Competing Through Cooperation: Standard-Setting in Wireless Telecommunications

Aija Leiponen[1]
Department of Applied Economics and Management, Cornell University
251 Warren Hall
Ithaca, NY 14853-7801
United States
aija.leiponen@cornell.edu
tel. +1-607-255-7588
fax +1-607-255-9984

Abstract

This study examines cooperative standard-setting in wireless telecommunications. Focusing on the competition among firms to influence formal standardization, the roles of standard-setting committees, private alliances, and technical consortia are highlighted. The empirical context is Third Generation Partnership Project (3GPP), an international standards development organization. Panel data analyses suggest that participation in external technical consortia significantly enhance firms' contributions to the development of new specifications in 3GPP committees. Then, once a firm has become a central player in technical committees, it can further influence the standard-setting outcome through change requests to ongoing specifications. External alliances with fellow 3GPP members may also improve change request success. These results suggest that if firms in network technological industries want to influence the evolution of their industry, they should identify both formal standard-setting committees and external cooperative arrangements in which they can discuss, negotiate, and align positions on technical features with their peers. For policymakers, these results suggest that it is important to ensure that technical consortia remain open for all industry actors and that membership fees do not become prohibitive to small and resource-constraint players.

Key words: Standard setting, technology strategy, inter-firm networks

[1] This research has been financially supported by the ETLA-BRIE research consortium of the Research Institute of the Finnish Economy and Berkeley Roundtable for the International Economy (University of California at Berkeley). ETLA-BRIE workshop participants have also provided invaluable comments on this work in various stages. This paper has also benefited from discussions with Talia Bar and from comments by Timo Ali-Vehmas, participants at the Wharton Technology Miniconference 2006, especially Harbir Singh, Lori Rosenkopf, Tim Simcoe, and Manuel Sosa; the DRUID conference 2006 at the Copenhagen Business School, especially Robin Cowan and Andrea Fosfuri; and the Academy of Management meeting in Atlanta, especially Pai-Ling Yin. Haim Bar generously helped me compute the network matrices, and Jiyoun An and Justin Byma provided able research assistance. The remaining errors are mine alone.

1. Introduction

Technical standardization is an important but relatively understudied aspect of technology strategy. This paper examines the cooperative creation of compatibility standards in the wireless telecommunications industry, particularly focusing on the roles of technical consortia and private alliances in driving the development of new features. We study the internal operation of one formal standards development organization, Third Generation Partnership Project (3GPP), and ask whether member firms' external cooperative activities have an impact on their ability to influence outcomes within 3GPP.

Compatibility standards are formal or informal agreements regarding how components within a technical system interact with one another. As such, they are basically technical and practical instructions for interacting with the system, yet they can have dramatic repercussions for firm performance, competition, and market evolution. They may lock in markets to specific, often partially proprietary, technical solutions for extended periods of time. The lock-in effect is compounded by network externalities that are present in many information and communication technology industries. Whatever standards are chosen can thus have a long-term impact on the market and its agents. As an example from the wireless telecommunications industry, the second generation technologies were developed in the late 1980s and early 1990s and continued to be used around the world in 2006. Companies that were able to incorporate their patents in one of the second-generation wireless standards may thus have been receiving royalty revenue for over 15 years. Moreover, Bekkers et al. (2002) have argued that the early standard-setting maneuvering by key intellectual property holders excluded certain other companies from the market for wireless telecommunication network equipment altogether. These were never able to catch up. As these examples suggest, standard-setting outcomes can determine firms' market outcomes for a long time.

Theoretical work in industrial economics has focused largely on market-based competitive standard-setting processes (Katz & Shapiro, 1985; Farrell & Saloner, 1985; Farrell, Monroe, & Saloner, 1998; with the exception of Farrell & Saloner, 1988), while in practice, and in many industries, standards are set in a more cooperative manner (see Kahin & Abbate, 1995 for an overview). For example, Chiao, Lerner and Tirole (2006) have collected comparative data from 60 standard-setting organizations and found that although specific governance arrangements vary, committee-based standard setting covers many electronics industries.[2] Lemley (2002) has compared the policies of 29 standard-setting organizations, mostly in the information and communication technology area. He also concludes that standard-setting organizations are highly diverse, particularly in their policies toward intellectual property rights and licensing, and that neither academic scholars, practitioners, nor policy-makers know enough about these policies to understand their implications. In response, a stream of empirical research on committee-based standardization is emerging (Rysman & Simcoe, 2006; Simcoe, 2004; Dokko & Rosenkopf, 2003; Fleming & Waguespack, 2004). Earlier descriptive work also emphasized the cooperative aspects of standard setting in telecommunications (Schmidt & Werle, 1998).

Building on this recent literature, this paper analyzes a field of standard setting where formal structures emphasize cooperation, while, informally, fierce competition to insert intellectual property and align the standard with private benefits also takes place. The empirical field of study is one of the third generation wireless telecommunications standards, Universal Mobile Telecommunication System (UMTS), the development of which started in the late 1990s. This technical field is characterized by extensive cooperation among firms. In addition to formal standard setting within 3GPP, an international standards development organization that coordinates the development of UMTS-related specifications, companies have formed private alliances and participated in other industry associations and consortia. Within these cooperative organizations, firms both cooperate and compete in trying to influence standards outcomes. The central research question here concerns how firms' activities in the different external cooperative arrangements—consortia and alliances—are related to their ability to influence formal standardization within 3GPP. This question is an important element in understanding the process of cooperative standard setting, and the answer may have both business strategy and competition policy implications. The empirical analysis here shows that firms that participate in external consortia are more

[2] Although 3GPP does not appear in the datasets of Chiao et al. or Lemley, their data do include ETSI, the European Telecommunications Standards Institute, whose policies 3GPP to a large degree adopted when it was organizationally spun out of ETSI in 1998.

influential in formal standardization. Earlier studies (Leiponen 2006a, b) demonstrated the correlations between the key concepts in cross-sectional setups. The contribution of the current paper is to develop a network analytical theoretical framework and test for the derived hypotheses using panel data that enable controlling for fixed unobserved firm characteristics.

Wireless telecommunications is an interesting field of technology to observe standard setting because of both rapid technological change and proliferation of cooperative arrangements. The switch to third-generation wireless technologies that started in 2001 involved a substantial technological discontinuity and a standards battle between the two main technologies. Third-generation networks are expected to transfer data and multimedia in addition to just voice, and this creates the need to substantially increase wireless bandwidth. UMTS is the third-generation system replacing GSM (Global System for Mobile communications) networks. It is challenged by the third-generation version of the IS-95 standard called cdma2000. Both systems are technically extremely complex and have taken years to develop. Additional uncertainty into this standards battle is being created by the concurrent evolution of computer-based wireless technologies. Thus, at least three types of technologies, two of them cellular and others based on completely different technological approaches as defined in the IEEE WiFi and WiMAX standards, are fighting for the wireless communication space. The convergence of computing and communications technologies that commentators have been talking about for years has thus truly arrived. Consequently, major computer technology companies entered the standard-setting negotiations for wireless telecommunications in the late 1990s, and the technological field became very highly contested.

Wireless telecommunications firms' response to the competitive situation can be described along the lines of Rosenkopf and Tushman's (1998) analysis of the market for flight simulators. Under eras of ferment, cooperative arrangements are formed and dissolved in an effort to reconfigure the market structure to respond to new technological and market opportunities. In wireless telecommunications, this has meant dozens of alliances, fora, and consortia focused on different aspects of technology and market creation. This paper examines the argument that such cooperative arrangements are used to advance firms' strategic goals: competition for markets works through constellations of cooperative activities.

The focal standard-setting organization analyzed here is 3GPP, the Third Generation Partnership Project. 3GPP was spun out of the European Telecommunications Standards Institute (ETSI) in recognition that the third generation wireless standard was no longer a European project, but equal participation by Asian and American wireless industries was necessary. Nevertheless, 3GPP inherited its operating procedures from ETSI, and as a result, it is a relatively typical open standards development organization with respect to its open membership, intellectual property provisions, committee structure, and working procedures. Although 3GPP itself is a relatively new organization (it was founded in 1998 and began operations in 2000), ETSI's standardization processes have been documented and examined in many comparative and qualitative studies (e.g., Ask, 1995; Lemley 2002; Chiao et al. 2006). Moreover, although the European approach to standard setting has traditionally been government driven, since the mid-1990s there has been a significant shift towards industry-driven standardization. On the other hand, although the U.S. approach has traditionally been market driven, there has been a considerable movement towards committee-based standardization in many electronics industries. As a result, 3GPP is a useful and informative empirical context for a quantitative case study of committee-based standard-setting activities.

The goal of this study is to contribute to our understanding of the processes and effects of cooperative standard setting. The results add to literatures on both technology strategy and policy. Management implications suggest that a broad cooperative standardization approach is more beneficial than concentrating on select few cooperative arrangements. However, participation in myriad cooperative movements requires substantial investments of financial and human resources. For small or otherwise resource-constrained firms, participation costs may become prohibitive. In this case, the results support focusing on institutionally closely related consortia to maximize learning and impact.

From technology policy perspective, results demonstrate that influential firms operate in both formal and open standards development organizations and private or semi-private consortia and alliances. Although this was not explicitly examined in this paper, a policy concern is that the private and unregulated nature of these latter cooperative arrangements can potentially be used in anticompetitive ways. While there are no theoretical studies regarding monopolization or small-group control of committee standard-setting processes, based on industrial organization theory of monopoly, these would probably generate inefficiency—higher royalties and fewer standards—than open standardization processes. Moreover, innovation studies such as Nelson's classic paper (1961) and many others building on it argue that technological advance critically depends on the diversity of inputs. There is no reason to believe that this would not be the case in the development of standards—multiple parallel and competing approaches to shared problems are more likely to come up with a satisfactory solution than one single approach. Again, this suggests that an open standard setting process is socially more desirable than a closed one, all else equal. To prevent monopolization of standard setting, policy makers should ensure that consortium governance and membership remain transparent and open. Supporting consortium participation of small or resource-constrained firms would be another option to ensure broad access to standard setting.

