Collaboration and Networking in Cooperative Standard Setting*

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Abstract

We examine factors behind firms' decisions to contribute private resources to the creation of a public good in cooperative standard setting. Our study highlights a novel explanation: firms seek to improve their positions in an inter-firm (social) network. The empirical analyses utilize panel data from wireless telecommunications. In the standard-setting organization we study, firms develop new technical specifications in small committees. Our results demonstrate that social network connections to peers influence firms' decisions to join and thus provide resources for these committees. Additionally, standard specifications tend to be produced by committees where participants complement rather than compete with one another.

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1 Introduction

Technical standards determine the terms of competition in network-technological industries such as communication and information technologies. As noted by Farrell, Monroe and Saloner (1998), the nature of "component competition" within a standard drastically differs from that of "systems competition" between standards. In many network industries, there is a strong cooperative element to standardization (see e.g. Greenstein and Stango, 2007: 1-15) and firms make substantial financial investments in cooperative standard-setting organizations. Nevertheless, to date, management and economic research have contributed relatively little to our understanding of cooperative standard setting. Our paper is among the first to examine the process of standard-setting committee work in detail and to empirically study social network formation by strategically motivated firms. Our approach highlights the networked nature of cooperative standardization. We examine the evolution of the committee network and firms' decisions to improve their position therein.

The main goal of this paper is to identify factors behind firms' decisions to contribute to the creation of an open standard. We study the standard-setting process in a major wireless telecommunications standards development organization, Third Generation Partnership Project (3GPP). 3GPP standard specifications are created in temporary work-item committees. Participation in a work-item committee entails non-negligible investment of human resources by firms. We analyze the repeated decisions of 44 member firms to support these committees. Our premise is that firms' participation in the cooperative standard-setting organization, and particularly their investment in work-item projects, reflect their desire to maximize private payoffs. Previous empirical studies of cooperative standard-setting organizations have highlighted the roles of market power and intellectual property in determining firms' ability to influence standardization processes (Weiss & Sirbu, 1990; Simcoe, 2004). However, firms with essential patents are a small minority in 3GPP: we argue that most firms participate in formal standard setting, because it presents opportunities for information exchange, and because through collaboration firms gain access to other firms' complementary R&D assets.

We support these claims with two sets of novel findings. First, we show that firms strategically position themselves in the evolving inter-firm network. Second, we find that firms are more likely to participate in committees when their technological assets are different from those provided by the original source of the technical feature (work item) idea, and when they have fewer ties with the source through other industry consortia. Firms also prefer work items with diverse industry participation. These latter results suggest that collaboration in work-item committees is based on R&D complementarities rather than on competition among similar IP holders. Work-item projects may create opportunities for firms to access complementary knowledge and expertise.

Our treatment of committee networks builds on Jackson and Wolinsky's (1996) connections model to quantify firms' net benefits from work-item network connections. Benefits from connections to other firms can arise from information exchange and integration of knowledge from the parties in a work-item project. Connections to potential clients may also enable advertising of a firm's expertise or technologies. As typically assumed in the social networks literature, direct connections are costly to form, but indirect ones are free. In our setting, directly connected firms need to work together in a committee. Following a large literature on alliance management, we argue that firms learn to cooperate with specific partners, and, therefore, the costs of cooperation are higher when firms work with new partners—form new direct connections (see Gulati, 1995; Heide & Miner, 1992; Ring & Van De Ven, 1992, among others).

In our empirical application, the social network evolves over time as more work-item projects are started. We collected a unique dataset of 62 consecutive work-item committees and firms that supported them in 3GPP's Radio Access Network subgroup for the period of 2000-2003. Using fixed-effects panel-data analyses, we find support for our hypotheses regarding the roles of network connections and technological complementarities within work-item projects.

This paper is organized as follows: Section 2 reviews related literature and describes the committee-based standard-setting processes in the Third Generation Partnership Project. Section 3 formally describes the affiliation and social networks and their formation. Section 4 presents the data; Section 5 the regression analyses; and Section 6 offers concluding remarks.

2 Committee-Based Standard-Setting Processes

2.1 Related Literature

Our study builds on and extends two distinct bodies of literature: standard setting and social networks. The early literature on standard setting focused primarily on market-based standards battles (e.g., Katz & Shapiro, 1985; Katz & Shapiro, 1994). More recent models of cooperative standard setting include Farrell & Saloner, 1988; Simcoe, 2004; Farrell & Simcoe, 2007; and Lerner & Tirole, 2006. The first three of these papers model the creation of committee-based standards as a war of attrition and examine the efficiency of this form of standardization. Simcoe (2004) and Farrell & Simcoe (2007) focus particularly on the role of intellectual property rights. Lerner and Tirole, on the other hand, examine the choice of standardization forum through a model of forum shopping. None of these studies have recognized the nature of standard setting activities as a network of cooperation and communication, which is the viewpoint taken in our research.

A network-analytical approach has been taken by a few earlier empirical studies of standard setting. Leiponen (2008) found that firms' ability to influence formal standardization depends on their connections to peers in other technical industry consortia. This suggests that firms operate in a network of influence and information exchange. In a related study, Rosenkopf and Tushman (1998) described how the nature of network evolution depends on the level of technological uncertainty. However, these studies examined firms' decisions to join multiple cooperative technical organizations (industry associations and consortia), while our focus is on the evolution of the committee network within one single standard-setting organization. Furthermore, our study more explicitly models firms' decisions to join committees that, in the aggregate, result in network evolution. The most closely related study examines strategic alliance formation in the mobile communication industry (Rosenkopf and Padula forthcoming). It highlights the entry of new firms into the network.

We contribute to a fledgling empirical literature on the process of firms' strategic network formation by examining the evolution of both direct and indirect connections. Our framework highlights an incentive to contribute to open standard setting beyond the opportunities to insert intellectual property in the standard in the expectation of royalty revenue. Informal discussions with practitioners and the observation that many firms without essential intellectual property invest in work-item projects suggest that firms want to influence the standardization outcome even without the potential of royalty revenue. Our results can be interpreted to mean that information exchange—learning, influencing, and advertising—is a strategically important aspect of cooperative standard-setting activities. In particular, we find that indirect social network connections carry significant private benefits.

