shifts from the dyad and triad to the system (Marsden and Friedkin 1993), while the analysis of the influence processes shifts from communication within a primary group to intrastatus- and interstatus-based dynamics (Burt 1987). In network analysis, the position an actor occupies in the structure is a function of the actor's relational pattern in this network (Winship and Mandel 1983). Scholars have frequently linked this position to the notion of "status" (Burt 1982; Podolny 1993, 1994; Han 1994; Podolny and Stuart 1995). In sociological terms, status evokes a series of observable characteristics associated with a particular position, or "role," in a social structure (Linton 1936; Merton 1957; Nadel 1957), that is, a relatively defined set of expected behaviors toward other actors. Because an actor's status is based on its affiliations and patterns of interaction, it is affected by the status of its exchange partners. When focusing specifically on an inter-organizational context, we can also view status as an attribution of the quality of products an actor provides when the quality cannot be directly observed (Podolny 1993). Following a similar logic, the observable features associated with a certain status can also become an important signal of how members of that status are likely to behave.

The cues provided by the position of organizations enlarge the realm of potential partners about which an organization can have *a priori* information beyond the circle of organizations directly or indirectly tied to it. The status of an organization in the network affects its reputation and visibility in the system. The greater this reputation, the wider the organization's access to a variety of sources of knowledge, as well as a rich collaborative experience, which makes it an attractive partner (Powell, Koput, and Smith-Doerr 1996).

The signaling properties of status are particularly important in uncertain environments, where the attractiveness of a potential partner can be gauged from its status, which in turn depends on the organizations (or type of organizations) already tied to this partner (Podolny 1994). This phenomenon has important behavioral consequences. If the status of whom they partner with enhances their own attractiveness, organizations will have a tendency to seek high-status partners. High-status organizations, however, do not have an incentive to accept low-status players, since they add little to (or, worse, may damage) their own attractiveness as high-status organizations. Furthermore, if status is a signal of quality, a low-status organization will be perceived by others to have little to offer substantively. The combination of these conditions implies that, other things being equal, inter-organizational ties should be more common among organizations that enjoy high-status positions in the emerging social network. This does not rule out the possibility that low-status organizations may be able to form ties with high-status players but suggests that this may be a rare occurrence. Although special reasons, such as the control of a new technology, may prompt a high-status organization to cooperate with a low-status

player, the "homophily principle" in terms of status that operates under conditions of uncertainty makes this an unlikely occurrence (Popielarz and McPherson 1995). Thus, we predict:

HYPOTHESIS 3. *The probability of a new cooperative tie of between two organizations increases with the level of the joint status of those organizations. .*

The Endogenous Evolution of Networks

We propose that the emergence of inter-organizational networks results from an evolutionary process driven by both interdependence and network embeddedness factors. Further, we suggest that inter-organizational networks are not static entities. Rather, they emerge out of a dynamic iterative process. In this process, new ties are embedded in the network of prior ties, which is in turn modified for subsequent periods. As organizations establish new ties, they add information to the social context that in turn can shape their future choices. In this iterative dynamic, action and network structure are closely intertwined as the actions (tie formation) are influenced by the prior structure of ties, but these actions in turn modify this same structure in the future. By looking at inter-organizational networks over time, we view the formation of those networks as a process that progressively acquires self-referential, endogenous properties. These self-referential characteristics become dominant in mature social structures, in which action reproduces the existing pattern of relations (White 1981). Our framework, however, avoids the "temporal reductionism" that often characterizes structural analysis by explicitly tackling the fact that mature social structures are themselves a historical product, patterned by the successive relational contexts in which new ties have developed (Granovetter 1992).

The iterative dynamic between action and structure has important consequences for the emergence of inter-organizational networks. Although the information added by newly created ties might be mostly redundant in mature networks, this is not necessarily the case during the formative stages of these same networks. Ties created during the nascent phases of an inter-organizational network may in fact contribute significantly to the growth and differentiation of this network, thus enriching the social context in which organizations operate. Once ties begin to form, even a poor social context can be transformed into an information-rich setting that enables organizations to find valuable information about the competencies and the likely behavior of potential partners by looking at the network profiles of these partners. [4]

[4] We would like to highlight the fact that organizations do not exist in a completely barren social context. Even early members may be able to count on some kind of pre-existing networks that may enable them to evaluate the risks and benefits of a prospective partnership. However, neither the existence of such networks nor their ability to provide adequate information should be taken for granted. Prior networks may fail to provide sufficient assurance against the risks associated with new forms of inter-organizational cooperation. In fact, the old relationships may have few or none of the requirements of the new tie. This is likely when the success of the new partnership depends on competencies untested in the prior relationships.

By adding non-redundant information to the emerging social context, the new ties may have a significant impact on future organizational action, which in turn further modifies the social context. Specifically, the newly created ties contribute to the differentiation among organizations in terms of their prior direct and indirect ties and their structural positions in the emerging network. This "structural differentiation" enables organizations to better discriminate among potential partners by means of their particular relational and structural network profiles, the two basic mechanisms through which embeddedness operates. Thus, we conceive of structural differentiation as a systemic property that internalizes relevant information in the emerging network, which enables the influence of relational and structural mechanisms of network embeddedness. The greater the structural differentiation, the more an actor can distinguish organizations from one another in terms of these organizations' network profiles, and the higher the level of information on potential partners.

Insofar as it captures differences among the organizations' network profiles, structural differentiation is not simply a function of the number of ties in the network. Although structural differentiation should typically grow with the number of ties in the network, it also depends on the specific distribution of those new ties, not merely on their number. The sheer number 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 regarding the "legitimacy" of this course of action (Hannan and Freeman 1989; Scott 1995), but offers no guidance as to which specific organizations could be worthy partners. Although an increasing density of partnerships may prompt more organizations to cooperate, density alone provides no information about how the ties are actually distributed among potential partners. Yet, it is precisely by looking at the distribution of those ties that an organization can distinguish among potential partners.

As information grows with structural differentiation, organizations become less reliant on exogenous factors and instead embed their ties in the emerging network. The internalization of valuable information in the network, together with the organizations' tendency to use that information when making partnership decisions, is the motor behind the evolutionary dynamic of network formation. This dynamic operates both at the system level, affecting the probability of formation of new ties, and at the dyad level, influencing which ties shall be ultimately formed. At the aggregate level, the emerging network can be viewed as a social system in which the growth of structural differentiation makes available additional information that lowers the uncertainty associated with building cooperative ties. This additional information lowers the level of systemic uncertainty faced by organizations, which positively affects their propensity to enter new ties. Thus:

HYPOTHESIS 4. *The probability of a new cooperative tie between any two organizations increases with the level of structural differentiation in the inter-organizational network.*

Since the structural differentiation of the network tempers the level of information available, it is likely to moderate the influence of some of the exogenous and endogenous factors on tie formation. In other words, we expect that the proposed effect of exogenous and endogenous factors on tie formation is contingent on the extent of differentiation of the social network. In early periods, when a network is relatively undifferentiated, it is likely to channel relatively limited information about potential partners. Unable to access the fine-grain information provided by embedded ties, organizations may still be prompted to cooperate by strong exogenous pressures that affect their interests. Consequently, exogenous factors are likely to be the primary driver of tie formation in the early stages of a network. As new ties are formed and the network becomes more differentiated, however, the availability of fine grain information about potential partners is likely to increase. This information not only allows organizations to assess potential partners, but also enables them to discover new joint opportunities with organizations with whom they are tied. Thus, organizations with prior direct or indirect ties may, through their interactions, identify new joint projects that would not have been uncovered otherwise. As a result, organizations become less reliant on exogenous factors and instead seek to embed their ties in the prior social network. In other words, while exogenous factors are still important, they become less influential as the network becomes more differentiated. Thus, we expect the structural differentiation of the network to assert a negative moderating role in the influence of exogenous factors on tie formation. This can also be stated as:

