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STRUCTURAL HOMOPHILY OR SOCIAL ASYMMETRY? THE FORMATION OF ALLIANCES BY POORLY EMBEDDED FIRMS

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Recent research shows that preexisting network structure constrains the formation of new interorganizational alliances. Firms that are poorly embedded in a network structure are less likely than richly embedded firms to form alliances, because they lack informational and reputational benefits. This study examines the types of ties that poorly embedded firms can form to overcome the constraints that their structural positions impose, in turn helping to explain how firms' actions can transform existing network structures. We argue that poorly embedded firms are more likely to participate in ties characterized by social asymmetry than in ties characterized by structural homophily. We analyze the terms of trade that socially asymmetric partners negotiate for alliance governance and discuss how such alliances influence network dynamics. To test our arguments, we use longitudinal data on the alliance activities of 97 global chemical firms from 1979 to 1991.

INTRODUCTION

Recent research highlighting the role of social context in influencing firms' alliance formation shows that, although the need for firms to manage interdependence and gain access to resources is an important influence on alliance formation (Pfeffer and Nowak, 1976; Kogut, 1988; Mitchell and Singh, 1996), firms' positions in the preexisting network structure also affect the formation of new alliances (Gulati, 1995b; Powell, Koput, and Smith-Doerr, 1996; Walker, Kogut, and Shan, 1997). Although resource interdependence clearly influences alliance formation, the network perspective on interfirm collaboration highlights the influence of structural embeddedness (Gulati, 1998) and proposes that alliance activity embeds in the wider network structure resulting from prior alliances (Walker *et al*., 1997; Gulati and Gargiulo, 1999; Jensen and Roy, 2008), just as economic activity embeds in the broader social system (Polanyi, 1944; Smelser and Swedberg, 1994). One of the main findings of the literature examining network embeddedness is that firms that are highly embedded in a network, that is, firms with many existing social ties, such as alliances with other firms that provide them with a central position in the network, are more likely to form additional alliances because of their ability to gather information about a wider set of potential collaborations (Gulati, 1995b), and because of their high status resulting from their central position in the network structure (Podolny, 1994). By contrast, poorly embedded firms, that is, firms having few connections and existing at the periphery of networks, lack informational and reputational benefits and are less likely to form alliances.

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As well as being more likely to form alliances, highly embedded firms are likely to form alliances with other highly embedded firms to mitigate collaboration hazards (Podolny, 1994; Gulati and Gargiulo, 1999; Chung, Singh, and Lee, 2000). Structural homophily is the term used to describe firms similarly embedded within the network. Early research suggested that other dimensions of homophily, such as similarity of resource profiles, facilitate interfirm collaboration (e.g., Pfeffer and Nowak, 1976; Mowery, Oxley, and Silverman, 1996; Lane, Salk, and Lyles, 2001). However, the network perspective on interfirm alliances highlights the similarity in the network positions occupied by two firms as an additional attractor that increases the chances of alliance formation.

The findings of network research on interfirm collaboration are important to our understanding of how social structure emerges in an interorganizational environment. However, they raise an intriguing question. If highly embedded firms disproportionately obtain the prerogative to form alliances and, in turn, if these highly embedded firms tend to link with each other, how does a poorly embedded firm form alliances or become a more connected part of the network?

The question of how poorly embedded firms manage to form alliances has important theoretical implications (Ahuja, 2000b; Rosenkopf, Metiu, and George, 2001; Baum, Shipilov, and Rowley, 2003; Rosenkopf and Padula, 2008). The alliance formation behavior of such firms provides an opportunity to test for the salience and ubiquity of the principle of structural homophily, and also to consider possible alternatives to it. Highly embedded actors tend to ally with other highly embedded actors for several reasons, including the prestige of associating with well-connected actors and the ability to reduce uncertainty by linking with other actors within a dense network. However, the literature has spent less time exploring whether structural homophily influences the actions of less embedded actors—for instance, it is not clear whether less embedded actors tend to ally with each other. Further, to the extent that structural homophily does not strongly influence less embedded actors, what alternative approaches might explain their alliance behavior?

Assessing alternative approaches in the context of interorganizational collaboration will help explain network dynamics. A strict interpretation of the embeddedness dynamic in prior research suggests that interorganizational networks reproduce themselves over time (Gulati and Gargiulo, 1999). Highly embedded firms use their prior connections to build new ties and remain deeply embedded in the network, while firms that are not as well connected remain at the periphery of the network. This view suggests a structural application of the Mertonian principle that the rich get richer: network structures are largely stable over time, with highly embedded firms having their choice of desirable new partnerships, and thereby remaining well connected to the wider network.

Despite the tendency toward the self-reproduction of network structures, prior work has shown that firms that are loosely connected can increase their participation in alliance activity over time (Ahuja, 2000b; Rosenkopf *et al.*, 2001), which can contribute to the transformation of the network structure, sometimes quite suddenly and sometimes gradually. For instance, in contrast to the self-reproducing conception of networks, theorists have raised the possibility that networks change because of revolutionary events outside the existing network. Exogenous structure-loosening events create opportunities for new actors and technologies, which overturns the established order (Madhavan, Koka, and Prescott, 1998). This alternate view explains changes in network structure in terms of the structure-loosening events and how they facilitate or encourage new partnerships.

However, another path may produce evolutionary change in networks rather than stable reproduction or revolutionary transformation. If less embedded actors could link up with more embedded actors, they could then use the ties to access other more embedded actors and slowly become more embedded themselves. This 'creeping' strategy of working one's way toward the center of the network would enable change to occur in network structures endogenously, without the need for an exogenous revolutionary disruption. Exploring the theoretical and empirical viability of such a mobility strategy remains an unaddressed task.

This study attempts to expand our understanding of how firms' actions can transform network structure by examining the types of ties that weakly connected firms create. We first consider the incentives of highly embedded firms to promote the inclusion of poorly embedded firms into the network. Previous studies have emphasized the *constraints* that poorly embedded actors face to ally with highly embedded actors but overlooked the *incentives* for highly embedded firms to create asymmetric ties with poorly embedded partners. Second, we analyze whether the structural homophily principle, which guides the formation of alliances between highly embedded firms, also extends to the creation of linkages between poorly embedded partners. Third, we investigate how the social asymmetry that forms the basis of ties between dissimilar firms affects the terms of trade between them. Finally, we evaluate how the ties between socially asymmetric allies influence network dynamics. Specifically, we ask whether these ties serve as launching pads for peripheral firms to form additional ties with more embedded partners and become more central themselves.

THEORY

The downside of embeddedness

Structural embeddedness assists interorganizational collaboration by mitigating the uncertainty of alliance formation and by providing prestige (Zaheer and Venkatraman, 1995; McEvily and Zaheer, 1999; Gulati, Nohria, and Zaheer, 2000). As a result, alliances are more likely to be formed between firms occupying central positions in the network structure (Podolny, 1994; Gulati and Gargiulo, 1999; Chung *et al*., 2000). Whereas the embedding of alliance activity on the wider network structure facilitates interfirm collaboration and encourages the formation of alliances between central partners, the use of embeddedness as a criterion in partner selection may provide decreasing marginal benefits for pairs of firms that are already deeply connected to the network structure. Previous literature has emphasized the positive consequences of embeddedness and often overlooked the potential for negative consequences.