2.2 Third Generation Partnership Project

Our study highlights firms' decisions to contribute to cooperative standard setting by analyzing the committee activities of one formal standard-setting organization, Third Generation Partnership Project (3GPP). The notion of third-generation wireless telecommunications (3G) refers to the shift from digital voice communication (2G) to the era of "mobile internet" or "broadband wireless," which expands the range of mobile communication services from transmission of voice to various kinds of data, including pictures and multimedia. These new services require substantially greater data transfer capabilities than does pure voice communication.

3GPP is the international standards development organization for one of the 3G standards, Universal Mobile Telecommunications System (UMTS). 3GPP evolved from the Special Mobile Group that operated under the European Telecommunications Standards Institute (ETSI) and was responsible for the development of Global System for Mobile (GSM) communication standards. Created in 1998, 3GPP is not a legal entity but a collaborative alliance among standardization organizations from three continents (North America, Europe, and Asia). Recognition of the need for worldwide standards for the next-generation cellular telephone systems implied that standardization activities be organized through a truly global organization. In 2000, there were 338 individual members in 3GPP ranging from telecommunication operators and equipment suppliers to various kinds of technical consultancies and R&D service firms. Individual members can participate in technical specification groups and working groups by attending meetings, contributing to specification development, and acting as group chairpersons.

The development of technical specifications in working groups proceeds formally through work items. Work items are specific technical features that are proposed by individual members to a working group. Supporting a work item implies that the firm takes shared responsibility of drafting the specification with other supporting firms. In 2000, 363 work items were proposed and started in all 3GPP technical specification groups, and 62 of these were in the Radio Access Network group studied here. Of the over 300 firms that were 3GPP members in 2000, only 62 firms participated in the committees that supported work item creation in all technical specification groups, and 51 of these organizations supported work items in the Radio Access Network group.[1] Moreover, such participation is highly concentrated within a few industry leaders (see table 1). These data are aligned with the view presented by Schmidt and Werle (1998) that many members in standards development organizations participate to learn about upcoming technologies and to align their innovation activities with the industry rather than to actively promote a standardization agenda driven by private benefits from the adoption of their preferred technical solutions. On the other hand, those members who invest resources in specification development are likely to be interested in outcomes that are associated with private benefits (Branscomb & Kahin, 1995).

Individual members of 3GPP are bound by the intellectual property rights (IPR) policies of their regional standardization bodies. In most cases this implies agreeing to license patents related to essential technologies under "fair, reasonable, and nondiscriminatory"

[1] Although 51 different organizations supported work items in the Radio Access Network group, supplementary data are only available for 44 of them. These 44 firms are included in the empirical analyses that follow.

(FRAND) terms. In reality, even if negotiations are open and nondiscriminatory, firms with the strongest patent portfolios and other technological assets may be the most influential. Thus the opportunities to influence standards negotiations may indeed motivate and direct technology development and patenting activities (see Gandal et al., 2004). As a result, intellectual property is one of the key elements in standards negotiations.

3GPP members are expected to declare a patent as "essential" when it is potentially implicated by a new specification under development in standard-setting committees. The European Telecommunications Standards Institute keeps track of 3GPP-related intellectual property. In 2005, their database contained 837 declarations of essential intellectual property rights related to the third-generation wireless telecommunication network and including patents registered in the United States. However, these declarations originated from just 18 firms. Major communication technology firms such as Motorola, Ericsson, InterDigital, Qualcomm, Nokia, and Siemens were the dominant companies, each with dozens or even hundreds of declarations of intellectual property rights initially registered with the United States Patent and Trademark Office. The small number of firms with any essential patent declarations suggests that participation in wireless telecom standard-setting committees is driven by other factors for the great majority of firms.

This paper examines how opportunities to exchange information with peers influence firms' contributions to open standard setting. We also examine how firms' intellectual property portfolios and other resources moderate this relationship.

3 Committee-Induced Social Networks

In this section we formally define the network that evolves in the context of the 3GPP standard-setting organization. In the network we study, the set of players consists of firms that are members of the Radio Access Networks technical specification group in the 3GPP standard setting organization. Links between pairs of firms are formed when firms collaborate in work-item committees—temporary committees that develop technical specifications for the standard.

3.1 Affiliation Networks and Induced Social Networks

An affiliation network describes links between nodes of two distinct types. Let the work-item affiliation network in our application be $AN = \{\mathbf{N}, \mathbf{T}, \widetilde{g}\}$ where $\mathbf{N} = \{1, 2, ...N\}$ are the firms $\mathbf{T} = \{1, 2...T\}$ are work-item committees and $\widetilde{g} \subseteq \mathbf{N} \times \mathbf{T}$ is a set of edges or links between firms and the work item committees they support. An element $(i, t) \in \widetilde{g}$ indicates that firm i supported work-item committee t.

To define a social network of firms within 3GPP we assume that a direct link is formed between two firms i and j in the network g if i and j belong to a common work-item committee in $\widetilde{g}$. As these firms interact and collaborate to jointly develop some aspect of the technological system, they are likely to exchange R&D ideas and know-how, share a common goal, and work together to achieve it. Their collaboration may also create personal relations among their representatives. Hence, collaborations in work-item committees induce network relations among the supporting firms. Let $ij = \{i, j\} \subseteq \mathbf{N}^2$ represent an unordered pair of players. For any committee network $\widetilde{g}$ we define the induced social network g as follows:

Definition 1 *The social network induced by the affiliation network* $\widetilde{g}$ *is*

$$g = \{ij : \exists t \ \ for\ which\ (i, t) \in \widetilde{g} \ \ and \ \ (j, t) \in \widetilde{g}\}.$$

Networks in our application are generated by the sequential creation of work-item committees. For simplicity we use a discrete time line, and identify each "period" with the formation of one work item. In the initial period $t = 0$, the work-item affiliation network and the induced network are empty $\widetilde{g_0} = g_0 = \varnothing$. In every period $t > 0$, the committee network $\widetilde{g_t}$ has links between every work item committee $1, ..., t$ and its members. Note that according to this definition, network connections last from the period they were first formed to all subsequent periods. Given that our data spans only four years and that each work-item project was active for a significant period of time (about one year on average) we found it reasonable to assume that the social connections last for the entire period we study.

