From the Bottom Up? Technical Committee Activity and Alliance Formation

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We examine how interaction between mid-level managers in technical committees facilitates subsequent alliance formation in a longitudinal study of 87 cellular service providers and equipment manufacturers. Joint participation by firms in technical committees helps them identify potential alliance partners and particular opportunities for technical collaboration. This effect is magnified by sustained participation by individuals on behalf of their firms, demonstrating that interfirm relationships are enhanced by the interpersonal bonds that are forged in technical committees. In contrast, we find that the effect of joint technical committee participation on alliance formation decreases as firms have more prior alliances, suggesting that technical committees provide a more critical avenue for knowledge exchange when firms do not have the luxury of exchanging information through contractual linkages. Taken together, these findings suggest one venue where managerial action can transform existing social structure, because technical committee activity facilitates the entry of less-established firms into alliance networks.•

Recent studies have made substantial headway linking numerous network contexts to alliance formation. These network contexts include such determinants as previous alliances (Gulati and Gargiulo, 1999; Ahuja, 2000; Chung, Singh, and Lee, 2000), executive mobility (Eisenhardt and Schoonhoven, 1996), director interlocks (Gulati and Westphal, 1999), and technological similarity (Mowery, Oxley, and Silverman, 1996; Stuart, 1998). Despite this progress, two issues remain largely unexplored. First, research on technological evolution suggests that technological discontinuities may provide an impetus that transforms networks (Rosenkopf and Tushman, 1994, 1998). Yet an emphasis on network endogeneity, where prior alliance network structure is expected to be a key determinant of subsequent alliance formation, suggests that networks are largely self-reproducing and simply elaborated over time. Unfortunately, when we focus our attention on the constraints imposed by the existing social structure on network evolution, we cannot explain how firms can gain access to alliance networks without having already established a position in these networks. Thus, while acknowledging these powerful inertial forces, research needs to examine how managerial volition can also shape network evolution. For example, Ahuja (2000) demonstrated that firms lacking various forms of capital (including the social capital of alliances) have a higher likelihood of alliance formation if they possess "important inventions." In what context do these firms engage partners if they have not been admitted to the alliance network? Clearly, research that emphasizes network contexts other than prior alliances is needed to examine such issues.

Second, a rich tradition of strategy process theory and fieldwork suggests that while top executives set the context that guides the actions of their subordinates, it is the front-line managers who develop the strategic initiatives from which top executives select (Bower, 1970; Burgelman, 1983, 1991). While this tradition encourages us to examine interorganizational networks derived from front-line managerial contacts,

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the alliance formation literature is surprisingly silent on the systematic exploration of interorganizational mechanisms that might enable managers at this level to identify and assess alliance opportunities. Rather, the focus has been on top-level social networks, such as top team members' mobility or director interlocks, or on proxies such as technological similarity that can only suggest propensities for interaction.

Our study addresses these gaps by focusing on a domain in which actual interaction among lower-level managers may be observed. We focus on cellular firms' participation in industrywide technical committee activities, viewing the front-line managers as agents of interfirm collaboration. Technical committee activity is voluntary and non-contractual. Firms' participation in these activities generates interfirm ties with the potential for knowledge sharing. As such, this activity represents a pre-alliance network context, because interaction by technical professionals in these committees can generate the seeds of future alliances. We also explore conditions when this bottom-up type of alliance formation is likely to be amplified or diminished.

COOPERATIVE TECHNICAL ORGANIZATIONS AND ALLIANCE FORMATION

Institutions such as professional societies, trade associations, and standards bodies provide an essential coordination function for technological innovation, particularly for systemic technologies (Farrell and Saloner, 1988; Tushman and Rosenkopf, 1992; Garud and Kumaraswamy, 1995). The working groups, task forces, and technical committees formed by these institutions provide venues in which representatives of various firms and other constituencies share technical information, adjudicate technological differences, select standards, and negotiate future developments. We call these entities cooperative technical organizations (CTOs). A CTO is "a group that participates in technological information exchange, decision-making or standards-setting for a community" (Rosenkopf and Tushman, 1998: 315). In systemic industries, such as telecommunications, there are institutions with extensive histories and well-established structures. One prominent example is the large number of technical committees housed in the International Telecommunications Union (ITU), which was founded in 1865 and became a United Nations agency in 1947. The cooperative activity engendered by committees of this sort may be considered an "engineered" process (cf. Doz, Olk, and Ring, 2000), whereby committees are formed with the expectation that a standard will emerge from the committee's deliberations.

Although there are benefits to firms participating in CTOs, such activity is not costless. It requires commitment of resources in several forms: membership fees paid to the sponsoring organizations, time and travel of engineers and managers participating in their various forums, and occasional hosting of forums. At the same time, firms bear the risk that they will lose proprietary information to competitors through the interactions that occur in CTOs. Obviously, firms perceive potential benefits that outweigh these costs. Chung and Granovetter (1998) argued that the functions of trade associations include regulation of market exchange and business coordination, two activities clearly geared toward disseminating and gathering knowledge among the member organizations.

The benefits of participation in cooperative technical organizations include access to and control of technical and strategic knowledge as well as opportunities to increase visibility as legitimate actors and potential partners in the technological community. With respect to technical and strategic knowledge, many firms participating in CTOs attempt to shape technological development in directions that favor their technological capabilities. Often, the technical exchanges within trade associations and research and development consortia are fueled by the need to bring new generations of products to market quickly (Aldrich et al., 1998). To do so, participants are obligated to share certain aspects of their technological know-how and strategy with other participants in these activities. This sharing provides the other CTO participants with access to technical knowledge. It is worth noting that much of this knowledge is tacit: while the standards process inherently encourages the codification of this knowledge, the deliberations leading to the standard are far more nuanced. At the same time, firms attempting to control technological development can do much more than simply share their approaches: if they maintain leadership roles in CTOs, they have more ability to set agendas and control decision premises, which may translate into the power to make their approaches all the more likely to succeed (Pfeffer, 1981).

Beyond these straightforward benefits, a firm can use CTO activity to place itself on the radar screens of other, more established organizations. By sending representatives to CTO meetings, the firm has the opportunity to increase other firms' awareness of its technological capabilities. According to one vice president at a prominent cellular equipment manufacturer, "the standards process is actually a way of popularizing [a firm's] technology if they are pioneers in a technology or method or procedure."[1] Increased visibility and awareness of a firm's technological capabilities can heighten its opportunities to form linkages (Ahuja, 2000), as well as lead the firm to be perceived as more legitimate (Oliver, 1990) and of higher status (Podolny, 1993). At the same time, the firm can also use the CTO venue as an opportunity to assess other firms as potential partners. As in many interorganizational domains, information about individuals and their employing firms circulates informally among the participants in this activity. This information serves as the context for subsequent decisions about interaction (Powell, Koput, and Smith-Doerr, 1996; Walker, Kogut, and Shan, 1997), thereby reducing uncertainty for partner selection.

