ETLA

ELINKEINOELÄMÄN TUTKIMUSLAITOS
THE RESEARCH INSTITUTE OF THE FINNISH ECONOMY
Lönnrotinkatu 4 B 00120 Helsinki Finland Tel. 358-9-609 900
Telefax 358-9-601 753 World Wide Web: http://www.etla.fi/

Keskusteluaiheita – Discussion papers

No. 1056

Aija Leiponen*

COMPETING THROUGH COOPERATION: STANDARD SETTING IN WIRELESS TELECOMMUNICATIONS

* Cornell University, Department of Applied Economics and Management

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.

ISSN 0781-6847 11.11.2006

LEIPONEN, Aija, **COMPETING THROUGH COOPERATION: STANDARD SETTING IN WIRELESS TELECOMMUNICATIONS.** Helsinki: ETLA, Elinkeinoelämän Tutkimuslaitos, The Research Institute of the Finnish Economy, 2006, 30 p. (Keskusteluaiheita, Discussion Papers, ISSN 0781-6847; no. 1056).

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

JEL-codes: L15, L41, L96, O34, O38

LEIPONEN, Aija, **KILPAILLEN YHTEISTYÖSSÄ: YRITYSVERKOSTOT LANGATTOMAN VIESTINNÄN TEKNISESSÄ STANDARDOINNISSA.** Helsinki: ETLA, Elinkeinoelämän Tutkimuslaitos, The Research Institute of the Finnish Economy, 2006, 30 s. (Keskusteluaiheita, Discussion Papers, ISSN 0781-6847; no. 1056).

TIIVISTELMÄ: Tutkimus tarkastelee langattoman viestinnän standardien muodostumista yritysten välisessä yhteistyössä erityisesti standardointikomiteoiden, allianssien ja teknisten toimialajärjestöjen piirissä. Keskeinen kansainvälinen standardointijärjestö kolmannen sukupolven langattomassa viestinnässä on Third Generation Partnership Project (3GPP). Tutkimuksessa kootun paneeliaineiston avulla arvioidaan toimialajärjestöjen, allianssien ja 3GPP:n työryhmien välisiä suhteita. Tulosten mukaan muissa toimialajärjestöissä toimiminen edistää yritysten vaikutusmahdollisuuksia 3GPP:ssä merkittävästi. Ulkopuolisissa järjestöissä toimivat yritykset ovat huomattavasti muita yrityksiä tuottavampia 3GPP:n työryhmissä. Aktiivisuus muissa järjestöissä ei kuitenkaan lisää yritysten mahdollisuuksia vaikuttaa 3GPP:n standardikehitystyön viimeiseen vaiheeseen jossa tehdään muutosehdotuksia viimeistelyä vailla oleviin spesifikaatioihin. Tässä työvaiheessa vaikutusvaltaisimpia ovat yritykset, jotka ovat solmineet eniten yhteistyösuhteita standardointityön aiemmissa vaiheissa. Yritysten standardointistrategioiden kannalta tulokset osoittavat, että on hyödyllistä tehdä yhteistyötä monella saralla ja solmia yhteistyösuhteita monien yritysten kanssa. Yritykset oppivat toimialan konsortioissa ja foorumeilla toisiltaan ja voivat esitellä muille omien teknologisten ratkaisujensa ominaisuuksia. Standardointi- ja innovaatiopolitiikan kannalta on tärkeää, että konsortiot ja foorumit ovat avoimia sekä pienille että suurille yrityksille. Pienten yritysten on usein erityisen vaikea löytää riittäviä taloudellisia voimavaroja ja teknisiä asiantuntijoita, jotka voivat täysipainoisesti osallistua konsortiotyöhön. Silti niiden panos voi olla merkittävä komponenttien ja sovellusten innovaatiotoiminnassa.