HYPOTHESIS 5. *The effect of interdependence on the formation of new cooperative ties between organizations decreases with the level of structural differentiation of the inter-organizational network.*

We also expect the structural differentiation of the network to moderate the influence of embeddedness on tie formation. However, not all embeddedness mechanisms are likely to be moderated by the growing differentiation of the network. The information an organization can obtain from its relational embeddedness (previous dealings with another organization or from trusted common parties) is readily available independent of the larger network in which these dyadic or triadic relations exist. The availability of this information depends on the ability of proximate social ties to act as conduits of fine-grain information, a property that is not contingent upon the development of the whole network. Since we do not expect structural differentiation to affect the quality of information on a previous partner or on third-

party ties, we do not predict that the impact of relational embeddedness mechanisms will be contingent on the level of structural differentiation in the overall network.[5]

We do expect the impact of structural embeddedness to be contingent on the extent of structural differentiation of the network. Structural embeddedness depends upon the informational value of the position, or "status," organizations occupy in the network. The singularity of a network position does not depend only on the ties of the occupants of that position, but also on the ties of all the other actors in the system. Although boundaries between positions tend to be stable in mature structures (Burt and Carlton 1989), the definition of those boundaries is not instantaneous; rather, it depends on the evolution of the overall network structure. Positions are likely to be ill defined at early stages of the network, when the scarcity of inter-organizational ties makes it difficult to identify classes of organizations by their overall pattern of relations in the system. Such poorly defined positions should carry little information about the unobservable qualities of their occupants, since the very distinction between "members" and "nonmembers" is problematic. The effectiveness of position as a signal of unobservable qualities of an organization depends on the consolidation of a social structure in which those positions become recognizable. Thus, the informational value of the position of organizations in a social network is likely to increase with the level of structural differentiation of that network. Consequently, we expect the impact of structural embeddedness on tie formation to increase with the level of structural differentiation of the network:

HYPOTHESIS 6. *The effect of structural embeddedness on the formation of new cooperative ties between organizations increases with the level of structural differentiation of the inter-organizational network.*

In sum, not only does the level of differentiation of the emerging network directly affect tie formation, but it also asserts a moderating role on the relative influence of exogenous (interdependence) and endogenous (structural embeddedness) mechanisms on tie formation. Figure 1 summarizes our recursive model of network production. The solid arrows represent the direct effects of the key variables on network production (strategic interdependence, relational and structural embeddedness, and structural differentiation). The dotted arrows from structural differentiation to the arrows for the direct effects of interdependence and structural embeddedness capture the interaction between structural differentiation and those factors in tie formation. The plus and minus signs indicate a strengthening or

[5] A cautionary note is necessary. Our reluctance to suggest that relational embeddedness is contingent on structural differentiation does not rule out alternative mechanisms through which the growth of the network may boost the effect of relational embeddedness. As we have previously suggested, the sheer growth of the network 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.

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 structural embeddedness, and the weaker the impact of strategic interdependence. Finally, the dashed arrow from network production to structural differentiation indicates the dynamic connection between these two variables, which captures the evolutionary link between action and structure.

Our framework suggests that the emergence of an inter-organizational network is driven by exogenous strategic interdependence that prompts organizations to seek cooperative ties and by an endogenous embeddedness that helps them choose among potential partners. The embeddedness approach, typically used to explain the nature and consequences of economic exchanges in a rich social context, is thus extended to explain the emergence of such a context. Empirical studies have shown how the preference to transact with trustworthy partners, and the reliance on networks to assess this trustworthiness, accounts for the reproduction and stability of mature exchange networks, even in contexts of environmental turbulence (Romo and Schwartz 1995) or in highly competitive, dynamic markets (Uzzi 1996). A similar intuition can be found in models of markets as self-referential networks (White 1981; Leifer and White 1988; Podolny 1993). These models stress that market players do not know *a priori* which actions will best serve their interests. Under these conditions, actors resort to the patterns and outcomes emerging from the network of inter-organization relationships as "the only tangible guidance" available (Leifer and White 1988:86). The social structure of the market, understood in terms of patterns of transactions among participants, is an important source of such signals (Podolny 1993). In a similar vein, the endogenous embeddedness proposed in this paper suggests that the network that results from the transactions between actors is also a force that helps create and reproduce the observed pattern of transactions.

Our endogenous embeddedness model suggests that the same self-referential mechanisms that help reproduce mature social structures may be at work during the formative stages of these structures. There is, however, an important difference in how these mechanisms operate in each of these stages, a difference that is related to the stability of the informational value of the network structure. The information contained in the network can be assumed constant in a mature social structure. In such structures, action largely reproduces an institutionalized pattern of relations among the players in the field and hence adds little information to the prior structure. This is not the case during the formative stages of the same structure, when organizational action actively contributes to the informational content of the network and thus to the network's impact on future organizational action.

Strategic Alliances

Inter-organizational strategic alliances provide an excellent context in which to observe the endogenous embeddedness dynamic proposed in this paper. We define inter-organizational strategic alliances to include any independently initiated linkage between business organizations that involves a significant exchange, sharing, or codevelopment and thus results in some form of enduring commitment between the partners. These alliances are organized through a variety of contractual arrangements ranging from equity joint ventures to arms-length contracts. What is common across this diversity of ties is that they are voluntary, and they are instrumental, that is, strategic objectives usually underlie their formation. The uncertainty associated with alliances and the paucity of information in the marketplace provide an ideal setting for studying network influences on organization behavior (Bleeke and Ernst 1991).

Several characteristics of strategic alliances make them an ideal setting to test our dynamic framework. First, alliances are a clear example of voluntary inter-organizational cooperation aimed at coping with environmental demands. Second, there has been an unprecedented growth in the rate of strategic alliance formation in the last fifteen years. This proliferation has occurred across a wide array of industries and both within and across geographical boundaries. There is considerable empirical evidence that suggests that the number of inter-organizational alliances prior to 1980 was very small, and there has been a virtual explosion with exponential growth since then (Harrigan 1986; Hergert and Morris 1988: Anderson 1990; Hagedoorn and Schakenraad 1991). The rapid growth of these ties provides a unique context in which to assess the emergence and the evolution of an inter-organizational network.

Third, although strategic alliances have become central to the core activities of many organizations and crucial to their survival, there are many risks and pitfalls associated with such ties (Kogut 1988; Bleeke and Ernst 1991; Doz 1996), and the global setting in which alliances take place further compounds these risks. Thus, organizations exercise caution in entering such relationships. Our field interviews suggest that many organizations engage in extensive information gathering and seek referrals before entering an alliance.

Fourth, as a result of the convergence of technologies, the flux in technological environments, and the emergence of the United States, Japan, and Europe as rival technology centers, organizations have been reaching out to a wide array of partners across geographical boundaries. In this study, we look at a global context in which there is considerable uncertainty and a paucity of readily available information across geographical boundaries. This creates a dynamic inter-organizational context of disparate organizations in the position to partner with each other. For an alliance to materialize, both partners must discover mutually beneficial opportunities in allying with each other. This occurs only when both learn about each other at the appropriate time. In this context, the network of prior ties increasingly becomes an active source

of information about the capabilities, needs, availability, and reliability of potential partners.

