GEERT DUYSTERS AND CHARMIANNE LEMMENS

Alliance Group Formation

Enabling and Constraining Effects of
Embeddedness and Social Capital in Strategic
Technology Alliance Networks

Abstract: *We examine the role of embeddedness and social capital in the process of alliance group formation in strategic technology alliance networks. In particular, we study the social mechanisms that enable and enforce alliance group formation. We argue that the enabling effect of embeddedness during the first stages of the group formation process may turn into paralyzing effects as the group formation process progresses. Through the formation of subsequent ties, firms in social systems tend to rely heavily on their direct and indirect contacts in forming new partnerships. This so-called local search enables firms to create trustworthy and preferential relations. Over time, those relations tend to develop into strong ties, as firms rely on the same partners by replicating their existing ties. This enabling effect of embeddedness at the group level can, however, turn into a paralyzing effect as actors become locked-in, because they rely on partners only in their closed social system. Searching for, or switching to, partners outside of the alliance group is not likely, particularly when trustworthy partners are already available in this system. The firms in alliance groups tend to become more similar over time as a result of contagion and the replication of their existing ties. This so-called phe-*

nomenon of over-embeddedness, induced by the paralyzing effects of embeddedness at the group level, can lead to decreasing opportunities for learning and innovation for the group members involved. By means of descriptive empirical evidence, we establish some of the enabling and paralyzing effects of embeddedness in the worldwide microelectronics industry from 1970 to 2000.

In the academic literature on strategic alliances, interdependence and complementarities have been addressed as the most common explanations of *why* firms form interorganizational ties (Richardson 1972; Pfeffer and Nowak 1976; Nohria and Garcia-Pont 1991). This stream of research has made significant progress in examining the factors that determine the propensity of firms to form alliances, in terms of their exogenous dynamics.

The decision as to which other firms they should bind themselves to is less clear, however (Gulati and Gargiulo 1999). This so-called endogenous dynamic refers to building preferential relationships, which are characterized by trust, stability, and a rich exchange of information among partners (Dore 1983; Powell 1990; Gulati and Gargiulo 1999). Some academic attention has focused on the role of social structural context as an important driving factor in the alliance formation process (e.g., Gulati 1995a; Walker, Kogut, and Shan 1997; Gulati and Gargiulo 1999; Chung, Singh, and Lee 2000). This social structural context refers to embeddedness as well as to social capital influencing the decision of with whom to tie up.

Embeddedness refers to the structure of a network of social relations and implies that the partners' relations affect economic actions, its outcomes as well as the behaviors of firms in the network (e.g., Granovetter 1992; Gulati 1998). Embeddedness thus influences the firms' tying behavior because it enables preferential relations to emerge from the social capital that firms have built up in their past partnerships. Thus, social capital is by its very nature dependent on history and enables firms to rely on both direct and indirect alliance-experiences in partner selection (Chung, Singh, and Lee 2000). Since the partner search process is costly and time-consuming, firms tend to engage in local search for forming their subsequent ties. Engaging in preferential partnering tends to reduce the search costs of finding the right partners with complementary resource configurations, and it eases the risk of opportunistic behavior among the partners involved (Gulati and Gargiulo 1999). In this way, social capital drives the alliance formation process (Chung, Singh, and Lee 2000), where the current relations of firms stem from their prior relational activities and form the basis on which the actor establishes future social relations (Gulati 1998; Walker, Kogut, and Shan 1997; Chung, Singh, and Lee 2000).

Most of the theoretical contributions on network evolution (e.g., Gulati 1998; Walker, Kogut, and Shan 1997) assert that network formation proceeds through the formation of new technology relationships, building on the experience with existing firm ties. Through preferential partnering, firms become embedded in densely connected networks of relations. Engaging in new collaborations based

on social capital by replicating existing ties typically results in the formation of densely connected cliques or groups of collaborative relationships consisting of firms that are all mutually connected through multiple alliances. We refer to this phenomenon as alliance group formation. These closely connected parts of the network are characterized by shared values, norms, and trust among alliance partners. This provides a strong basis of trust and intimacy for the companies involved (see Krackhardt 1992; Brass, Butterfield, and Skaggs 1998; Granovetter 1973) and for further reproduction of this collective asset.

Apart from this network-enabling effect of embeddedness, the academic literature has given much less attention to the constraining effects of embeddedness in the decision of with whom to partner. Therefore, in this article, we try to study empirically how the social mechanisms that cause the enabling effect of embeddedness in alliance formation that is based on preferential relations can turn into a paralyzing effect as actors become locked-in, when they rely on partners only in their own closed social system in alliance groups. Over time, those firms may start to suffer from "over-embeddedness" (Uzzi 1997) in technological as well as in relational terms. We will discuss questions such as: does the network-enabling effect result in alliance group formation as the alliance network formation process proceeds? Do firms replicate their ties within the alliance group? And does the paralyzing effect of embeddedness result in technological similarity and over-embeddedness when firms replicate their existing ties? Do these alliance groups create lock-out effects for newcomers in the network and cause relational over-embeddedness?