ASIASANAT: Tekniset standardit, innovaatiotoiminta, yhteistyöverkostot

JEL-koodit: L15, L41, L96, O34, O38

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. They are thus rather mundane institutions per se, yet they can have dramatic repercussions for firm performance, competition in an industry, 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 had thus 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 & Shapiro, 1988), while in practice, and in many industries, standards are set in a more cooperative manner. 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 industry associations and consortia. Within these cooperative organizations, firms both cooperate and compete in trying to influence standards outcomes. The empirical analysis here shows that firms that participate in external cooperative arrangements are more 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 new network analytical theoretical framework and test for the derived hypotheses using panel data that enable controlling for unobserved heterogeneity.

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 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-constraint 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, cooperative standard-setting arrangements can potentially be used in anticompetitive ways. To prevent this, policy-makers should ensure that consortium governance and membership remain open. Supporting consortium participation of small or resource-constraint firms would be another option.

The paper is organized as follows. We first describe the empirical context of study and review extant literature to derive empirical hypotheses. 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). 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 while 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.[1] The research question concerning the effects of consortia on standard-setting outcomes is thus a controversial and contentious issue for industry practitioners.

Open telecommunication standards have many features 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. First, firms that hold intellectual property that becomes incorporated in the standard 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). The process of making technical choices in

[1] 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.

formal standard setting thus involves high technical and market uncertainty, which gives rise to a political game of influence.

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, 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. The strategic choices in wireless telecommunications thus appear to involve setting up a constellation of cooperative arrangements rather than choosing the optimal one arrangement.

Empirical work on cooperative standardization processes includes studies by Weiss and Sirbu (1990), Bekkers et al (2002), and Simcoe (2004), also 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. They may thus become both more efficient at developing formal technical specifications and more powerful in subsequent negotiations. As a result, consortia and alliances may accelerate standards development work, which benefits the whole industry, but it is also possible that they attempt to fix standards 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, 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). 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) in the consortia in which it participates.

sums of members (excluding the focal firm) in the consortia in which it participates.

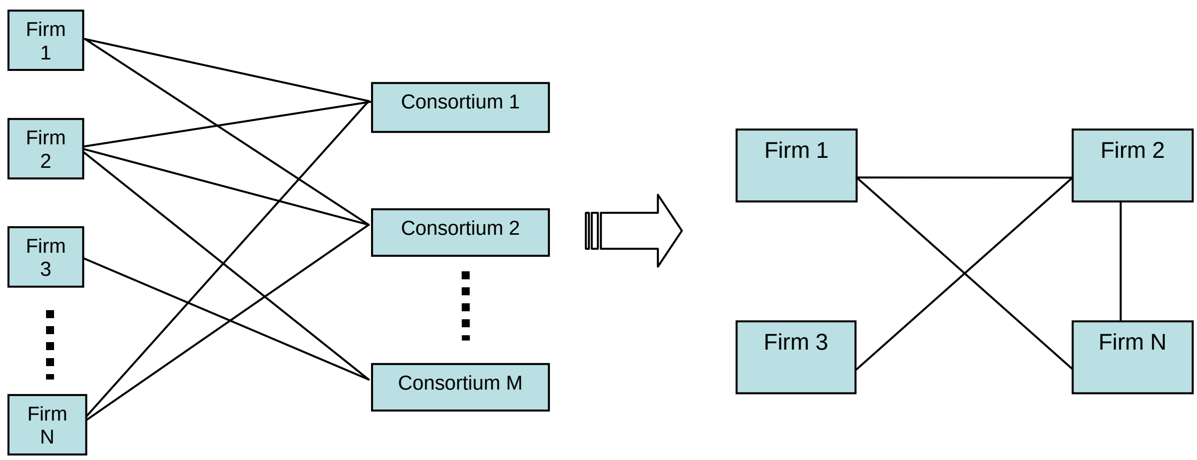

Figure 1: Bipartite consortium network and the unipartite projection

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).

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' 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 facilitate influencing 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 *Connections to other focal SDO members formed through private alliances help align positions and support on technical decisions, thus making firms with more alliance partners more influential in formal standardization.*

H3b *Private strategic alliances with other focal SDO members provide fora for developing expertise relevant for standard-setting negotiations, thus making firms with more alliances more influential in 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.