The benefits of CTO participation accrue to individual participants and entire communities as well as firms. In technology-driven industries, CTO participants represent critical boundary spanners (Tushman, 1977), as they provide crucial technical information on which firms' future strategies and innovative directions depend. As one engineer from a well-known service-provider asserted, "Participating in standards meetings benefits individuals most. The whole group becomes more

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All quotes included in this paper were obtained via structured interviews with various stakeholders in the Telecommunications Industry Association (TIA) process. Names and firm affiliations are not revealed to protect confidentiality.

knowledgeable. The individual takes the higher awareness back and shares it with others at home." Clearly, cooperative technical organizations represent important avenues for the exchange of knowledge among firms.

Although research on the technical committee domain is virtually non-existent in the managerial literature, other social sciences have shown the fundamental role played by associations in the coordination of economic activity. A long tradition in sociology, starting in 1893 with Durkheim (1984), has argued that firms with adversarial goals need an institutional context for resolving problems because contracts cannot completely specify contingencies and ways to resolve them. Associations provide such a context, as they enable interactions that transform economic exchanges into conversations through which actors learn about each other and about their common interests (Sabel, 1994).

The broader literature on associational forms demonstrates the historical record of associations facilitating coordination and cooperation between their members in various industries and countries. In the mid-nineteenth century, associations of railroad managers were formed to standardize equipment and procedures, and "middle managers were the persons who devised the organizational procedures and worked out the technological standardization necessary to achieve a national railroad system " (Chandler, 1977: 123).

These dynamics are not limited to industries with strong network externalities like railroads and telecommunications. During the pro-associational regime of Herbert Hoover in the U.S., for example, government heavily supported similar coordination efforts to standardize sizing in the lumber industry and to oversee moral content in the motion picture industry (Hawley, 1981).

At the same time, associations provide a context for the provision of collective goods in various industries. Often, firms need to solve problems that go beyond transactions between particular firms. Schneiberg's (1999) study of the fire insurance industry during the first half of the twentieth century shows how firms had to create the associational context that enabled the production of knowledge about loss data by region and risk class, a collective good that was grossly underdeveloped in a non-associationalist regime. Similarly, Saxenian (1992: 377) described the Semiconductor Equipment Manufacturers International (SEMI) in Silicon Valley as an "integrative organization" that "fosters information exchange and collaboration among specialist producers in highly fragmented industries." SEMI provided firms in Silicon Valley with the context for solving shared technical problems and established a forum for the provision of such collective goods as standards and education programs that allow individual firms to undertake exploratory projects and promote the flexible production regime characteristic of the region (Saxenian, 1992). In Silicon Valley, repeated interfirm interactions via common association affiliation and intense job mobility lead to the development of a common language among engineers in the region, language not easily understood by members of the same profession on the East Coast of the U.S. (Saxenian, 1996). In turn, such common language further facilitates interpersonal communication and interfirm cooperation. Through repeated interaction via industry associations, transactions among actors linked by common interests and, increasingly, through common knowledge and language, become increasingly relational. As such, associations constitute a network context, a setting with interrelated actors and enduring memberships. Such a context provides a fertile background for the formation of additional relationships among firms.

Joint CTO Participation and Alliance Formation

When two firms participate in the same cooperative technical organization activities, several mechanisms are engaged that can engender subsequent alliance formation, including increasing similarity in interests and goals, awareness of participants as potential partners, and explicit interaction between participants. Joint CTO participation can increase similarity in firms' interests and goals. The shared norms and common language of industry members are enhanced through their continued participation in industrywide forums. A firm's membership in a CTO, at minimum, enables access to explicit knowledge generated by this community—drafts of standards proposals, summaries of debates about technological alternatives, results of experiments commissioned by the CTO, and the like. Such benefits are available even with nominal membership, and ongoing exposure to such information can come to shape the firm representatives' perceptions of technical goals. Ocasio (1997) has conceptualized the firm as an entity whose actions are based on how it distributes attention to various issues. He argued that exposure to the same knowledge and issues shapes the perceptions of decision makers by providing them "with a structured set of interests and identities that shape their understanding of the situation and motivate their actions . . ." (Ocasio, 1997: 193). Joint CTO participation, then, by exposing two firms to similar knowledge, affects the participants' views of technological development and hence influences their actions.

Similar interests and goals lay the groundwork for subsequent collaboration, but just as important is any participant's awareness that particular firms share these goals. Thus, joint CTO participation can draw firms' attention to partners, generating a feasible opportunity set of partners for potential collaboration toward these goals. While the initial attendance and distribution of attention may be based strictly on a firm's interests and need to gain information on technological directions, the potential for future interaction among joint CTO participants becomes an important motive for continued attendance.

The knowledge gained through CTO participation, however, is not limited to technical standards. It also includes important process-related knowledge about the ways in which various firms collaborate—or not—in the standard-setting process and in technical deliberations. Ongoing exchanges in prescribed CTO activities, such as conducting experiments, drafting position papers, or developing standards proposals, reduce uncertainty by exposing participants to strategies and techniques employed by other participating firms while they are looking to reach consensus. In this context, "firms can assess continuously through direct experience whether particular partners are able to advance a joint program or not, and whether, if they are, the result could be a fusion of identities that creates enduring mutual interests . . ." (Sabel, 1994: 146).

The interactions that occur between firm representatives as a result of joint participation also reduce uncertainty because they enable the exchange of knowledge that helps the representatives identify specific collaboration opportunities. The propensity for engineers to engage in informal know-how trading has been well-documented (von Hippel, 1987). The CTO context provides a rich set of opportunities for face-to-face meetings and in-depth conversations among participants. CTO meetings are multiple-day events held on a regular basis; in telecommunications, for example, most of the critical committees meet for a several-day period every month. They are frequently held in appealing locales, and opportunities for socializing outside of the meeting sessions abound, enabling the technical professionals to bond socially. These patterns of repeated interaction—formal sessions and informal socializing for multiple days on a regular basis—allow the firms' representatives to develop embedded ties, which lead to trust, fine-grained information exchange, and joint problem-solving efforts (Uzzi, 1997).

Taken together, these mechanisms suggest that cooperative technical organizations facilitate the identification of both potential partners and specific opportunities for collaboration, which can be formalized subsequently by the formation of an alliance.

Hypothesis 1a (H1a): Joint CTO participation is associated with subsequent alliance formation.

Such a hypothesis, however, suggests that the alliance formation benefits of joint CTO participation are unbounded. While the benefits of repeated interaction have been made clear above, the marginal benefit of one more common meeting is likely to erode after some point. In other words, if we consider the joint participation the potential channel for communicating information necessary to recognize the possibility of an alliance, the more channels already available, the less valuable each additional channel will be. Hence, the effect of joint CTO participation on subsequent alliance formation is likely to diminish at higher levels of joint CTO participation:

Hypothesis 1b (H1b): The relationship between joint CTO participation and subsequent alliance formation increases at a decreasing rate.