This article empirically studies these questions relating to the social mechanisms that cause the constraining or paralyzing effects of embeddedness. This article is one of the first descriptive empirical attempts to study the dynamics of interorganizational networks in the worldwide microelectronics industry from a longitudinal perspective. These networks involve strategic technology alliances and can range from sparse dyadic to dense multilateral relations where actors tend to cluster in alliance groups.[1]

The article is organized into three sections. We start with a literature review on the enabling and constraining effects of embeddedness, which will result in the development of our main hypotheses. We will hypothesize that the main social mechanisms such as local search and replication of ties create the enabling effects of embeddedness and enable alliance group formation. In addition, we will hypothesize why these social mechanisms can also result in the paralyzing effects of embeddedness that enforce alliance group formation. These paralyzing effects like "relational inertia" (Uzzi 1997; Gargiulo and Benassi 2000), also known as "strategic gridlock" (Gomes-Casseres, 1996), force firms to exclude attractive partners and therefore are likely to put a severe strain on their ability to move flexibly into other "resource niches" or into new windows of opportunity. In the second section, we will describe our data and sample. Finally, in the last section we will discuss the conclusion, addressing the questions and hypotheses we have raised in this article.

Theoretical background and hypotheses

Social networks are the embedded social relations that surround the actors in the alliance network and indicate how these actors are connected and related. By investing in these social relations through the replication of their existing ties, firms build up social capital. Social capital relates to the investment in social relations that generates expected returns (Lin 1999). It is defined as "the sum of resources that accrue to a firm by virtue of possessing a durable network of relationships" (Bourdieu and Wacquant 1992; 119; Koka and Prescott 2002). Thus, social capital refers to the potential beneficial network of relations with external parties as well as the resources embedded in that network that may be accessed and mobilized for purposive actions (Lin 1999; Burt 1992; Nahapiet and Ghosal 1998; Chung, Singh, and Lee 2000). This capital creates an advantage for individuals or groups in attaining their goals, as their interconnectedness gives them access to certain resources embedded in the network, which results in higher returns (Burt 2000). Thus, in the literature we find consensus that investing in social relations and, hence, improving connectedness enable accessing and using the resources embedded in those social networks, and result in gaining returns (e.g., Bourdieu, 1986; Coleman 1988, 1990; Lin 1999).

Most of the literature on social capital has taken a focal firm perspective. However, in order to describe the full dynamics of group formation in social networks, the effect of social capital at the group level has to be taken into account (Lin 1999). Social capital at the group level refers to aggregation of individual returns that benefits the collective (Lin 1999). Most of the literature on this subject focuses on how certain groups develop and maintain their social capital as a collective asset and how such a collective asset enhances group members' life chances (Bourdieu 1986; Coleman 1988, 1990; Putnam 1993; Lin 1999). Through dense or closed networks, collective social capital can be maintained and reproduction of the group can be achieved. Norms and trust play an important role in producing and maintaining the collective asset (Lin, 1999). Then, being part of a dense, cohesive, and redundant network promotes a normative environment that involves trust and cooperation among its members (Coleman 1988, 1990; Gargiulo and Benassi 2000) and eventually leads to a situation of strong social cohesion within these subgroups in the network (Wasserman and Faust 1994).

*Enabling embeddedness: From loosely coupled alliance
networks to densely tied alliance groups*

Current alliance networks provide future alliance opportunities (Gulati 1995a), and early participation may provide firms with potentially valuable partnering possibilities for the future. Alliance-proactive firms in networks are therefore more likely to possess the specific knowledge related to the identification and selection

of appropriate alliance partners (Sarkar, Echambadi, and Harrison 2001). Alliance proactiveness is a first-mover advantage since early-mover firms tend to capture advantageous positions resulting from their choice of partners. Thus, preemption of valuable and scarce resources in partner space can be a source of strategic advantage (Dyer and Singh 1998; Sarkar, Echambadi, and Harrison 2001). As a result, some partners are not available because they are already tied to the focal firm's competitors.

Since trust is an important basis for knowledge sharing and partner selection, firms tend to be locally biased in their search strategies (e.g., Nelson and Winter 1982; Cyert and March 1963; Stuart and Podolny 2000). They often engage in "local search" in forming their subsequent ties. They tend to initiate new partnerships that relate to the outcomes of prior searches.[2] In their technological positioning, firms thus search for those technologies that enable them to extend their established technological capabilities (Stuart and Podolny 1996). They generally search for partners with whom they share technological content and with whom they are either directly or indirectly linked in the technological network. These preferential relations are path-dependent as prior ties determine the formation of future linkages (e.g., Gulati 1995a, 1995b; Levinthal and Fichman 1988; Walker, Kogut, and Shan 1997; Tsai 2000). Furthermore, these ties ameliorate information sharing, reduce resistance, and provide comfort among the partners.