Several arguments suggest that highly embedded firms face limits to the decreased uncertainty and prestige benefits of linking with other firms occupying equally central positions in the network structure. A firm with rich social contacts can use its informational advantages to assess the capabilities and reliability of potential partners without having to rely on the signals that the structural position of potential allies conveys. Thus, the uncertainty-reducing signals that a highly embedded potential partner offers may be redundant to another highly embedded firm, which can use the informational benefits inherent in its own structural position to assess a potential partner. Given this, a highly embedded firm can leverage its superior information to reach out to potential partners that occupy less central positions in the network. Likewise, by being highly central in a network, a firm already enjoys visible reputation, which reduces the marginal reputational value of a new alliance with another firm in a central network position.

Moreover, a high level of embeddedness may, of itself, be an obstacle. The same social mechanisms that favor a relationship between highly embedded actors also introduce rigidities and hinder the ability of firms to pursue instrumental goals (Portes, 1998; Gulati and Gargiulo, 1999). Excessive embeddedness and overreliance on the same partners can increase interdependence and restrict firms' actions outside the pool of highly embedded actors (Granovetter, 1973; Podolny, 1994; Uzzi 1997).

An additional limitation of embeddedness as a guide in partner choice is that, although embeddedness mitigates the uncertainty involved in interorganizational collaboration, it can cause firms to ignore potentially successful alliances, produce systematic biases, and make substantially flawed judgments (McEvily, Perrone, and Zaheer, 2003). A search strategy that focuses on the pool of firms occupying central positions may reduce some hazards of interorganizational collaboration. Nonetheless, whereas such a search strategy helps identify reliable partners, the strategy does not ensure that the partnerships will be those that have the greatest potential. By opting for safe partnerships, firms may forgo the benefits of collaborating with less embedded but more valuable partners. Some firms that appear to have little to offer, based on their low levels of centrality in the network structure, may possess valuable resources to contribute to a partnership.

Thus, the embeddedness reflected in firms' positions in the network structure initially facilitates alliance formation but ultimately imposes limits to alliance value. Consistent with prior studies, we expect the combined network centrality of two firms to increase their propensity to ally. However, we expect that, after a threshold level, combined centrality creates disincentives for collaboration, thereby diminishing the likelihood that two firms will form an alliance.

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Hypothesis 1 (H1): The combined network centrality of two firms has a nonmonotonic effect on the likelihood that they will form an alliance: an initial level of combined centrality has a positive impact, but after a threshold level, greater combined centrality has a negative impact on the propensity of alliance formation.

Structural homophily versus social asymmetry

Firms at the periphery of a network do not enjoy the informational and reputational benefits that accrue to firms occupying central positions. Given those difficulties, the question then becomes how do poorly embedded firms manage to form alliances? One possibility is that firms create exchange relations with other firms in similar conditions. Several scholars have proposed that coalitions among poorly embedded actors help restore balance in the distribution of network resources (Emerson, 1972; Cook, 1977). A related concept is that of insurgent partnering, that is, a strategy in which peripheral firms improve their network positions by allying with other peripheral firms (Baum *et al.*, 2003). By allying with partners occupying similar network positions, poorly embedded firms can gain access to resources, accumulate experience in interorganizational collaboration and, as a consequence, become more attractive as potential partners of highly embedded firms.

Despite the seeming plausibility of coalition-building or insurgent partnering as a social mobility strategy, we argue that this will often be an inferior strategy. Two reasons inhibit this strategy. First, the same factors that hinder the formation of alliances between firms with asymmetric levels of embeddedness make collaboration between peripheral firms less likely. For instance, concerns about partner unpredictability and uncertainty will be as or more salient between peripheral firms relative to partnering with a central firm. Second, one must assess partner choices not just in terms of the obstacles to alliance formation but also in relation to the potential benefits resulting from collaboration. Despite the obstacles that inhibit alliances between a non-central and a central firm, the benefits that poorly embedded firms can derive from such alliances may exceed the benefits of collaborating with peripheral partners.

Peripheral firms have less information than highly embedded firms to assess the capabilities and reliability of potential partners. The information paucity will be particularly limiting for assessing potential ties with other peripheral firms. By contrast, information about the capabilities and reliability of central firms can reach poorly embedded actors even in the absence of direct or indirect links between them, due to the higher social visibility associated with centrality (Podolny, 1994; Gulati and Gargiulo, 1999). Thus, information availability creates greater incentives for peripheral firms to form alliances with central firms.

Poorly embedded firms face the additional constraint that they often possess little to offer potential partners, which reduces their attractiveness not only to highly embedded firms, but also to their poorly embedded counterparts. Firms occupying central network positions commonly possess more resources to contribute to an alliance. Even if we suppose that two potential partners—one rich and the other poor in interorganizational ties—have identical technical resources to contribute to an alliance, a firm with low network centrality can still benefit more from collaborating with the former because the prestige associated with its partner's centrality can also provide reputational advantages and vouch for the reliability of that firm to other potential allies (Podolny, 1994; Stuart, Hoang, and Hybels, 1999; Rosenkopf and Padula, 2008). Therefore, from the perspective of poorly embedded firms, associating with highly embedded firms offers greater benefits than allying with poorly embedded firms.

A question, of course, is why would highly embedded firms want to ally with poorly embedded partners? The straightforward answer is that the partners may offer specific resources that the highly embedded firm could not obtain from other firms (Mitchell and Singh, 1996). Network information flows often tend to be localized, with firms in one neighborhood having access to somewhat different information relative to firms in another part of the network. Forming an alliance with a peripheral firm may give a central firm a window into activity in a different part of the network. For instance, Gulati and Gargiulo (1999) suggested that central firms may create alliances with peripheral firms to gain access to a new technology, while Ahuja (2000b) found that firms poor in social capital increase their chances of entering alliances when they possess pathbreaking inventions. Thus, a peripheral firm with strong resources may be able to wait for a partnership with a central firm rather

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than jump into an inferior alliance with a loosely connected partner. When combined with the earlier arguments about the limits of alliances between firms with high levels of combined centrality, this logic suggests a second hypothesis.

Hypothesis 2 (H2): A firm with low network centrality is more likely to form an alliance with a firm with high network centrality than with another firm with low network centrality.

Social asymmetry and terms of trade

Another question about the formation of alliances spanning asymmetric levels of embeddedness is whether social asymmetry affects the terms of trade that the partners negotiate. Specifically, we examine the extent to which the asymmetry in the network centrality of joint venture partners affects the control structure of the alliance. We predict that highly embedded firms are likely to obtain control of joint ventures with less embedded firms. This introduces a second-order benefit to firms occupying central positions in network structures: they are not only more likely to form new alliances, but also more likely to secure better terms of trade when partnering with less central counterparts.

Following the notion that organizations seek to gain control over elements of their task environment on which they depend (Thompson, 1967; Pfeffer and Salancik, 1978), previous research has discussed the ways in which alliance partners seek control to alleviate interorganizational hazards (Kogut, 1988; Gehringer and Herbert, 1989). Firms can exercise control to alleviate hazards through the adoption of more hierarchical governance structures (Gulati, 1995a; Gulati and Singh, 1998) and the holding of majority ownership control in joint ventures (Gehringer and Herbert, 1989; Steensma and Lyles, 2000). By holding majority ownership, a firm is able to influence the activities of the alliance and to adjust its effort on the basis of the observed effort of the partner, which helps the firm protect itself from the hazards inherent in interfirm collaboration. Majority ownership can also help overcome friction that stems from disagreements between partners about the best ways to allocate resources or responsibilities within an alliance, even in the absence of opportunistic behavior (Conner and Prahalad, 1996). Further, because the venture might face some uncertainty on how markets and technologies develop, having control over the venture positions the controlling partner better in terms of guiding the alliance along a path more in line with its own strategic interests. Thus, other things being equal, firms have strong incentives to retain control of the venture.