The paper is organized as follows. We first describe the empirical context of study and review extant literature to derive empirical hypotheses about the different types of . Next, the panel dataset of wireless telecommunications firms is introduced and used for testing the hypotheses. The final section discusses the results and their implications for management, policy, and further research.

2. Standard setting in wireless telecommunications: The case of Third Generation Partnership Project (3GPP)

This study focuses on whether and how firms benefit from participation in cooperative technical organizations. Cooperative technical organizations (see Rosenkopf and Tushman, 1998) can include industry associations, consortia, private alliances, and formal standards development organizations (see Leiponen, 2006, for a typology, and Lemley, 2002, and Chiao, Lerner, & Tirole, 2006, for empirical comparisons). Background interviews with industry executives provided mixed evidence regarding the effects of participation in various kinds of cooperative arrangements. A standard-setting manager of one major equipment company was doubtful of the benefits and very cognizant of the costs of participation, whereas another leading company continued to be very active in consortia and its standardization manager believed in the broad cooperation strategy. Perhaps the most intriguing interview evidence came from smaller technology and telecom service providers. Their managers alleged that the leading equipment firms were explicitly using consortia to drive their private benefits, i.e., their preferred technologies.[3] The research question concerning the effects of consortium participation on standard-setting outcomes is thus a controversial and contentious issue for industry practitioners.

Wireless telecommunication standards have many characteristics of public goods—they are accessible to all industry parties and enable interoperability among parties who wish to enter the market—yet they also involve significant private benefits. The UMTS wireless standard, the creation of which is studied here, is open in the sense that it is governed by the so called FRAND agreement. FRAND (or RAND as it is often called in the United States) is an institution adopted by many standards consortia (see Lemley 2002 and Chiao et al. 2006) that requires that any intellectual property owned by consortium members and incorporated in the standard has to be made available to all comers under (Fair,) Reasonable And Non-Discriminatory licenses. In practice, however, the terms of F/RAND licensing have not been explicitly determined.[4] Partly as a result this ambiguity, significant private benefits can be derived from intellectual property inserted into standards. First, if firms hold intellectual property that becomes incorporated in the standard, they can receive substantial royalty revenue for an extended period. Second, by being able to influence the characteristics of the technical specifications early on, firms can align system features with their own complementary technologies and other assets. Then the features developed for the standard will work better on their proprietary systems or will better fit their business models. These aspects create incentives to try to influence standard-setting outcomes. At the same time, many participants in formal standard setting are relatively ignorant regarding the fundamental characteristics of proposed solutions, or these solutions may be associated with significant uncertainty about their technical or market implications (Schmidt & Werle, 1998).

---

[3] Interviews were carried out between 2002-2005 with standard-setting managers of two major network and terminal equipment manufacturers, a small and specialized technology vendor, and a small operator.

[4] Although in a recent lawsuit against Qualcomm, Nokia essentially asks the court to define the FRAND terms (Nokia press release 8/9/2006).

The process of making technical choices in formal standard setting thus involves substantial technical and market uncertainty, which gives rise to a political game of influence. The channels for influencing industry peers include bilateral communications and negotiations, private bilateral or multiparty alliances or joint ventures, consortium participation and contributions to specification drafts therein, and formal standards development organizations (SDOs) (Leiponen 2006: 344). Within the more formally organized consortia and SDOs, firms' representatives can influence the standard-setting outcome by simply attending meetings to learn about new specifications and to participate in voting or consensus-building discussions. They may also take a more proactive approach and contribute to working group specification development projects, assume leadership positions as working group chairpersons, or request changes to existing specifications.

Each of these formal ways to influence the consortium or SDO process has different effects and requires different resources. For example, while attending meetings and voting therein only necessitates financial and human resources to send a representative to meetings, meaningful contributions to specification development require technical expertise. Successful chairpersonships, on the other hand, demand both technical expertise and the more social skills of leadership, negotiation, and diplomacy (cf. Spring et al., 1995), and requesting changes to existing specifications may additionally necessitate political capital—market power or other forms of inter-organizational power (Pfeffer & Salancik, 1978)—in addition to technical and social assets. Similarly, these different ways to influence vary by their impact on standardization outcomes. Discussing and voting in meetings probably has the least impact compared to technical contributions, agenda-setting through chairpersonships, and direct changes to specifications through change requests.

Theoretical studies of cooperative standardization have examined the relative benefits of cooperative and market processes (Farrell & Saloner, 1988) and the optimal choice of standardization forum (Lerner & Tirole, 2006; Farhi, Lerner, & Tirole, 2005). The current study does not develop a formal model but argues that in many industries, in contrast to the work of Lerner and Tirole (2006), the strategic choice is not about which one forum to choose for certification, but in which multiple fora to participate in order to accumulate sufficient influence capital. Standard-setting strategies in wireless telecommunications thus appear to involve setting up a constellation of cooperative arrangements rather than choosing the optimal one arrangement. In line with this argument, the dataset used here shows that many firms participate in multiple, sometimes competing, consortia. There is little evidence of competing subsets of the industry organizing into separate consortia, as in Axelrod et al. (1995).

Empirical work on cooperative standardization processes includes studies by Weiss and Sirbu (1990), Bekkers et al (2002), and Simcoe (2004), and Simcoe and Rysman (2006), who emphasize the roles of market power and intellectual property rights in determining standard-setting outcomes. While the current study controls for the effects of these factors, we focus here on a new set of variables: external networks of cooperation. By participating in and contributing to external cooperative arrangements, firms are able to advertise their expertise and technologies, learn from their peers, and discuss, develop, and evaluate technical alternatives with them. As a result, they may become, first, more knowledgeable and thus more efficient at developing formal technical specifications and, second, more influential (powerful) in subsequent negotiations over technical details. We thus argue here that consortia and alliances are venues, on one hand, for exchanging valuable knowledge about new technologies, and on the other hand, for advertising firms' own technological assets, aligning positions with like-minded peers, and possibly signaling their commitment to certain strategies in the focal standardization body.[5]

Consequently, consortia and alliances may accelerate standards development work, which benefits the whole industry, but it is also possible that they attempt to align standards with a small group's private benefits before they are even submitted to formal standards development organizations. This could be detrimental to the industry since better solutions, for example, by small innovators, might get excluded from standard setting for their lack of resources to participate in a multitude of consortia. In the empirical analysis to follow, we examine the main hypothesis that participation in external cooperative arrangements involves communication about preferences and technical alternatives among members,

[5] I'm grateful to an anonymous reviewer for suggesting the last idea.

resulting in their improved ability to contribute to and influence the focal formal standards development organization:

H1 *Participation in external consortia and alliances improves firms' ability to influence formal standard setting.*

Technical consortia—industry associations, technical fora, and multi-party joint ventures—give rise to affiliation networks, also called bipartite networks (see Borgatti & Everett, 1997; Newman, Watts, & Strogatz, 2002; also see Wasserman & Faust, 1994, Ch. 8, for an overview). Bipartite networks have two types of nodes, in our case individual member companies and consortia. Companies can only connect to consortia, not to other companies directly (see figure 1). Indirectly, however, companies can be said to form a link if they are members of the same consortium. The bipartite network thus gives rise to a unipartite projection where companies are connected to others if they are co-members. In the bipartite network, firms' degree is the number of memberships, while consortia's degree is the number of members. In the projected unipartite network, a firm's degree is the sums of members (excluding the focal firm and any duplicate alters) in the consortia in which it participates.

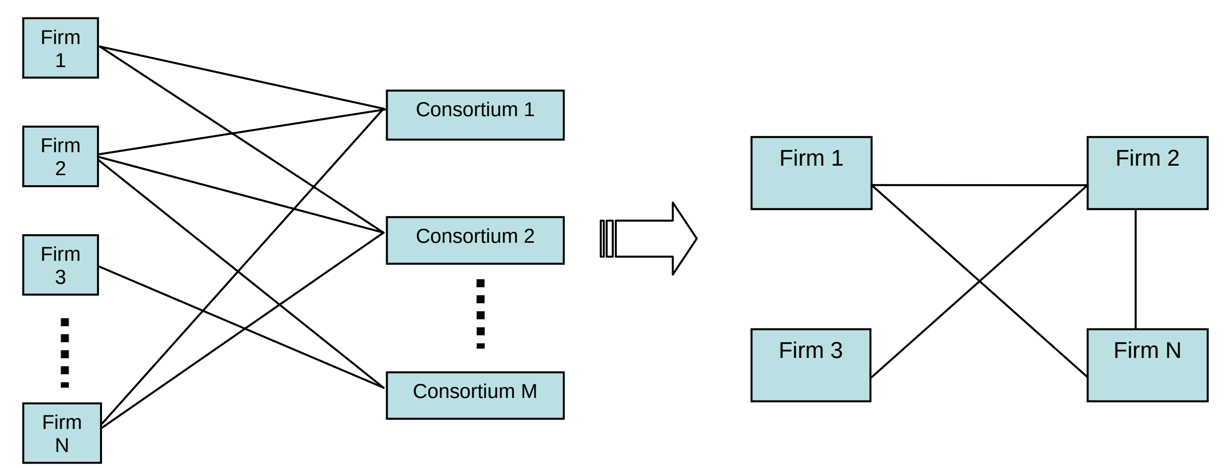

Figure 1: Bipartite consortium network and the unipartite projection

While much of the research on networks with affiliation characteristics has abstracted away from the bipartite structure and examined only the unipartite projection (although see e.g. Cornwell & Harrison, 2004 for a recent study, and Davis, Gardner, & Gardner, 1941 and Galaskiewicz & Marsden, 1978 for classical examples), we will here examine firms' consortium activities from both perspectives. If it is the indirect connections to other 3GPP members that matter, then firms' unipartite degree should be the best indicator of consortium network centrality (hypothesis H2a). However, if the structure of the affiliation network matters, in other words, if it is relevant where those unipartite connections were formed, then other indicators will better explain standards development success.