Sustained individual participation on behalf of firms. Thus far, our discussion of joint CTO participation has rested on the notion that two firms send representatives to the same meeting, without any consideration of the identities of these individuals. The discussion of the importance of embedded ties between firms, however, draws heavily on the ongoing interpersonal relationships between individuals. For example, Uzzi (1996, 1997) relied on the long-time tenure of the informants with their firms, which would be expected in small, family-owned businesses such as garment firms. Gerlach (1992: 132) described how the cross-promotion of managers within Japanese alliance networks sustains the interpersonal relationships between partners. Likewise, Dyer (1996) has documented how frequent and sustained face-to-face meetings among firm representatives engender trust and collaboration among alliance partners.

Conversely, mobility of professionals between firms has been shown to have deleterious effects on the firms they leave, as much of the professionals' social capital moves with them rather than continuing to provide benefits for the old firm (Pennings, Lee, and van Witteloostuijn, 1998). Similarly, difficulties in the establishment of stable alliances between physician and hospital organizations have been attributed to the institutionalized rotation of physician leaders and hospital executives, who thus lack the basis for establishing long-term relationships (ProPAC, 1993). Findings such as these suggest the importance of decoupling the interfirm interaction resulting from joint CTO participation from the interpersonal interaction that also results. The CTO context enables us to consider whether the same individuals represent their firms continuously or whether the firm representatives fluctuate more dramatically.

Several mechanisms make sustained individual participation likely to enhance the relationship between joint CTO participation and alliance formation. Ongoing participation allows the participant to understand and use networks more effectively (Krackhardt, 1996). Sustained participation enables one to know more about the capabilities and interests of the other firms (and their representatives), making the representative better able to identify potential partners. At the same time, ongoing tenure in the role of "Firm X representative" leads the individual to identify more strongly with the role and to take actions that are more consistent with the needs of the firm (Thoits, 1991). Such identification should increase the likelihood that the individual detects opportunities that are acceptable to the firm.

Beyond the individual's capability to understand his or her role and the other actors in the network, the nature of the interactions between individuals who interact repeatedly will be richer than between those who are new to the role of firm representative. Sustained interaction at the dyadic level leads individuals to define their roles in relation to one another (Nadel, 1957; Stryker, 1968). Thus, while roles have an important prescribed component, they are also emerging through processes of social interaction. These processes lead to the emergence of shared behavioral expectations. As individuals interact repeatedly and develop interpersonal ties, they are more likely to request information and explanations freely, without the fear that their inquiries would be seen as intrusive. Thus, their relationships move away from the transactional realm and into the relational realm governed by norms of common understanding and trust.

The friendships and relationships that develop among representatives to cooperative technical organizations enable knowledge-sharing that can reveal specific opportunities for their firms to collaborate on technological developments. This tendency is heightened by repeated interaction, and when the repeated interaction between firms is coincident with repeated interaction between particular individuals, the result is most likely to be enduring interpersonal relationships in which both members have developed trust, common language, and understandings of each other's needs and capabilities, both as individuals and as representatives of their firms. In sum, sustained CTO participation leads individuals to internalize their roles, identify with them, and to interact effectively to develop strong relationships with other participants. All of these mechanisms increase the likelihood that joint CTO participation enables the identification of opportunities for collaboration.

Hypothesis 2 (H2): The relationship between joint CTO participation and alliance formation increases with the level of sustained participation by individuals on behalf of their firms.

Previous alliances. The tendency of alliance partners to form additional alliances has been well documented. Alliance partners develop routines that enable knowledge-sharing (Dyer and Singh, 1998), and the alliance participants develop interpersonal relationships within which they share more tacit knowledge (Uzzi, 1997). Alliance partners understand each other's needs and capabilities (Gulati, 1995), thereby facilitating the identification of subsequent alliance opportunities. Of course, this effect reverses beyond some "optimal" level of alliances, due to concerns of carrying capacity (Baum and Oliver, 1991) and overembeddedness (Uzzi, 1997). While we recognize these well-documented effects, our interest is in exploring the interaction between previous alliances and joint CTO participation for subsequent alliance formation. The mechanisms that propel additional alliance formation between current alliance partners bear some similarity to the mechanisms we have proposed to propel alliance formation between joint CTO participants. In other words, firms that are already connected through contractual arrangements have more direct means by which to explore subsequent collaboration opportunities. In contrast, firms without prior alliances do not have this type of channel available for knowledge exchange. Such firms face more uncertainty about the technical and collaboration capabilities of potential partners and thus should be more dependent on CTO channels for interfirm communication as well as more responsive to cues generated by the CTO context.

Greater use of cooperative technical organizations by firms with lower social capital is further facilitated by the strong technological orientation of this type of association. Proposals and ideas are discussed openly, regardless of whether the item is offered by an incumbent or a new member. Engineers constitute the majority of CTO participants, and their main criterion for judging technologies or proposals is technical excellence. According to one engineer from a well-known service provider:

I would not say that there are no politics or policy behind these [committee deliberations]. Technical issues are driven by business issues. But we don't discuss business issues. Opposition (or support) will be on technical merit. In the engineering committees, we are not allowed to discuss cost or business issues! Outside the meeting you can talk about it.

Of course, the stock of existing alliances that large, established firms possess provides an alternative channel to generate this information. Consequently, firms most likely to identify alliance opportunities as a result of CTO activity are those without a preexisting stock of alliances.

Hypothesis 3 (H3): The relationship between joint CTO participation and subsequent alliance formation decreases with the number of prior alliances formed.

Patents. While both the alliance and CTO network contexts provide venues for the exchange of technical knowledge, other means can indicate technical knowledge more explicitly. Patents, for example, represent a main avenue for the codification of firms' technological knowledge and hence suggest technological competence (Arora and Gambardella, 1990). Ahuja (2000) demonstrated that technical capital, measured by the firm's stock of patents, is one of the primary determinants of alliance formation in the chemicals industry. Likewise, Stuart (1998) showed that alliance formation rates in the semiconductor industry are higher among firms with more patents.

While the role of patents in facilitating alliance formation has been well demonstrated, our interest is in exploring how patents might facilitate or inhibit the effect of CTO participation on alliance formation, and arguments about the moderating effect of patents may be derived in either direction. To the extent that patents represent firms' technological capabilities, it is reasonable that firms with more patents will exert more influence and gather more attention in the CTO venue. Such attention and influence would likely garner substantial opportunities for interaction in the CTO context, thereby facilitating alliance formation. In contrast, CTO participation engenders the sharing of more fine-grained and tacit information regarding firms' interests in the future and their views of the direction of the technology and industry. It also facilitates learning about the willingness to cooperate and the ways of conducting collaborative efforts by various firms. Patents, however, serve as explicit indicators of technological knowledge that are available to any interested parties without dyad-specific contact.[2] Firms with few patents cannot rely on this alternative mechanism to broadcast information about their technological capabilities and opportunities.