Asymmetry in structural position between two firms is also likely to translate into asymmetry in negotiating power when they form an alliance. Firms that are more deeply embedded have more access to certain resources, such as reputation and access to other prominent firms, which can result in an imbalance in an exchange relation with less embedded partners (Emerson, 1972; Cook, 1977). Even if two socially asymmetric partners expect to realize the same levels of tangible benefits within the scope of a particular alliance, the implications of such an alliance will be farther reaching for the partner that is less central in the network structure for several reasons. A loosely connected firm can use partnerships with a highly embedded ally to collect prestige and enhance its own visibility (Podolny, 1994; Stuart, *et al*., 1999). Further, apart from the positive reputational spillovers, collaboration with prominent actors represents an avenue for peripheral firms to access the partner's network resources. As a result, the less embedded firm can enjoy increased insertion into the network structure. Moreover, poorly embedded firms have a smaller pool of potential partners to choose from, because they tend to be less attractive as alliance partners (Podolny, 1994; Gulati and Gargiulo, 1999), which implies that they will impose fewer conditions on alliance partners that are richer in interorganizational relationships. Given the advantages accruing to highly embedded actors when maintaining exchange relations with other central actors, poorly embedded firms will often offer favorable terms of trade to entice central allies into an exchange relation (Gulati, 1998; Stuart, 1998).

Hypothesis 3 (H3): The greater the asymmetry in the network centrality of two joint venture partners, the greater the likelihood that the firm with the highest centrality will hold a majority ownership position in the joint venture.

Terms of trade and network dynamics

As we discussed above, firms are more likely to accept unfavorable terms of trade when partnering with firms that exhibit high levels of embeddedness

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in the social structure. This prompts the question: does relinquishing control to a highly embedded partner foster subsequent acceptance of a poorly embedded firm by other highly embedded partners, thereby providing a strategy for gaining network centrality? Whether accepting a minority ownership position in a relationship with a central partner will contribute to the social mobility of a peripheral firm depends on what that behavior signals to potential collaborators about the reliability and the capabilities of the firm accepting such a position.

On the one hand, a relationship with a high centrality firm may signal status and reliability of the low centrality firm. The firm's acceptance by a highly embedded ally confers legitimacy, signaling that a central firm believes the peripheral firm has strong enough resources to merit forming a partnership. Moreover, the minority positions that poorly embedded firms hold in existing joint ventures with partners rich in social capital may leave them in a hostage position through which their allies can sanction opportunistic behavior (Kogut, 1988; Gulati and Singh, 1998). This logic suggests that low centrality firms that accept less favorable terms of trade when allying with central firms are more likely to form subsequent alliances with other central firms, because their minority positions will limit their ability to act opportunistically.

However, this argument makes a relatively strong assumption about reliability. For the prediction to hold, reliability would have to transfer across relationships. That is, subsequent partners would have to believe that a minority position in one relationship would inhibit the peripheral firm from acting opportunistically in any of its relationships. Such transferability of reliability often will not hold, which would lead to no relationship between minority ownership and subsequent alliance formation with central firms.

Moreover, the act of accepting a minority position in a relationship with a more central firm might actually inhibit subsequent partnerships, for two reasons. First, while the above argument presumes that potential partners will read a 'reliability' message in the minority ownership that a firm accepts when building a relationship with the more central ally, it is possible that the minority stake signals something quite different. Rather than interpreting the willingness to accept a minority position as a signal of reliability, potential partners may interpret the minority position as a sign of weakness. The stronger the resources that a peripheral firm possesses, the stronger its bargaining position with a potential partner, even a highly central partner. Thus, a peripheral firm that settles for a minority position may possess only moderately strong resources—strong enough for the central firm to be willing to form a relationship, but not strong enough for the peripheral firm to obtain a parity position in the relationship. The willingness to accept unfavorable terms of trade may lead potential partners to infer that the firm is not an especially attractive partner.

Second, the minority position may limit the firm's future independence (Singh and Mitchell, 2005), which could deter other partners. The fact that the high centrality firm has a majority position may inhibit other firms from allying with the peripheral firm if they fear that the first partner could use its controlling position to control future activities of the low centrality firm. Thus, minority acceptance in one partnership may inhibit subsequent acceptance by other central firms, rather than encourage new partnerships.

Hypothesis 4 (H4): The acceptance of a minority ownership position in joint ventures with firms having higher network centrality has a negative impact on the likelihood that a firm with low network centrality will form subsequent alliances with firms having higher network centrality.

In summary, the hypotheses focus on factors that will lead highly embedded and poorly embedded firms to form alliances. We expect combined centrality to have a nonmonotonic impact on alliance formation by pairs of firms, first increasing and then decreasing (H1). We expect peripheral firms to prefer heterophilous alliances with central firms rather than alliances with other peripheral firms (H2). We expect partners with low network centrality to be willing to take minority positions in their relationships with more central firms (H3). Finally, we suggest that acceptance of minority positions in ventures with more central firms will likely reduce their attractiveness to subsequent more central partners (H4). Together, the arguments help trace conditions under which poorly embedded firms may be able to move toward the center of a network structure, as well as constraints to such movement, thereby helping develop an endogenous theory of network evolution.

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DATA AND METHODS

To test the hypotheses, we used data on alliance activities of 97 leading firms from the global chemical industry over the period 1979–1991. Interorganizational collaboration is common in the global chemical industry and affects the technological performance of chemical firms (Ahuja, 2000a), thus making this industry an appropriate empirical setting for the study. Because obtaining information on collaborative linkages for smaller firms over an extended period of time is extremely difficult, we selected the leading chemical companies in Western Europe, Japan, and the United States. Previous studies on alliance formation have used a similar strategy of focusing on the leading firms in an industry to ensure data availability and reliability. For instance, Gulati (1995b) studied the alliance activity of the 50 to 60 largest publicly traded firms in new materials, industrial automation, and automotive products. Likewise, Rosenkopf and her colleagues (2001) limited their analysis of the alliance activity of cellular service providers and equipment manufacturers to 87 firms for which financial data were available. We identified the leading chemical firms based on lists in trade journals such as *Chemical Week* and *C&E News*. We chose companies regardless of whether they had formed an alliance in a given year, to avoid sampling on the dependent variable. From an initial sample of 107 distinct firms, we settled on a final sample of 97 firms after dropping 10 companies that lacked reliable data.

Previous research shows that interorganizational hazards are greater in alliances involving technology (Gulati and Singh, 1998). Because higher interorganizational hazards enhance the difficulties involved in collaborations between highly embedded and poorly embedded firms, we considered only collaborations that included a technical component. The 97 firms of the sample created 338 alliances (178 joint ventures and 160 technical agreements) between 1983 and 1991, which is the period for which we predict the likelihood of alliance formation. We used data on sample firms' alliance activity from 1979 to 1982 to construct a baseline network structure to predict alliance formation in 1983. Prior studies have suggested that alliance activity was relatively low until 1980 (Hergert and Morris, 1988; Gulati and Gargiulo, 1999). Hence, by starting our analysis in 1979 and by using the first four years to construct a baseline network structure, we minimize potential left-censorship effects.