First, if the consortium contexts matter more than the connections generated therein, then firms' bipartite network degrees will be more significantly affiliated with standard-setting power than the unipartite degree (H2b). This would be true, for example, if multi-consortium contact gives rise to mutual forbearance among companies—if A supports B in consortium X, then B will support A in consortium Y. In the end, both A and B might have each other's (and their fellow consortium members') support in the formal standards development organization. This argument is closely related to that on multimarket contact and competition (see e.g., a recent study by Fuentelsaz & Gomez, 2006). However, bipartite network degree might also be the most important indicator of connectedness, if each consortium gave access to specialized knowledge. Then, firms would maximize learning from peers by attending as many consortia as possible.

Second, external consortia that are technologically or institutionally closely related to the formal SDO might generate more relevant knowledge and be seen as more legitimate, thus creating more standard-setting power than unrelated consortia (H2c). Technological closeness is reflected in highly overlapping memberships—firms with similar technological profiles are likely to participate in the same consortia. In this case, consortia where 3GPP members form a large *share* of membership would be more influential than those where most members are not members of 3GPP. Institutional closeness is reflected in the consortia's formal relationships with 3GPP. Then, memberships or connections in consortia that are institutionally allied and therefore aligned with 3GPP might be most beneficial.

Hypotheses H2b and H2c that utilize information about the affiliation network structure can be compared and contrasted against the main hypothesis H2a which implies that the structure of the affiliation network does not matter as much as the connections to other firms created by co-memberships.

H2a *Firms' unipartite (indirect) connections through consortia to other firms improve their ability to influence formal standard setting.*

H2b *Firms' bipartite connections in the consortium affiliation network (number of memberships) improve their ability to influence formal standard setting.*

H2c *Memberships in or connections through consortia that are closely related to the formal SDO in terms of the share of membership or institutional affiliation improve firms' ability to influence formal standard setting.*

Similarly, the effects of alliances on standard-setting power can be argued to work through two channels. First, if the unipartite alliance connections (number of partners) matters the most, then, from the standard-setting perspective, alliances act as a vehicle for lining up positions and gathering support on subsequent technical decisions. While strategic alliances are rarely set up for this purpose, mutual standard-setting support may be a by-product of joint R&D. On the other hand, firms' bipartite degrees in the alliance network (number of alliances) would be a significant predictor of their ability to influence standard-setting if alliances were most useful as venues for developing technical assets and expertise that matter in the standards development work. These two possibilities are expressed in hypotheses H3a and H3b.

H3a *The number of alliance partners is correlated with firms' ability to influence formal standardization.*

H3b *The number of alliances is correlated with firms' ability to influence formal standardization.*

Firms are also likely to accumulate standard-setting power through their activities in the standards development organization itself (Weiss & Sirbu, 1990). Expertise is accumulated and demonstrated by participating in the development of new technical features. In 3GPP, features are developed through the work item process, whereby new features are proposed, accepted, developed, and certified. An important characteristic of this process within 3GPP is that firms need the support of three peers in order to propose a new work item. These work item committees thus give rise to yet another affiliation network, where we can track companies' contributions and cooperation partners. We argue that active participation the work item process enables influencing subsequent decisions. In particular, we assess whether the connections firms have made through work item committees (H4a) or the extent of firms' committee contributions (H4b) better explain firms' ability to influence subsequent standardization decisions. Once again, we exploit the characteristics of both the bipartite affiliation network and the projected unipartite network. If the number of (unipartite) connections is found to be more relevant, then the impact of firms' committee activities is primarily political and social in nature, while if the number of (bipartite) contributions themselves is found to be more relevant, then committee activities are primarily about developing and utilizing expertise.

H4a *Firms with a higher number of connections formed through standardization subcommittees have a greater ability to influence standard-setting outcomes.*

H4b *Firms with a higher number of contributions through standardization subcommittees have a greater ability to influence standard-setting outcomes.*

3. Empirical analyses of the sources of influence in standard setting

3.1 3GPP technical specification development process and the empirical model

The empirical context of study is Third Generation partnership Project (3GPP) that develops specifications for the UMTS standard. 3GPP took over specification development from the European Telecommunications Standards Institute (ETSI) which coordinated the development of the GSM standard. It is formally an alliance among six regional SDOs (two Japanese organizations, and one Korean, American, European, and Chinese organization each). 3GPP has been very active during the period of study, 2000-2003, and has generated a publicly available paper trail of technical specification development. The period of study also coincided with a flurry of external cooperation and consortium activity by the members of 3GPP. The purpose of the following empirical analyses is to examine whether this is a coincidence or whether the statistical association appears even when controlling for control variables and unobserved heterogeneity.

The technical specification development work in 3GPP is organized into technical specification groups and working groups.[6] During the period of study, there were five technical specification groups, each overseeing a subfield of the technological system. Under each technical specification group there are a few working groups in which the actual specification development is carried out. Within working groups, new technical features are developed through the work item process (see figure 2). Any working group participant can propose a new work item (e.g., a new feature) but they need to find support from at least three other working group members to place the item on the agenda. Each work item is thus associated with a group—or a committee—of four or more company representatives. This mandatory cooperation is intended to weed out frivolous proposals that only benefit one single company or are not technically reasonable or feasible.[7] Indicators from this work item affiliation network will be used first as dependent variables and later as explanatory variables in the empirical analysis. Unfortunately, unsuccessful work item projects are not observed.

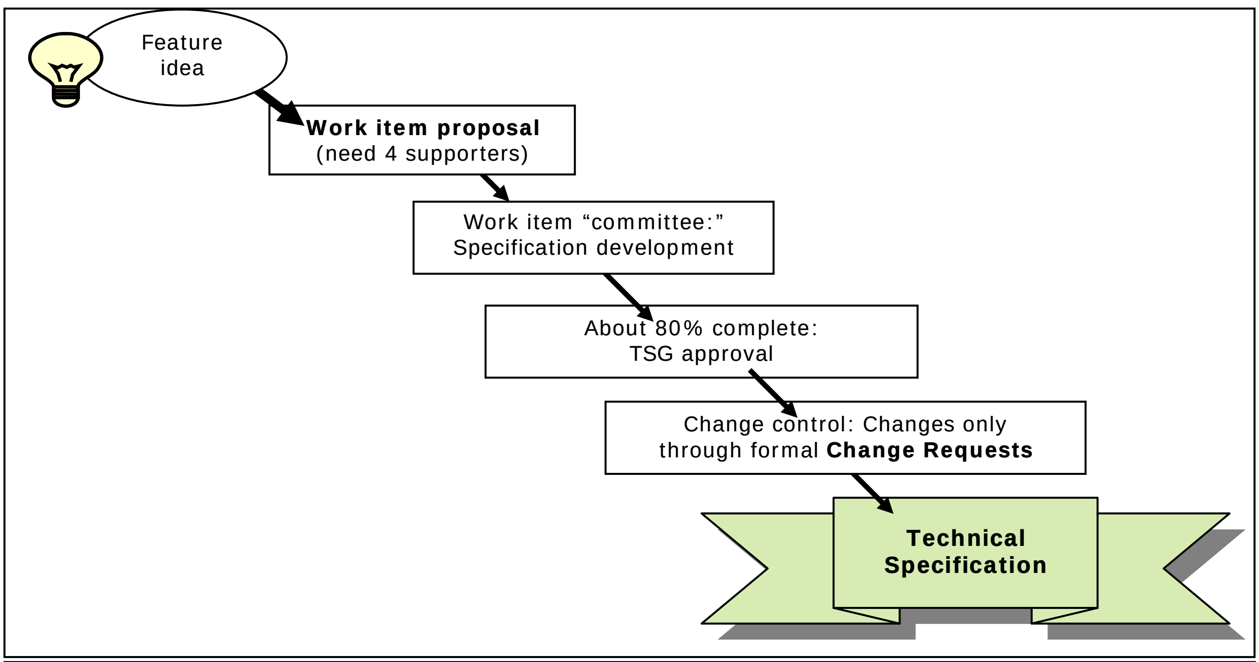

Figure 2 3GPP work item process

[6] This discussion relies on information from the 3GPP Working Procedures (http://www.3gpp.org/About/WP.htm).
[7] According to Adrian Scrase, the CTO of ETSI, the requirement of four supporters ensures that "the work program is not clogged up with proposals that have little chance of progressing" (e-mail exchange September 2005).

Once a work item is under way, the supporting companies coordinate and contribute to the specification development possibly in cooperation with other members of the working group. The work item support group has the mandate to design the feature until it is "sufficiently stable," or approximately 80% complete (as judged by the working group as a whole). After that point, the work item will be brought up for decision in the respective higher level technical specification group and, thereafter, incorporated in the technical specification. It also enters change control: from now on, changes in the specification must be made through a formal change request process. Written change requests can be submitted to the technical specification group by individual companies or groups of companies. Some change requests are also submitted by the whole working group, suggesting that a technical error or omission has been found. Individually submitted change requests, on the other hand, provide relevant information about how influential different working group members are. According to the interview evidence with standardization practitioners, firms' success in change requests is a valid measure of their standard-setting influence. This is the second dependent variable of our empirical analyses.

Table 1 Technical consortia

Cooperative Technical Organization	**3GPP-related**	**Unrelated to 3GPP**	**% of total membership that are 3GPP members**
UMTS Forum	x		47
GSA (Global mobile Suppliers Association)	x		91
GSM Association	x		n.a.
IPv6 Forum general members	x		49
IPv6 Forum founders	x		40
T1 Telecommunications (USA)	x		37
ARIB (Association for Radio Industries and Businesses; Japan)	x		9
ETSI (European Telecommunication Standards Institute)	x		30
TTC (Telecommunication Technology Committee; Japan)	x		28
UWCC (Universal Wireless Communication Consortium)	x		26
3GPP2 (Third Generation Partnership Project 2)		x	59
CDG (CDMA Development Group)		x	44
WECA (Wireless Ethernet Compatibility/Wi-Fi Alliance)		x	52
Hiperlan2 Global Forum		x	56
MWIF (Mobile Wireless Internet Forum)		x	57
Voice XML		x	8
Bluetooth Special Interest Group		x	100
3G.IP		x	100
TIA (Telecommunication Industry Association; USA)		x	9

Note: The membership share numbers are from 2000.