3.2 Connections Value and Payoffs

To empirically test the hypothesis that firms value network connections, we need to quantitatively represent the value of the network to each firm. We take the approach suggested in Jackson and Wolinsky (1996). In their *connections model*, player i has an intrinsic value w_{ij} from a connection to player j, and in the symmetric case $w_{ij} = w$. Players' value from a connection also depends on the length of the shortest path between them. Distant connections are valued less than closer ones. In Jackson and Wolinsky's model, when the shortest path between i and j is of length ℓ_{ij}, its value is discounted with a factor $\delta^{\ell_{ij}}$ where $\delta \in (0, 1)$ is a constant discount factor. In a truncated version of the connections model, values are obtained from paths of length $\ell \leq D$, and no value is obtained from more distant connections (see Jackson and Rogers 2005). More generally, (allowing for non-exponential discounting) in our empirical model, we take the value of connections to be

$$CV_i(g) = \sum_{\ell \leq D} \beta_\ell \times conn\ell_i(g) \tag{1}$$

where $conn\ell_i(g)$ is the number of connections with a path of length ℓ firm i has in network g. For example, $conn1_i(g)$ is the number of direct connections, and $conn2_i(g)$ is the number of indirect connections with a shortest path length 2.

As in Jackson and Wolinsky, we assume that only direct links are costly: player i bears a cost c_{ij} for a direct connection with player j, and $c_{ij} = c$ when assuming symmetry.[2] The cost associated with player $i's$ connections in g is given by,

$$c_i(g) = \sum_{\{j:\ ij \in g\}} c_{ij} = conn1_i(g) \times c.$$

In the Jackson-Wolinsky connections model, as in most of the economics literature on social networks, players (firms) form pairwise connections. In our application, however, connections between firms are induced by joining work-item committees. This can involve connections to several other firms at once. Supporting a work item brings two types of benefits to the firm: a value that arises from social connections with other firms and a direct value from the project itself. Firm i's payoff in the t^{th} period depends on whether it joins this work-item committee. Let the net direct value to firm i of participation in work item t be v_{it}, and zero if the firm does not participate. The value of network connections depends on the structure of the network in period t. Fixing the behavior of all other firms, let g_t^{+i} denote the induced social network if player i joins the work item and let g_t^{-i} be the induced social network if this player does not join the work item.

In the empirical analysis we construct the networks g_t^{-i} and g_t^{+i} as follows. For a firm

[2] In practice, network costs and benefits may depend on firm characteristics. In the empirical analysis we control for firm characteristics and also examine their interaction effects with the network connections.

i that was not a supporter of work item t, g_t^{-i} is the network that was actually observed in the data in period t : $g_t^{-i} = g_t$. For this firm, g_t^{+i} is the network that would have resulted if the firm had joined work item t while all other firms kept the same actions as observed. Thus, it is the network induced from $\widetilde{g}_t \cup \{(i,t)\}$—the actual committee network in period t, only with the addition of player i to work item t. For a firm i that was a supporter of work item t, g_t^{+i} is the network that was actually observed in the data in period t : $g_t^{+i} = g_t$. For this firm, g_t^{-i} is the network that would have resulted if the firm had not joined work item t while all other firms kept the same actions as observed. According to the 3GPP policies, a committee can only form if it has at least four supporters. Hence, the network that would result if a supporter i did not support work item project t depends on the number of supporters in the committee. If the actual number of supporters in work-item committee t was at least five, then g_t^{-i} is the social network induced from the actual committee network in period t only with the exception of firm i not being included in work item t, $\widetilde{g}_t \backslash \{(i,t)\}$. If, on the other hand, work item t had four members, then, if supporter i did not support, and all other firms kept the same actions, the work item would not have formed, and g_t^{-i} would have been the same is it was the previous period $g_t^{-i} = g_{t-1}$. Using these definitions we can now derive the payoffs to each firm from supporting and from not supporting a work-item project.

Given the behavior of all other firms, firm $i's$ immediate payoff in period t if it joins or if it does not join period t work-item committee are:

$$\begin{aligned} u_{it}(g_t^{+i}) &= v_{it} + CV_{it}(g_t^{+i}) - \left(conn1_i(g_t^{+i}) - conn1_i(g_{t-1})\right) \times c, \qquad (2) \\ u_{it}(g_t^{-i}) &= CV_{it}(g_t^{-i}). \end{aligned}$$

where CV_{it} is defined in (1).

We know that $conn1_i(g_{t-1}) = conn1_i(g_t^{-i})$, because the number of a firm's direct connections if it does not join would be the same as the number of direct connections it previously made. Let us now denote

$$\Delta conn\ell_{it} = conn\ell_{it}(g_t^{+i}) - conn\ell_{it}(g_t^{-i}) \tag{3}$$

The difference between payoffs from joining and not joining is:

$$\Delta u_{it} = u_i(g_t^{+i}) - u_i(g_t^{-i}) = v_{it} + \sum_{1<\ell\leq D} \Delta conn\ell_{it} \times \beta_\ell + (\beta_1 - c)\, \Delta conn1_{it} \tag{4}$$

where D is the longest path for which indirect connections carry benefits for.

The formulation of payoffs in (2) assumes the cost of direct connections is only incurred in the period when the link was established. Hence, if a firm supports a new work item, it will pay for every new direct connection $conn1_i(g_t^{+i}) - conn1_i(g_{t-1})$, while if the firm does not join it incurs no additional cost from existing direct connections. We note however that the equation we estimate (4) defining the difference in payoffs would be the same if we alternatively assume that direct connections are costly to maintain and thus a cost is incurred for every existing direct connection in every period.

3.3 Work Item Formation

In every period, a randomly chosen firm which is referred to in 3GPP as a *source* initiates a work-item project. There are two stages to the formation of each work-item committee. In the first stage, the source informally suggests the committee composition for the proposed work-item project. This stage has no direct effect on payoffs. In the second stage the work item is formally proposed in a meeting with all firms. All firms simultaneously choose an action to support or not to support the work-item project. Work item formation is repeated every period, a process which creates a sequence of work item affiliation networks $\{\widetilde{g}_t\}_{t=0}^{T}$ and an associated sequence of induced social networks $\{g_t\}_{t=0}^{T}$.

We assume that, in every period, firms' simultaneous decisions to join or not to join the work item constitute a Nash equilibrium in a game where payoffs associated with the decision are current-period payoffs. That is, for every t, the affiliation network $\widetilde{g}_t$ is such that

(i) For all $i \in M_t \quad \Delta u_{it} \geq 0$,

(ii) For all $i \notin M_t \quad \Delta u_{it} \leq 0$.

where M_t denotes the members of work item committee t and Δu_{it}, defined in (4).