The technical culture of engineers that dominates the cooperative technical organizations is less accepting of heavily patenting firms. Agreement on standards that embody the intellectual property of certain participants locks the other participants into continuing financial commitments through licensing agreements, so participants without patents are motivated to adjust the standards enough to sidestep patents. Likewise, strategic patenting has become a practice in many firms that view patents as ways to increase their bargaining position in cross-licensing situations. Engineers, however, often believe that excessive patenting hinders

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See Miner and Haunschild (1995) for a discussion of population-level learning via broadcast (many-to-one) and contact (one-to-one) transmission.

access to knowledge that should be in the public domain and could be further developed. This view has been recently supported by research that decries the strong regime of intellectual property protection (David, 2000). For example, in an empirical study of the biotechnology industry, Lerner (1995) found that innovation by smaller firms was effectively deterred by the numerous patents held by large firms.

The same attitude of mistrust of firms who hoard patents is present among CTO engineers, who are driven by technical excellence. One technical committee chair from a well-known cellular equipment provider discussed how patents can raise challenges for firm representatives as they interact in technical committees: "Companies with patents have to work harder in the standards bodies. They have a more difficult time. They need to provide more technical support and justification—because of competitive reasons. The companies with patents are there to protect their patents." Because of the reluctance of engineers to accept readily firms that patent heavily, and because CTOs enable the transmission of less explicit knowledge, we propose that the fewer patents owned by the firm, the more the firm will rely on the CTO venue to transmit information and the stronger the relationship between joint CTO participation and alliance formation:

Hypothesis 4 (H4): The relationship between joint CTO participation and subsequent alliance formation decreases with the number of patents owned by the firms.

METHODS

The cellular industry is a suitable context in which to examine these issues, particularly during the time frame of our study. Between 1990 and 1995, the industry grew at a rapid pace, as revenues from the U.S. market alone increased from $4.5 billion to $19 billion. Similarly, capital expenditure rose from $6.2 billion to $24 billion, and subscribers grew from 5.3 million to 35 million during this same time. As a network industry, cellular telephony requires standards for effective development and usage of technology, so the set of technical committees devoted to these efforts are long-standing institutions with many active participants. The effectiveness of these associations in providing business coordination and collective goods (mainly standards) was partly responsible for the healthy growth of the industry, particularly in an era when competing standards could have led to destructive competition.

Our study period is also characterized by technological ferment. Established analog cellular service was challenged by multiple variants of digital technology. Specifically, Ericsson's time-division multiple access (TDMA) technology tripled bandwidth capacity and was first endorsed by the Cellular Telecommunications Industry Association (the U.S. trade association for service providers) in 1989. Qualcomm's code-division multiple access (CDMA) technology followed, with the claim to expand bandwidth by ten times or more, and CDMA was adopted as a digital standard by the Telecommunications Industry Association (TIA) in 1993. Concurrent with the establishment of digital technology was the effort to develop protocols for the suite of personal communications services (PCS) that enable the operation of hand-held devices. These PCS efforts were concentrated in the latter part of our study period, in conjunction with the 1994 federal auction of the higher frequency (1.8 to 2.0 gigahertz) spectrum.

To enable systematic data collection and analysis, we focus on the wireless communications activities sponsored by TIA, a U.S.-based trade association located in Arlington, Virginia. TIA is accredited by the American National Standards Institute (ANSI) to develop voluntary industry standards for a wide variety of telecommunications products. Membership in TIA is voluntary, meaning that any organization is welcome to pay dues in order to attend meetings and receive correspondence. Approximately 200 organizations are currently TIA members. While most of these members are commercial firms, providing either cellular service, equipment, or consulting services, other entities, such as governmental bodies and related trade associations, also maintain memberships.

There are two cellular-oriented committees in the wireless communications division of TIA. TR-45 and TR-46 (Public Mobile and Personal Communication Services Standards) develop performance, compatibility, interoperability, and service standards for cellular telephone and personal communication services. Each of these committees is further divided into subcommittees that split functional responsibilities (e.g., TR-45.1). A total of nine subcommittees and their associated meetings form the basis of our analyses.

The participants in these meetings are people intensely involved with technology. One-quarter of participants in our study have patented. The deeply technical nature of these committees was also corroborated by qualitative evidence. The interviewees stressed that the vast majority of the participants are technical professionals situated at the intersection of engineering and management. The technical professionals attend the meetings regularly. In contrast, non-technical participants (i.e., strategy, legal, marketing) attend on an occasional basis, and these minority groups are viewed as outsiders:

> To a great extent they [the participants] are engineers . . . . They have a credibility to protect—with respect to their engineering skills and knowledge. Some strategy guys turn up, for example, [*cites a specialized service provider*]. They are not technical people. These are the ones who create trouble.

In this technical environment, marketing and strategy professionals are regarded with suspicion, as their motives may not be primarily the achievement of technical excellence. Even the engineers and managers who do not patent possess in-depth technical knowledge. Because many of the participants understand both technical issues and managerial implications, they can effectively balance technological development and business coordination.

Data Sources

CTO participation data were obtained from *Communications Standards Review* (*CSR*), a trade publication that summarizes the activities of standards body activity in various telecommunications domains. The bimonthly radio-communications issues of *CSR* report on all TR-45 and TR-46 subcommittee meetings, publishing meeting minutes and attendance rosters. The publisher of CSR provided us with these rosters in electronic form from all issues of *CSR* from 1991 to 1995.

Meeting rosters are generated as meeting attendees sign their names and firm affiliations on lists generated and kept by TIA, the sponsor of each meeting. Over the five-year study period, the rosters listed over 150 separate meetings, attended by over 700 different individuals, for a total of more than 5,000 participants over all meetings. While these rosters offer the most comprehensive information about which individuals represented which firms in which committees at which times (compared with self-reported recall data, for example), there were two limitations to address. First, we consulted corporate databases and industry contacts to refine names in our set of initial firm references to create a consistent set of parent entities. For example, a representative might one month sign in on behalf of "AT&T–Network Systems" and in a subsequent meeting on behalf of "AT&T–NS." Second, participants who were heavily involved in the preparation of standards reports (thus interacting with other players) but not attending the actual meeting would not be listed. Preliminary comparisons of roster data with self-reported participation data by a subset of 25 individuals indicated some discrepancies, but when confronted with these discrepancies, most individuals attributed these instances to faulty recall.

Alliance announcement data for 1988–1996 were obtained from the Securities Data Corporation (SDC) database, which lists all joint ventures and strategic alliances worldwide. The database includes agreements in which two or more entities have combined resources to form a new, mutually advantageous business arrangement to achieve predetermined objectives. Types of alliances covered in the database range from intensive relationships, such as joint ventures, to arm's-length relationships, such as licensing and distribution pacts. This information comes from SEC filings and their international counterparts, trade publications, wires, and news sources. We focused most of our attention on the subset of alliances that contained a research and development component to insure that they could be realistically associated with the technical professionals' deliberations in the CTO context. Finally, patent data were collected from LEXIS/NEXIS and financial data from COMPUSTAT.