Data

The data used in this study were gathered from a variety of sources. Initially, field interviews were conducted with 153 managers in eleven large multinational corporations. These managers typically had authority over their alliance decisions. The interviews were open-ended and unstructured, conducted with the intention of broadly understanding the factors associated with the decision to enter new alliances. They provided initial clues on the importance of the social network of prior ties in alliance formation, as well as insights into the mechanisms underlying the network factors. We tested our endogenous network-production model using longitudinal data on inter-organization strategic alliances in a sample of American, European, and Japanese organizations in three different industries over a twenty-year period. We collected data on a sample of 166 organizations in new materials, industrial automation, and automotive products. We selected a panel of fifty to sixty 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 sixty two organizations in new materials, fifty two organizations in automotive products, and fifty two organizations in industrial automation. Of these organizations, fifty four were American, sixty six were Japanese, and forty six were European.

For each organization, we collected financial data for each year between 1980 and 1989 from *Worldscope* volumes, which list 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 *Daiwoo Investor's Research Guide* as well.[6] We also collected information for each organization about the subsegment of its industry within which it had expertise from numerous industry-specific trade journals. To make sure that these classifications were correctly recorded, we cross-checked these with multiple experts from each of the industries.

[6] 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.

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 between 1970 and 1989. More than half the data came from the Cooperative Agreements and Technology Indicators (CATI) database collected by researchers at MERIT (a research unit at the University of Limburg). We collected additional alliance data using numerous additional sources, including industry reports and industry-specific articles 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* (1988-1989). 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, only alliances that had actually been formed were recorded, reports of probable alliances being excluded. To our knowledge, these are the most comprehensive data on alliances within each focal sector in both depth and duration of coverage.

Since the unit of analysis was the dyad, for each panel we listed all possible dyads within the organizations in each sector. To avoid double counting of the same pair of organizations, we discarded reverse-ordered dyads. These data were then used to construct an event history for each dyad: a record was created for each dyad for each year studied (1981-1989). 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 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 in the past 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 very comparable. Those reported here are based on the complete set.

One additional concern with such a design is left censoring, which in this case 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 eleven years, dating back to 1970, and used to create the initial matrix for 1980. These data only confirm what previous

studies have reported—alliance activity was negligible until 1980, when there was an explosion of alliances (Anderson 1990; Harrigan 1986; Hergert and Morris 1988).

Variables

Alliance formation. The focus of this study is on understanding the factors that influence the likelihood that a pair of organizations will enter an alliance in a given period.[7] 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.

Interdependence. Although our primary focus was on the structural mechanisms that shape the endogenous network production of the alliance network, we also need to account for the role of exogenous interdependence on tie formation. Identifying and measuring interdependence across organizations in an organizational field is not an easy task. Broadly speaking, interdependence between organizations can be assessed by the specific capabilities each organization possesses. Organizational capabilities, however, are multifaceted and ambiguous. Consequently, constructing a measure of such capabilities based on observable factors presented a problem that was further compounded by the need to use these capabilities to construct an index of interdependence across all possible dyads. To address this task, we segmented each industry panel into sets of organizations with similar resource profiles.[8] Since we were interested in gauging the distinctive competencies that could lead to dyadic interdependence, the partitioning allowed us to identify groups of organizations that possessed similar capabilities that were in turn distinct from those possessed by organizations in other groups. It was our expectation that dyads in which the organizations spanned different groups would share greater interdependence than dyads involving organizations that belonged to the same group. It is important to note that the members of each group did not need to be connected with each other through prior alliances.

To conduct the partitioning analysis, for each industry we entered a set of attributes for each organization into a hierarchical clustering algorithm employing the agglomerative complete linkage method and using Euclidean distances to assess structural similarity at each stage of agglomeration. We used the following organizational attributes in the clustering algorithm: (1) Size. This variable,

[7] 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, use cross-sectional data.

[8] Our partitioning of industries here is similar to the notion of strategic groups, on which there is a vast and fragmented literature (for reviews, see Thomas and Venkatraman 1988; Barney and Hoskisson 1990; Reger and Huff 1993). The definition here is perhaps 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. Movement of organizations across strategic groups is limited by "mobility barriers" that can result from prior tangible and intangible investments (Caves and Porter 1977).

measured as the average value over the period 1980-1989 of total assets in U.S. dollars, indicated an organization's financial and managerial resource endowment as well as its level of economies of scale and scope. (2) National origin. There were three categories: American, Japanese, and European. (3) Subsegment of industry. For each industry there were some broadly identifiable subsegments into which organizations could be placed. The new materials sector contained two subsegments: ceramics and polymer composites. In industrial automation, the subsegments were: discrete automation, process automation, software, and robotics. In the automotive sector, the two broad categories of organizations were automobile assemblers and suppliers.

Through the partitioning analysis, we identified seven distinct groups in the new materials sector and nine groups each in the industrial automation and automotive sectors. The groups' classifications were checked against the K-means clustering algorithm. We tried to ensure the temporal robustness of these groups by conducting separate analyses for 1980 and 1989 and observed no significant differences in the groups for the two end points. The validity of these groups was further cross-checked with multiple industry experts and against recent studies of similar industries (Nohria and Garcia-Pont 1991). Each industry expert was given the list of industry participants on index cards and asked to group them into up to ten groups, each group including organizations with similar strategic and financial capabilities. There was excellent convergence in the results obtained from the experts and those obtained with the clustering analysis. We discussed anomalies with the experts later and made assignment on the basis of these discussions. We used the groups created to construct the variable interdependence, coded "1" if the organizations in a dyad belonged to different groups and "0" if they belonged to the same group.[9]

Inter-organization Networks. To compute our network measures, we constructed adjacency matrices representing the relationships between the organizations. We constructed separate matrices for each industry for each year. For each matrix, we included all alliance activity among industry panel members until the prior year. Additional data on alliances announced by the panel members between 1970 and 1980 were entered into the initial matrix for 1981 to minimize left-censorship effects. All matrices were input into UCINET IV, a versatile software package that allows the computation of various network measures (Borgatti, Everett, and Freeman 1992). We made a number of choices in constructing these matrices that related to 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

[9] This operational definition avoids instances in which similar firms with supplementary capabilities can benefit from allying. Indeed, as Hawley (1950) pointed out, mutualism can result when units have complementary differences or supplementary similarities. Furthermore, strategic interdependence measured at the organization level can mask synergies that may or may not exist at lower levels (e.g., division, subunit) in an organization. Unfortunately, we could not address these concerns because of limitations on the data available.

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 checked against a simple dichotomous measure. Second, in order 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 included all previous alliances in the construction of the social networks but checked the results against a separate analysis using a moving window of five years of prior alliances. The length of the window was chosen on the basis of research suggesting that the normal life span for most alliances is usually no more than five years (Kogut 1988).

Relational Embeddedness. Our operationalization of relational embeddedness included separate cohesion measures for direct and indirect ties. For the direct mechanism, we computed a measure of "repeated ties," defined as the number of prior alliances between the members of each dyad. We operationalized indirect cohesion, or "common ties," as the number of prior third partners shared by each pair of organizations. To clearly differentiate indirect cohesion from the direct ties, we set common ties to zero if the members of a dyad sharing common ties had entered into a previous direct alliance with one another (*cf.* Mizruchi 1992:126).