Over time, partner attractiveness will remain high or will become even stronger (Madhavan, Koka, and Prescott 1998), and preferential relations tend to develop into strong ties since there is frequent interaction and partners commit heavily to the relationship. Strong ties (Granovetter 1973) are characterized by solid, reciprocal, and trustworthy relationships. This type of relationship creates a large basis of trust and intimacy among the partners (Brass, Butterfield, and Skaggs 1998; Granovetter 1973). As those firms replicate these preferential relations based on their social capital at the group level (Lin 1999) and their embeddedness, the network self-generates and reproduces over time. Being embedded in a densely connected network as a result of a high amount of social capital makes engagement in subsequent ties more likely (Walker, Kogut, and Shan 1997). Social capital at the group level (Lin 1999), in particular, is crucial in the process of alliance group formation as the network becomes denser. The network increasingly turns into a growing repository of information on the availability, competence, and reliability of prospective partners (Walker, Kogut, and Shan 1997; Gulati 1995a; Powell, Koput, and Smith-Doer 1996). Thus, when the size of the network grows and the density of the network increases as the actors engage in multiple relationships, the possibility increases that alliance groups are formed. The latter results from actors who develop strong, densely connected, and cohesive ties through local search. We conclude that if the size of the network increases, alliance group formation is likely.

When the size of the network increases, alliance group formation becomes more likely

Alliance groups

Alliance group membership can be seen as one of the strongest forms of embeddedness. In the conceptualization of alliance groups, there are four general properties that apply: the mutuality of ties, the closeness or reachability of sub-group members, the frequency of ties among members and the relative frequency of ties among subgroup members compared to nonmembers (Wasserman and Faust 1994). Specifically, the number of ties an individual has with a group and the closeness of the entire group to outsiders do matter (Wasserman and Faust 1994). Alliance group members have more numerous or more intense relations with each other than nonalliance group actors. Alliance groups are generally characterized by highly cohesive subsets of similar actors in a network (Knoke and Kuklinski 1982). Cohesion refers to the extent of a relatively direct strong interaction among individuals in a social system, requiring only few intermediaries, that is, indirect links (Bovasso 1996). Social forces operate through direct and indirect contacts among subgroup members and through the cohesion achieved within the subgroup, as compared to the outside of the group (Wasserman and Faust 1994). When actors have relatively frequent contacts (face-to-face) and when they are linked through intermediaries (Wasserman and Faust 1994), greater homogeneity is expected.

The engagement in subsequent ties in these dense and cohesive parts of the networks can also be explained from a transaction-cost perspective. When information about the competencies and reliabilities of potential partners is lacking, developing a relation with a new actor involves uncertainty (Tsai 2000). Hence, firms invest a substantial amount of time and energy in establishing strong relationships (Burt 1992) through preferential partnering. However, the commitment and specificity of investments required in the relationship generate sunk costs (Gomes-Casseres 1996). Therefore, changing transaction partners in the short run is not likely, since it involves significant switching costs and implies a risk that existing relationships will dissolve (Chung, Singh, and Lee 2000). Furthermore, as actors develop "specific routines for managing an interface with each other" (Gulati 1995a; 626), they tend to become blind to new partnership opportunities and instead rely on previous partners and routines only (Tsai 2000). Thus, when trustworthy partners are readily available, searching for, or switching to, new partners is hard to rationalize in the alliance formation process (Chung, Sing, and Lee 2000). Therefore, actors instead replicate their existing ties (Gulati 1995a, 1998; Walker, Kogut, and Shan 1997) through local search and look for partners they know and with whom they share similarities in technological content in their densely connected social system. Another reason why firms tend to replicate their existing partnerships is the danger of reputation effects. This fear deters firms in a web of relations from behaving opportunistically against each other, and it increases the

Table 1
The alliance network formation process

Alliance network formation		Alliance group formation	
Why do firms create ties?	With whom do firms create ties?	enabling social mechanisms	constraining social mechanisms
Strategic interde-pendence (exogenous)	Preferential relations through social capital (endogenous)	Social capital at group level: -local search-replication	Social capital at group level- similarity- relational inertia

stability and longevity of their alliance formation in their closed system. The like-lihood that a firm acts unethically decreases when the firm is embedded in a net-work of relations, since this behavior is communicated quickly to other partners in the network. Actors then update their evaluation of the opportunistic actor and may not trust or interact with that firm in the future, since the opportunistic actor violates the trust created at the network level as well as on the dyadic level (Rowley, Behrens, and Krackhardt 2000). In the past, several scholars have addressed the fact that social relations develop in a path-dependent way, in the sense that previ-ous ties determine how the future relationships evolve (e.g., Gulati 1995a, 1995b; Levinthal and Finchman 1988; Walker, Kogut, and Shan 1997; Tsai 2000). This suggests the following hypothesis:

> *When looking for new partners, firms replicate their existing ties within the subgroup*

So far, we have addressed the embeddedness and social capital that drive the alliance network formation process in general and the group formation process in particular (see Table 1). In particular, the social mechanisms of local search and replication of previous ties through preferential partnering behavior cause the network to evolve, as those mechanisms provide the enabling effects of embeddedness. In the next sec-tion, we will address the paralyzing effects of embeddedness at the group level that are caused by constraining social mechanisms in the group formation process.