This assumption reflects myopic behavior. Firms behave as if they are not taking into account the consequences of their current decisions for the dynamic process of network formation and for expected future payoffs. In assuming this simple dynamic process we follow Jackson and Watts (2002). Forward-looking behavior would require much information and sophistication on the part of the firms. In a complex and random environment (e.g. firms do not know which future work items will be proposed, what information is available to other firms, what their future payoffs will be, and for how long the organization will remain active), an assumption of myopic decision making appears to be reasonable.

We note that in every period at least one pure strategy Nash equilibrium always exists – no firms supporting is always an equilibrium. This is true despite there being a direct value to a each committee because the organization requires that each work item to have at least four members. There could be multiple Nash equilibria. While no equilibria are formally refined, we assume that the source's pre-play communication serves as a focal point. That is, our hypothesis is that the source suggests a committee of supporters that constitutes his preferred pure strategy Nash equilibrium, and that this equilibrium will be played by the firms in the second stage, when they can choose to support or not to support.

When firm i joins work item t it must be that $\Delta u_{it} \geq 0$. This is more likely to hold when committee t has a large (direct) value to player i, and when the potential increase in indirect connections is large. The effect of direct connections is theoretically ambiguous and will be determined empirically. In the empirical analysis that follows, we test these network-related hypotheses and additional hypotheses related to factors that affect the direct value of joining work items.

4 The Data

The empirical analyses utilize data on firms' participation in 3GPP work-item committees collected from 3GPP meeting documents available online, and data on firm size, intellectual property holdings, industry affiliations, and activities in other technical consortia collected from sources such as company and consortium websites and various databases including Hoover's, Micropatent, and the ETSI IPR database. Because the organization only started operations in 2000, we can track the origins and the evolution of this network of cooperative committees. We focus on the evolution of work item cooperation networks within one single technical specification group, Radio Access Networks (RAN), which is a central technical field within the whole UMTS system. This is where the highly-contested air interface and protocol specifications are negotiated and developed.

Specification development work is carried out continuously through email communication, but decisions and group discussions take place in meetings three or four times a year. Our data follow specification development through 62 work items discussed in 14 meetings over a period of four years (2000 - 2003).[3] Each work item proposal presents an opportunity for firms to decide whether to join the project and thus possibly improve their network positions. The state of the network is observed each time a new work item has been proposed. The 62 consecutive work items thus represent the time dimension of our panel. On average, a handful of work items are proposed in each meeting. The most frequent contributors to the 3GPP committee work are listed in table 1. The top three on the list are major European technology vendors, pointing to the European origins of 3GPP, but a clear majority of the fifteen most active contributors are non-European—Asian or North American. With the exception of InterDigital, these companies are large telecom equipment vendors or operators.

There is great variation in terms of essential intellectual property declarations made by work-item contributors (table 1). Most firms declare none, while the IP leaders in the group (Nokia, Ericsson, Motorola, and Samsung) have indicated that they have hundreds of patents that may be related to some standard specifications. An interesting observation is that Qualcomm, a firm that had over 200 essential IP declarations, is not among the most frequent contributors (its work-item contributions are below sample mean). Clearly, it has followed a different cooperation strategy than Nokia, Ericsson, and Motorola.

The estimation sample consists of firms that supported at least one work item and for whom additional information is available. Table 2 displays the descriptive statistics for these 44 firms and their 62 consecutive work-item decisions, resulting in 2728 observa-

[3] To make sure that the results are not driven by one outlying large work item, we exclude from the analysis a work item that was supported by 18 firms. All other work items are supported by $4-9$ firms. Results remain unchanged if we include this work item. Either way we accounted for the work item in the definition of the network variables.

tions. Pairwise correlations are provided in appendix A1. The dependent variable is WI supporter, which is a binary variable equal to one if a firm i decided to support work item t. Source is the firm that initially proposed a specific work item, and, arguably, significantly influenced the composition of the work-item group. Information about work-item sources is used to form the technology distance and consortium ties variables.

Table 2 also features all the network variables used in the empirical analyses. The main explanatory variables of interest describe changes in a firm's network connections should it decide to join the current work item. The variable $\Delta conn1_{it}$ captures the change in the number of direct connections (see section 3 equation (2)), while $\Delta conn2_{it}$, $\Delta conn3_{it}$, and $\Delta conn4_{it}$ measure changes in indirect connections of length two, three, and four, respectively.

We account for the unobserved technological content of the work-item project by including two measures of the technological relationship between a firm and the work-item source. For our first measure we consider 15 key wireless telecommunications patent classes and define each firm's patent portfolio as the share of US patents it has in each class out of its total holdings in the 15 patent classes. We then find firm i's Euclidean distance to the work-item source in terms of their patent portfolios.[4] The second measure we define is consortium ties that counts the number of firm i's overlapping memberships with the source of the current work item in other technical consortia.[5] The consortia considered here include 24 cooperative technical organizations that develop or promote various wireless communication technologies.[6]

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[4] The Euclidean distance between firms i and j is defined as $E_{ij} = \sqrt{\sum_k (p_{ik} - p_{jk})^2}$, where p_{ik} referes to the share of patents in each class k.

[5] A similar variable measuring repeated ties has been used in prior network research, for example Rosenkopf and Padula (2008).

[6] The list of these organizations is available from the authors on request.

These two variables are intended to capture underlying, unobservable technology preferences, because firms' participation in work-item committees may be driven by specific R&D interests. They also reflect the composition of the work-item committee, because sources are usually also supporters of the work item they proposed, and because sources may influence expectations regarding other firms' decisions to join. These variables also have the benefit that they only require knowledge of the source firm, which is determined before other firms decide whether to join a work item.

Control variables include a set of binary indicators of firm size and natural logarithms of firms' patents in three jurisdictions—Europe, United States, and Japan. Firm size classes are identified from six sample quantiles. Additionally, small privately-held firms for which employee information is not available are included in the first group. In the estimations, size class six is the reference group. We also have information about firms' holdings of intellectual property (IP) that they have declared as potentially "essential" to the standard. Essential IP means that these patented technologies may become part of the standard, in which case other firms may have to pay royalty fees to the firm if they want to implement the standard in their own products. We use the natural logarithm of the number of essential IP declarations. All these control variables are observed annually.