Structural Embeddedness. We measured the position of an organization in the emerging network of alliances using the Bonacich (1987) eigenvector measure of network prominence. Like other centrality measures, network prominence is a function of the number of alliances entered by the organization. Bonacich's measure, however, also takes into account the prominence of the organization's partners. Thus, prominent organizations are those linked to many organizations that are in turn linked to several other organizations.[10] Our choice is consistent with prior efforts to capture the status of an organization in a relational network (Podolny 1994). The measure is also believed to capture the "role" occupied by the actor in the network (Mizruchi 1993). We computed an eigenvector measure of the network prominence of each organization for each year and expressed the scores relative to the most prominent organization in the network ($P_{max} = 1$). Since prominence is measured at the organization level, we needed to construct a score to adequately represent the "joint prominence" of the dyad. We computed a measure of joint prominence calculated as the multiplication of the prominence scores for each member of the dyad ($P_i * P_j$).

[10] Network prominence is often discussed as "centrality" by some network theorists concerned with the flow of information along social ties (Freeman 1979). Bonacich's (1987) prominence formulation, however, best captures the impact of an organization's partners' involvement in relationships on the status of the organization in the alliance network. In this formulation, the most prominent organizations are those building ties with organizations that are themselves heavily involved in partnerships.

Following Mizruchi (1993), we took the geometric mean of this product for each dyad to control for the skewness of the measure.

Structural differentiation. Structural differentiation was a system-level variable that captured the extent to which organizations in a network differ from one another in terms of their direct and indirect linkages and their position in the network structure. The more structurally differentiated a system, the easier it was for an organization in that system to distinguish among potential partners by looking at their relational profiles. We first computed a measure of relational profile for each pair of organizations and then used this as a basis to construct a system-level measure. In network analysis, differences in relational profiles are best captured by the concept of "structural equivalence" (Lorrain and White 1971); two actors are structurally equivalent to the extent that they are equally tied to the same third parties. We used Euclidean distance, a standard measure of structural equivalence first proposed by Burt (1976), to capture differences in relational profiles between organizations. The larger the Euclidean distance, the more dissimilar the relational patterns of two organizations.

We computed separated Euclidean distance matrices for each network by year and industrial sector. For our system-level construct, we were interested in the relative dissimilarity of organizations' relational profiles within the industry in a given year. This dissimilarity across organizations indicates the extent to which participants in the network were able to differentiate actors from each other. The absolute value of the cells in a Euclidean distance matrix is a direct function of the number and strength of the ties among organizations and thus is bound to grow larger as alliances accumulate over the years. However, small differences in the relational patterns between players—which translate into small absolute differences in Euclidean distances—carry more informational value at earlier stages of the system, when most organizations are "equivalent" because they have never entered an alliance. In contrast, in a complex system, where each organization's relational pattern is, strictly speaking, unique, small differences in relational patterns (and thus in Euclidean distances) are more likely to go unnoticed and therefore carry less informational value. To account for these differences, we normalized each matrix by the maximum Euclidean-distance value possible in the industry for that year.

We computed our system-level indicator for structural differentiation as the standard deviation of the normalized Euclidean distances among the organizations in each industry/year. Since the matrices had been normalized to allow Euclidean distances to vary from zero for perfectly equivalent organizations to one for the most dissimilar organizations in the network for that year, our measure was comparable across years. The measure captured the *relative* heterogeneity of the system in terms of the relational profiles of its members. In a system of perfectly equivalent pairs of organizations, the variance in Euclidean distances between players would be zero. As organizations enter into alliances, the social homogeneity of the system can become

eroded and this variance can go up, capturing the growing level of information in the system.

It is important to note that while structural differentiation may correlate with time and with network density, the two measures capture different properties of the network. As such, the magnitude of the correlation between these two variables may vary across systems. While density automatically increases with the simple accumulation of new ties, the growth of structural differentiation depends on how these new ties are actually distributed in the network—that is, on the specific organizations linked by the new ties. Structural differentiation is also likely to be positively correlated with time, since the creation of new ties necessarily has a temporal dimension. Again, the magnitude of this correlation may vary across systems, depending on the speed at which new ties are created and on the distribution of those new ties. Our measure of structural differentiation displayed an expected upward-sloping distribution over time, ranging from .25 in t_0 (1981) to .56 in t_8 (1989). This distribution is consistent with our evolutionary perspective of network production in which the growth of inter-organizational ties is likely to be associated with a progressive differentiation of the emerging network structure.

We checked our results against an alternative indicator for structural differentiation, namely, the standard deviation of the prominence scores of individual organizations. This measure is strongly correlated with our measure based on structural equivalence (r = .78). This measure indicates the extent to which organizations can differentiate others by their relative prominence in the network. In a socially homogenous system, all organizations are likely to be equally prominent, providing little or no information to separate one from the other. As the network becomes more differentiated, there is likely to be greater variance in the prominence of organizations. The results obtained with this alternative measure also closely replicated by those generated using the measure based on structural equivalence.

Control Variables. We included as controls a number of variables known or expected to affect the alliance activity of organizations but not included in the discussion of the hypotheses. These included industry trends, time, sector, and organization-level effects, as well as a set of financial measures.

The endogenous dynamic proposed in this paper suggests that increasing structural differentiation in the alliance network enables organizations to obtain *ex ante* information about potential partners, which translates into the growing impact of pre-existing structure on the formation of future ties. An alternative interpretation for this dynamic is a density-dependence argument linking the number of previous alliances to the legitimacy of this new form of business relationship. Such an argument would be akin to the ecological claims 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 1989:132). A related suggestion is that the growth in alliances may be the result of a bandwagon effect

(Koh, Loh, and Venkatraman 1990). Translating this claim into our context, one could argue that structural differentiation may simply be capturing the progressive legitimization of alliances as a valid form of inter-organizational cooperation. If this were the case, the growth of alliances could be driven by the effects of density-dependence legitimization rather than by our account, in which structural differentiation is influential because of its growing ability to provide information to participants. To control for this alternative explanation, we included a variable called "cumulative industry history," computed as the number of alliances within the industry up to the previous year (Baum and Oliver 1992). If structural differentiation is only a proxy for density-driven legitimacy, the inclusion of alliance density should wash out the effect of structural differentiation, thus questioning the validity of our claims. It is important to note that claims for density dependence and those for the role of structural differentiation are not mutually exclusive; the significance of density-dependence is not sufficient to reject our fourth hypothesis. Indeed, the endogenous network dynamic model does not preclude a legitimization effect. Rather, we suggest that legitimization alone cannot account for the specific dynamic of network production, which our model links directly to network-based mechanisms.

To control for unobserved temporal factors that may influence alliance formation, we included dummy variables for each year. Such factors could include legitimization phenomena 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 re-estimated 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 industry as the default sector.

Organization-level effects were captured by two variables indicating the prior alliance experience of each partnering organization. Thus, for each dyad we computed two measures, one for each firm, that captured the total number of prior alliances it had previously entered. These variables, labeled "alliance history," capture the possibility of repetitive momentum in individual organizations' alliance activities. We included a series of financial measures to capture the differences across the organizations in each dyad in a number of key dimensions. For each such dimension, we computed a ratio of the smaller to the larger organization. In this way, we controlled whether relative differences in financial resources and performance influenced the likelihood of alliance formation between the two organizations. The first dimension included was size, measured as total sales in the industry. The second dimension was performance, captured as return on assets normalized to the industry mean—a common measure of performance employed in managerial research. The third financial indicator 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; Mizruchi and Stearns 1988). 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.

Table 1 presents the list of variables and their summary definitions, while table 2 displays descriptive statistics and correlation matrix for all the variables in the analysis.