Sample

Our sample of cellular firms includes both service providers and manufacturers of cellular equipment. While we identified 174 firms through the *CorpTech Directory* and the *Million Dollar Directory*, we were obliged to limit our analyses to the 87 firms for which financial data were available for at least two of the years in our study period. While this may introduce some bias toward larger firms, we did so because of the necessity of controlling for some proxy of size, since size is strongly associated with both alliance formation and CTO participation. Focusing on a subset of firms with available data is consistent with several other current studies of alliance formation (cf. Stuart, 1998; Gulati and Gargiulo, 1999; Ahuja, 2000). Nonetheless, of our 87 firms, 67 (or 77 percent) participated in at least one CTO meeting. In contrast, of the 174 firms in the unrestricted sample, 107 (or 62 percent) did so, suggesting that smaller firms are slightly less active in the CTO venue.

Table 1 summarizes the CTO and alliance formation activity for our 87 firms over the study period. The number of firms forming technical alliances during 1991 to 1996 varied between 19 and 30. Over the entire period, 59 of the firms formed at least one technical alliance, while 27 did not form any. Similarly, in each year, the distribution of firms forming technical alliances is skewed strongly leftward. In other words, the greatest number of firms (more than half) form no technical alliances, and few firms have more than two technical alliances in a year. The total number of technical alliances formed between firm dyads in each year varied from 40 to 85. In addition, we can observe that CTO activity proliferated over the study period, as the total number of CTO meetings grew from 16 in 1991 to 47 in 1995, and the average number of meetings attended by firms grew correspondingly, from 5.95 in 1991 to 13.7 in 1995.

Variables

Alliance formation. Out of all cellular alliances listed in the SDC database, we extracted those in which at least two partners were firms in our sample. We constructed measures of dyadic alliances as counts of alliances formed by any two firms in the sample in a given year. For alliances that involved more than two firms, we counted the alliance as linking every possible dyad in the agreement. Approximately 13 percent of the alliances recorded included more than two firms; the maximum number of firms in an alliance was six. *Technical alliances formed by dyad* ranged from 0 to 5, with a mean of .020. This mean indicates that the vast majority of dyads do not form technical alliances. Similarly, the total alliances (both technical and non-technical) formed by dyads ranged from 0 to 7, with a mean of .031, and followed similar distributional characteristics.

Table 1

Yearly Counts of CTO Participation and Technical Alliance Formation for Sample

Sample characteristic	1991	1992	1993	1994	1995	1996
Firms forming technical alliances*	21	25	30	18	24	19
Total technical (dyadic) alliances formed	46	47	74	85	40	42
Total dyads in sample	2145	2485	2701	3160	3568	na
Firms participating in CTOs (out of 87)†	40	46	40	41	37	na
Total CTO meetings held	16	19	34	39	47	na
Average number of meetings attended	5.95	6.96	10.1	11.1	13.7	na
Total (dyadic) CTO interactions	1774	2684	2338	2807	2755	na

* Of the 87 firms, 59 formed at least one alliance, while 28 never formed an alliance.
† Of the 87 firms, 67 participated in at least one CTO, while 20 never participated.

CTO participation. *Joint CTO participation* is the number of CTO meetings in a given year in which both of the firms in the dyad participated. Mathematically, let $firm\_attend_{ikt} = 1$ if firm i attended meeting k in year t. Then for the dyad composed of firms i and j,

$$\text{joint CTO participation}_{ijt} = \sum_k (firm\_attend_{ikt} * firm\_attend_{jkt})$$

This variable ranges from a minimum of 0 to a maximum of 46, while the average is .80. Because the number of CTO meetings increased yearly, we controlled for the yearly CTO meeting count in all analyses.

Sustained individual-level participation. We constructed a variable to assess the degree to which firms (and dyads) maintained participation by the same individuals by comparing the set of individuals representing both firms in year t with those in the prior year. *Same individuals* is, for each dyad, the percentage of representatives in a given year that have CTO experience from the prior year. Mathematically, let $ind\_att_{pmt} = 1$ if person p attended a CTO meeting on behalf of firm m during year t. Then for the dyad composed of firms i and j,

$$\text{same individuals}_{ijt} = \frac{\sum_p (ind\_att_{pit-1} * ind\_att_{pit}) + (ind\_att_{pjt-1} * ind\_att_{pjt})}{\sum_p (ind\_att_{pit} + ind\_att_{pjt})}$$

Previous dyadic alliances. We included the number of technical alliances formed by the dyad during the previous three years, as well as its square, to control for the inverted U-shaped relationship between previous alliances and subsequent ones.

Patents. We identified each firm's explicit strength in cellular technology with yearly counts of all patents in the cellular classes 371, 375, 333, 370, 379, 455, 380, and 273 of the U.S. patent system. For each dyad, we summed patents of both firms and then logged this figure because the variable was highly skewed. Alternative formulations with differences and ratios did not change the results.

Controls. Several of our controls are specific to the CTO context. Since leadership roles of CTOs may grant firms power to generate agendas and select decision premises (Pfeffer, 1981), such roles may allow firms to shape the direction of technology in ways that favor them, making them more attractive alliance partners. We controlled for this possibility by noting the firms whose representatives were chairs or vice chairs of committee meetings. We constructed *CTO leadership* as a dummy variable, valued 1 when either of the firms in the dyad had served as a chair or vice chair of any CTO up to the current year. Alternative formulations using the number of firms in the dyad that have served as leaders (zero, one, or two), as well as dummy variables indicating whether both firms were leaders or only one firm was a leader, yielded comparable results.

Another possible concern with CTO participation data is that similarity in firms' CTO participation profiles might indicate some other unobserved mechanism related to firms' positions in the overall CTO network. For this reason, we derived a measure of similarity in CTO network position for each dyad. After calculating each firm's yearly betweenness centrality in the CTO network, for each dyad-year, we divided the centrality of the lower-centrality firm by the centrality of the higher-centrality firm. This control variable, *centrality ratio*, approaches its maximum of 1 for dyads in which both firms have similar structural positions in the CTO network and should obtain a positive effect if arguments of structural homophily (Gulati and Gargiulo, 1999) are correct. If both firms had a centrality of zero, we set the measure to zero. Alternative constructions of centrality, such as sums and differences, generated similar results.

The network externalities inherent in standards development and telecommunications service encourage the development of horizontal alliances among firms of the same type (either service providers or equipment manufacturers). Firms were coded as either service providers or manufacturers through inspection of their product/service lines. We created a binary variable coded 1 if both firms in the dyad were of the same type, offering the possibility of a *horizontal alliance*. Since alliance formation is positively associated with the *size* of the firms (Stuart, 1998), we included the logged sum of each firm's sales. Alternative formulations using differences and ratios of sales did not change the results. We also included separate counts for each firm's *total number of alliances* formed with any cellular firm during the previous year to control for firm-level propensities toward alliance formation. Such a control serves as an additional curb against unobserved heterogeneity (Heckman and Borjas, 1980).