As a descriptive analysis of the relationships among explanatory variables and the dependent variable, table 3 provides means and standard deviations for key control variables separately for firms that joined at least one work-item committee and those that did not join any committees. Firms that supported at least one work item clearly differ from the rest of the 3GPP members. On average, they are larger, devote more resources to standard setting as measured by the average number of representatives in each meeting, and have more patents in all jurisdictions and more intellectual property declared as essential for 3GPP standards. Firms that acted as sources of new work item proposals are even larger than other work-item supporters, and have an even greater interest in standard setting, evident in the larger number of meeting representatives. To a significant degree, this interest is probably driven by their intellectual property holdings. Finally, we note that in the Radio Access Network technical specification group of 3GPP, equipment vendors and telecommunications operators carry a disproportionate load in supporting and proposing new work items.

Table 4 displays our final set of descriptive statistics, now at the level of work-item committees. On average committees have about 6 members from 2.5 different industries. Usually one of the members is a small company, defined as belonging to the smallest third of the sample in terms of number of employees. There are no committees consisting entirely of members without any patents, and most committees have some members with large and diverse patent portfolios. However, some committees do not include any members that have essential IP.

5 Regression Analyses

5.1 Empirical Model

Next we empirically examine firms' decisions to support work items in a panel data framework. The dependent variable indicates whether firm i of joined work item committee t. As described in equation (4) in section 3, we expect the probability of joining a work-item committee to depend on the costs and benefits associated with the work item itself as well as on those associated with changes in firms' network connections. We are particularly interested in firms' networking behavior, and thus our empirical analysis focuses on variables that account for network-related costs and benefits associated with joining a work-item committee. These depend on changes in the focal firm's direct and indirect connections.

Our main hypothesis is that firms will respond to opportunities to form new network connections through work-item committees. Firms may enjoy information benefits from both direct and indirect connections to peers and join work-item committees simply to learn from other committee members or advertise their own products and technologies to potential clients. Thus, by improving its network position a firm may get access to a richer and more diverse set of information. However, working with new partners is more costly than working with familiar ones. Firms learn to cooperate with one another and become a more effective team as they repeat projects with the same partners. Hence, the effect of indirect connections is expected to be positive, and the effect of direct connections can be positive or negative depending on the balance between costs and benefits of new direct connections.

To control for other possible explanations for joining work-item committees, we include variables that may affect the direct value of joining a work-item committee. First, the benefits of joining a work-item committee include opportunities to insert proprietary intellectual assets into the standard specification so that others have to pay royalties. Firms with essential intellectual property may thus receive higher direct benefits from work items. We control for this with the IP variables.

Second, the expected benefits from work-item committees may depend on the technological content and the composition of the committee. We consider two alternative hypotheses: firms participate in work-item committees primarily to compete with and monitor rival firms; or firms participate in work-item committees primarily to develop new technologies and learn from and utilize the expertise of other firms in the organization. If the former hypothesis is true, we would find that firms are more likely to join committees where other firms are similar to them in terms of R&D portfolios and committees that are homogeneous in terms of industry representation. If the latter hypothesis is true, we expect firms to join committees consisting of other firms with complementary technological assets. Technological composition of the committee is reflected by two variables: (i) the technological distance of the focal firm from the source of the work item (the firm that originally proposed the work item), (ii) the number of overlapping memberships in technical consortia between the firm and the work-item source.

Finally, the direct costs of joining a work-item committee arise from the need to devote human resources to work-item development. Cost of resources (capital) is likely to be higher for small firms, and hence, committing resources to specification development work may be more costly to them. Hence, we include a set of firm size variables. The main specification of our empirical model can be written as follows:

$$\Delta u_{it} = \alpha + \beta_1 size_{it} + \beta_2 IP_{it} + \beta_3 RS_{it} + \beta_4 \Delta conn_{it} + \gamma_i + \psi_t + \varepsilon_{it} \qquad (5)$$

where $size$ represents a vector of firm size variables; IP is a vector of intellectual property variables, entered in natural logarithms; RS is a vector of variables representing the relationship between the firm and the source of the work item; $\Delta conn = (\Delta conn1, \Delta conn2, \Delta conn3, \Delta conn4)$ is a vector of variables representing changes in firms' direct and indirect connections should they join the current work item; and γ_i and ψ_t account for firm effects and work item effects, respectively. Work item effect can captures how attractive a certain work item committee is. They also serve as our time dummies. Observations are indexed with $i = 1...44$ (firms), $t = 1...62$ (work items). As the empirical dependent variable is binary, the above equation can be written in terms of a latent variable Δu and the observed binary variable Δu^*:

$$\begin{aligned} \Delta u_{it} &= x\beta + \gamma_i + \psi_t + \varepsilon_{it}, \qquad (6) \\ \Delta u^*_{it} &= 1[\Delta u_{it} > 0] \end{aligned}$$

In other words, we should observe a firm joining a work-item committee when the net benefits are greater than zero. To estimate the parameters of the empirical model we apply standard panel-data estimation techniques for binary outcomes. We first compare pooled probit and fixed effects conditional logit results. For most models, the Hausman test rejects the random-effects approach, especially when network variables (connections to peers) are included. Hence, we primarily rely on fixed-effects models. Random-effects models confirm the results but may not provide consistent estimates.

Identification of the effects of social interactions is often subject to the so-called reflection problem. Manski (1995: 129) explains that "the reflection problem... arises when the researcher observes the distribution of behavior in a population and wishes to infer whether the average behavior in some group influences the behavior of individuals that compose that group." Our empirical model doesn't rely on peer group averages of the dependent variable, thus the perfect collinearity problem that Manski describes does not arise. We observe the same firms repeatedly deciding whether to join emerging work items, and also to observe multiple firms' decisions to join the same work item. This richness of the data allows us to include in the empirical analysis both a set of firm fixed effects and a set of work item fixed effects. These alleviate concerns about unobserved heterogeneity influencing firms' decisions to support work-item committees. Firm fixed effects capture unobserved firm characteristics that can affect their decisions to join work items, and work item fixed effects control for unobserved characteristics of the work item project as well as its source.

5.2 Estimation Results

5.2.1 Baseline Model

Before introducing the network variables into the empirical model, we present baseline specifications that include our control variables. The first set of estimation results in table 5 suggest that, after controlling for fixed firm effects, firm size that proxies general resources or market power is not a strong factor behind firms' choices of joining work item committees, although size was correlated with this behavior in table 3. Intellectual assets, in contrast, appear to be slightly more relevant factors behind firms' investments in specification development; European patents are statistically significantly and positively associated with supporting work-item development. However, coefficients of other IP variables are not different from zero in the fixed-effects models.