Table 1
Definitions and Predicted Signs of Variables

Variable	Definition	Prediction
Alliance	Whether two firms formed an alliance in a given year	Dependent
Structural differentiation	Standard deviation of the normalized Euclidean distances among firms in the industry	+
Interdependence	"1" if the firms belong to different groups, "0" otherwise	+
Repeated ties	Number of prior alliances between the firms	+
Common ties	Number of common partners shared by previously unconnected firms	+
Joint prominence	Geometric mean of multiple of prominence of both firms	+
Cumulative industry history	Cumulative number of alliances announced in the industry until prior year	+
Time	Year value for each record, ranging from zero to eight	NP
New materials	"1" if firms are in the new materials sector	NP
Industrial automation	"1" if firms are in the industrial automation sector	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
Solvency	Ratio of solvency (long-term debt) of lesser to greater firm value	NP
Liquidity	Ratio of liquidity (quick ratio) of lesser to greater firm value	NP

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	18
1. Alliance	0.21	0.09	0	1.00	.-																	
2. Sructural differentiation	0.39	0.12	0.25	0.56	.12	.-																
3. Interdependence	0.74	0.44	0	1.00	.22	-.01	.-															
4. Repeated ties	0.12	0.40	0	5.00	.19	.06	.04	.-														
5. Common ties	0.56	1.21	0	9.00	.15	.09	.08	.32	.-													
6. Joint Prominence	0.21	0.32	0	1.00	.16	.11	.20	.25	.38	.-												
7. Struc. dif. * interdependence.	0.19	0.14	0	0.35	.02	.12	.89	.05	.09	.21	.-											
8. Struc. dif. * joint prominence	0.06	0.04	0	0.36	. 06	.17	.20	.25	.39	.89	.23	.-										
9. Cumulative industry history	485.78	247.37	11	804	.14	.51	.15	-.07	-.19	-.17	.23	-.09	.-									
10. Time	5.72	1.98	0	8.00	.02	.64	.00	.06	.08	.13	.12	.18	.44	.-								
11. New materials	0.44	0.49	0	1.00	.00	-.13	.16	-.05	-.12	-.10	.15	-.10	.12	.00	.-							
12. Industrial automation	0.23	0.42	0	1.00	-.01	.12	.05	-.03	-.08	-.14	.07	-.13	-.15	.00	-.24	.-						
13. Alliance history, firm1	3.00	2.79	0	16	.12	.31	.15	.21	.32	.35	.20	.38	.15	.32	.03	-.06	.-					
14. Alliance history, firm 2	3.13	2.90	0	16	.10	.34	.15	.18	.27	.42	.20	.45	.06	.35	-.05	-.13	.14	.-				
15. Size	0.27	0.25	0.09	0.94	.02	.02	-.43	.05	.06	-.03	-.42	-.03	-.02	.01	-.03	.00	-.01	-.05	.-			
16. Performance	0.35	0.29	0.13	0.90	.00	-.01	.00	.00	.00	.00	.00	.00	.00	-.01	.00	-.01	.00	.00	.00	.-		
17. Liquidity	0.24	0.19	0.07	0.88	.01	.04	-.13	.02	.03	.00	-.13	.00	.014	.04	.00	.013	.03	.00	.38	.17	.-	
18. Solvency	0.64	0.22	0.02	0.80	.00	-.04	.03	.01	.03	.00	.02	.00	.02	-.03	.05	-.05	.04	.05	.05	.00	.08	.-

Methods

We modeled alliance formation using the following dynamic panel model, in which a variable's positive coefficients indicate that it promotes alliance formation:[11]

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

where:

$p_{ij}(t)$ = the probability at time (t) of the announcement of an alliance between organizations i and j;

x_{ij} = a time-constant vector of covariates characterizing organizations *i* and *j*;

$y_{ij}(t\text{-}1)$ = a time-varying vector of covariates characterizing organizations *i* and *j*;

u_{ij} = unobserved time-constant effects not captured by the independent variables;

Φ = the normal cumulative distribution function.

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 indeed occurs (Heckman 1981a, 1981b). 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

[11] It is important to note that this approach is distinct from that using the class of models known as network effects or endogenous feedback, that 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.

systematic for the same unit over time, it could lead to a serial correlation among the error terms for those observations that 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, Moffitt, and Warner 1990; Heckman 1981a, 1981b; 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. However, most statistical models suffer from some degree of omitted variable bias. Another, related 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 mis-specification 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. However, the difference in propensity is frequently a result of unobservable factors, making it impossible to *a priori* 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). In other words, 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, on the other hand, 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, a number that 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 *et al.* 1984).

To address concerns of heterogeneity, we employed a random-effects panel probit model, developed by Butler and Moffitt (1982), for the statistical analysis.[12] 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, Jain, and Vilcassim 1991; Heckman 1981; 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 computation 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.

Results

Table 3 presents maximum likelihood 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 a population-level effect capturing the density of alliances in the sector (labeled cumulative industry history), a variable for time, dummy variables for industrial sectors, and controls for each organization's previous alliance experience (labeled alliance history). We also include ratios measuring the similarity between pairs of organizations in size, performance, liquidity, and solvency. Cumulative industry history has a positive impact on alliance formation ($p < .01$). This effect suggests a possible legitimization phenomenon within the industry, where the acceptance of alliances as a valid form of collaboration increases with the number of prior alliances in the industry. The presence of prior industry history in the model renders the effect of time nonsignificant, suggesting that there are no important unobserved time-related factors not captured by cumulative industry history.

[12] Within random-effects models, numerous alternatives are possible, depending upon the choice of form for the distribution of unobservables. Although Butler and Moffitt specified a normal distribution, other functional forms are also possible. Very recent efforts have moved away from functional specification of heterogeneity toward semi-parametric random effects approaches that estimate the probability distribution directly from the data (*cf.* Chintagunta, Jain, and Vilcassim 1991).