3GPP member firms' external cooperative arrangements analyzed here include private alliances and public or semi-public consortia, associations, fora, and joint ventures. We include alliances among 3GPP members only. Consortia can be classified as either institutionally related or unrelated to 3GPP itself (see table 1). Consortia are institutionally related to 3GPP if they are its designated market representative partners or organizational partners. Institutional relatedness implies that the goals of these organizations are highly aligned. In contrast, many of the unrelated cooperative organizations listed in table 1 are not in any formal way aligned or may even compete with 3GPP (e.g., CDG and 3GPP2). Nevertheless, many of 3GPP's members participate in these organizations as well—see the last column in table 1. Consortia can also be technologically related to 3GPP without an institutional connection, an example of which would be Bluetooth Special Interest Group where key intellectual property is held by Ericsson, one of the leading 3GPP members. We assume that the shares of 3GPP members in the membership of each organization reflect the technological relationship between the organization in question and 3GPP. These shares are used to compute a weighted indicator of consortium membership for the empirical analyses.

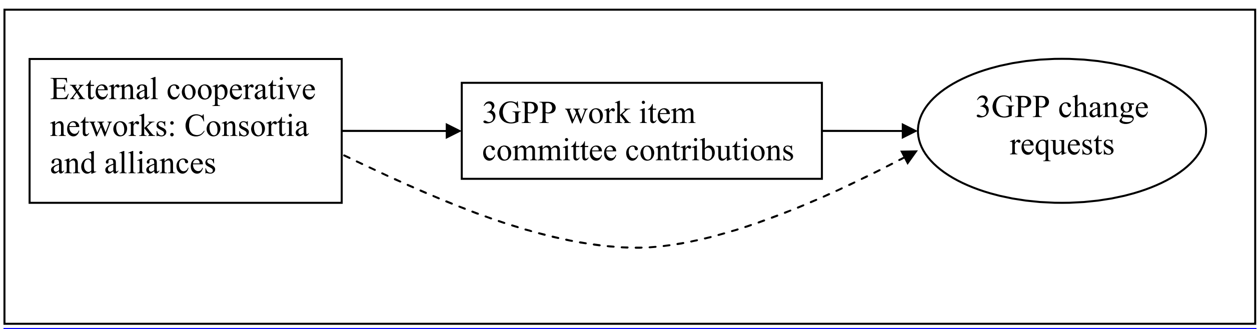

Figure 3 Effects of external networks on 3GPP standard setting

The empirical analyses that follow will examine whether activity in external cooperative arrangements is beneficial in terms of making work item proposals or successful change requests, controlling for firms' size, intellectual property, industry segment, geographic origins, and unobserved fixed firm characteristics. Figure 3 illustrates the effects. In the first set of specifications, we will test for the effects of external cooperative networks in the form of consortia and alliances on work item committee contributions, and, in the second set of specifications, assess the effects of both work item committee activities and external cooperation networks on change request success. Additionally, we will analyze whether closely related or unrelated external organizations generate the most impact, and whether centrality in terms of unipartite connections or bipartite affiliations most correlates with the ability to influence work within 3GPP. The empirical models to be estimated are summarized in equations 1 and 2, with expected signs in parentheses. Other firm characteristics may include industry segment, geographic origins, and unobserved heterogeneity, depending on the estimation method.

(1) Work item committee contributions = f(market power (+), technological capabilities (+), position in external cooperation networks (+), other firm characteristics)

(2) Successful change requests = g(position in work item committee network (+), market power (+), technological capabilities (+), position in external cooperation networks (+), other firm characteristics)

Next, we describe the panel dataset of wireless telecommunication firms and the empirical methods to be used in the analyses, and then carry out tests for the hypotheses developed in the previous section.

3.2 Data sources, variables, and descriptive statistics

The unit of analysis is the annual observation of a firm. The dependent variables measure the firms' ability to influence standard setting within 3GPP, and the main explanatory variables include firms' consortium activities, alliances with other 3GPP members, intellectual property positions, and size. All data cover the period 2000-2003; the data on patents, alliances, and consortia are also available for 1998-1999. The data on consortium and committee participation were collected directly from the consortium and 3GPP websites using the Internet Archive. Table 2 displays the variables and descriptive statistics. Correlations among the estimation variables are provided in the Appendix. Dependent variables measure the number of firms' contributions to work items and the number of their approved change requests to existing specifications made by each firm in each year. Additionally, to examine the robustness of these results we also estimate the probability of making any work item contributions and the probability of making any change requests.

Table 2 Variables and descriptive statistics

	Variable name	Description	Mean	Std. dev.	Minimum	Maximum
Work item process Variables	WI committees	Number of work item committees participated in	2.271	7.700	0	68
	WI connections	Number of unique connections made in work item committees	4.132	9.732	0	63
	CR	Number of sole authored change requests	3.292	20.144	0	257
	CR dummy	Binary indicator for CR>0	0.113	0.316	0	1
	CR approvals	Number of approved sole authored change requests	2.164	12.416	0	145
	Approval dummy	Binary indicator for CR approvals>0	0.098	0.298	0	1
Firm-level control Variables	Employees	Number of employees	46 635	74 722	4	450 000
	USPTO patents	Number of patents granted by the US Patent and Trademark Office	151.826	410.466	0	3 487
	EPO patents	Number of patents granted by the European patent office	290.424	1471.672	0	14268
	Japanese PTO patents	Number of patents granted by the Japanese patent office	28.868	92.592	0	1197
	Essential IPR declarations	UMTS-related essential IPR declarations at ETSI	1.546	14.683	0	264
External network Variables	Private alliances	Number of alliances with other 3GPP members	0.396	1.096	0	8
	Alliance partners	Number of 3GPP member alliance partners	0.556	1.677	0	13
	Consortium memberships	Total consortium memberships	2.797	3.912	0	24
	Related memberships	Memberships in consortia institutionally related to 3GPP	1.079	1.546	0	8
	Unrelated memberships	Memberships in consortia unrelated to 3GPP	1.718	2.669	0	17
	Weighted memberships	Consortium memberships weighted by the share of 3GPP members in the consortium's total membership	1.112	1.784	0	12.805
	Consortium connections	Unique connections to other 3GPP members through the unipartite consortium network	107.156	78.459	0	280
Additional control variables	Asia	Asian	14.9%			
	North America	North American	34.0%			
	Europe	European	47.9%			
	R&D services	R&D service provider, including equipment testing	7.2%			
	Component	Component provider for telecom networks or terminals	14.9%			
	Computer	Computer or consumer electronics industry	5.2%			
	Consulting	Technical consulting service provider	5.7%			
	Equipment	Network or terminal equipment (hardware) vendor	23.2%			
	Operator	Telecom operator	25.3%			
	Software	Software provider	18.6%			

Firms' positions in the work item committee network are also used as explanatory variables in the second empirical model. Here we use two alternative measures for network positions: the number of committees (bipartite degree) and the number of connections made in these committees (unipartite degree). Degree centrality is a commonly used indicator from the literature on social network analysis (e.g., Powell, Koput, & Smith-Doerr, 1996; Tsai, 2000), and it arguably best reflects an actor's access to information and knowledge. We include only unique connections here, i.e., we do not double count multiple committee co-memberships with the same partners.

Firm size is used to proxy firms' market power and general resources. Sales or the number of employees are available for publicly traded firms, but, to also include small and privately-held firms, we define size classes as explained in table 3. Small private startup firms, for which these measures are typically not available or associated with significant measurement error, are included in the first class. This approach enables estimating a nonlinear effect and preserves a larger sample size. As a robustness check, we also estimated the main models with a more traditional measure of natural logarithm of the number employees as the firm size variable. The key results are not affected qualitatively or in terms of statistical significance, even though the sample size is reduced. Additionally, we estimated all models with the differences between firm size and industry averages to check whether the firm's relative size within its industry matters more than the absolute size. None of the results were affected by these alternative size formulations.

Table 3 Firm size classes

Size class	Number of employees	% of total observations
Size 1	0 – 100	3.4
Size 2	101 – 1 000	10.2
Size 3	1 001 – 10 000	17.1
Size 4	10 001 – 50 000	16.2
Size 5	50 001 – 100 000	7.4
Size 6	100 000 –	45.7

NB: firms may change size classes over the period of observation

Firms' intellectual property positions measure their technological capabilities. We use the numbers of patents granted in the United States Patent and Trademark Office (US PTO), European Patent Office (EPO), and Japanese Patent Office (JPO) to measure firms' general technological assets. Alternative specifications used firms' deviations from industry-level means. These did not influence any of the main results. A different concern is that the patents of certain types of firms in the sample may be related to technological fields that have little to do with wireless telecommunications. Industry dummies should account for some of these differences. Nevertheless, patents are argued to proxy for firms' technological potential in the wireless telecommunications area. Holdings of patents are highly skewed, and most firms hold very few if any patents and the technology giants such as Matsushita or IBM obtain thousands of patents annually. In the estimations we use the natural logarithm of patents obtained each year.

In addition to patent portfolios, we have information about firms' declarations of essential intellectual property (IP) with the European Telecommunications Standards Institute that coordinates these IP declarations for 3GPP. The advantage of this variable is that it measures technological assets that are highly relevant from 3GPP's point of view. Unfortunately, IP declarations are highly sporadic, varying for individual companies between hundreds of declarations one year and none the next year. Firms thus appear to disclose IP in a very lumpy way, which may not reflect true technological evolution and may incorporate a lot of measurement error. Nevertheless, we include this control variable in all models in natural logarithmic form.