In specification three we include two variables representing firms' relationships with the work-item source. Technology distance is the Euclidean distance in terms of patent portfolios to the work-item source. This variable obtains a highly significant and positive coefficient. Consortium ties to the source variable measures connections of the focal firm with the work-item source in other consortia outside of 3GPP. Its coefficient is negative and statistically significant. These results thus suggest that firms are more likely to join a work-item committee where they are technologically and strategically different from the source firm. These results are aligned with the idea that there are complementarities in the inputs different firms provide in the committee.

In specification four we add work-item fixed effects. They make the coefficients of technological distance and consortium ties unstable, because these variables contain partly overlapping work-item specific information. Otherwise the coefficients in this specification are aligned with the models without work-item fixed effects.

Overall, we can conclude from table 5 that committee-specific factors dominate the firm-specific factors in driving committee participation once firm fixed effects are included, and that committee members tend to be technologically and strategically different from, not similar to, the work-item source.

5.2.2 Main Results

In tables 6A and 6B we focus on the effects of variables representing changes in firms' relationships with others planning to join the committee on the probability of supporting work items. Firm size and IP variables as well as the set of firms' fixed effects are included in all specifications, but for space considerations, they are not reported. In panel A we do not include work item fixed effects and in panel B we include them. The first two models in either panel in table 6 estimate the effects of the potential changes in direct and indirect connections to peers if the firm decides to join the work-item committee. We consider both the linear probability model (1) and the conditional logit model (2). The linear model also utilizes clustering of the standard errors. The results from the two methods are qualitatively aligned and show that changes in direct connections, $\Delta conn1$, have a significant negative coefficient. This variable reflects both the costs and benefits of making new direct connections. According to these estimates the costs of direct connections dominate the benefits. Indirect connections $\Delta conn2$, $\Delta conn3$, and $\Delta conn4$, on the other hand, are assumed to be associated with no costs. $\Delta conn2$ has a significant positive coefficient and $\Delta conn3$ and $\Delta conn4$ have insignificant coefficients.

Models 3 and 4 include the two measures for the relationship between the focal firm and the work-item source. Here, we exclude the observations where the focal firm was the work-item source, because sources' decision-making processes may be quite distinct from those of the other supporters. We thus get a clearer view into firms' decisions to support other firms' work-item proposals. The coefficients of $\Delta conn1$ and $\Delta conn2$ remain strongly statistically significant, the former with a negative sign and the latter with a positive one. In panel A column 4 the coefficient of $\Delta conn3$ also becomes positive and (marginally) significant. In panel A, the technological distance and consortium ties variables continue to be strongly significant and with similar coefficients as before. Controlling for work-item effects, the coefficients of dconn1 and $\Delta conn2$ become slightly larger, however, the effects of technological distance to the source and consortium ties are not longer significant.

The last specification includes the proxy for work-item cost, namely, work-item project duration. Unfortunately this information is only available for 37 work items, for which reason the number of observations is much lower for this model. Nevertheless, the earlier results regarding the effects of $\Delta conn1$ and $\Delta conn2$ are corroborated, and in addition, in column 5 of panel B, work-item duration is statistically significantly and negatively associated with firms' decisions to support. Firms thus seem to have some understanding of the complexity and difficulty of the work item at hand when making supporting decisions, and, at the margin, avoid work items that are more costly.

5.2.3 Additional Tests

We tested a number of alternative explanations for supporting work items: committee size, the number of different industries represented by firms in the committee, the number of patents held by the other committee members, the number of essential patents held by them, the diversity of their patent classes, and the technological distance to the other committee members. Most of these variables are intended to capture the unobserved technological characteristics of the work item. However, none of the additional variables had noticeable effects in the coefficients of network connections. We conducted several additional robustness checks by splitting the sample in various ways: holders and non-holders of essential IP; small and large firms; and firms with more less than eight and less than eight (the mean) committee participations. We found no significant differences in the effects of direct and indirect connections between these subsamples. Our findings were also robust to the exclusion of the first 10 work items. The results on the effects of the network variables on the probability of supporting work items are thus remarkably stable across the different types of firms in the sample. We also examined the possibility that firms in different industry segments behave differently in the inter-organizational network. While there are some industry specificities in the effects of potential network connections on firms' decisions to join work-item committees, these appear to be highly correlated with the average firm size in these industries. In particular, (small) R&D service providers benefit the least from the inter-organizational network, while (large) equipment providers and computer and consumer electronics firms benefit the most.

6 Conclusions

This empirical study proposes a novel perspective on firms' motivations to contribute private resources to the creation of a public good in a standard setting organization. Firms benefit from the social network created by cooperation in standard-setting committees. Our results demonstrate that firms value connections with peers and seek to improve their positions in the inter-organizational network. Connections can be beneficial for learning about new technologies and rivals' strategies and for generating opportunities to advertise capabilities or expertise to potential clients.

Firms tend to work with and reinforce pre-existing connections, but they benefit from new connections to partners who are well connected. We find that network benefits and costs are significant drivers of firms' behavior in the 3GPP standard-setting organization, and that new indirect connections substantially increase the unconditional probability of joining a committee. In our dataset, the effects of network connections are more significant than the effects of intellectual property and market power that have been emphasized in earlier literature. Nevertheless most of the variation in the data is explained by firm and work-item committee fixed effects—firms' permanent characteristics that drive their strategic choices, and work items' unobserved technological nature. Most specification development is supported by the core group of large firms. The resulting central network positions of these active participants may further reinforce their dominance, but smaller firms occasionally contribute and thus benefit from the information exchange.

Committee composition also significantly influences firms' decisions to join. Firms appear to attach a greater value to a work-item committee if their technological inputs are different from the firm that originally proposed the work item, and if the committee consists of firms from a diverse set of industries and with a diverse set of technological assets. In our interpretation, standard specifications are most effectively produced by committees where participants complement, rather than compete with, one another. This finding challenges the extant view that standard setting is mostly about competition to insert proprietary intellectual property in standard specifications. Firms do not tend to join committees populated by firms similar to themselves. The work-item source firms appear to play an important role in pre-selecting the supporters and thus the equilibrium composition of the committee. Nevertheless, intense technological competition may play out at the level of work-item sources, where source firms, possibly associated with cliques of supporting firms, may compete to propose technological features beneficial to them. Analysis of this level of competition is left for future work.