We also controlled for the *number of CTO meetings* held during the year, because this number varies from 16 to 47 and serves as an upper bound to the total interaction between firms. Including such a control is critical but, due to its firm-invariant nature, precludes the inclusion of year dummies in the analyses. In separate analyses not reported here we observed significant year effects that highlighted the peak of alliance formation during the key years of convergence on CDMA technology (1993 and 1994) and then a subsequent decrease in the following two years. These changes in the rate of alliance formation are consistent with other studies that suggest alliance formation rates may vary between periods of high technological uncertainty and subsequent convergence on technical standards (Gomes-Casseres and Leonard-Barton, 1997). Results on the CTO meeting count control variable must be interpreted with this trend in mind.

Table 2

List of Variables and Predictions

Variable name	Definition*	Hypothesis	Predicted sign
Technical alliances	Number of technical alliances formed by dyad		Dep. var.
Joint CTO participation	Number of CTO meetings in which both firms in dyad participated	1a	+
(Joint CTO participation)^2	Number of CTO meetings in which both firms in dyad participated squared	1b	–
Same individuals x Joint CTO participation	Interaction term	2	+
Previous dyadic alliances x Joint CTO participation	Interaction term	3	–
Patents x Joint CTO participation	Interaction term	4	–
Same individuals	Percentage of dyad's individual representatives who also participated in previous year		NP†
Previous dyadic alliances	Number of alliances formed by dyad over 3-year window (t-1 through t-3)		NP
(Previous dyadic alliances)^2	Number of alliances formed by dyad over 3-year window (t-1 through t-3) squared		NP
Patents	Sum of the two firms' patents, logged		NP
CTO leadership	Dummy variable, valued 1 when either of the firms in the dyad has served as a chair or vice-chair of any CTO up to the current year		NP
Centrality ratio	CTO network betweenness centrality ratio: lower firm's value divided by higher firm's value		NP
Horizontal alliances	Dummy, valued 1 if both firms in the dyad are service providers or equipment manufacturers		NP
Size	Sum of the two firms' sales, logged		NP
Firm alliances	Total number of alliances formed by the focal firm with any other cellular firm		NP
CTO meetings	Number of CTO meetings held		NP

* All variables calculated on a calendar year unless otherwise specified.
† NP = no prediction.

Table 2 lists all the variables, their definitions, and posited effects. Table 3 displays descriptive statistics and correlations.

Analyses

We used the firm dyad as our level of analysis. Although we derived our sample at the firm level, every dyadic relation among them is a candidate case for our analyses. Given 87 firms and five years of observations, an upper bound to the size of our cases is 18,705 dyads.[3] Due to entries and exits of firms during the study period, however, our longitudinal dataset is unbalanced, resulting in 14,059 dyads for predicting alliance formation.

To explore the effect of joint participation on subsequent alliance formation, we regressed alliance formation in a given year (during 1992–1996) on all independent and control variables for the previous year (1991–1995). Since our dependent variable is a count, Poisson methods are appropriate. Given the high variance relative to the mean, however, negative binomial regression is indicated (Hausman, Hall, and Griliches, 1984). In addition, we employed a random effects model, as dyads may differ in their propensity to form alliances in ways that are unaccounted for by our explanatory variables (Stuart, 1998; Gulati and Westphal, 1999).

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In each of five years, there are (87x86)/2 possible dyads.

Table 3

Descriptive Statistics and Correlations for Dyads (N = 14,059)

Variable	Mean	S.D.	Min.	Max.	1	2	3	4	5	6
1. Technical alliances	.020	.18	0	5	–	–	–	–	–	–
2. Joint CTO participation (t-1)	.80	3.07	0	46	.05	–	–	–	–	–
3. (Joint CTO participation)^2	10.05	71.70	0	2116	.03	.89	–	–	–	–
4. Same individuals x CTO part.	.32	1.43	0	25.84	.05	.94	.87	–	–	–
5. Previous dyadic alliances x CTO part.	1.14	1.65	0	52	.04	.42	.44	.39	–	–
6. Patents x CTO part.	1.03	5.15	0	105.95	.04	.94	.93	.89	.45	–
7. Same individuals	.22	.29	0	1	.03	.16	.10	.21	.05	.13
8. Previous dyadic alliances	.055	.36	0	9	.32	.08	.07	.07	.32	.08
9. (Previous dyadic alliances)^2	.13	1.80	0	81	.24	.02	.01	.01	.13	.02
10. Patents	.56	.57	0	2.46	.07	.33	.25	.30	.15	.36
11. CTO leadership (t-1)	.12	.32	0	1	.03	.31	.23	.29	.10	.29
12. Centrality ratio (t-1)	.085	.21	0	.99	.05	.50	.33	.43	.19	.39
13. Horizontal alliances	.51	.50	0	1	.05	.01	–.01	–.01	.01	–.02
14. Size	8.63	2.00	.028	12.0	.11	.20	.12	.18	.07	.16
15. Alliances formed by firm 1	7.74	15.02	0	76	.17	.12	.11	.13	.10	.13
16. Alliances formed by firm 2	8.12	13.82	0	76	.13	.07	.06	.07	.07	.09
17. CTO meetings	33	11.74	16	47	–.03	.01	.04	.05	.02	.04

Variable	7	8	9	10	11	12	13	14	15	16
8. Previous dyadic alliances	.04	–	–	–	–	–	–	–	–	–
9. (Previous dyadic alliances)^2	.02	.85	–	–	–	–	–	–	–	–
10. Patents	.29	.15	.07	–	–	–	–	–	–	–
11. CTO leadership (t-1)	.25	.05	.02	.44	–	–	–	–	–	–
12. Centrality ratio (t-1)	.13	.06	.02	.17	.10	–	–	–	–	–
13. Horizontal alliances	–.01	.06	.05	.04	–.03	–.01	–	–	–	–
14. Size	.29	.15	.08	.46	.19	.20	–.01	–	–	–
15. Alliances formed by firm 1	.13	.24	.14	.24	.19	.07	.04	.37	–	–
16. Alliances formed by firm 2	.13	.19	.13	.25	.13	.09	.03	.35	–.01	–
17. CTO meetings	.16	.03	.02	.21	.07	–.09	.00	–.01	.04	–.03

We ran several models to explore these effects. Model 1 included all non-hypothesized variables to provide a baseline. Models 2 and 3 tested alternative forms of the basic relationship between joint CTO participation and alliance formation. Since each of our three hypothesized interactions involve the joint participation measure, models 4–6 introduced each interaction term independently. Model 7 included all interaction terms simultaneously. Since all of the interaction terms contained the joint participation measure, in model 8 we reduced collinearity by centering each term of the product around its mean before forming interaction terms (Jaccard, Turrisi, and Wan, 1990). In model 9, we regressed the total number of alliances on the same terms to assess the generalizability of the findings. To ensure comparability of results with model 8, model 9 also includes mean-centered interaction terms.