Firms' external cooperative arrangements involve alliances and industry consortia. The alliance data used here are obtained from the CATI database of technology intensive strategic alliances.[8] As argued by Rosenkopf, Metiu and George (2001), alliance- and consortium-based cooperative activities are closely related. We focus on alliances with 3GPP peers, assuming that the goals of these alliances are more likely to be related to the technologies discussed in 3GPP, and therefore, these alliances are more

[8] CATI is a large database of R&D and technology alliances and joint ventures developed by John Hagedoorn at the Maastricht Economic Research Institute on Technology (MERIT) in the Netherlands. Access to the database in this study is provided through cooperation with the Research Institute of the `Finnish Economy and granted by Marc Van Ekert and John Hagedoorn.

likely to be beneficial in terms of the partner firms' 3GPP activities. Firms' industry consortium activities are measured as the memberships in and connections to fellow 3GPP members through the cooperative technical organizations listed in table 1. These consortia were selected by searching for organizations that are related to the wireless telecommunication technology field but not necessarily to the UMTS standard. Consortia that are *institutionally related* to 3GPP include organizations that were formally designated as 3GPP market representatives or organizational partners. Their objectives are closely aligned with those of 3GPP. Consortia *unrelated to* 3GPP include organizations that develop completely different, and possibly competing, wireless communication standards or component technologies, and organizations that promote services related to the UMTS standard but are not affiliated with 3GPP as market representatives. To gauge the impact of firms' different affiliation strategies, we compare the effects of memberships in related and unrelated consortia, and the effects of connections to other 3GPP members through related and unrelated consortia. Finally, we assess a weighted membership indicator which is the sum of memberships weighted by the share of other 3GPP members in the total membership of each consortium. This last variable measures both the extent and the technological relatedness of firms' consortium activities.

The sample size is 193 firms. The total membership of 3GPP excluding corporate subsidiaries and government or non-profit agencies was 247 firms in 2000, thus the sample contains 78% of the population. Firms are included if enough information about them is publicly available through the Internet Archive, company websites, or business information databases such as Hoovers or Compustat. In particular, because many of the small and privately-held 3GPP members either merged or were acquired during the period of study, it was not possible to obtain their data. Meanwhile, information about publicly-held firms is available in the Internet Archive or other databases even after such organizational events. As a result, the sample is likely to be slightly biased towards large, successful, and publicly held companies. Inclusion of small or failing firms would probably increase the accuracy of the results obtained here, particularly regarding the effects of firm size (market power).

Table 2 also provides information about industry affiliations and geographic origins of firms. The sampled firms were classified in terms of their main markets into telecom operators, telecom equipment vendors, software suppliers, network or terminal component suppliers, R&D service providers, and consulting firms. Additionally, firms such as IBM, HP, Fujitsu, and Toshiba that have their technological roots in the computer or consumer electronics industries were grouped separately. These firms have tremendous capabilities in rather different technological fields, but, because of the convergence of telecommunications and computing, they are relatively recent entrants in wireless communications. Regarding geographic distribution of the sampled firms, most firms originate from Europe (45%), followed by North America (34%), and Asia (15%, of which more than half are from Japan). Most of the remaining firms come from Israel.

3.3 Statistical inference

The econometric methods employed in the next section include the panel data variants of logistic and negative binomial maximum likelihood models. The dependent variables are either binary or count data. All models are estimated with both standard random effects, conditional fixed effects, and Chamberlinian fixed effects as suggested by Wooldridge (2002: 487-488, also p. 679). As with linear panel data models, random effects models are efficient but not consistent if explanatory variables are not independent with respect to the unobserved effect. Conditional fixed effects relax this assumption, but this method can only include observations where there is variation in the dependent variable. In other words, firms with only zeroes or only ones in the dependent variable are dropped. To preserve the sample size, we also estimate using Wooldridge's procedure, where the firm-level means of the time-varying explanatory variables are included as additional regressors in the random effects procedure. Insignificance of the coefficients of these "firm-mean variables" would imply that the correlations between the unobserved effects and the time-varying explanatory variables are insignificant, as well. According to Wooldridge, this method is less robust but more efficient than the conditional fixed effects approach. The additional assumption this approach requires is that the firm effects are normally distributed conditional on the explanatory variables. Although this is a rather reasonable assumption, we have no direct evidence of the distributional characteristics of the firm effects. Therefore it is useful to compare the results from the three different estimation methods.

Regarding the count data models, tests for overdispersion indicated that negative binomial models are preferred to poisson ones. Additional tests suggested that constant dispersion is a more appropriate method than mean dispersion. Again, we estimate with both random effects, conditional fixed effects, and Chamberlinian fixed effects as in the binary dependent variable case explained above.

4. Empirical results

In this section, we report the results of panel regression analyses to assess the statistical determinants of firms' ability to influence standard setting in the 3GPP standards development organization. In particular, we are interested in the effects of external alliances and consortia. The first dependent variable is a binary measure for whether a firm participated in at least one work item project in a year, related to the empirical model (1) specified earlier. The results in table 4 on the main explanatory variables of interest are qualitatively aligned across the different estimation methods, but there are differences in terms of the control variables, particularly the patent variables. Overall, adding the Chamberlinian mean variables improves the log likelihood value, but not quite significantly, according to a likelihood ratio test (χ^2=.1853).

More specifically, a consistently strong coefficient is found for consortium memberships. Firms' bipartite degrees in the consortium network (memberships) clearly dominate their unipartite degrees (connections) here. We interpret this to mean that consortia are useful venues for learning about the ongoing technological evolution, which lowers the threshold of joining work item committees. Similar results were obtained with the weighted membership and related and unrelated membership variables. All of these were highly significant, and there was no clear difference between memberships in related and unrelated consortia. Firms thus appear to learn about relevant technologies from both types of consortia. Control variables suggest that firm size may have a marginally positive nonlinear effect on the probability of joining any committees, while European patents have a significant negative effect in the fixed effects models. The latter result may reflect more a European orientation in a firm's strategy than a causal effect from patenting inventions to joining. Other intellectual property measures are not statistically significant.

Table 4 Explaining the probability of participation in 3GPP work item committees

	Random effects		Conditional fixed effects		Chamberlinian fixed effects	
	Coef.	SE	Coef.	SE	Coef.	SE
Constant	-3.565***	0.569	NA		-3.486***	0.651
Size 3	0.293	0.293	-0.336	1.344	0.404	0.315
Size 4	0.606*	0.310	1.514	1.385	0.714*	0.377
Size 5	-0.065	0.417	-0.011	1.631	0.111	0.528
Size 6	0.334	0.255	1.134	1.238	0.424	0.428
Log of USPTO patents	-0.016	0.082	-0.163	0.383	-0.160	0.189
Log of EPO patents	0.013	0.101	-0.997**	0.443	-0.417**	0.195
Log of JPO patents	0.003	0.060	0.130	0.246	0.046	0.128
Log of essential IPR declarations	0.086	0.190	-0.070	0.684	-0.063	0.226
3GPP alliance partners	0.023	0.093	0.111	0.238	0.013	0.111
3GPP alliances	0.058	0.161	-0.084	0.397	0.091	0.206
Consortium connections	0.002	0.002	0.005	0.004	0.003	0.002
Consortium memberships	0.268***	0.049	0.459***	0.166	0.217***	0.084
Industry dummies	Incl.				Incl.	
Regional dummies	Incl.				Incl.	
Year dummies	Incl.		Incl.		Incl.	
Firm-mean variables					Incl.	χ^2=.1853
Log Likelihood	-295.06		-91.36		-289.41	
Observations	772		344		772	
Groups	193		86		193	

Note: Dependent variable: WI committee dummy. *** implies significance at the 99% level of confidence, ** at the 95% level and * at the 90% level. SE indicates standard errors. All models are estimated with Stata/SE 9.2.

Table 5 shows the estimation results for the number of work item committee contributions. Again, the results of random and fixed effects models are qualitatively aligned. The Hausman test does not indicate any systematic biases in the random effects model, however, the firm-mean variables are now significant as a group (χ^2=.0144). It thus makes sense to consider both random and fixed effects models.

The results concerning the two main variables of interest, alliances and consortia, are very similar in the three types of models: both consortium connections and memberships are positively related and the number of alliances is negatively and almost significantly related to work item committee contributions. The effect of consortium connections (unipartite degree) is more robust to estimation method than consortium memberships (bipartite degree), which becomes insignificant with the Chamberlinian approach. The number of alliance partners is not significantly different from zero in any of the models.

Taken together, industry consortia and formal standardization thus appear to be strongly complementary strategies, but private strategic alliances and formal standardization may be substitutable. Hence, we obtain partial support for hypothesis 1: Firms that increased their consortium activities were also likely to increase their formal work item committee contributions, holding all other firm and industry factors, including fixed unobserved heterogeneity, constant. Industry consortia may thus provide opportunities for learning from and influencing other 3GPP members regarding specifications that subsequently come up for discussion in the formal standard-setting forum, 3GPP. The fact that consortium connections were more important than memberships points to the possibility that consortia are not only about learning but also about politics: a broad set of connections probably better enable influence activities than a broad set of memberships, holding the other variable constant.

Table 5 Explaining the number of contributions to 3GPP work item projects

Estimation method	(1) Random effects		(2) Fixed effects		(3) Chamberlinian fixed effects	
	Coef.	SE	Coef.	SE	Coef.	SE
Constant	-4.937 ***	0.898	-2.195 **	0.876	-4.714 ***	0.984
Size 3	0.298	0.394	-0.473	0.847	0.301	0.413
Size 4	0.687 *	0.379	0.407	0.803	0.668	0.457
Size 5	0.398	0.383	0.109	0.801	0.353	0.492
Size 6	0.575	0.363	0.215	0.795	0.509	0.505
Log of USPTO patents	0.204 ***	0.074	0.392 ***	0.116	0.306 **	0.147
Log of EPO patents	-0.025	0.071	-0.017	0.073	-0.077	0.084
Log of Japanese PTO patents	-0.023	0.056	-0.010	0.074	0.021	0.083
Log of essential IPR declarations	0.023	0.035	0.017	0.034	0.009	0.034
3GPP alliance partners	0.034	0.055	0.019	0.046	0.047	0.056
3GPP alliances	-0.127	0.080	-0.104	0.071	-0.126 *	0.079
Consortium connections	0.009 ***	0.002	0.008 ***	0.002	0.008 ***	0.002
Consortium memberships	0.129 ***	0.028	0.078 ***	0.030	0.051	0.034
Industry dummies	Incl.				Incl.	
Regional dummies	Incl.				Incl.	
Year dummies	Incl.		Incl.		Incl.	
Mean variables					Incl.	χ^2=.0144
Observations	772		436		772	
Groups	193		109		193	
Log likelihood	-778.070		-377.62		-768.53	
Hausman test (d.f.), p	13.79(15)	0.542				

Note: Dependent variable: WI committees. Year dummies are included in all models. *** implies significance at the 99% level of confidence, ** at the 95% level and * at the 90% level. Panel data negative binomial maximum likelihood models are estimated with Stata/SE 9.2.