Constraining embeddedness: Similarity and relational inertia

As discussed above, the decision with whom to partner is influenced by the net-work of past partnerships (Gulati and Gargiulo 1999) and depends on the embed-ded relations the firm is already engaged in (Granovetter 1985; Gulati 1998). Because of repeated alliance formation caused by local search, frequent interaction, and in-creased commitment in the relationship, trust and intimacy have grown strong be-tween the partners (Granovetter 1973; Brass, Butterfield, and Skaggs 1998).

   As partners have become more familiar with each other because of frequent

and face-to-face contacts, "familiarity breeds trust" (Gulati 1995b) and greater homogeneity is expected than when they have fewer contacts. "The more tightly that individuals are tied into network, the more they are affected by group standards" (Wasserman and Faust 1994, 250). Actors who form cohesive cliques directly influence each other through strong ties, resulting in homogeneous attitudes, behaviors, and beliefs (Wasserman and Faust 1994, 250). Social contagion emerges when actors take up the attitudes or behaviors of others who influence them (Bovasso 1996). Social contagion is both an individual and a group phenomenon (Burt 1992; Bovasso 1996). Therefore, the cohesion approach suggests that similarity in attitudes stems from the proximity of actors, implying that directly linked actors will be more similar and homogeneous than indirectly linked individuals (Brass, Butterfield, and Skaggs 1998). This holds especially for actors connected by strong ties rather than weak ties (Brass, Butterfield, and Skaggs 1998).

Actors who are densely connected and who maintain strong ties among themselves, like in alliance groups, are more likely to act similarly, to share information, to develop similar preferences, or to act in concert (Knoke and Kuklinski 1982). In a similar vein, social-identity theory (Gómez, Kirkman, and Shapiro 2000) states that similarity strengthens a self-image as actors are attracted to similar others. Furthermore, actors tend to treat those similar others more favorably than different ones (Gómez, Kirkman, and Shapiro 2000). Thus, similarity can induce interaction or be the cause of attraction. Scholars refer to this process as "similarity breeds attraction" and "interaction breeds similarity" (Brass, Butterfield, and Skaggs 1998). From a technological point of view, we expect that firms thus need to have some pre-alliance technological overlap or absorptive capacity (e.g., Cohen and Levinthal 1990; Hamel 1991; Lane and Lubatkin 1998; Mowery, Oxley, and Silverman 1996) in order to absorb their partners' technological capabilities (Tsai 2001). Hence, some technological similarity in their technology portfolio is required for the replication of the actors' ties.

The extent to which these firms are able to learn from their partners depends on their intent. We expect that if actors intend to internalize their partners' technological capabilities (Hamel 1991), instead of only accessing them, their post-alliance technological profiles will be converging and will become more similar (Mowery, Oxley, and Silverman 1996). Hence, similarity can increase the group members' tendency to replicate their existing ties. Therefore we hypothesize that:

As firms replicate their existing ties within groups, their technology profiles become more similar

Actors tend to face several endogenous constraints in the alliance network formation process. This relational inertia manifests itself in many ways. For example, the resources they can devote to the search process for new partners can be limited. This means that the resources used up for forming ties with one actor can constrain them in forming ties with others (Gulati, Nohria, and Zaheer 2000). Furthermore,
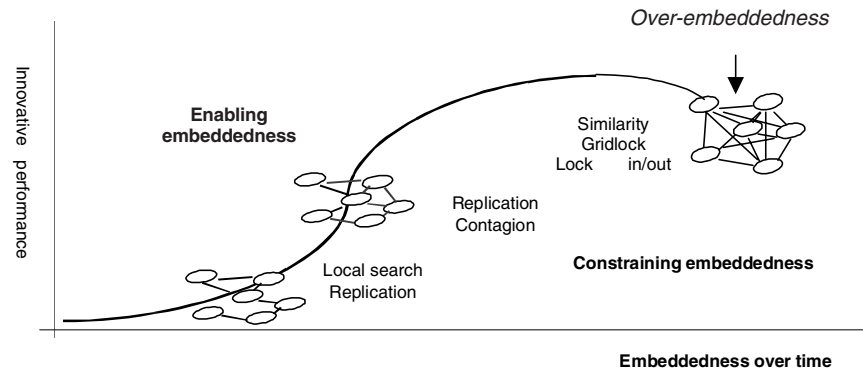
Figure 1. The enabling and constraining effects of embeddedness

the familiarity and strong ties that have been built up through the replication of ties and the increasing similarity of firms within the alliance groups can constrain the partner choice when facing opportunities for linking up with actors of another strategic group. As a group member intends to engage in a new partnership, it can experience the implicit social pressure from its partners to replicate its ties within the group. Once firms have established links in a specific group, the formation of ties outside that group can be difficult because of conflicting interests among its partners (Nohria and Garcia-Pont 1991). This implies that some actors in groups are locked in as a result of initial alliance choices so that actors outside the group are locked out. Hence, there is an implicit expectation of loyalty to group members, since many alliances preclude group members from allying with firms from competing groups (Gulati, Nohria, and Zaheer 2000). As a result, certain partners are not available because they are already tied to the focal firm's competitors. Another reason for locking out actors of other groups is to prevent knowledge leakage to competing groups.