RESULTS

Table 4 displays the random effects negative binomial estimates of the rate of technical alliance formation by dyads. Joint CTO participation obtains a significant positive first-order effect on alliance formation along with a significant negative second-order effect. Taken together, these results confirm the diminishing increasing relationship proposed in hypothesis 1b. We used the coefficients from model 8, our full model, to evaluate the effect of joint CTO participation on subsequent alliance formation. At its mean, joint CTO

Table 4

Random-Effects Negative Binomial Estimates of Dyad-level Technical Alliance Formation (N = 14,059)*

Independent variable	1	2	3	4	5
Joint CTO participation (t-1)		.014	.091••	−.013	.134•••
(Joint CTO participation)^2			−.003•	−.004••	−.003••
Same individuals x CTO participation				.256•••	
Previous dyadic alliances x CTO participation					−.107•••
Patents x CTO participation					
Same individuals	.069	.071	.056	−.173	.084
Previous dyadic alliances	.730•••	.732•••	.711•••	.716•••	.947•••
(Previous dyadic alliances)^2	−.074•••	−.073•••	−.070•••	−.071•••	−.098•••
Patents	−.105	−.130	−.190	−.098	−.106
CTO leadership (t-1)	−.038	−.090	−.151	−.196	−.186
Centrality ratio (t-1)	.708•••	.586••	.367	.471	.379
Horizontal alliances	.597•••	.598•••	.588•••	.566•••	.572•••
Size	.518•••	.520•••	.523•••	.515•••	.482•••
Alliances formed by firm 1	.028•••	.028•••	.029•••	.028•••	.028•••
Alliances formed by firm 2	.025•••	.025•••	.026•••	.026•••	.025•••
CTO meetings	−.027•••	−.027•••	−.025•••	−.028•••	−.027•••
Constant	−7.774	−7.793	−7.910	−7.701	−7.583
Log likelihood	−1010.606	−1010.222	−1007.882	−1003.878	−998.025

Independent variable	6	7	8	9
Joint CTO participation (t-1)	.153•••	.068	.098••	.104•••
(Joint CTO participation)^2	−.001	−.004••	−.004••	−.002••
Same individuals x CTO participation		.211••	.211••	.163••
Previous dyadic alliances x CTO participation		−.102•••	−.102•••	−.049•••
Patents x CTO participation	−.064••	−.021	−.021	−.038•
Same individuals	.012	−.134	−.034	.023
Previous dyadic alliances	.737•••	.943•••	.861•••	.751•••
(Previous dyadic alliances)^2	−.073•••	−.098•••	−.098•••	−.097•••
Patents	−.053	.001	−.016	.061
CTO leadership (t-1)	−.202	−.218	−.218	.174
Centrality ratio (t-1)	.335	.458	.458	.457•
Horizontal alliances	.540•••	.541•••	.541•••	.746•••
Size	.493•••	.473•••	.473•••	.419•••
Alliances formed by firm 1	.029•••	.028•••	.028•••	.025•••
Alliances formed by firm 2	.027•••	.026•••	.026•••	.026•••
CTO meetings	−.026•••	−.029•••	−.029•••	−.023•••
Constant	−7.709	−7.405	−7.429	−6.378
Log likelihood	−1005.749	−994.217	−994.217	−1393.236

• $p < .10$; •• $p < .05$; ••• $p < .01$.

* Estimates in models 8 and 9 are products of mean-centered interaction terms; model 9 includes non-technical alliances in addition to technical ones.

participation multiplies the rate of alliance formation by a factor of 1.08 ($e^{[(.098*.8)-(.004*.64)]}$).[4] In contrast, at one standard deviation above its mean, joint CTO participation multiplies the rate of alliance formation by a factor of 1.38, and at two standard deviations above its mean, joint CTO participation multiplies the rate of alliance formation by a factor of 1.63. Therefore, joint CTO participation increases alliance formation at a diminishing rate.

Table 4 also shows that all hypothesized interactions are in the expected directions. The interaction of sustained individual participation and joint CTO participation is positive and significant, confirming hypothesis 2. The interaction of previous alliances and joint CTO participation is negative and significant, confirming hypothesis 3. The interaction of patents

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Joint CTO participation also appears in the interaction terms. Since the interaction terms are products of mean-centered terms, at the mean values of these variables, the interaction terms are zero.

and joint CTO participation is also negative, but not significant in the full model. Apparently, sustained individual participation and previous alliances have stronger effects on the relationship between joint CTO participation and alliance formation than patents.

To illustrate the two significant interactions, we must use the coefficients from model 7, in which the interaction terms are not mean-centered. For a dyad with mean levels of joint CTO participation, sustained individual participation, previous alliances and patents, the marginal effect of joint CTO participation on this dyad is that it multiplies the alliance formation rate by a factor of 1.08 ($e^{[(.068*.8)-(.004*.64)+(.211*.8*.22)-(.102*.8*.055)-(.021*.8*.56)]}$). In contrast, consider a dyad with its level of sustained individual participation one standard deviation above its mean while the other variables are at their means. In this case, the marginal effect of joint CTO participation is that it multiplies the alliance formation rate by a factor of 1.13 ($e^{[(.068*.8)-(.004*.64)+(.211*.8*.51)-(.102*.8*.055)-(.021*.8*.56)]}$). Therefore, joint CTO participation has stronger effects on the alliance rates of dyads with greater sustained individual participation.

The same logic applies in illustrating the interaction of previous alliances and joint CTO participation. For a dyad with its level of previous alliances one standard deviation above its mean while the other variables are at their means, the marginal effect of joint CTO participation is that it multiplies the alliance formation rate by a factor of 1.05 ($e^{[(.068*.8)-(.004*.64)+(.211*.8*.22)-(.102*.8*.415)-(.021*.8*.56)]}$), a reduction from its original level of 1.08. Therefore, joint CTO participation has stronger effects on the alliance rates of dyads with fewer previous alliances.

For the most part, our control variables have the expected effects. Previous alliance formation demonstrates an inverted U-shaped relationship with subsequent alliance formation. Size, horizontal dyads, and firm-specific alliance propensities are positively associated with subsequent alliance formation. Centrality ratio, however, is significantly associated with subsequent alliance formation in models 1 and 2 but loses significance in subsequent models with the curvilinear specification for joint CTO participation. No relationship is observed between sustained individual performance, CTO leadership, or technological strength with subsequent alliance formation. Finally, the number of CTO meetings is negatively related to alliance formation. Since this CTO meeting count is a proxy for year effects, this negative relationship indicates that alliance formations are decreasing while the number of CTO meetings is increasing on a year-by-year basis.

To assess the generalizability of our results, in model 9, we regressed the negative binomial counts of total alliances (rather than technical alliances) on the same variables as in model 8. Our results are generally comparable. The interaction effect for patents and joint CTO participation approaches significance ($p < .10$) in the full model when predicting all forms of alliances.

One might question whether the causal linkages might operate in the reverse direction: alliances might change patterns of CTO participation as alliance partners bring their partners into their CTO activities. We explored our CTO interaction patterns, however, and found that they did not deviate significantly from the random interaction that would be generated given each firm's level of CTO participation and the fixed number of CTO meetings each year.