Regarding control variables, intellectual assets measured by patents granted in the United States are very important for making work item committee contributions, as expected. Firm size is also positively associated with committee contributions, but none of the coefficients are significant in the fixed effects models. Size thus correlates with standard-setting contributions but is unlikely to be a causal factor. Additionally, the random effects and Chamberlinian model indicate that firms that make a lot of work item contributions tend to be equipment vendors, operators, or software providers. This information comes from industry dummy coefficients which were not reported in the tables (but are available from the author on request).

Specifications in table 6 introduce the alternative measures for consortium memberships. We report results from conditional and Chamberlinian fixed effects, because the likelihood ratio test indicates that the firm mean variables are at least marginally significant as a group. Consortium connections are included as a control variable, and it remains highly stable and significant independent of which measure of consortium memberships is included.

Comparing results in table 6 to those in table 5 reveals that the weighting of membership counts based on how overlapping the consortia are in their membership adds very little information to the model over the simple count of memberships. The last two specifications in table 6 separate the membership variable into those organizations that are institutionally related and unrelated to 3GPP. Only institutionally related memberships remain significant in the conditional fixed effects mode, and only marginally so in the Chamberlinian model. The difference between the two membership variables is significant, according to a χ^2-test. This provides evidence for hypothesis 2c. Thus, the results support all of the hypotheses 2a-c, although the evidence for 2c is not very strong. In contrast, we have clear evidence that both external consortium connections and memberships are valuable in contributing to formal standardization. Extensive connections appear to help firms join more committees, while memberships appear to lower the threshold of joining at least one committee.

Table 6 Explaining participation in 3GPP work item committees with weighted, related, and unrelated consortium memberships

Estimation method:	(1) Fixed effects		(2) Chamberlinian fixed effects		(3) Fixed effects		(4) Chamberlinian fixed effects	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Constant	-2.250 **	0.872	-4.748 ***	0.984	-2.301 ***	0.865	-4.715 ***	0.986
Size 3	-0.462	0.844	0.288	0.412	-0.486	0.834	0.303	0.414
Size 4	0.404	0.800	0.650	0.455	0.405	0.790	0.674	0.458
Size 5	0.145	0.797	0.346	0.490	0.093	0.787	0.360	0.493
Size 6	0.229	0.791	0.489	0.504	0.243	0.781	0.522	0.508
Log of USPTO patents	0.390 ***	0.114	0.303 **	0.147	0.399 ***	0.118	0.307 **	0.147
Log of EPO patents	-0.055	0.075	-0.098	0.084	0.008	0.072	-0.072	0.085
Log of Japanese PTO patents	0.001	0.073	0.032	0.082	-0.026	0.074	0.017	0.084
Log of essential IPR declarations	0.015	0.033	0.009	0.033	0.028	0.033	0.010	0.034
3GPP alliance partners	0.024	0.047	0.050	0.056	0.030	0.045	0.048	0.055
3GPP alliances	-0.102	0.071	-0.124	0.078	-0.137 *	0.071	-0.130	0.080
Consortium connections	0.009 ***	0.002	0.008 **	0.002	0.008 ***	0.002	0.008 ***	0.002
Weighted memberships	0.175 ***	0.061	0.119 *	0.070		0.062		
Related memberships					0.185 ***	0.032	0.118 *	0.067
Unrelated memberships					0.058 *	0.032	0.033	0.035
Industry dummies			Incl.				Incl.	
Regional dummies			Incl.				Incl.	
Year dummies	Incl.		Incl.		Incl.		Incl.	
Firm mean variables			Incl.	χ^2=.0696			Incl.	χ^2=.0192
Observations	436		772		436		772	
Groups	109		193		109		193	
Log likelihood	-376.99		-769.81		-375.80		-768.49	

Notes: Dependent variable: WI committees. Negative binomial maximum likelihood estimation. *** implies significance at the 99% level of confidence, ** at the 95% level and * at the 90% level.

Next we examine the second stage of the specification development process: change requests to ongoing specifications. The first step is to estimate the determinants of firms making any change requests, to better understand the characteristics of firms participating in this process. In the second step we estimate the number of successful change requests. The second dependent variable reflects the absolute volume of changes that a firm has made to almost finished specifications. It is thus a different kind of a measure of influence than work item committee contributions. Work items provide an opportunity to draft new specifications, while change requests provide an opportunity to directly change specifications that most likely someone else has drafted. As before, results in table 7 come from the random effects and the two types of fixed effects models. The main independent variables of interest include work item committee contacts and contributions; alliance partners and numbers of alliances; and consortium connections and memberships. Although we report the conditional fixed effects results, it should be noted that these are based only on information from those 43 firms that changed their change request status over the period of estimation. In other words, both firms that never made change requests and those that made at least one change request every year are excluded. The resulting sample is thus very small.

Table 7 Explaining participation in the change request process

Estimation method:	Random effects probit			Conditional fixed effects logit			Chamberlinian fixed effects probit		
	Coef.		SE	Coef.		SE	Coef.		SE
Constant	-4.668	***	0.915				-4.797	***	1.162
Size 3	0.170		0.499	-2.204		3.902	0.083		0.528
Size 4	0.285		0.502	-2.683		2.432	0.535		0.570
Size 5	1.383	**	0.611	1.228		3.133	1.555	**	0.765
Size 6	0.159		0.418	0.589		1.507	0.629		0.594
Log of USPTO patents	-0.029		0.127	-0.436		0.671	-0.111		0.273
Log of EPO patents	-0.167		0.147	0.241		0.604	-0.029		0.256
Log of Japanese PTO patents	0.136		0.099	0.322		0.787	0.223		0.232
Log of essential IPR declarations	-0.276	*	0.161	-0.832	*	0.441	-0.414	**	0.193
WI connections	0.069	***	0.020	0.066		0.059	0.066	***	0.023
WI contributions	0.015		0.029	0.145		0.140	-0.014		0.037
3GPP alliance partners	0.107		0.118	0.455		0.315	0.106		0.134
3GPP alliances	-0.254		0.223	-1.394	**	0.678	-0.271		0.269
Consortium connections	0.004		0.003	0.015		0.009	0.003		0.004
Consortium memberships	0.045		0.069	-0.435		0.280	-0.116		0.119
Industry dummies	Incl.						Incl.		
Regional dummies	Incl.						Incl.		
Year dummies	Incl.			Incl.			Incl.		
Firm mean variables							Incl.		χ^2=.0543
Log likelihood	-167.05			-30.17			-158.03		
Observations	772			172			772		
Groups	193			43			193		

Notes: Dependent variable: CR dummy. Random effects probit or conditional fixed effects logit maximum likelihood estimation. *** implies significance at the 99% level of confidence, ** at the 95% level and * at the 90% level.

According to results from all models, firm size is positively associated with the probability of at least one change request, the size effect peaking around the fifth class (50 001 – 100 000 employees). Consistent results are also obtained for declarations of essential IPR—a negative and at least marginally significant coefficient—and for connections from the work item process—a very stable positive coefficient. The result on essential IPR declarations is surprising. However, it is consistently negative across the different estimation methods and also in the subsequent estimation of the number of approved change requests (table 8), and thus seems to imply that essential IPR holders attempt to rather influence specifications in the drafting phase (a positive although not significant coefficient in tables 5 and 6) than in the change request phase. The coefficient on work item connections is significant and positive, as expected, and suggests that the change request process may be political since connections rather than contributions matter for participation in the change request stage. In contrast, no consistently significant results are obtained for alliance or consortium activities. External networks are thus not very useful in helping firms to participate in the later stages of formal specification development.

The last set of estimations reported in table 8 uses the number of approved change requests as the dependent variable. We estimate similar specifications as in table 7, first without and then with the total number of each firm's change requests. Overall, more precise estimates are generated when the total number of change requests is included in the model. However, the Chamberlinian method may not work very well here. Many of the coefficients appear to be out of alignment with the other two methods. We thus slightly prefer the conventional methods, but will report the Chamberlinian results as well.

According to the random and conditional fixed effects results, first, size provides an advantage in getting requests approved. Second, connections created in the work item stage of the standards development process are very useful. Third, the number of alliance partners shows up positively and marginally significantly in the conditional fixed effects model when total change requests are included. The Chamberlinian estimates, on the other hand, suggest that size does not matter for change request approval, while essential IPR declarations retain their strongly negative coefficient and work item connections their positive effect, although the latter becomes only marginally significant. A contrasting result from this third estimation method concerns firms' consortium activities. Consortium memberships have a significant and negative effect on change requests, while the effect of consortium connections becomes positive in the last specification. It is difficult to assess the robustness of the last result, but considering this is the only specification where it appears, we put less weight on it in the interpretation.