Another aspect of relational inertia is that finding partners outside the group is difficult as further opportunities for partnering are foreclosed by competing groups. As these groups team up with their desirable partners, they gradually become unavailable to others as the alliance formation process continues (Gomes-Casseres 1996). Therefore, some potential partners are simply excluded in the partner-selection phase. This exogenous network phenomenon of strategic gridlock (Gomes-Casseres 1996) forces firms to engage in local search for partners within its own group (see Figure 1). This relational inertia makes group members rigid and cognitively locked in (Uzzi 1997; Gargiulo and Benassi 2000). The cognitive lock-in effect filters the information and perspectives that reach the group members and isolates them from actors outside of the group. In this state of rigidity and over-embeddedness (Uzzi 1997) caused by similar actors and relational inertia, alliance group members suffer from decreasing opportunities for learning and innovation.

This state of over-embeddedness (Figure 1) is likely to put a severe strain on the group members' ability to move flexibly into other "resource niches" or into new windows of opportunity.

In their partner choice nongroup members are restricted as well. The entry barriers rise as alliance groups evolve and become more important, merely caused by scale and scope requirements in the industry (Gomes-Casseres 1996). This leads us to the following hypothesis:

As the size of the network increases, established group members lock out newcomers from the network

Figure 1 summarizes the social mechanisms and points at the enabling and constraining effects of embeddedness they induce.

Sample and data

The data on strategic alliances and characteristics of companies involved in these alliances is derived from the MERIT-CATI databank on strategic technology alliances (Hagedoorn 1993). The database covers the period between 1970 and 2000 and contains information on nearly 15,000 alliances of parent companies active in biotechnology, information technology, new materials technology, and "noncore" technologies. The most important data sources are international and specialized trade and technology journals for each sector of industry and for many fields of technology. From the primary modes of cooperation presented in this database, such as joint ventures and research corporations, joint R&D agreements, technology exchange agreements, direct investments, customer-supplier relations and cooperative agreements with one-directional technology flows, we will address those alliances that are characterized by two-directional technology flows and that have a strategic focus affecting the long-term strategic positioning of companies.

In this article, we study strategic technology alliances in the microelectronics industry. We will test our hypotheses from a longitudinal perspective by examining alliance network formation in the microelectronics industry during the period 1970–2000 (see Figure 2). Strategic technology alliances are defined as the establishment of common interests among independent (industrial) partners, which are not connected through (majority) ownership (Hagedoorn 1993). Thus, strategic technology alliances are cooperative agreements for reciprocal technology sharing and joint undertaking of research between independent actors that keep their own corporate identity during the collaboration.

The transfer of technology or the undertaking of joint research has to be part of the arrangement. Mere production or marketing alliances are excluded. Examples of strategic technology alliances are joint research pacts, joint development agreements, R&D contracts, (mutual) second sourcing, cross-licensing, research corporations, agreements and joint ventures with technology sharing or R&D programs,
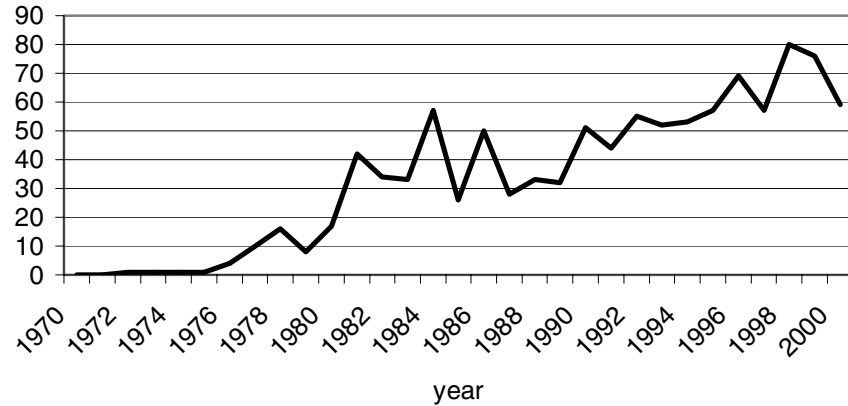
Figure 2. Number of alliances formed in microelectronics, 1970–2000

and cross-holdings. For our purpose, information was used regarding the industrial sectors in which companies operate, their core business, the year of establishment of the strategic technology alliance, and the industry affiliation of the alliance.

Our sample was drawn from an update of the CATI database, which covered the period 1970–2000. In the information technology sector, that is, computers, industrial automation, microelectronics, software and telecom, 3,833 strategic technology alliances were formed during this period. Strategic technology alliances in microelectronics accounted for 1,047 alliances.