Because our aim is to study the formation of alliances by poorly embedded firms and examine whether these firms ally with other poorly embedded or with highly embedded partners, it is important that our sample include firms with varying degrees of embeddedness. At the start of the period of analysis, 40 firms were loosely connected to the network structure: 17 firms were isolates that had formed no alliances, while 23 firms had created linkages with only one partner. By the end of the period of analysis, four firms were still isolates, whereas 48 firms had created 10 or more ties to other firms. Thus, our sample comprises not only firms that are richly embedded in the network structure, but also firms that are only loosely connected. Also, our analysis captures a period in which firms became increasingly involved in interfirm collaboration, allowing us to observe the gradual insertion of poorly embedded firms into the network structure.

We obtained financial data for the firms from Compustat, Worldscope, trade publications, company annual reports, *Japan Company Handbook*s (published quarterly by Toyo Keizai, Inc., Tokyo, Japan), and Daiwa's *The Analyst's Guide* (published by Daiwa Institute of Research Ltd.). We converted financial data to constant (1985) U.S. dollars. We lagged all independent variables.

Dependent variables

Alliance formation

The dependent variable in Hypotheses 1, 2, and 4 is the formation of an alliance between two firms in a given year from 1983 to 1991. The unit of analysis is the dyad; we considered all possible dyads, excluding reverse-ordered pairs. We adjusted the dataset to account for mergers and acquisitions that occurred during the study period. Adopting the full risk set to avoid selection bias is consistent with the research strategy in studies of alliances at the dyadic level (Gulati and Gargiulo, 1999). Such a strategy is particularly important in this study, because we want to examine the formation of alliances by firms that are poorly embedded in the network structure, including firms that have not previously engaged in interorganizational collaboration. For each dyad-year observation, we

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coded a dichotomous dependent variable indicating whether that pair of firms formed a technology-related alliance during that year. We considered all dyadic observations for alliances involving more than two partners.

Majority ownership

The dependent variable in Hypothesis 3 is the holding of a majority ownership position by a firm in a joint venture. We gathered data on the ownership structure at the time of creation for each joint venture in the sample. We initially obtained information on the ownership structure of 140 dyads among the 178 joint ventures the firms formed between 1983 and 1991. We were unable to obtain financial data on 12 of these dyads, which reduced our final sample to 128 dyads. We created a dummy variable with value set to one if the firm with the highest level of embeddedness in a dyad held a majority ownership position, that is, if its share in the equity of the joint venture was greater than 50 percent. We also defined an alternative measure, calculated as the ratio between the share owned by the partner with the highest centrality score and the share of the partner with the lowest centrality score.

Independent variables

Combined centrality (H1)

In line with prior work, we measured the position of each firm in the network using Bonacich's (1987) eigenvector measure. This measure captures either status or centrality, depending on whether the network structure captures asymmetric or symmetric ties, respectively (Bonacich, 1987: 1173). Podolny (1994) examined ties between investment banks, as reported in announcements of security offerings. These ties are asymmetric because the ordering of banks in those announcements indicates differences in prestige across banks in a syndicate network. Hence, Bonacich's (1987) eigenvector measure captures banks' status in syndicate networks. Gulati and Gargiulo (1999) examined network structures emerging from the formation of alliances between firms. Interfirm alliances represent symmetric ties since an alliance between two firms does reflect their position relative to each other. As a result, Bonacich's (1987) eigenvector measure captures firm centrality in networks mapping strategic alliances. The network we examine also consists of interfirm alliances, where the eigenvector measure appropriately captures firm centrality (Bonacich, 1987). This measure results in higher centrality scores for firms that are linked to many firms, which are in turn linked to many other firms. Higher centrality scores correspond to higher levels of embeddedness. To keep our measure consistent with that used in prior studies, we used the centrality score of a firm in a given year relative to the most central firm in that year (Gulati and Gargiulo, 1999) and computed the geometric mean of the centrality scores of the two members of the dyad (Mizruchi, 1993; Gulati and Gargiulo, 1999). Models with an alternative measure considering the arithmetic mean of the centrality scores of the firms in the dyad produced a similar pattern of results.

To compute network centrality scores, we constructed the industry network for each year, considering the alliance activities of the sample firms in the previous years. We followed the same procedure of prior work (e.g., Gulati, 1995b; Gulati and Gargiulo, 1999) and constructed the network structure for a given year based on the alliances that firms formed in the previous years. The results we report in the study are based on network structures that consider ties in the previous four years. Results are robust to the use of alliance activity in the previous three or the previous five years when building the network structure. We constructed adjacency matrices for each year to compute the centrality scores, where the matrices represent the relationships between the 97 firms in the previous four years. We weighted the interorganizational links to account for differences in strength between technical agreements and joint ventures (Contractor and Lorange, 1988; Nohria and Garcia-Pont, 1991). To assess the robustness of the results, we constructed alternative network structures, considering non-weighted ties. We computed the centrality scores using UCINET 5 (Borgatti, Everett, and Freeman, 1999).

Dyad asymmetry (H2)

The measure Combined Centrality described above does not fully capture dyads with asymmetric centrality scores because the measure results in similar values for asymmetric dyads, that is, dyads in which one firm has a high and the other has a low centrality score, and dyads in which the two firms have moderate centrality scores (Mizruchi, 1992). Hence, we adopted Mizruchi's (1992) procedure for distinguishing those cases, using dummy variables to identify dyads involving firms with low centrality and dyads between firms with asymmetric levels of centrality. To characterize alliances between poorly embedded firms, we created the variable *low centrality dyad*, which equaled one if both firms in the dyad had centrality scores lower than the mean score in the observation year and zero otherwise. Similarly, we created the variable *socially asymmetric dyad*, which equaled one if one of the firms in the dyad had a centrality score lower than the mean while the other had centrality score equal to or greater than the mean observed in a given year and zero otherwise.

Minority positions (H4)

We needed to examine how a firm's acceptance of minority position in a joint venture with a highly embedded partner influences its ability to form subsequent alliances with partners that are more deeply embedded in the network structure. To do so, we identified the proportion of minority positions that the firm with the lowest centrality score in a dyad formed with a partner with higher centrality relative to all alliances formed by that firm. We obtained similar results when we ran additional analyses with the pure count of the minority positions held by the firm with the lowest centrality score. Hypothesis 4 refers to the effect of those minority positions on the propensity of peripheral firms to form new alliances. For the cases in which the less embedded firm in a dyad was poorly embedded, we created the variable *proportion of minority positions-peripheral firm*. To control for the effect of minority positions on the formation of new alliances by central firms, we created the variable *proportion of minority positions-central firm.*

Centrality asymmetry (H3)

We measured the difference in the level of embeddedness between two partners in a joint venture by subtracting the centrality score of the firm with lower centrality from the centrality score of the other firm in the dyad.