DISCUSSION AND CONCLUSIONS

Our purpose in this paper was to show that the CTO venue provides a pre-alliance context in which firms communicate and identify opportunities for future collaboration. We demonstrated that the effect of joint participation in cooperative technical organizations was more strongly connected to subsequent alliance formation for firms without alternative means for this communication and identification, such as prior alliances. We also demonstrated that this effect was enhanced for firms that used the same individuals as representatives repeatedly, suggesting that the interpersonal ties forged by individuals serve as the microsocial building blocks for interfirm connections.

Several issues merit discussion as a result of these findings. The first is the issue of managerial agency and strategic participation. By focusing on a domain in which less-established firms can break into alliance networks, our results suggest how networks may be transformed through managerial agency. These findings stand in sharp contrast to the majority of studies of alliance network evolution, which have stressed the structural characteristics that inhibit network transformation (e.g., Walker, Kogut, and Shan, 1997; Gulati and Gargiulo, 1999). Instead, our results join a small group of studies that examine strategic activities firms may undertake to sidestep these dynamics, such as Ahuja (2000) on important inventions, Gulati and Westphal (1999) on director interlocks, and Stuart (1998) on technological positioning. While each of these studies demonstrates the role of specific managerial activities that may shape subsequent alliance formation, unlike our study, none of them directly addresses a network context that allows mid-level managers to interact. Given the anecdotal concerns about alliances being more prone to failure when they are forged by top-level managers without buy-in from lower-level personnel (Kanter, 1994; Handy, 1995), our study offers a starting point to think about testing the performance of alliances formed through a more bottom-up process and comparing them with those forged through top-down channels, such as director interlocks or executive mobility.

More generally, our results suggest the importance of considering participation in cooperative technical organizations as part of a larger strategy for knowledge acquisition and partner identification. In most firms, the decisions of which CTOs to participate in, and how many people to send, are made by local work groups. In keeping with our focus on bottom-up initiatives, we do not advocate top-down managerial control of this activity. Rather, we view the role of top managers as one of reinforcing the importance of this pre-alliance context, seeking to manage their technical professionals to generate the benefits of sustained individual participation, and encouraging dissemination of knowledge gathered in CTO activity more broadly within the firm. It appears that these approaches may be particularly important for less-established firms.

Second, our findings contribute to the growing literature on the benefits of associational activity. While the critical role of associations in promoting flexibility, innovation, and competitiveness for firms and industries through the production of collective goods like skilled workers, technical information, and standards has been well-documented, our research supports the asserted but rarely documented argument that networks are also one of the critical collective goods produced by associations. The American context of our study, where associations are circumscribed in their influence, may serve as a conservative test relative to other countries, particularly in Western Europe, where trade associations are more well developed, powerful, and interlinked (Schneiberg and Hollingsworth, 1990). In Germany, for example, sectoral associations are positioned to coordinate relationships among firms (Herrigel, 1993), promoting country-level competitiveness (Best, 1990).

Relatedly, it is important to note that the rules of such institutions are consequential for the outcomes of their activities and for firm strategies and ultimate success. The American associations observe the rule one-company, one-vote, which is enforced by the American National Standards Institute (ANSI). ANSI audits TIA every five years to make sure that TIA complies with the rule that ensures minority voice. In this context, the voice of small companies is more likely to be heard than in the European context, for example, where large firms can buy votes. It is a matter of policy what types of rules should be promoted at this supra-firm level. While antitrust concerns have always plagued industry associations (Scherer and Ross, 1990), it is actually the rules of such institutions that influence their outcomes (competitive or noncompetitive) as opposed to the existence of associations per se.

Third, our results bear on current approaches and findings in the network literature. It is worthwhile to reiterate that our results are generated by a very basic indicator of interaction in the CTO community—joint participation. This measure is strictly relational because it is derived for each dyad. More structural network measures, such as centrality calculations, do not help to predict technical alliance formation beyond our basic measures of interaction. If anything, our results suggest that joint CTO participation mediates the relationship between centrality ratios and alliance formation. Empirically, this is true because centrality derives from an aggregation of joint CTO participation counts, and the correlation between the two variables is substantial. Theoretically, however, much of the network literature in which actor centrality is found to be an important predictor of organizational outcomes relies on more diffuse information on firms' reputations. For example, Gulati and Gargiulo (1999) found that firms that have high centrality in an alliance network are more likely to form subsequent alliances. This effect is predicated on two effects of a central network position: access to fine-grained information about potential partners and increased visibility to interested parties. The information exchanged in CTOs, however, is not simply information about firms' reputations as alliance partners. In the CTO context, the type of knowledge being circulated is highly specific, capturing the heart of technological information exchange.

Similarly, our focus on participation by people in CTOs leads us to straddle boundaries between firm-level and individual-level constructs. Our measure of sustained individual participation acknowledges that it is not sufficient for the study of interfirm mechanisms to aggregate all individual-level activity on behalf of firms. Of course, our specific measure is but a small step toward what has been called "meso" research (Rousseau and House, 1994), as far more can be done to examine particular individual dyads, as well as the roles specific individuals play for their firms. For example, future research needs to examine how the career mobility of engineers between firms can reshape not only the CTO context but the alliance context as well.

Fourth, our results for the interaction between patents and joint CTO participation were inconclusive. When the other interactions were included in the model simultaneously, the patent interaction was not significant. This suggests that the explicit knowledge communicated by patents may not be sufficient to displace technical collaboration in CTOs. In contrast, when we included licensing and other non-technical alliances along with our dependent variable, we found that the patent interaction approached significance in the full model. This suggests that the seeds of licensing agreements may rely more heavily on the codified knowledge captured in patents. More broadly, it is plausible that the patents simultaneously attract and repel CTO interaction, as patents may also serve as "admission tickets" to the forum of knowledge exchange in CTOs.

Fifth, the generalizability of this study may be limited. While cooperative technical organizations exist in most industries, their scope and influence may vary dramatically. It is unlikely to be a coincidence that industries like pharmaceuticals and biotechnology, with well-developed intellectual property regimes, exhibit less CTO activity. Future research could compare these dynamics across industries with varied appropriability regimes, technological complexity, regulatory strength, and/or market concentration. In addition, while our findings bear on the ability of less-established firms to benefit from CTO activity, firms for which no size data are available cannot be included in the analysis. So the question of how firms emerge and prosper sufficiently to appear in industry databases, and begin to utilize the CTO venue effectively, remains open.

In conclusion, our examination of the supra-structure of industrywide technical committees demonstrates how and when the actions of managers may help transform networks. Of course, recognition of the community processes that structure technological exchange and determine technological outcomes is but a first step in understanding how firms and individuals might attempt to reconfigure such structures to their advantage. Studies such as ours reinforce the strategic importance of community participation, particularly in the informal venues, where resource commitment can be more minimal. At the same time, the overall flows of knowledge between similar and complementary firms occur through many mechanisms, and further study of the interrelationships among these mechanisms will be key to our understanding of technological and organizational evolution.

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