For an evaluation of our main hypotheses, we computed several social network measures by constructing adjacency matrices representing the relationships between the firms in the strategic technology alliance network. Network measures like lambda sets were calculated using UCINET 5 (Borgatti, Everett, and Freeman 1999).

Methodology

As described in our theory section, we expect alliance group formation to be likely if the size of the network increases. We argued in our first hypothesis that as the size of the network grows and the actors engage in multiple relationships, the possibility that alliance groups are formed does increase. The latter results from actors developing strong, densely connected, and cohesive ties through local search.

To measure the size of the network, we calculated the actors active in alliance formation in the period 1970–2000. We operationalized alliance groups by using a hierarchical clustering measure for cohesive subgroups: lambda sets. A set of nodes is a lambda set "if any pair of nodes in the lambda set has larger line connectivity than any pair of nodes consisting of one node from within the lambda set and a second node from outside the lambda set" (Wasserman and Faust 1994, 270). The lambda level indicates the mutuality of ties, the closeness or reachability of sub-

group members, the frequency of ties among members, and the relative frequency of ties among subgroup members, compared to nonmembers (Wasserman and Faust 1994). In graph theory, the smaller the value of the lambda level (in our case level two), the more vulnerable group members are to being disconnected by removal of lines (ties). The larger the value of lambda (in our case level four), the more lines must be removed from the graph in order to leave no path between group members.

Concerning our second hypothesis, we argued that when trustworthy partners are available in a densely connected social system, searching for, or switching to, new partners is difficult to rationalize in the alliance formation process (Chung, Singh, and Lee 2000). Instead, actors replicate their existing ties (Gulati 1995a, 1998; Walker, Kogut, and Shan 1997) through local search, and, as noted earlier, they look for partners they are familiar with and with whom they share similarities in technological content in their densely connected social system.

In order to assess the degree of replication of ties in alliance groups, we used an in-group/out-group ratio similar to the one mentioned in Wasserman and Faust (1994). The numerator of this ratio is the number of ties that firms engage in within their group, while the denominator is the number of ties that firms form outside their core group over a certain period of time. Thus, the ratio provides an indicator for in-group strength. Clearly, if the ratio is higher than one, firms are found to engage particularly in ties within their subgroup, as compared to ties outside their core group.

In our third hypothesis, we argued that similarity in terms of technology profiles among group members could increase a firm's tendency to replicate its existing ties in the group. However, this requires some pre-alliance technological overlap (e.g., Cohen and Levinthal 1990; Hamel 1991; Lane and Lubatkin 1998; Mowery, Oxley, and Silverman 1996) in order to facilitate the absorption of their partners' technological capabilities (Tsai 2001). We expected, that if actors intend to internalize their partners' technological capabilities (Hamel 1991), their post-alliance technological profiles would be converging and become more similar (Mowery, Oxley, and Silverman 1996). Therefore, through our third hypothesis, we expected that, as firms replicate their existing ties within groups, their technology profile would become more similar.

To test this hypothesis, we picked out those firms that were group members in the periods 1980–1982, 1983–1985, 1986–1988, and 1989–1991 at the lambda four level. These group members included Advanced Micro Devices, Inc. (AMD), International Business Machines (IBM), Intel Corporation (INTEL), Motorola, Inc. (MOTOROLA), and Nippon Electric Corporation (NEC). The technology profiles were composed of semiconductor technology classes in which those firms have patents. We consider the similarities of these technology profiles to be indicators of pre-alliance technological overlap.

The technology profiles show the number of patents that a certain firm has applied for in a specific semiconductor class in a specific period. We expected that
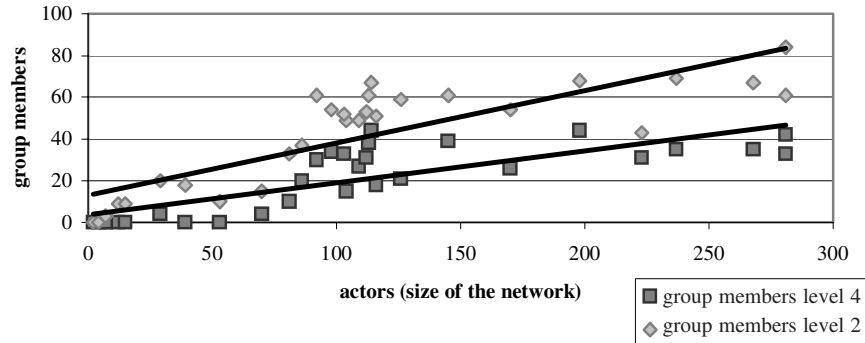
Figure 3. Alliance group members and network size in period 1970–2000

the technology profiles of AMD, IBM, INTEL, MOTOROLA, and NEC would become more similar as they work together in an alliance group for some years in a row. Hence, we assumed that, as a result of the learning effects associated with the strategic alliances within their group, their technology profiles as indicated by the number of applied patents would become more similar over time.