Control variables

Resource similarity

Previous literature shows that resource needs influence alliance formation. Some scholars have argued that firms possessing similar resources are more likely to become allies, either because resource similarity is associated with interdependence (Pfeffer and Nowak, 1976), or because it is conducive to mutual learning (Mowery *et al*., 1996; Lane *et al*., 2001). Other authors have argued that the quest for complementary capabilities and resources drives alliance formation (Gulati and Gargiulo, 1999; Chung *et al*., 2000). These two sets of arguments suggest that alliances result at times from firms' intention to pool similar resources, and other times from their desire to combine complementary resources (Dussauge, Garrette, and Mitchell, 2000). To control for the impact of resources on the propensity of certain dyads to create alliances, we constructed measures of resource similarity in regard to technical, geographic, and product-market resources. To account for the possibility of a nonmonotonic effect of resource similarity on alliance formation, we estimated models with the squared terms for each of these three types of resources. The analysis showed a curvilinear effect only for technical similarity; hence, the results we report consider only the squared term for the similarity of technical resources.

To measure the similarity of the technical resources that two firms possessed, we considered the distribution of firms' inventions across 80 technological classes that chemical companies use. Previous studies have used patents as indicators of technological resources (Griliches, 1990; Patel and Pavitt, 1995; Hall, Jaffe, and Trajtenberg, 2001). For each firm in the sample, we counted the number of patent applications in each technological class in a given year. Then, for each firm, we computed the proportion of all patents in each technological class. To capture the resource similarity between firms i and j in year t, we created the variable *technical similarity*. The variable took the value $2 - \Sigma_{k=1,80}\ (PP_{ikt} - PP_{jkt})^2$, where PP_{ikt} (PP_{jkt}) corresponds to the proportion of patents that firm i (firm j) applied for in technological class k in year t.

To measure geographic resources, we considered the number of subsidiaries that each firm owned in each of 156 countries in each year. For each

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firm we identified all the subsidiaries it owned in the period between 1982 and 1990 and computed the proportion of subsidiaries in each country. To measure the geographic similarity between firms i and j in year t, we created the variable *geographic similarity*. The variable took a value equal to $2 - \Sigma_{k=1,156}\ (PS_{ikt} - PS_{jkt})^2$, where PS_{ikt} (PS_{jkt}) corresponds to the proportion of subsidiaries that firm i (firm j) owns in country k in year t.

We created the variable *product-market similarity* to capture the similarity between two firms in terms of the product markets they are active in, based on the proportion of sales they obtained in each of 120 market segments defined at the level of four-digit Standard Industrial Classification code. This variable took a value equal to $2 - \Sigma_{k=1,120}\ (PM_{ikt} - PM_{jkt})^2$, where PM_{ikt} (PM_{jkt}) corresponds to the proportion of sales that firm i (firm j) obtained in market k in year t.

Previous alliances

Previous studies show that two firms are more likely to ally if they accumulate a history of direct ties (Gulati and Gargiulo, 1999; Chung *et al*., 2000). We created the variable *previous alliances* to control for that effect, using the number of links that any pair of firms had formed in the past. We obtained similar results when considering only alliances formed in the previous three, four, or five years. To account for the possibility that the effect of prior direct ties on the likelihood of alliance formation increases nonmonotonically (e.g., Chung *et al*., 2000), we also included the variable *previous alliances squared*.

Financial measures

We included several financial controls to account for the possibility that differences between firms in terms of financial performance or financial resources affect their propensity to collaborate. The control variable for performance was based on return on assets and subtracted the lesser from the greater value within each dyad. For *size, liquidity*, and *debt-equity*, we used the ratio of the lesser to the greater value within the dyad. Size was total assets in chemical industry that each firm possessed. Liquidity was the ratio of current assets to current liabilities. Finally, we included the debt-equity ratio to address leverage. Previous work at the dyadic level has used similar ratio measures as control variables (Gulati and Gargiulo, 1999).

Technical resources

Two control variables addressed the possibility that differences between two firms in relation to the amount of technical resources they possess influence their propensity to create an alliance. *Chemical patents* contains the ratio between the chemical patents that each firm possessed in a given year, from the lesser to the greater number. *Chemical R&D* is a similar ratio, based on the amount that each firm invested in research and development in the chemical industry.

Year dummies

To control for the possibility that unobserved temporal factors or other unspecified events affected the propensity of firms to create alliances, we added dummy variables for each year between 1984 and 1991 with 1983 as the default year.

Our test for how social asymmetry influences terms of trade (H3) includes several control variables. We control for the possibility that the number of participants in a joint venture affects the likelihood that a given firm will hold majority ownership. We also account for the possibility that similarity between the partners in terms of technical, geographic, and product market affects the propensity of the partner with the highest embeddedness in a joint venture to secure a majority ownership position. Moreover, we control for the effect of previous collaborations on the propensity of more embedded firms to hold a majority ownership position. Finally, we account for the influence that financial and technical resources have on the equity positions that partners negotiate.

Tables 1 and 2 report descriptive statistics for the dependent and independent variables we use in the study. The correlations report no particularly strong associations among the independent variables, other than between the main and squared term for combined centrality, technical similarity, and prior alliances.

Model estimation and econometric issues

The dependent variable in Hypotheses 1, 2, and 4 denotes whether two firms formed an alliance in a given year (alliance formation$_{ijt} = 1$ or alliance

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Table 1. Descriptive statistics and correlation matrix—alliance formation

Variable	Mean	S.D.	Min	Max	1	2	3	4	5	6	7
1. Alliance formation	0.01	0.10	0	1							
2. Combined centrality	0.08	0.12	0	0.97	0.09						
3. Combined centrality squared	0.02	0.06	0	0.95	0.09	0.89					
4. Socially asymmetric dyad	0.44	0.50	0	1	0.00	0.00	−0.11				
5. Low centrality dyad	0.45	0.50	0	1	−0.05	−0.45	−0.30	−0.80			
6. Proportion minority positions - peripheral firm	0.05	0.19	0	1	−0.02	−0.10	−0.07	0.01	0.05		
7. Proportion minority positions - central firm	0.00	0.02	0	0.5	0.02	0.24	0.21	−0.10	−0.09	−0.03	
8. Technical similarity	1.51	0.22	0.59	2	0.06	0.28	0.20	0.09	−0.20	−0.04	0.07
9. Technical similarity squared	2.32	0.62	0.35	4	0.06	0.29	0.21	0.09	−0.21	−0.05	0.08
10. Geographic similarity	1.47	0.41	0	2	0.05	0.14	0.12	−0.07	−0.01	0.02	0.02
11. Product-market similarity	1.29	0.15	0.78	1.96	0.06	0.22	0.16	0.07	−0.17	−0.07	0.04
12. Previous alliances	0.07	0.32	0	7	0.14	0.30	0.33	−0.03	−0.11	−0.02	0.07
13. Previous alliances squared	0.11	0.80	0	49	0.13	0.22	0.26	−0.03	−0.07	−0.01	0.05
14. Size	0.37	0.27	0	1	0.01	0.04	0.03	−0.03	0.02	−0.01	0.03
15. Performance	0.03	0.03	0	0.27	−0.03	−0.09	−0.06	−0.03	0.08	0.13	0.00
16. Liquidity	0.70	0.19	0.14	1	0.03	0.10	0.08	−0.03	−0.01	−0.07	0.02
17. Debt-equity	0.49	0.26	0.01	1	0.02	0.07	0.04	0.00	−0.02	−0.04	0.02
18. Chemical R&D	0.33	0.28	0	1	0.01	0.00	0.01	−0.04	0.04	0.01	0.00
19. Chemical patents	0.70	0.39	0	1	0.03	0.18	0.11	0.01	−0.09	0.02	0.04