Table 8 **Explaining the number of successful change requests**

	(1) Random effects		(2) Fixed effects		(3) Chamberlinian fixed effects		(4) Random effects		(5) Fixed effects		(6) Chamberlinian fixed effects	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Constant	-5.835 ***	1.401	-4.751 ***	1.063	-8.043 ***	1.086	-7. 396 ***	0.962	-5.010 ***	1.053	-9.640 ***	1.051
CR							0.019 ***	0.003	0.011 ***	0.003	0.010 ***	0.002
Size 3	0.344	0.769	2.016 *	1.049	-0.097	0.758	0.198	0.647	2.628 **	1.122	-0.833	0.635
Size 4	0.603	0.718	1.151	0.930	0.117	0.700	0.736	0.611	1.302	0.876	-0.118	0.533
Size 5	1.930 ***	0.735	2.532 ***	0.887	0.980	0.668	1.850 ***	0.644	2.482 ***	0.840	0.466	0.564
Size 6	0.454	0.668	1.508 *	0.826	0.466	0.614	0.110	0.578	1.287 *	0.756	-0.102	0.377
Log of USPTO patents	-0.158	0.187	0.192	0.256	0.397	0.320	-0.116	0.160	0.007	0.261	0.018	0.279
Log of EPO patents	0.112	0.187	0.187	0.233	0.364	0.188	-0.143	0.163	0.048	0.212	-0.177	0.203
Log of Japanese PTO patents	-0.068	0.138	-0.271 **	0.131	-0.373 **	0.166	0.064	0.099	-0.145	0.142	-0.110	0.155
Log of essential IPR declarations	-0.190 *	0.100	-0.130 *	0.069	-0.036	0.046	-0.482 ***	0.100	-0.296 ***	0.086	-0.267 ***	0.068
WI connections	0.061 ***	0.020	0.057 ***	0.022	0.052 **	0.021	0.061 ***	0.019	0.054 **	0.021	0.040 *	0.023
WI contributions	-0.004	0.016	-0.007	0.015	-0.013	0.013	-0.025 *	0.013	-0.018	0.014	-0.001	0.015
3GPP alliance partners	0.129	0.126	0.131	0.114	0.003	0.108	0.279 **	0.112	0.206 *	0.111	0.157	0.113
3GPP alliances	-0.231	0.227	-0.211	0.213	0.033	0.193	-0.450 **	0.188	-0.305	0.191	-0.152	0.194
Consortium connections	0.011 ***	0.004	0.001	0.004	0.003	0.005	0.009 **	0.004	0.003	0.003	0.008 **	0.004
Consortium memberships	-0.030	0.074	-0.085	0.061	-0.200 **	0.090	0.080	0.061	-0.009	0.065	-0.240 **	0.110
Industry dummies	Incl.				Incl.		Incl.				Incl.	
Regional dummies	Incl.				Incl.		Incl.				Incl.	
Year dummies	Incl.		Incl.		Incl.		Incl.		Incl.		Incl.	
Firm mean variables					Incl.	χ^2=.0001					Incl.	χ^2=.0000
Log likelihood	-427.41		-169.13		-408.81		-409.46		-162.74		-365.89	
Observations	772		164		772		772		164		772	
Groups	193		41		193		193		41		193	

The two most consistent results in table 8 concern the negative association of essential IPR declarations and the positive association of work item committee connections with change request success. One way to interpret the first result is that it is possible that firms with essential patents are less likely to make requests since they prefer the drafting phase, or alternatively, these firms' requests are discounted by other firms as attempts to insert proprietary technologies into the specifications. This result is intriguing and would probably require more data to fully explain. At the same time, none of the other patent measures are significant, which implies that IPR is simply not an important factor in this stage of the standard-setting process. Firm size and connections from the work item development stage are more relevant. This, again, suggests political capital is of essence in the change request game.

To summarize the empirical results, our analyses provide evidence for hypothesis 1: external cooperative networks are important factors in formal standard setting. Participation in technical consortia helps firms contribute to the development of new features. Regarding the competing hypotheses H2a-c, the results suggest that consortium memberships are more important than consortium connections for becoming a work item contributor in the first place. This corroborates the learning perspective: consortia enable firms to develop better proposals and learn about others' technologies, which strengthen their contributions to the formal specification process in 3GPP. However, the total number of a firm's work item contributions depends on both its consortium connections and memberships—both learning and political capital matter. Evidence for H2c regarding the effects of related vs. unrelated consortia suggests institutionally related consortia are more useful, perhaps because these fora deal with more closely related technologies and are viewed as more legitimate in formal standardization.

Our evidence concerning hypotheses H3a and H3b—the role of external private alliances—is mixed: alliances have an insignificant relationship with work item contributions and a weakly negative relationship with the probability of making any change requests, but, in attempting to influence specifications in progress through change requests, the number of alliance partners has a positive and weakly significant effect. We thus have partial support for H3a—connections made through private alliances may sometimes facilitate influencing formal standards negotiations. Finally, the evidence on the fourth set of hypotheses that studied the effects of committee activities within 3GPP is clear: supporting work items where firms can make new committee connections is a more successful strategy than maximizing the quantity of contributions. Committee connections positively and significantly explain both the probability and the number of change requests (H4a). This result is aligned with the argument that social and political forces are at play in formal standard setting, and, hence, forming linkages with as many peers as possible improves firms' potential to influence the outcome.

Regarding the control variables, larger size correlates with standard-setting impact, but in moast fixed effects models the effect disappears. Influential firms thus tend to be large but this is usually not a causal factor. In contrast, intellectual assets as measured by patents obtained in the United States are very significant explanatory variables of work item contributions even controlling for unobserved heterogeneity. This result is in line with earlier research that has argued that intellectual property is pivotal in the game of standard setting (Bekkers et al. 2002). In contrast, influential players in the change request stage do not depend on intellectual property portfolios. In fact, substantial essential IP declarations may interfere with the ability to make successful change requests. We interpret this to mean that intellectual property holders typically try to influence the standard-setting process in the work item development phase, while firms that do not have such holdings (e.g., small firms or service providers) attempt to influence the process in the change request phase.

Among the other control variables, year dummies are highly significant, and the significance of industry dummies varies, but generally speaking there are significant differences among industry segments. The work item development process appears to be dominated by equipment vendors, operators, and software providers, but these are not any more influential in terms of change requests. Interestingly, Asian firms consistently contribute less to the work item process than do firms from other regions, yet they are significantly more successful in making change requests. Asian firms thus seem to play a very special role in the 3GPP standard setting.

5. Conclusions

This empirical paper has studied the characteristics and activities of wireless telecommunication firms that make them influential in formal technical standardization. The results suggest that, in addition to intellectual assets and active participation in technical committees that develop new specifications, cooperative activities outside of the focal formal standards development organization are important for standard-setting success. We focus particularly on the effects of private alliances and technical consortia. Both are positively correlated with some of the measures of standard-setting success used in the study. More specifically, participation in consortia is very important for being able to contribute to new specifications, or work items. Alliances may be important for successful change requests, although the effect is not very consistent.

In trying to understand why external cooperative activities may matter for standard setting, we have distinguished between affiliations and connections. More specifically, consortia, multiparty alliances, and work item committees can be seen to give rise to bipartite networks, where firms form links with the consortia or committees and not directly with one another. Recognizing this, we have tested hypotheses concerning the effects of *affiliations* with consortia, alliances, or committees and compared the results against the effects of *connections* formed through consortia, alliances, or committees. We argued that if affiliations (bipartite network degrees) are more relevant in standardization, controlling for connections, we have evidence of knowledge accumulation through joint research and development within these cooperative arrangements, while if connections (projected unipartite network degrees) are more relevant, controlling for affiliations, we have evidence of the social and political nature of formal standardization: it doesn't matter exactly what the joint activities are as long as firms form connections to as many 3GPP peers as possible.

Connections turn out to be clearly the most significant measure in the work item committee network, while in the external cooperation networks, affiliations matter about as much for standard setting as do connections. Thus, we argue that the ability to contribute to formal standardization through work items depends on both the learning and networking opportunities provided by broad consortium activities.

However, within 3GPP, it is more useful to form connections with peers rather than to make extensive contributions. The role of private alliances is very different from that of consortia, however. Alliances are negatively related to firms' contributions to specification development. This result makes sense if private alliances are a substitute for formal standardization. Nevertheless, alliances are weakly positively related to the number of approved change requests. Alliances may thus help firms build capabilities that also facilitate influencing, but not necessarily contributing to, formal standardization. From a network analytical perspective, these results suggest that not all network ties are equal: it is important to account for the structure and the nature of the affiliation network.

For managers, the results obtained underline the importance of a multipronged cooperation strategy. Having access to a large number of standard-setting peers in multiple venues appears to be useful in terms of being able to contribute to formal standardization. Defining and aligning technical preferences with like-minded peers ahead of their introduction in formal standardization helps in forming a unified front when the decisions are being made. However, for small firms this may present a daunting challenge because of the extensive human, technological, and financial resources required to effectively participate in consortia and technical subcommittees. According to our results, and depending on membership fees, resource-constrained firms may be able to maximize their influence and economize on participation costs by focusing on institutionally closely related consortia.

For policymakers interested in making the playing field level for all types of innovators and competitors, it is important to make sure that memberships to consortia remain open, the costs of participation remain reasonable, and the rules governing formal standard setting encourage contributions from small players. While we find no causal effect of firm size on standard-setting success, there is reason to believe that small firms find it very difficult to engage in an equally broad cooperation strategy as large firms. Thus, considering that cooperative standardization has both theoretically and empirically observed benefits (Farrell & Saloner, 1988; Funk & Methe, 2001), it is very important in network technology industries to facilitate open standard-setting processes that enable contributions from firms of all sizes or resource bases.

In interpreting the results, it is important to consider how valid and generalizable they are. First, this research utilized a panel dataset of wireless telecommunications firms, which alleviated issues of unobserved industry and firm heterogeneity. However, it is still possible that time-varying unobserved events influence firms' incentives to participate in both consortia and 3GPP working groups. For example, an emerging technological opportunity might be lucrative only to certain members of 3GPP, who might as a result increase their participation in both consortia and 3GPP. Then, we would observe a change in both consortium and 3GPP activities without a causal linkage. In other words, consortium activities would be endogenous. While we have attempted to control for these kinds of events with essential intellectual property declarations, these measures may not fully capture endogenous movements in consortium behavior.

Second, we are essentially examining a quantitative case study of cooperative standard setting, and it is not known how relevant these results are for understanding, for example, North American standard-setting organizations in other fields of information technology. External validity of the results thus depends on how representative the 3GPP case may be for other industries and regions. There has been very little comparative research on standardization bodies, but the studies by Lemley (2002) and Chiao et al. (2006) suggest that ETSI, on which 3GPP policies are based, is not in any way an outlier among the over 60 standard-setting organizations analyzed. Committee-based standardization has become commonplace (see e.g., Cargill, 1989), and 3GPP has instituted policies that are applied in many other standardization committees. It should thus give us some valid indication regarding how firms might behave in other standardization projects. Nevertheless, it would be interesting to study other standards development organizations in different fields of technology to gauge how specific our results are to the technological context. Relatedly, this study examines the creation of open standards governed by F/RAND licensing. It would be worthwhile to directly compare cooperative dynamics found here against those in areas where firms produce proprietary standards, on one hand, or completely free standards, on the other hand. It is likely that the results obtained here apply mainly to open/FRAND standards.