Table 3
Random Effects Panel Probit Estimates

Variable	1	2	3	4	5	6	7	8
Constant	2.20•	1.47•	.65	.73	.60	.61	.68	.83
	(.14)	(.08)	(.91)	(.53)	(.58)	(.38)	(.75)	(.63)
Interdependence	--	.79•	.54•	.22•	.20•	.18•	.98•	.20•
		(.01)	(.01)	(.05)	(.05)	(.05)	(.26)	(.04)
Structural differentiation	--	--	11.27•	8.83•	8.05•	7.68•	7.52•	7.59•
			(3.11)	(1.36)	(1.23)	(1.11)	(1.37)	(1.17)
Repeated ties	--	--	--	.66•	.63•	.55•	.51•	.45•
				(.03)	(.03)	(.03)	(.03)	(.07)
Common ties	--	--	--	--	.066•	.061•	.057•	.050•
					(.002)	(.002)	(.002)	(.002)
Joint prominence	--	--	--	--	--	.44•	.40•	.41•
						(.04)	(.04)	(.04)
Struc. Dif. * Interdependence	--	--	--	--	--	--	-2.07•	--
							(.22)	
Struc. Dif. * Joint prominence	--	--	--	--	--	--	--	8.33•
								(.78)
Cumulative industry history	.07•	.07•	.09	.08	.08	.08	.08	.08
	(.01)	(.01)	(.11)	(.11)	(.11)	(.11)	(.12)	(.12)
Time	.11	.11	.13	.12	.13	.13	.11	.11
	(.09)	(.09)	(.09)	(.09)	(.09)	(.09)	(.09)	(.09)
New materials	-.30	-.28	-.33	-.29•	-.27•	-.27•	-.26•	-.23•
	(.17)	(.17)	(.17)	(.09)	(.09)	(.09)	(.10)	(.08)
Industrial automation	.11	.12	.15	.22•	.29•	.27•	.25•	.20•
	(.19)	(.18)	(.17)	(.05)	(.05)	(.05)	(.05)	(.05)
Alliance history, firm 1	.27•	.27•	.26•	.25•	.24•	.24•	.24•	.22•
	(.003)	(.003)	(.003)	(.003)	(.003)	(.003)	(.003)	(.003)
Alliance history, firm 2	.16•	.17•	.14•	.14•	.14•	.14•	.15•	.14•
	(.005)	(.005)	(.004)	(.006)	(.006)	(.006)	(.005)	(.005)
Size	-.67•	-.67•	-.61•	-.60•	-.60•	-.62•	-.62•	-.63•
	(.01)	(.01)	(.01)	(.02)	(.02)	(.02)	(.02)	(.02)
Performance	.001	.001	.003	.003	.005	.005	.005	.005
	(.009)	(.008)	(.007)	(.007)	(.007)	(.007)	(.007)	(.007)
Solvency	.12	.12	.13	.13	.15	.16	.16	.17
	(.15)	(.15)	(.15)	(.14)	(.15)	(.15)	(.15)	(.15)
Liquidity	-.16	-.16	-.19	-.22•	-.23•	-.23•	-.23•	-.21•
	(.10)	(.09)	(.09)	(.05)	(.05)	(.05)	(.05)	(.05)
Rho	.53•	.53•	.54•	.52•	.52•	.53•	.52•	.50•
	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)
N	7266	7266	7266	7266	7266	7266	7266	7266
Chi square	39.73•	44.61•	52.35•	62.77•	65.42•	70.21•	79.98•	80.76•

• $p < .01$.

It is worth noting that there was a significant improvement in the chi-square statistic once we added cumulative industry history, which suggests that perhaps the influence of time on tie formation is mediated by the cumulative industry history.

Dyads that include individual organizations with prior experience with alliances are also more likely to build new alliances. Although similarity of financial indicators does not have a significant impact on the probability of alliance formation, alliances are more likely to occur between organizations of different size.

Model 2 adds our measure of interdependence between the members of the dyad. As predicted in hypothesis 1, organizations that belong to different strategic groups are significantly more likely to build a new alliance with one another. This result confirms the findings of previous research and validates the adequacy of our indicator. This effect is stable across all models in our analysis.

The nature of the effect of industry trends becomes clearer after the introduction of structural differentiation in model 3. As predicted by hypothesis 2, structural differentiation has a strong positive impact on alliance formation ($p < .01$). In addition, the introduction of structural differentiation makes the effect of cumulative industry history nonsignificant, and there is a significant improvement in the chi-square statistic. This suggests that the effects of cumulative industry history on tie formation may be mediated by the structural differentiation of the network. Although hypothesis 2 was not formulated as an alternative to an explanation based on density-dependence legitimacy, the disappearance of the industry-history effect suggests that the density effects observed in models 1 and 2 are best explained as changes in the network structure. Thus, the upward-sloping rate of alliance formation during the eighties may be more the result of 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 accumulation of ties over time.

Models 4 to 6 test the effect of the embeddedness mechanisms on alliance formation predicted by hypotheses 2 and 3. The results confirm the impact of these mechanisms on the formation of alliances between organizations. Models 4 and 5 confirm the expected effects of both direct and indirect cohesive ties on subsequent alliance behavior as postulated in hypothesis 2. Model 4 shows that the presence of prior ties between organizations positively influences the likelihood of their forming a new alliance. Model 5 shows that the effect of shared common ties between previously unconnected organizations is positive and significant, as expected. The greater the number of shared ties between two organizations, the more likely they are to ally. The effects of both direct and indirect cohesive social ties on alliance formation remain significant across the different models. Taken together, the models corroborate the predictions about the impact of direct and indirect cohesive social ties on alliance formation.[13]

[13] We also tested polynomial transformations of the two cohesion variables to account for nonlinear effects (Gulati 1995). The results suggest that the relationship between previous alliances and future alliances within the dyads is best described as an inverted u-shape 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,

Model 6 investigates the role that the position of organizations in the emergent structure of inter-organizational ties plays in their alliance behavior. The results confirm hypothesis 3, which suggests that organizations are status sensitive when deciding on alliance partners; the probability of two organizations forming a new alliance is a function of their joint prominence ($p < .01$). Although this result does not rule out the possibility that peripheral organizations may build ties with central ones, it does suggest that these alliances are less likely to occur than those between central organizations. Moreover, the results indicate that alliances between two peripheral organizations are unlikely. This finding suggests that the alliance network may evolve into a center-periphery social structure in which central organizations are more likely to build ties among themselves, thus further increasing the centralization of the network.

Models 7 and 8 introduce interactions between structural differentiation and both endogenous and exogenous drivers of alliance formation. We had predicted that structural differentiation in the system would moderate the influence of structural embeddedness on alliance formation (hypothesis 6): The greater the structural differentiation, the greater the impact of status-based endogenous embeddedness mechanisms on future alliance formation. This prediction should translate into a significant and positive coefficient for the interaction between structural differentiation and joint prominence. On the other hand, we predicted that the effect of exogenous interdependence on alliance formation should decrease with structural differentiation (hypothesis 5). 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.

Model 7 introduces an interaction term between interdependence and structural differentiation. The negative coefficient for the interaction term ($p < .01$) supports hypothesis 5 and suggests that the impact of interdependence, albeit positive, diminishes as the emerging social structure becomes increasingly differentiated. To adequately interpret this result, however, we should keep in mind that interdependence does have a stable positive impact on alliance formation across all our models; exogenous factors do influence which ties will be created. However, as the network becomes differentiated, the impact of interdependence is weakened by the organizations' tendency to build embedded ties rather than simply rely on attributional assessments of a partner's suitability. The increasing structural differentiation of the network internalizes the information about the adequacy of potential partners, which results in a weaker effect of exogenous factors on alliance formation.

Model 8 introduces the interactions between structural differentiation and joint prominence, which was our indicator of structural embeddedness. This model tests the

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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, which we report here for the sake of simplicity.

contingent influence of structural embeddedness on alliance formation (hypothesis 6). As predicted, it shows significant effects for the interaction between structural embeddedness and structural differentiation. The impact of joint prominence increases with the level of structural differentiation of the emerging network. Although the overall impact of structural embeddedness on alliance formation is consistently positive (as documented by model 6), this impact does not remain constant as the social structure evolves. Rather, the effect of structural embeddedness on the probability of new alliances increases as the emerging network structure becomes more differentiated. The effective impact of structural embeddedness mechanisms on subsequent tie formation is thus contingent upon the evolutionary stage of the network.

The results of our analysis show that both interdependence and network embeddedness factors have a significant impact on alliance formation. The salience of these factors, however, is contingent upon the level of structural differentiation of the social system. As the network structure becomes more differentiated, the explanatory power of endogenous factors on organizational action increases while the role of exogenous instrumental factors diminishes. The results also present evidence supporting an endogenous embeddedness dynamic between action and structure. Our longitudinal approach allows us to show how organizational action is driven by the existing network structure and contributes to the future evolution of this same structure.