Variable	8	9	10	11	12	13	14	15	16	17	18
9. Technical similarity squared	0.99										
10. Geographic similarity	0.12	0.12									
11. Product-market similarity	0.30	0.32	0.07								
12. Previous alliances	0.11	0.12	0.13	0.12							
13. Previous alliances squared	0.07	0.07	0.09	0.07	0.84						
14. Size	0.02	0.02	0.02	−0.02	0.03	0.03					
15. Performance	0.01	0.01	−0.12	−0.10	−0.07	−0.05	0.03				
16. Liquidity	0.03	0.03	0.26	0.01	0.07	0.05	0.03	−0.14			
17. Debt-equity	0.08	0.08	0.17	0.05	0.06	0.04	−0.05	−0.25	0.31		
18. Chemical R&D	0.00	0.00	0.00	−0.08	0.02	0.02	0.54	0.04	0.01	−0.06	
19. Chemical patents	0.22	0.22	0.07	0.15	0.06	0.05	−0.07	0.00	−0.02	0.05	−0.14

formation$_{ijt} = 0$). We tested these hypotheses using the probit specification, which models the likelihood of alliance formation, that is, π_{ijt}, where $\pi_{ijt} = \text{Pr (alliance formation}_{ijt} = 1)$ and $(1 - \pi_{ijt}) = \text{Pr (alliance formation}_{ijt} = 0)$. In the probit model, $\Phi^{-1}(\pi_{ijt}) = X_{ijt-1}\beta + \varepsilon_{ijt}$, where X_{ijt-1} is a vector of lagged time-varying covariates, β is a vector of estimated coefficients, ε_{ijt} is a normally distributed error term, and Φ^{-1} is the inverse of the cumulative normal density function. Unobserved time-invariant effects that the remaining variables do not capture may influence the propensity of alliance formation. Consequently, we ran additional models using the random-effects panel probit specification, which accounts for the presence of such effects. These additional analyses showed that the dyadic-level variance was unimportant and that the random-effects estimator is not different from the probit estimator. In sensitivity analyses, we found similar results with a logit specification. We report results from the probit model with robust standard errors adjusted for clustering at the dyadic-level to allow for nonindependence of observations referring to the same pair of firms and correct for heteroskedasticity (Greene, 2003).

To test Hypothesis 3, we used a probit regression model predicting the likelihood that a firm will hold a majority position in a joint venture. In the specification, $\Phi^{-1}(\pi_{ijt}) = X_{ijt-1}\beta + \varepsilon_{ijt}$, where π_{ijt} represents the likelihood that firm i, the one with the greatest centrality score in a dyad, will

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Table 2. Descriptive statistics and correlation matrix—term of trade

Variable	Mean	S.D.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12
1. Majority ownership	0.13	0.34	0	1												
2. Centrality asymmetry	0.27	0.27	0	1	0.14											
3. Number of partners	2.60	0.97	2	7	−0.11	0.11										
4. Previous alliances	0.53	0.80	0	5	−0.05	−0.05	0.20									
5. Technical similarity	1.64	0.16	0.94	2	−0.01	0.11	0.08	0.20								
6. Geographic similarity	1.58	0.40	0.39	1.99	−0.15	0.20	0.38	0.16	0.16							
7. Product-market similarity	1.37	0.16	1.03	1.88	0.06	−0.01	−0.10	0.23	0.31	−0.04						
8. Size	0.39	0.26	0.02	1	0.18	0.01	−0.02	0.21	0.16	0.01	0.29					
9. Performance	0.03	0.03	0.00	0.22	0.07	−0.02	−0.23	−0.10	0.05	−0.24	−0.01	0.04				
10. Liquidity	0.74	0.17	0.27	1	−0.07	−0.03	0.23	0.05	−0.01	0.30	−0.03	−0.04	−0.29			
11. Debt-equity	0.54	0.24	0.06	1	−0.03	−0.01	0.02	0.00	0.01	−0.01	0.00	0.04	−0.17	0.49		
12. Chemical R&D	0.31	0.26	0	1	−0.06	0.01	0.16	0.21	0.05	0.13	0.07	0.58	−0.08	−0.01	0.10	
13. Chemical patents	0.83	0.33	0	1	0.00	0.04	0.16	0.19	0.25	0.08	0.21	0.06	−0.12	−0.04	−0.01	−0.05

hold a majority ownership position in a joint venture formed with firm j in year t; X_{ijt-1} is a vector of parameters with lagged independent and control variables; β is a vector of estimated coefficients and Φ^{-1} is the inverse of the cumulative normal density function.

RESULTS

Table 3 presents the results of the probit models for Hypotheses 1, 2, and 4. The regression models added variables reflecting the hypothesized effects sequentially. Model 1 is the base model, containing only the control variables. The results concerning hypothesized effects are consistent across all models.

The results in Table 3 support Hypothesis 1, showing that combined embeddedness has a nonmonotonic impact on alliance formation. The coefficient on *combined centrality* in Model 2 is positive and statistically significant. This is consistent with previous studies showing that the informational and reputational benefits accruing to central firms make two firms occupying central positions in the preexisting network structure more likely to ally with each other (Podolny, 1994; Gulati and Gargiulo, 1999). Nonetheless, as our analysis shows, very high levels of centrality have a negative impact on the formation of interorganizational ties. The coefficient on *combined centrality squared* reveals that the combined embeddedness of two firms has a positive impact on alliance formation up to a level, but, beyond that level, reduces their propensity to create a tie. Moreover, in sensitivity analysis we verified that the addition of the squared term actually improves model fit, which further enhances confidence that combined centrality exerts a nonmonotonic effect on the likelihood of alliance formation. The combined centrality of two firms has the largest positive impact on alliance formation when it is around 0.55, which lies well within the observed data range of 0 to 0.97. Beyond that threshold level, combined centrality decreases firms' propensity to ally. However, the number of dyads exhibiting combined centrality beyond such a point is relatively small. Despite the evidence that for at least some dyads combined centrality exerts a negative effect on alliance formation, which indicates an inverted U relationship between combined centrality and the likelihood of alliance formation, the

Table 3. Probit estimates of influences on likelihood of alliance formation by firm dyads