Third, we examined the effects of co-memberships in alliances and consortia using only very simple methods of bipartite network analysis. Future research could investigate the affiliation network structure based on emerging research on bipartite networks (e.g., Field et al., 2006) with more complex techniques that preserve the duality of cooperative arrangements and their members while uncovering cliques and other patterns of interaction through the consortium network.

To summarize, we found that firms' ability to contribute to and influence formal standardization significantly depends on both their connections in the technical specification work of the formal standards development organization and their activities in external cooperative arrangements. In particular, interactions with other 3GPP members through external consortia are important in explaining contributions to new specification development. We controlled for a number of factors that have been identified in earlier research to be relevant, including firm size, intellectual property positions, industry segment, geographic origins, and fixed unobserved heterogeneity. Cooperative activities were found to be at least as relevant as intellectual assets in explaining firms' influence on standard setting. Joint learning as well as social and political capabilities thus are very important in the standardization game. As a result, firms are advised to engage in a broad cooperative approach if they wish to actively contribute to and drive standard-setting outcomes.

References

Ask F. 1995. Interoperability and Intellectual Property. In B Kahin, J Abbate (Eds.), *Standards Policy for Information Infrastructure*: 405-409. The MIT Press: Cambridge MA.

Axelrod R., S. Bennett, E. Bruderer, W. Mitchell, R. Thomas. 1995. Coalition formation in standard-setting alliances. *Management Science* **41**(9): 1493-1508.

Bekkers R., G. Duysters, B. Verspagen. 2002. Intellectual Property Rights, Strategic Technology Agreements and Market Structure: The Case of GSM. *Research Policy* **31**(7): 1141-1161.

Borgatti S.P., M.G. Everett. 1997. Network analysis of 2-mode data. *Social Networks* **19**: 243-269.

Cargill C.F. 1989. *Information Technology Standardization: Theory, Process, and Organizations*. Digital Press: Digital Equipment Corporation.

Chiao B., J. Lerner, J. Tirole. 2006. The Rules of Standard Setting Organizations: An Empirical Analysis. Harvard University: Cambridge, MA.

Cornwell B., J.A. Harrison. 2004. Union members and voluntary associations: Membership overlap as a case of organizational embeddedness. *American Sociological Review* **69**(December): 862-881.

Davis A., B.B. Gardner, M.R. Gardner. 1941. *Deep South*. University of Chicago Press: Chicago.

Dokko G., L. Rosenkopf. 2003. Social Capital for Hire? The Mobility of Technical Professionals and Firm Centrality in Wireless Standards Committees. Unpublished manuscript: University of Pennsylvania.

Farhi E., J. Lerner, J. Tirole. 2005. Certifying new technologies. *Journal of the European Economic Association* **3**(2-3): 734-744.

Farrell J., H.K. Monroe, G. Saloner. 1998. The Vertical Organization of Industry: Systems Competition vs. Component Competition. *Journal of Economics & Management Strategy* **7**(2): 143-182.

Farrell J., G. Saloner. 1985. Standardization, compatibility, and innovation. *RAND Journal of Economics* **16**(1): 70-83.

Farrell J., G. Saloner. 1988. Coordination through committees and markets. *RAND Journal of Economics* **19**(2): 235-252.

Field S., K.A. Frank, K. Schiller, C. Riegle-Crumb, C. Muller. 2006. Identifying Positions from Affiliation Networks: Preserving the Duality of People and Events: University of Texas, Austin.

Fleming L., D. Waguespack. 2004. Private Benefit from Public Good? Startup Strategies for Participation in an Open Standards Community. Unpublished manuscript: Harvard Business School.

Fuentelsaz L., J. Gomez. 2006. Multipoint competition, strategic similarity and entry into geographic markets. *Strategic Management Journal* **27**(5): 477-499.

Funk J.L., D.T. Methe. 2001. Market- and committee-based mechanisms in the creation and diffusion of global industry standards: the case of mobile communication. *Research Policy* **20**: 589-610.

Galaskiewicz J., P.V. Marsden. 1978. Interorganizational Resource Networks: Formal Patterns of Overlap. *Social Science Research* **7**: 89-107.

Kahin B., J. Abbate (Eds.). 1995. *Standards Policy for Information Infrastructure*. The MIT Press: Cambridge MA.

Katz M.L., C. Shapiro. 1985. Network Externalities, Competition, and Compatibility. *American Economic Review* **75**(3): 425-440.

Leiponen A. 2006a. National Styles in the Setting of Global Standards: The Relationship between Firms' Standardization Strategies and National Origin. In J Zysman, A Newman (Eds.), *How Revolutionary was the Revolution? National Responses, Market Transitions, and Global Technology in the Digital Era*: 350-372. Stanford University Press: Palo Alto.

Leiponen A. 2006b. Cooperative strategies in the standardization of wireless telecommunications. Unpublished manuscript: Cornell University.

Lemley M.A. 2002. Intellectual Property Rights and Standard Setting Organizations. UC Berkeley School of Law: Berkeley, CA.

Lerner J., J. Tirole. 2006. A Model of Forum Shopping. *American Economic Review* **96**(4): 1091-1113.

Nelson R.R. 1961. Uncertainty, Learning, and the Economics of Parallel Research and Development Efforts. *Review of Economics and Statistics* **43**: 351-364.

Newman M.E.J., D.J. Watts, S.H. Strogatz. 2002. Random graph models of social networks. *Proceedings of the National Academy of Sciences* **99**(supplement 1): 2566-2572.

Pfeffer J., G.R. Salancik. 1978. *The External Control of Organizations*. Harper and Row.

Powell W.W., K.W. Koput, L. Smith-Doerr. 1996. Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology. *Administrative Science Quarterly* **41**: 116-145.

Rosenkopf L., A. Metiu, V.P. George. 2001. From the Bottom Up? Techical Committee Activity and Alliance Formation. *Administrative Science Quarterly* **46**: 748-771.

Rosenkopf L., M.L. Tushman. 1998. The Coevolution of Community Networks and Technology: Lessons from the Flight Simulation Industry. *Industrial and Corporate Change* **7**(2): 311-346.

Rysman M., T. Simcoe. 2006. Patents and the Performance of Voluntary Standard Setting Organizations. Unpublished manuscript: Boston University and University of Toronto.

Schmidt S.K., R. Werle. 1998. *Coordinating Technology: Studies in the International Standardization of Telecommunications*. The MIT Press: Cambridge, MA.

Simcoe T. 2004. Delays and de jure Standards: What Caused the Slowdown in Internet Standards Development? Unpublished manuscript: University of Toronto.

Spring M.B., C. Grisham, J. O'Donnell, I. Skogseid, A. Snow, G. Tarr, P. Wang. 1995. Improving the Standardization Process: Working with Bulldogs and Turtles. In B Kahin, J Abbate (Eds.), *Standards Policy for Information Infrastructure*: 220-250. The MIT Press: Cambridge MA.

Tsai W. 2000. Social Capital, Strategic Relatedness and the Formation of Intraorganizational Linkages. *Strategic Management Journal* **21**: 925-939.

Wasserman S., K. Faust. 1994. *Social Network Analysis: Methods and Applications*. Cambridge University Press: Cambridge.

Weiss M.B.H., M. Sirbu. 1990. Technological choice in voluntary standards committees: An empirical analysis. *Economics of Innovation and New Technology* **1**: 111-133.

Wooldridge J.M. 2002. *Econometric Analysis of Cross Section and Panel Data*. The MIT Press: Cambridge, MA.

Appendix

Correlation coefficients among variables used in the estimations

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Log(employees)	1																
2. WI connections	0.411	1															
3. WI committee dummy	0.396	0.729	1														
4. Consortium memberships	0.313	0.868	0.455	1													
5. Alliance connections	0.397	0.190	0.235	0.111	1												
6. Alliances	0.412	0.199	0.231	0.129	0.917	1											
7. Log(US PTO patents)	0.641	0.321	0.264	0.286	0.548	0.580	1										
8. Log(JPO patents)	0.496	0.218	0.187	0.160	0.563	0.544	0.726	1									
9. Log(EPO patents)	0.640	0.366	0.273	0.329	0.526	0.548	0.873	0.731	1								
10. Log(IPR declarations)	0.169	0.402	0.192	0.489	0.155	0.165	0.276	0.182	0.300	1							
11. Consortium connection	0.488	0.435	0.412	0.334	0.364	0.388	0.498	0.413	0.495	0.223	1						
12. Consortium memberships	0.530	0.664	0.511	0.631	0.436	0.479	0.649	0.480	0.603	0.470	0.749	1					
13. Weighted memberships	0.481	0.696	0.505	0.687	0.378	0.426	0.583	0.397	0.543	0.502	0.657	0.970	1				
14. Related memberships	0.555	0.555	0.424	0.508	0.444	0.475	0.622	0.534	0.587	0.346	0.725	0.845	0.781	1			
15. Unrelated memberships	0.446	0.637	0.492	0.616	0.374	0.419	0.579	0.387	0.532	0.477	0.664	0.955	0.949	0.649	1		
16. Change requests	0.065	0.416	0.154	0.544	0.091	0.105	0.116	0.052	0.152	0.465	0.111	0.349	0.424	0.208	0.381	1	
17. CR>0 dummy	0.221	0.482	0.334	0.454	0.127	0.107	0.195	0.173	0.194	0.211	0.225	0.383	0.409	0.305	0.375	0.469	1
18. CR approvals	0.053	0.400	0.143	0.523	0.082	0.097	0.104	0.047	0.144	0.443	0.106	0.330	0.404	0.190	0.365	0.986	0.464