Discussion

The central message of this research is that the formation of a new inter-organizational network structure results from an evolutionary dynamic in which action and structure are closely intertwined. Building on the idea of the embeddedness of economic action, we stressed the scarcity of information about potential partners and the role of the network structure of prior ties as sources of that information to suggest that new network ties are contingent on the previous network structures. Prior research has either left aside the question of the initial formation of inter-organizational networks or has conceived of this as driven by factors that are exogenous to the social structure that they help to create. To address these limitations, we proposed an evolutionary model in which the production of network structures results from the interplay between exogenous factors and an endogenous embeddedness dynamic. The endogenous dynamic is one in which the formation of new ties is influenced by the existing network structure and the structure is then modified by the newly created ties. Networks are thus viewed as both the residual effect of past behavior and a driving force for future action. We showed that although exogenous factors play an important role in tie formation, as the social network becomes increasingly differentiated the production of inter-organizational networks is progressively driven by network mechanisms.

The longitudinal analysis of inter-organizational alliances over a ten-year period offered empirical evidence in support of our evolutionary model of network production. The analysis presented here largely supports our hypotheses concerning the influence of embeddedness and the structural differentiation of the social network on the formation of new ties. Longitudinal panel data analyses consistently revealed a positive and significant association between endogenous network embeddedness factors and alliance formation throughout the observation period. Both relational and structural embeddedness assert a positive influence on the creation of new ties.

In addition, the significant interaction between structural differentiation and both interdependence and structural embeddedness suggest that the influence of these factors is moderated by the extent of structural differentiation of the network. In particular, the influence of structural embeddedness increases with the level of structural differentiation of the emerging inter-organizational network. With increasing differentiation, the network provides greater information, which is reflected in the growing influence of structural embeddedness concomitant with structural differentiation. The impact of exogenous factors on alliance formation is also contingent on the level of structural differentiation, and its effect declines with increasing structural differentiation. These findings support our argument that the growing differentiation of social structure provides firms with access to additional information on potential partners. Consequently, their decisions about partnerships are increasingly guided by socio-structural considerations, which provide an important criterion for partner selection, thus eroding the impact of exogenous factors.

The nature of our data, which cover only a segment in the evolution of the observed inter-organizational networks, did not allow us to test whether the effects of structural differentiation on tie formation are linear. Although our model has assumed linearity for the sake of simplicity, it is reasonable to expect that, at least in the long run, the effects of structural differentiation on tie formation may be nonlinear. The reasons for this become clear when we consider the informational value of the network profiles of organizations. Actors are practically indistinguishable by their network profiles at low levels of structural differentiation, since most organizations have a similar pattern of relationships in the system. Thus, poorly differentiated networks carry little of informational value about the capabilities of the actors in that network. The other extreme, however, is equally uninformative. In a system where organizations have truly unique relational profiles, it is impossible to identify classes of actors in terms of their network profiles, since each organization occupies a unique position in the network. Thus, in a system of unique organizations it is difficult to identify unique status groups, which render structural embeddedness ineffectual. If such a dynamic occurs, we can expect the enhancing effects of structural differentiation on structural embeddedness to level off and eventually to decline as organizations in the system become unique.

Most real systems, however, may never display a continuous increase in the level of structural differentiation. Studies of mature social structures suggest that the formation of distinctive positions occupied by actors with similar network profiles is a common phenomenon (White 1981; Burt and Carlton 1995). Thus, the growth of structural differentiation should taper off as the social structure reaches equilibrium. It should be noted, however, that this evolution of structural differentiation does not invalidate our model. Rather, unchanging levels of differentiation simply render the inclusion of this variable unnecessary, as one would expect for mature, self-reproducing social structures. Unfortunately, we cannot test this proposition with our data, since alliance networks were far from stabilizing at the end of our observation period.

Although this paper has focused on the emergence of cooperative inter-organizational ties that take transactions out of the market logic, it nevertheless has implications that are pertinent for the development of the sociology of markets. Sociologists have demonstrated that under conditions of uncertainty and imperfect information, market players use the network of inter-organization relationships to guide their action. The reliance on existing networks ultimately leads to a self-reproducing market schedule (White 1981; Leifer and White 1988). Our results suggest that the social mechanisms that sustain a mature social structure may also play an important role during the formation of that social structure. We also suggest, however, that there may be an important difference between the network dynamic in the formative and mature stages of a social structure. This difference lies not in the nature of the mechanisms that guide the behavior of organizations, but rather in the effective impact of these mechanisms on organizational action.

By theorizing that the relative impact of alternative mechanisms is contingent upon the informational content of the network and then modeling this informational content as a function of the level of development of the network, we show that the difference between the formative and mature stages of an inter-organizational network is one of a variable versus a stable impact of embeddedness mechanisms on organizational action. We expect that a similar dynamic may be likely to operate in the formation of market ties. During its formative stages, the information content of the social structure of the market is not likely to be constant. As a result, models predicting organizational action in a market context should include an element accounting for the changing informational content of the evolving network that shapes the structure of the market. In a mature market, the informational content of this network stabilizes, and thus its inclusion in the models of organizational behavior may no longer be necessary. This stability results in what White (1981:518) has described as "self-reproducing social structures among specific cliques of firms and other actors who evolve roles from observations of each other's behavior." 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 research also contributes to the development of network theory in two important ways. The first contribution arises from its distinctive focus on the origin of social networks. 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 variegated set of social phenomena ranging from social influence (see Marsden and Friedkin 1993) to individual and organizational performance in competitive situations (Burt 1992). Yet this research has not tried to use its own theories of action, which typically result from purposive action under constraints, to explain the origin of social ties. At best, social ties are explained as the result of the success of actors in "embedding" new relations in a pre-existing, different network structure to minimize uncertainty (Romo and Schwartz 1995) or to attain control (Burt 1983; Gargiulo 1993). By showing how the formation of cooperative inter-organizational networks results from an evolutionary process in which networks build upon themselves, we provide a framework to advance our understanding of this fundamental question of network origination. Although our framework focuses on the emergence of inter-organizational networks, we believe that social networks in other settings involving cooperative exchanges may also witness a similar dynamic and merit further research.

A second contribution of this study is that it raises the possibility that the effect of network mechanisms on social action may be contingent on the evolutionary stage of the social structure underlying those mechanisms. Most network research assumes a relatively stable social structure that creates constraints and opportunities for individual behavior. Network effects on that behavior may vary across systems and situations, as the array of social-influence studies demonstrates (see Marsden and Friedkin 1993 for review). Yet, because of the limited number of longitudinal studies of networks, the varying influence of network effects and their connection with the evolutionary stage of the network structure has received limited attention. Our study suggests that the explanatory power of network mechanisms may be contingent on the evolutionary stage of the network structure being examined. Many network studies assume that the observed social structures are in a stage of dynamic equilibrium. Although there is no straightforward way of determining the adequacy of this assumption (especially when using cross-sectional data), our study suggests that such an assumption should be carefully assessed.

The endogenous network dynamic 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 the behavior of the organizations, that is, their decisions about whether and with whom to create new ties; on the other hand, this structure is produced and reproduced as a result of the (structurally shaped) decisions of individual organizations to establish relations with one another. This

dynamic between action and structure resembles the dialectic between "agency" and "control" proposed by White (1992). In the formative stages of a social structure, organizational action actively contributes to the informational content of the network, making the impact of agency on the emerging structure noticeable. By building new ties, however, organizational agency creates structures that progressively inform its future behavior. The more the structure takes form, the more it shapes—"controls" — future organizational action. In a mature social structure, control processes ultimately pervade over agency and organizational action. In other words, when building new ties, organizational agency generates network structures that shape subsequent action. This structurally informed action in turn introduces further systematic differentiation—and thus, information and control—in the social structure. When the structure reaches maturity, control processes are dominant and organizational action is practically devoid of agency and limited to reproducing the "role structure" (White 1981) that initially informed action. In mature network structures, endogenous embeddedness is only disturbed by external forces or by the occasionally successful efforts of agency to upset the status quo.