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Table 1 Top 15 firms in 3GPP Radio Access Network work item support committees sorted by frequency of participation, 2000-2003

Firm	# work item committees supported	Home country	# employees (2003)	# essential IPR declarations
Ericsson	34	Sweden	51,583	1,124
Siemens	33	Germany	417,000	1,122
Nokia	32	Finland	51,359	5,644
Motorola	23	United States	88,000	1,682
Nortel Networks	23	Canada	35,160	8
Vodafone	20	United Kingdom	60,109	15
Samsung	16	Korea	88,447	2,220
InterDigital	15	United States	320	1,003
NTT, NTT DoCoMo	14	Japan	205,288	0
Panasonic	13	Japan	16,685[+]	0
Fujitsu	10	Japan	157,044	0
NEC	10	Japan	143,393	0
AT&T Wireless	9	United States	31,000	0
Cingular Wireless	9	United States	39,400	0
T-Mobile	9	Germany	43,427	0
Means				
Top 15 contributors	18.00		95,214	854.53
The estimation sample of 44 firms	8.02		71,092	405.34

[+] Panasonic's employee count is from 2001. Essential IPR declarations are the total for 2000-2003.

Table 2 Variables and descriptive statistics (N=2728)

Variable	Description	Mean	Std. Dev.	Min	Max
WI supporter	Binary variable=1 if firm supported work item *t*	0.122	0.327	0	1
WI source	Binary variable=1 if firm proposed work item *t*	0.029	0.167	0	1
ΔConn1	Potential change in direct connections from WI committee *t*	4.03	2.31	0	9
ΔConn2	Potential change in 2-degree connections from WI committee *t*	4.16	9.67	-8	38
ΔConn3	Potential change in 3-degree connections from WI committee *t*	0.15	4.74	-35	30
ΔConn4	Potential change in 4-degree connections from WI committee *t*	-0.11	1.07	-7	4
WI duration	The duration of work-item committees (months)	12.838	9.548	0	63
Consortium ties to source	Sum of all firm *i*'s pre-existing connections in other standard-setting consortia to the source proposing work item *t*	4.090	6.943	0	60
Technological distance to source	Euclidean patent portfolio distance from firm *i* to the firm proposing the work item *t*	0.644	0.354	0	1
Employees	Number of employees (annual)	77,397	88,279	20	450,000
Size1 – Size6	6 sample quantile dummies of firm size (annual)				
US patent	Patents granted at the US PTO (annual)	324.55	507.10	0	2,111
EPO patent	Patents granted at the EPO (annual)	63.56	141.54	0	1,197
JPO patent	Patents granted at the JPO (annual)	549.69	1833.99	0	12,571
Essential IP	Essential IP declarations (annual)	6.38	27.74	0	264

Note: firm size and IP variables are observed annually. Work-item duration information is available for 37 work items only. These data were collected at a later date allowing the maximum duration to exceed the duration of the panel.

Table 3 Summary statistics for non-supporting, supporting, and source firms attending 3GPP Radio Access Network meetings

	Never supporter	Supporter but never source	Source	All observations
Employees	53,396	63,775	86,978	68,007
Meeting representatives	0.296	0.917	2.13	1.02
Annual US patents	220.90	174.19	438.83	278.63
Annual EPO patents	43.89	36.42	84.19	54.85
Annual JPO patents	1003.54	432.18	638.99	750.76
Annual essential IP	0.006	2.22	9.54	3.55
Work-item committees (2000-2003)	0	4.26	10.88	4.46
R&D services	0	0	0.080	0.025
Components	0.343	0.158	0.160	0.241
Computer and consumer electronics	0.143	0.053	0.080	0.101
Network and terminal equipment	0.143	0.211	0.320	0.215
Telecom operators	0.371	0.579	0.360	0.418
Observations	2,170	1,178	1,550	4,898

Note: employee numbers are only available for 3 742 observations in total. The above statistics are the means over 2000-2003 for firms in each category. The group "never supporter" includes firms that were members of 3GPP and attended some RAN meetings over the period of study but did not support any work items.

Table 4 Summary statistics per work item committee

Variable	Mean	Std. deviation	Minimum	Maximum
Number of supporters	5.68	1.96	4	9
Number of different industries	2.50	0.74	1	4
Number of small firms	0.79	0.73	0	2
Patents held by supporting firms	20,887	8,849	4	36,483
Number of different patent classes by supporting firms	14.79	1.53	3	15
Total number of essential patents declared 2000-2003 by supporting firms	5,585	3,359	0	11,807

Note: Small firms include firms smaller than the median firm.

Table 5 Baseline specification

Estimation method:	(1) Logit with clustered standard errors		(2) Fixed effects conditional logit		(3) Fixed effects conditional logit		(4) Fixed effects conditional logit		
WI supporter	Coef.	SE.	Coef.	SE.	Coef.	SE	Coef.	SE	Odds ratio
Constant	-2.782 ***	0.592	NA		NA		NA		
Size1	0.074	0.599	NA		NA		NA		
Size2	-0.318	0.690	NA		NA		NA		
Size 1-2			-1.813	1.298	-0.636	1.256	-0.577	1.280	0.562
Size3	0.258	0.555	0.002	0.692	0.666	0.491	0.795	0.511	2.215
Size4	0.514	0.528	-0.816	0.747	0.109	0.351	0.088	0.371	1.092
Size5	0.123	0.584	-0.469	0.713	NA				
Log(US patent)	0.035	0.131	-0.071	0.261	-0.323	0.296	-0.330	0.303	0.719
Log(JPO patent)	-0.079	0.089	-0.186	0.136	-0.091	0.157	-0.105	0.162	0.901
Log(EPO patent)	0.247 *	0.136	0.275 ***	0.104	0.313 ***	0.115	0.353 **	0.154	1.426
Log(essential IP)	0.181 **	0.077	-0.017	0.068	-0.042	0.080	-0.020	0.086	0.980
Technological distance to source					1.023 ***	0.261	2.096 ***	0.669	8.130
Consortium ties to source					-0.034 **	0.014	0.088 **	0.036	1.092
Firm fixed effects	No		Yes		Yes		Yes		
Work-item fixed effects	No		No		No		Yes		
Log likelihood	-934.4	(pseudo)	-727.9		-558.9		-522.2		
Observations	2728		2728		2344		2468		