	Model 1	Model 2	Model 3	Model 4	Model 5
Combined centrality (H1: +)		1.60•••		1.59•••	1.54•••
		(0.32)		(0.47)	(0.47)
Combined centrality squared (H1: −)		−1.45••		−1.30••	−1.24•
		(0.51)		(0.57)	(0.58)
Socially asymmetric dyad (H2: > low centrality dyad)			−0.12••	0.09	0.10
			(0.06)	(0.08)	(0.08)
Low centrality dyad			−0.30•••	0.00	0.01
			(0.07)	(0.11)	(0.11)
Proportion minority positions - peripheral firm (H4: −)					−0.36•
					(0.21)
Proportion minority positions - central firm					0.10
					(0.70)
Technical similarity	−2.68••	−2.40•	−2.57•	−2.45•	−2.39•
	(1.10)	(1.13)	(1.13)	(1.13)	(1.13)
Technical similarity squared	1.18••	1.04••	1.11••	1.05••	1.03••
	(0.38)	(0.39)	(0.38)	(0.39)	(0.39)
Geographic similarity	0.27•••	0.25•••	0.27•••	0.26•••	0.27•••
	(0.06)	(0.07)	(0.06)	(0.07)	(0.07)
Product-market similarity	0.66•••	0.58•••	0.58•••	0.58•••	0.57•••
	(0.13)	(0.13)	(0.13)	(0.13)	(0.13)
Previous alliances	0.54•••	0.44•••	0.48•••	0.44•••	0.44•••
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
Previous alliances squared	−0.04•	−0.03	−0.03†	−0.03	−0.03
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Size	0.01	−0.01	0.01	−0.01	−0.01
	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)
Performance	−3.43•••	−2.92••	−3.16••	−2.86••	−2.70••
	(1.00)	(1.02)	(1.01)	(1.01)	(1.02)
Liquidity	0.26•	0.21†	0.25•	0.21†	0.20
	(0.12)	(0.12)	(0.12)	(0.13)	(0.13)
Debt-equity	−0.02	0.00	−0.01	0.01	0.01
	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)
Chemical R&D	0.03	0.04	0.05	0.04	0.04
	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)
Chemical patents	0.21••	0.17••	0.20••	0.17••	0.18••
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
Constant	−2.73••	−2.71••	−2.42••	−2.72••	−2.75••
	(0.86)	(0.88)	(0.87)	(0.88)	(0.88)
Year dummies	included	included	included	included	included
Log-likelihood	−1828.17	−1810.68	−1816.20	−1808.69	−1806.70
Observations	37 124	37 124	37 124	37 124	37 124

† $p < 0.10$; • $p < 0.05$; •• $p < 0.01$; ••• $p < 0.001$; one-tailed tests for hypotheses.
Robust, heteroskedasticity-adjusted standard errors in parentheses.

relatively small number of observations in that category calls for caution in the interpretation of this relationship.

To test Hypothesis 2, we compare the coefficients on *socially asymmetric dyad* and *low centrality dyad* using a Wald Test for difference of coefficients. The hypothesis predicts that the coefficient on *socially asymmetric dyad* will be higher than the coefficient on *low centrality dyad*. The inclusion of these two dummies leaves dyads between two high-centrality firms as the omitted category. Because the *combined centrality* variable also partly captures the influence that arises from high centrality of two firms (Mizruchi, 1993), we first include these two variables in Model 3 without the variable for combined centrality. As expected, the coefficient on *socially asymmetric dyad* is statistically greater than the coefficient on *low centrality dyad* at p-levels < 0.001. This comparison supports Hypothesis 2, showing that

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poorly embedded firms are more likely to ally with highly embedded firms than to partner with firms that are also poorly embedded in the network structure. Moreover, both coefficients are negative and statistically significant, confirming the evidence found in prior studies that alliances involving peripheral firms are less likely than alliances involving central partners. This pattern of results continues to hold even in models that add the variables for *combined centrality, socially asymmetric dyad*, and *low centrality dyad* simultaneously. The coefficient on *socially asymmetric dyad* is still significantly greater than the coefficient on *low centrality dyad* in Models 4 and 5, although the significance levels decline (p-levels < 0.07) due to the confound with *combined centrality*.

A concern in the interpretation of the results supporting Hypothesis 2 is that such evidence might be affected by right-skewed centrality scores. In this case, the fact that poorly embedded firms are more likely to ally with central firms rather than with peripheral firms could arise from the existence of more high-centrality firms that could be considered as potential partners. However, the distribution of centrality scores in our sample is skewed to the left, with only between 26 percent and 37 percent of firms having centrality score above the mean in a given year. This evidence dispels the concern that skewness in centrality scores might have affected our results.

The results in Table 3 also support Hypothesis 4. As Model 5 shows, the coefficient on the variable *proportion of minority positions–peripheral firm* is negative and significant. This result reveals that poorly embedded firms that have accepted unfavorable terms of trade in the form of a minority ownership position in joint ventures with more embedded firms, are less likely to form new alliances with firms that are more deeply embedded in the network structure. This finding is consistent with the argument that accepting unfavorable terms of trade indicates that peripheral firms have less to offer to potential partners and/or will face constraints on their future activities. The coefficient on the variable *proportion of minority positions–central firm* is not significant. This indicates that the finding relative to minority positions hinders the formation of alliances with more central partners only for poorly embedded firms. That is, accepting unfavorable terms of trade does not affect the formation of subsequent ties for central firms, even though minority positions inhibit the creation of subsequent relationships by peripheral firms.

Several control variables in Table 3 influence alliance formation. The coefficients on *technical similarity* and the respective squared term suggest that moderate levels of technical similarity are conducive to alliance formation. When technical resources are too dissimilar, partners have difficulty understanding the partners' technologies; when they are too similar, allies have less to learn from partners (Cohen and Levinthal, 1990; Mowery *et al*., 1996; Lane *et al*., 2001). Both cases diminish firms' propensity to form an alliance. The coefficients on *geographic similarity* and on *product-market similarity* are positive and statistically significant. Additional analyses with the squared term of these two types of resources did not suggest the presence of a nonmonotonic effect. Thus, the propensity of alliance formation increases when the firms' geographic and product-market resources are similar. Most likely this is because the similarities increase firms' abilities to affect each other's performance in those markets, encouraging them to form an alliance to manage competitive interdependence (Pfeffer and Nowak, 1976). Whereas prior studies have proposed that both similarity and dissimilarity of resources can make firms more likely to ally, our findings indicate that the effect of similarity or dissimilarity varies across types of resources.

The coefficients on *previous alliances* and the respective squared term indicate that the formation of alliances is more likely to occur between partners that have collaborated in the past. However, as firms accumulate direct ties, they may anticipate diminishing returns from forming an additional alliance, thus avoiding the creation of an additional direct tie (Chung *et al*., 2000). The negative coefficient on *performance difference* indicates that firms with great differences in performance are less likely to form alliances, and the more similar the performance of two firms, the more likely they are to create a tie. Finally, the coefficient on *chemical patents* suggests that firms with a similar number of patents have greater propensity to ally.

Table 4 reports the tests of Hypothesis 3. The results support the prediction that a firm is more likely to hold a majority ownership position in a joint venture when it is significantly more embedded than its partner. The coefficient on *centrality asymmetry* is positive and statistically significant

Table 4. Probit estimates of influences on likelihood of majority ownership by central firm

	Model 1	Model 2
Centrality asymmetry (H3: +)		1.06••
		(0.54)
Number of partners	−0.08	−0.11
	(0.15)	(0.17)
Technical similarity	−0.18	−0.43
	(1.04)	(1.03)
Geographic similarity	−0.53	−0.78
	(0.48)	(0.50)
Product-market similarity	0.08	−0.10
	(0.86)	(0.91)
Previous alliances	−0.11	−0.03
	(0.19)	(0.19)
Size	1.69•••	1.71•••
	(0.63)	(0.65)
Performance	0.39	0.07
	(3.56)	(3.86)
Liquidity	−0.10	0.09
	(0.93)	(0.98)
Debt-equity	−0.03	0.00
	(0.70)	(0.68)
Chemical R&D	−1.17•	−1.30•
	(0.69)	(0.70)
Chemical patents	−0.10	−0.12
	(0.52)	(0.49)
Constant	0.06	0.61
	(1.89)	(1.94)
Log-likelihood	−44.66	−42.81
Observations	128	128

• $p < 0.10$; •• $p < 0.05$; ••• $p < 0.01$; one-tailed test for hypothesis.
Robust standard errors in parentheses.

at p-levels < 0.05. Thus, the greater the difference in the embeddedness of two firms, the greater the chances that the less embedded firm will accept a minority ownership position in the joint venture. In sensitivity analyses, we checked that the results are robust to including year dummies in the model as well as to specifying the dependent variable as the logarithm of the ratio between the share of the partner with the high embeddedness and the share of the partner with low embeddedness. We also ran models without financial controls, so as to use all 140 dyads in the regression and obtained similar results for *centrality asymmetry*.