Although often neglected in empirical analyses, the dynamic between action and structure depicted in our model is a central feature of structural analysis. In this analysis, the structure of ties shapes the behavior of actors by creating and providing them with access to unique opportunities. As Burt (1982:9) pointed out:

> Actors find themselves in a social structure. That social structure defines their social similarities, which in turn pattern their perceptions of the advantages to be had by taking each of several alternative actions. At the same time, social structure differentially constrains actors in their ability to take actions. Actions eventually taken are therefore a joint function of actors pursuing their interests to the limit of their ability where both interests and ability are patterned by social structure. Finally, actions taken under social structural constraint can modify social structure itself and these modifications have the potential to create new constraints to be faced by actors within the structure.

A unique duality of structure results from this recursive feature: it is a condition of action and at the same time a consequence of action (Haines 1988; Barley and Tolbert 1997). As such, our endogenous network framework shares some similarities with Giddens's (1984) "structuration" theory of the emergence and reproduction of social systems. Although we stress the same dialectic between action and structure that is central in Giddens's work, our definition of network production is more specific. We conceptualize social structure as the pattern that emerges out of the observable relations among actors. This is closer to the notion of social structure proposed by British social anthropologists (Radcliffe-Brown 1940; Nadel 1957) and adopted in modern network analysis (Lorrain and White 1971) than to Giddens's broader definition of social structure as "recursively organized sets of rules and resources" (Giddens 1984:25).

The framework presented in this paper contributes to our understanding of an important concern in sociological theory, commonly discussed as the micro-macro

link (Alexander *et al.* 1987). Although the micro-macro link has been discussed from multiple perspectives, several scholars view it as an analytical distinction between interactions among actors and the relational patterns that result from those interactions (Wippler and Lindenberg 1987; Gerstein 1987; Coleman 1990). Thus posed, the micro-macro link question refers to how existing social structures pattern individual action and how individual action aggregates into social structures.[14] Our network-production model portrays the social structure of inter-organizational relations as a macro phenomenon emerging out of the micro decisions of bounded-rational organizations seeking to gain access to resources and to minimize the uncertainty associated with choosing alliance partners. At the same time, the emergent structure increasingly becomes a source of information for the organizations, thus patterning their subsequent actions. The dialectic between macro and micro is thus translated into a dialectic between structure and action (Gargiulo 1988). Our notion of endogenous embeddedness suggests a specific mechanism through which this dialectic operates. Our theory accounts for both the effects of social structure and those of exogenous factors on organization behavior, thus avoiding the drawbacks of both the "under-" and "over-socialized" images of social actors (Granovetter 1985).

The embeddedness dynamic introduced in this paper has important consequences for organization theory also. It suggests that the organizational search for partners may result in a path-dependent process in which the gradual production of a network structure increases the information available to organizations, albeit also limiting the effective range of potential partners an organization is likely to consider (Arthur 1989). Organizations may thus become victims of their own history, restricting their searches for partners to a circle of socially "trustworthy" players, perhaps even at the expense of strategic considerations.[15] This confinement of cooperation to embedded ties diminishes the uncertainty faced by the organizations, but it may also deter the search for partners outside the "reliable" circle. Consequently, organizations may be locked into redundant cooperation that fails to realize the full potential of partnerships. Such a system not only makes partner selection suboptimal, but may also effectively ostracize newcomers to alliances. As other scholars have pointed out, the benefits of embeddedness may turn into disadvantages when the actor is "overembedded" in a network of stable, thick relations (Portes and Sensenbrenner 1993; Uzzi 1997). Social structure is thus both a

[14] Wippler and Lindenberg (1987) refer to these as the "bridge" and the "transformation" problem respectively.

[15] The potential decoupling between an exogenous structure of interdependencies and an endogenous social dynamic suggested by our results is not alien to organization theory. Scholars who analyze interlocking directorates have documented the emergence of "spurious" interlocks—that is, interlocks that are not correlated with underlying resource dependence. This suggests that even co-optation networks may develop an "endogenous" dynamic that is partially autonomous from the resource dependencies triggering their formation. In the case of interlocks, the failure of organizations to replace "spurious" broken ties suggests that this dynamic is constantly kept in check by the demands of the structure of interdependence (Mizruchi 1993).

resource—a source of information—and a constraint insofar as it limits the search to a limited, localized pool of potential partners (Burt 1992). By relying upon an evolving social structure, bounded-rational organizations effectively diminish the uncertainty associated with picking partners. Yet, gains in partner reliability may be offset by the limitations on the choice of potential partners.

In sum, the recursive framework presented in this paper contributes to several areas of sociological theory, including the sociology of markets, the origins of inter-organizational networks, and the relationship between action and structures. It also contributes to a key discussion in organizational theory about the advantages and perils of reliance on social mechanisms to orient organizational decision making under uncertainty, a topic that has often confronted sociological and economic approaches to organizational theory. By expanding our understanding of network production processes, the endogenous embeddedness model also opens the way to more detailed studies focusing on specific aspects of the dialectic between action and structure that is at the core of most social processes. Seeking an answer to our original question—Where Do Inter-Organizational Networks Come From?—we have shown that inter-organizational networks result not only from exogenous drivers such as interdependence, but also from an endogenous evolutionary dynamic in which these networks are both the driving force and the result of organizational action.

APPENDIX

Additional Controls and Verification

Interdependence

We did a number of additional tests to address concerns of interdependence across observations resulting from the presence of the same firm across multiple dyads. First, 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). We ran 500 iterations of a completely specified random-effects model with a new randomized dependent variable obtained by random permutations of the rows and columns in the alliance matrix. 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, 501) indicates the statistical reliability (pseudo t-test) of the original results. This test can be interpreted like conventional tests of significance: a result of less than 5 percent (or, even better, 1 percent), 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 distribution function. This procedure allowed us to assess the efficiency of our results, a primary concern resulting from any dyadic interdependence. Our approach differs from MRQAP in that we used the random-effects probit model instead of OLS regression for each iteration of the simulation. The percent frequency with which the results in the random-sample simulations exceeded the original estimates was far less than 5 percent in all instances. Thus we can say with some confidence, that for these data, reasonable coefficients were obtained.

Second, the problem of cross-sectional dyadic interdependence can also be understood as one of model mis-specification (Lincoln 1984). If a statistical model incorporated all essential nodal (firm-level) characteristics that influence alliance formation, no unobserved effects resulting from common nodes would remain. The models used here account for unobserved heterogeneity and address this problem to the extent that they adjust for such systematic biases resulting from missing variables. We expected the unobserved heterogeneity term (rho) to capture any residual dyad-level effects not included in the model. To capture any firm-level effects across dyads sharing the same firm, as mentioned above, we also controlled for each firm's cumulative history of alliances.

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 (1) alliance formation among firms arises from the flow of information underlying the networks of pre-existing relationships and (2) the specific structural models used to reflect these information flows cluster firms that are densely connected by such informational links (Friedkin 1984).

To verify our claims of systematic inter-organizational alliances, we compared the results for this study's sample against results obtained with a sample in which 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 ten 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 network effects explain the systematic pattern of alliances.

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