Our fourth hypothesis stated that, as the size of the network increases, established group members lock out newcomers in the network. These lock-out effects result, among other factors, from resource constraints on forming ties with others (Gulati, Nohria, and Zaheer 2000), but also from the implicit expectation of loyalty to group members, since many alliances preclude the group members from allying with firms from competing groups (Gulati, Nohria, and Zaheer 2000), as argued in our theoretical section.

To measure these lock-out effects, we have to investigate whether a growing number of actors in the network go together with a relatively stable amount of group members in the network, because this indicates that these newcomers are not absorbed in groups.

Results

In order to test our first hypothesis, we plotted the size of the network against the number of group members and against the number of groups in Figures 3 and 4, respectively. Figure 3 indicates that as the size of the network increases (i.e., the number of actors in the network increases), the number of group members in the network increases at both lambda levels two and four. Figure 4 also shows a similar trend as the number of alliance groups increases as the network grows, especially at the lambda two level. This seems to confirm our expectation that, as alliance networks evolve into denser ones, the likelihood of the formation of alliance groups increases.
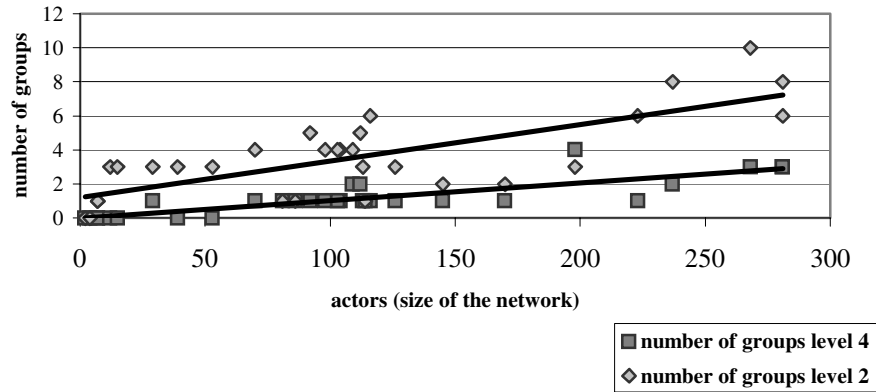
Figure 4. Number of alliance groups and network size in period 1970–2000

Concerning our second hypothesis, we first identified densely tied group members using the lambda four level statistics. Furthermore, we calculated the number of in-group ties for firms at the lambda four level and divided this number by the total amount of ties that were formed in the network in that particular period. The resulting ratio indicates the percentage of ties formed in alliance groups compared to the number of total linkages engaged in by all members of the network in that period. We focused on the periods 1980–1982, 1983–1985, 1986–1988, and 1989–1991. These ratios are shown in Table 2.

We clearly see an increase in the in-group/out-group ratio and the in-group/total ratio for the periods 1980–1982, 1983–1985, and 1986–1988, and a slight decrease in these ratios for the period 1989–1991. This hints at the tendency of firms to replicate their ties within the subgroup as they continue to engage in new relationships over time.

To test our third hypothesis, we calculated the relative differences among the technology profiles of the firms involved. We measured the amount of patents in a certain semiconductor class relative to the total amount of patent applications in all selected semiconductor classes of the firm. We calculated this ratio for all five group members and then subtracted those ratios in each semiconductor class from each other to find out the differences among the group members. This resulted in five outcomes per class that we summed up and subsequently divided by the number of companies to come up with the mean per class. We summed up these means per class over all semiconductor classes, and this resulted in a number indicating the difference in technology profiles of the group members involved in this period.

We found in the period 1980–1982 an indicator of the difference in technology profiles of the group members involved of –8; in the period 1983–1985 an indicator of –3; in the period 1986–1988 an indicator of –3; and in the period 1989–1991 also an indicator of –3. This seems to indicate that, when the firms start working

Table 2
Ratio measuring in- /out-group strength

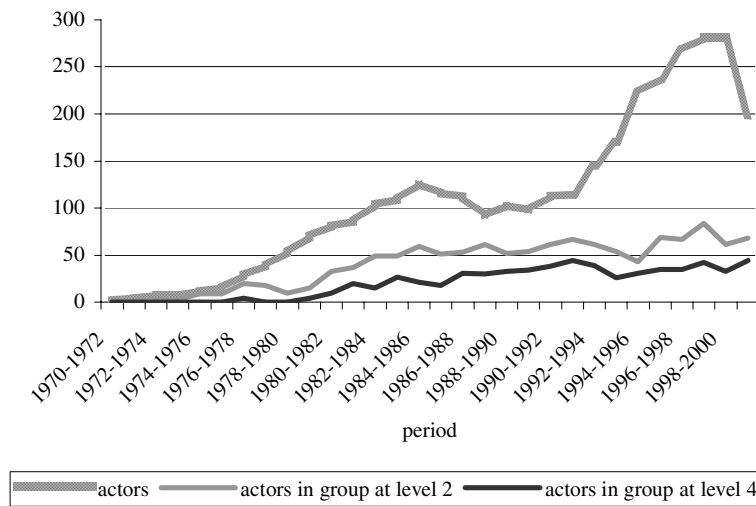| Period	In-group/out-group ratio	In-group/total ties ratio
1980–82	0.6	0.2
1983–85	2.3	0.6
1986–88	3.4	0.7
1989–91	2.2	0.6