Notes: Estimated with Stata 9.2. Dependent variable: WI supporter. Specifications 3 and 4 exclude observations where the focal firm is the work-item source. Firm size class 6 (the largest 17% of firms) is the omitted size group. In specifications 2-4, the first size class cannot be identified alone because of too little within-firm variation, so its dummy is combined with the second size class. In specifications 3 and 4, only three size class dummies can be identified. *** implies statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Table 6 Models with network variables

Panel A: Excluding work-item fixed effects

	(1) Linear fixed-effects regression		(2) Conditional fixed-effects logit			(3) Linear fixed-effects regression		(4) Conditional fixed-effects logit			(5) Conditional fixed-effects logit		
	Coef.	SE	Coef.	SE	Odds ratio	Coef.	SE	Coef.	SE	Odds ratio	Coef.	SE	Odds ratio
ΔConn1	-0.035 ***	0.005	-0.566 ***	0.049	0.568	-0.045 ***	0.007	-0.641 ***	0.057	0.527	-0.668 ***	0.072	0.513
ΔConn2	0.003 ***	0.001	0.069 ***	0.015	1.071	0.004 ***	0.001	0.064 ***	0.018	1.066	0.129 ***	0.024	1.138
ΔConn3	-0.001	0.002	0.031	0.033	1.032	-0.001	0.001	0.074 *	0.038	1.076	0.095 *	0.056	1.100
ΔConn4	0.005	0.007	0.054	0.128	1.055	0.001	0.005	0.053	0.153	1.055	0.140	0.190	1.150
Technological distance to source						0.228 ***	0.052	1.947 ***	0.312	7.010	1.971 ***	0.450	7.175
Consortium ties to source						-0.004 ***	0.001	-0.038 **	0.016	0.963	-0.100 ***	0.029	0.905
WI duration											0.006	0.012	1.006
R^2	0.125					0.065							
Log likelihood			-631.9					-460.6			-166.2		
Observations	2728		2728			2465		2344			1172		

Panel B: Including work-item fixed effects

	(1) Linear fixed-effects regression		(2) Conditional fixed-effects logit			(3) Linear fixed-effects regression		(4) Conditional fixed-effects logit			(5) Conditional fixed-effects logit		
	Coef.	SE	Coef.	SE	Odds ratio	Coef.	SE	Coef.	SE	Odds ratio	Coef.	SE	Odds ratio
ΔConn1	-0.114 ***	0.006	-1.399 ***	0.099	0.247	-0.109 ***	0.006	-1.510 ***	0.124	0.221	-1.488 ***	0.170	0.226
ΔConn2	0.009 ***	0.001	0.147 ***	0.019	1.159	0.008 ***	0.001	0.152 ***	0.022	1.164	0.205 ***	0.032	1.227
ΔConn3	-0.003	0.002	0.052	0.040	1.053	-0.002	0.002	0.072	0.046	1.074	0.098	0.075	1.102
ΔConn4	-0.010	0.008	-0.192	0.154	0.826	-0.008	0.007	-0.072	0.185	0.931	0.086	0.262	1.090
Technological distance to source						0.033	0.041	1.270	0.864	3.563	0.192	1.206	1.212
Consortium ties to source						-0.002	0.001	0.071	0.043	1.074	-0.014	0.068	0.986
WI duration											-0.056 ***	0.018	0.946
R^2	0.355					0.333							
Log likelihood			-477.5					-337.1			-160.5		
Observations	2728		2728			2465		2344			1172		

Notes: Dependent variable is WI supporter. Models 1, and 3 are estimated with linear fixed-effects regression clustering standard errors; models 2, 4, and 5 are estimated with conditional fixed-effects logit. Firm size and IP variables are included in all specifications but not reported here for space considerations. Full results are available from the authors on request. Specifications 3–5 exclude observations where the focal firm was the work-item source. *** implies statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Appendix

Table A1 Correlations

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 WI supporter	1																	
2 source	0.401*	1																
3 size1	-0.082*	0.020	1															
4 size2	-0.087*	-0.041	-0.211*	1														
5 size3	-0.018	-0.021	-0.236*	-0.209*	1													
6 size4	0.132*	0.068*	-0.207*	-0.183*	-0.205*	1												
7 size5	0.034	0.017	-0.204*	-0.181*	-0.202*	-0.177*	1											
8 size6	0.029	-0.036	-0.200 *	-0.177*	-0.198*	-0.173*	-0.171*	1										
9 us patent	0.158*	0.042	-0.300*	-0.263*	-0.141*	0.184*	0.294*	0.312*	1									
10 jpo patent	0.168*	0.020	-0.215*	-0.186*	-0.139*	0.025	0.050	0.536*	0.591*	1								
11 epo patent	0.002	-0.018	-0.145*	-0.129*	-0.130*	-0.087*	0.468*	0.071*	0.501*	0.164*	1							
12 essential IP	0.160*	0.133*	-0.080*	0.015	-0.110*	0.263*	-0.051	-0.011	0.146*	0.172*	-0.028	1						
13 Δconn1	-0.365*	-0.099*	0.103*	0.126*	0.026	-0.174*	-0.038	-0.047	-0.216*	-0.203*	-0.036	-0.168*	1					
14 Δconn2	-0.112*	-0.031	0.052*	0.159*	0.055*	-0.123*	-0.028	-0.101*	-0.237*	-0.204*	-0.031	-0.095*	0.354*	1				
15 Δconn3	0.014	-0.007	0.041	0.121*	-0.132*	0.004	0.031	-0.056*	-0.053*	-0.092*	0.004	-0.02	-0.051*	0.242*	1			
16 Δconn4	0.037	0.007	-0.014	0.084*	-0.121*	0.051	-0.034	0.039	0.026	-0.005	-0.017	0.032	-0.028	0.108*	0.528*	1		
17 consortium ties	0.059*	0.125*	-0.214*	-0.029	-0.049	0.155*	0.103*	0.049	0.221*	0.061*	0.189*	0.119*	-0.229*	-0.077*	-0.054*	-0.055*	1	
18 technol. distance	-0.124*	-0.270*	0.271*	0.129*	0.036	-0.213*	-0.170*	-0.134*	-0.325*	-0.222*	-0.149*	-0.164*	0.370*	0.148*	0.054*	0.039	-0.2318*	1

* implies significant correlation at the 99% level of confidence