DISCUSSION AND CONCLUSIONS

Previous research shows that above and beyond the need to access resources, firms' positions in the preexisting network structure affect the formation of new alliances. Further, prior research demonstrates that firms that are highly embedded in the network structure are more likely to ally with highly embedded counterparts, which prompts the question of whether and how poorly embedded firms participate in alliances. Our examination of global chemical firms' alliance activities between 1979 and 1991 explores the factors that influence the formation of alliances by peripheral firms.

Four results stand out. First, the degree of combined centrality of two firms has a nonmonotonic impact on the likelihood that they will form an alliance. Thus, firms that are more central in the network structure are initially more likely to form an alliance, a pattern that is consistent with evidence that prior studies found. However, as the level of combined centrality increases, its effect on alliance formation diminishes, eventually making firms with very high levels of combined centrality less likely to ally. This finding points to the decreasing marginal benefits of embeddedness as a guide in alliance formation and suggests the existence of incentives for central firms to ally with less embedded partners. Second, peripheral firms are more likely to ally with central partners than to create ties with other peripheral firms. Third, a firm is more likely to secure more favorable terms of trade, in the form of a majority ownership position in joint ventures, when allying with a less embedded partner. Thus, central firms can use their embeddedness as positions of power in negotiating relationship agreements. Finally, we found that accepting unfavorable terms of trade, which is a strategy that can help a poorly embedded firm attract a highly embedded partner, hinders subsequent social mobility by reducing the chances of that firm to participate in new alliances. Thus, minority positions may offer initial expansion opportunities but constrain further expansion.

We began this study with two overarching questions. First, we were interested in understanding how poorly embedded firms form linkages. Second, we wanted to explore how the alliance choices of less embedded firms influence network dynamics. Our findings have implications for both issues.

The initial overarching implication is that structural homophily offers only a partial explanation of partnering choices. While structural homophily

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may explain the linkage behavior of embedded firms, there are limits to its strength in predicting the linkage behavior of less embedded firms. This study suggests that at least three factors limit the influence of structural homophily in explaining the alliance behavior of peripheral firms. First, alliance formation is likely to derive from a calculus of incentives as well as of constraints. Previous research has emphasized the constraints that poorly embedded firms face when searching for alliance partners, but has underemphasized the incentives for creating ties between allies with asymmetric levels of embeddedness. A densely embedded firm may be willing to link with a peripherally positioned partner and thereby avoid overreliance on embeddedness when choosing allies. Second, while forming coalition or insurgent partnerships with other peripheral firms is possible (Emerson, 1972; Baum *et al*., 2003), in practice this strategy must take into account that peripheral partners may not be as attractive, in instrumental or social terms, as more densely embedded ones (Podolny, 1994; Gulati and Gargiulo, 1999). Finally, a third reason why the focus on structural homophily may be overstated is because prior research has not focused on the possibility that the terms of trade in an alliance provide a mechanism by which less embedded firms may entice more embedded firms to link with them, thus making heterophilous relationships more likely. This last point draws attention to a secondary benefit of embeddedness: embeddedness not only makes a firm more likely to participate in alliances, but also enables it to obtain favorable terms of trade in those relationships.

The second overarching implication concerns network dynamics. Prior research on interorganizational networks shows that firms highly connected in the preexisting network structure are more likely to form subsequent ties with highly connected partners, implying that network structures tend to self-reproduce themselves over time (Gulati and Gargiulo, 1999). This study shows that although reliance on the structural positions of firms in the preexisting structure encourages alliance formation between well-connected firms, poorly embedded firms do manage to form alliances, sometimes by offering central partners better terms of trade in relationship governance. As a result, the formation of alliances between socially asymmetric partners partially attenuates the self-reproducing character of interorganizational networks.

Examining situations under which poorly embedded firms may be able to form ties with well-connected partners also has implications for studies on the mechanical properties of complex networks. Models assuming that networks expand continuously and that new nodes attach preferentially to well-connected nodes have enabled scholars to show that even very large networks, such as those mapping links between documents in the World Wide Web and those capturing patterns of citations to scientific papers, can achieve a high degree of self-organization (Barabasi and Albert, 1999). These models, whereas assuming that new nodes are more likely to form ties with central nodes, do not explain why a connected node is willing to form a tie with a new node. Explaining the formation of ties between a well-connected and a poorly connected node is important in the context of interorganizational networks, given that firms face constraints in the amount of resources they allocate to the formation and maintenance of interfirm alliances and, as a result, cannot simply scale up and keep carrying increasingly more ties.

At the same time that this study shows that poorly connected firms can offer central partners better terms of trade in relationship governance, it suggests that there are limits to the utility of governance discounting as a mechanism for social mobility. In particular, the results reveal strong constraints on poorly embedded firms' abilities to undertake a strategy of 'creeping toward the center.' We find that less embedded firms frequently are willing to undertake minority positions to obtain relationships with more central firms. Such partnerships increase their own centrality. In turn, however, the minority positions then inhibit subsequent partnerships and make it difficult to move further toward the center. Thus, the most effective strategy for creeping toward the center is to develop sufficient strength that a central firm will be willing to form a parity relationship making it easier for the peripheral firm to form additional central relationships. Clearly, peripheral firms face strong constraints in the ability to develop superior resources. Hence, the evolution of network structure will tend to be gradual, rather than dramatic and transformational.

This study focuses on the impact of social asymmetry on alliance formation rather than alliance performance. The effects of structural homophily and heterophily on alliance outcomes offer intriguing questions that merit investigation. For instance,

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the compatibility of informational and reputational benefits enjoyed by highly embedded firms may enable them to form more stable partnerships. On the other hand, alliances between structurally similar partners may be redundant, thereby reducing the longevity of such ties.

In terms of network dynamics, this study shows that, despite the possibility of peripheral firms to ally with central partners by accepting less favorable terms of trade, the network will tend to evolve gradually. Prior work has suggested that the more firms form alliances and the more their positions in the network becomes apparent, the more difficult it becomes for a peripheral firm to ally with a central partner (Gulati and Gargiulo, 1999). Another possibility is that, as alliance activity becomes more intense, central firms attend less to social cues and become more inclined to partner with peripheral firms, thus discounting the negative signal associated with these potential allies' acceptance of less favorable terms in prior alliances. Future research can elucidate whether firms will attend more or less to social cues over time.

Finally, exogenous shocks represent another possibility for the transformation of preexisting structures. It would be useful to explore whether the gradual inclusion of peripheral firms into the network structure affects the vulnerability of that structure to disruption by radically new technologies. It is possible that firms in a network structure with ties that span socially asymmetric partners will be more able to respond to technological shocks. Whether shortening social distance between the members of a network provides a hedge against exogenous transformational effects needs to be further examined.

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