Figure 5. Number of alliance group members, 1970–2000

together in a group, their technology profiles show some technological overlap (absorptive capacity) but are not quite similar because there are differences in their technology profiles. However, after three years of replicating ties within their group, their technology profiles become more similar. After six years, their technology profile is relatively similar to the profiles of three years before. This could be seen as an indication of decreasing learning effects and over-embeddedness because their technology profiles do not differ compared to years before. From these results, we can conclude that, by replicating ties in cohesive subgroups, the technology profiles of the group members involved tend to become similar (see Hypothesis 3).

To indicate the possibility of lock-out effects (see Hypothesis 4), Figure 5 seems to point out that, as the number of actors in the network increased dramatically from 1991–1993 onward (see Figure 5), the number of group members at levels two and four remained relatively stable and showed only a slight increase in this period. This may indicate that the established groups do not absorb newcomers in
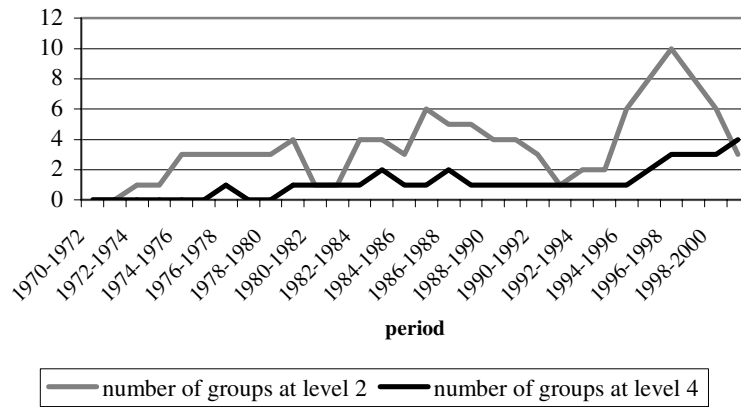
Figure 6. Number of alliance groups in period 1970–2000

the network. Thus, although the number of potential partners increases in the growing network, it is possible that they are not eligible, for they can be tied to competitors of the established group members. This would suggest that the newcomers in the network possibly form groups among themselves, as they are lockedout of the established groups.

We zoom in on this phenomenon by examining Figure 6, which shows that from the period 1991–1993 onward, the number of groups increased at level two (the less densely tied groups). At level four, this increase started in the period 1994–1996. Note the sharp increase in the number of groups at level two from the period 1993–1995 onward. This seems to confirm our previous suggestion that newcomers in the network possibly form groups among themselves, as they are locked out of the established groups. However, starting in the period 1996–1998 there is a sharp decrease in the number of groups at lambda level two (Figure 6). This could be explained by the fact that these groups are less densely tied and, as a result, are less stable and fall apart easily, as the sharp decrease indicates. Altogether, we find strong indications that a growing size of the network can cause lock-out effects when the number of group members stays relatively stable.

Conclusion

This article provides one of the first descriptive empirical attempts to study the process of alliance group formation from a longitudinal perspective and points at the underlying social mechanisms. In order to shed more light on these subgroup formation processes, we investigated the social mechanisms that enable and enforce alliance group formation over time. Our main argument is that embeddedness,

in the first instance, can be seen as an enabling factor for alliance group formation. Over time, however, the enabling effect of embeddedness can turn into a paralyzing effect that locks in partners in their closed social system and locks out newcomers. We tested our main hypotheses by an empirical analysis of alliance group formation patterns in the microelectronics industry from 1970 to 2000. Our empirical results support our theoretical hypotheses as we were able to reveal the dynamics of interorganizational networks, caused by the social mechanisms we identified.

We found that, in an evolving alliance network, an increasing network size induces the formation of alliance groups. Furthermore, we were able to show a tendency for firms to replicate their ties within the subgroup as they engage in new relationships. This supports the enabling effect of embeddedness on alliance group formation. Subsequently, we showed that by replicating ties in the group for several years, the technology profiles of the group members involved tend to become more similar. Finally, we pointed out that a growing size of the network can cause lock-out effects for newcomers in the network. This supports our arguments related to the paralyzing effect of embeddedness, which reduces group members' flexibility and innovative strength and which can even cause a state of over-embeddedness. This analysis has its limitations in terms of the degree to which we can generalize its outcomes, in particular since we investigated only one high-tech industry. Thereto, future research might provide further insight into the enabling and constraining effects of embeddedness through more in-depth empirical research.

Notes

1. In this article we use (alliance) groups and (cohesive) (sub) groups interchangeably.
2. Local search concerns initiating new R&D projects that have a common technological content regarding the outcome of their prior searches (Stuart and Podolny 1996).

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