H4a *Connections formed through standardization subcommittees help align firms' positions on technical proposals and, therefore, firms that have made more connections through work item committees have a greater ability to influence standard-setting outcomes.*

H4b *Contributions in formal standardization subcommittees demonstrate firms' technical expertise and, therefore, firms that participate in more work item committees 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

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). This standards development organization 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 causal arguments are supported.

The technical specification development work in 3GPP is organized into technical specification groups and working groups. 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 that are not technically reasonable or feasible.[2] Indicators from this work item affiliation network will be used first as dependent variables and later as explanatory variables in the empirical analysis.

---

[2] 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).

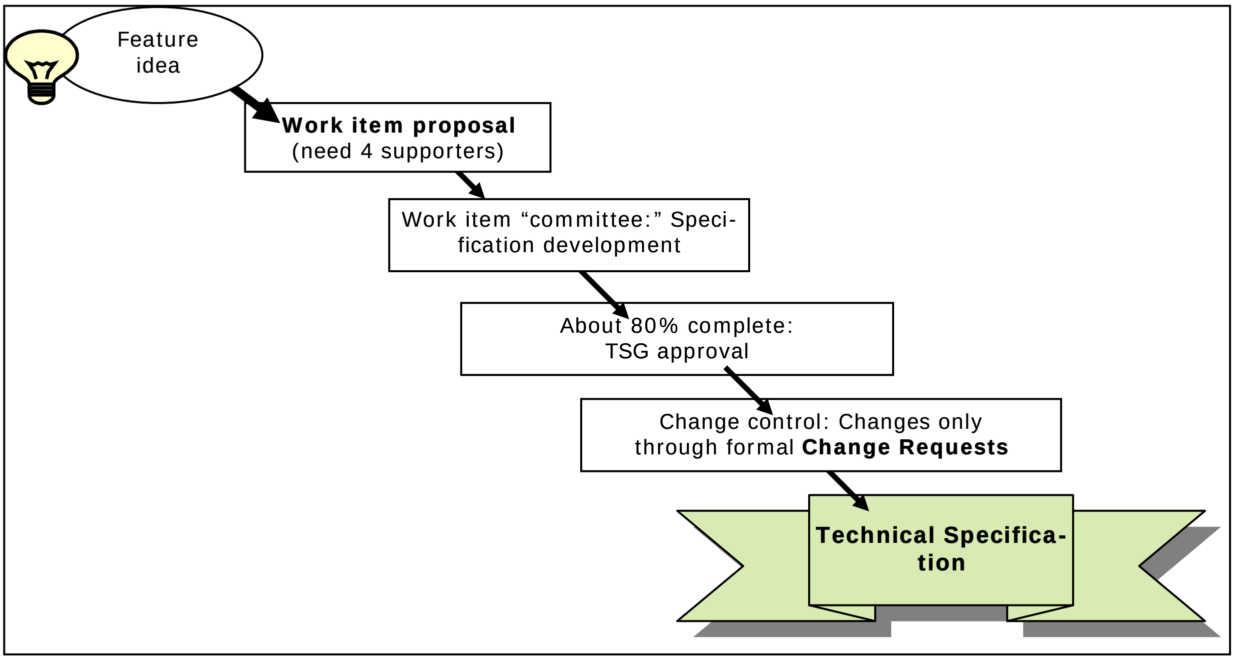

Figure 2: 3GPP work item process

Once a work item is under way, the supporting companies coordinate the specification development in cooperation with other members of the working group. When the working group deems the feature approximately 80% complete, it will be brought up for discussion in the respective (higher level) technical specification group and it enters change control. This means that changes in the work item must be made through a formal change request process. Written change requests can be submitted to the technical specification group by individual 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 the 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.

3GPP member firms' external cooperative arrangements 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. Nevertheless, many of 3GPP's members participate in these organizations as well—see the last column in table 1. In fact, consortia can 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 consortia membership for the 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.

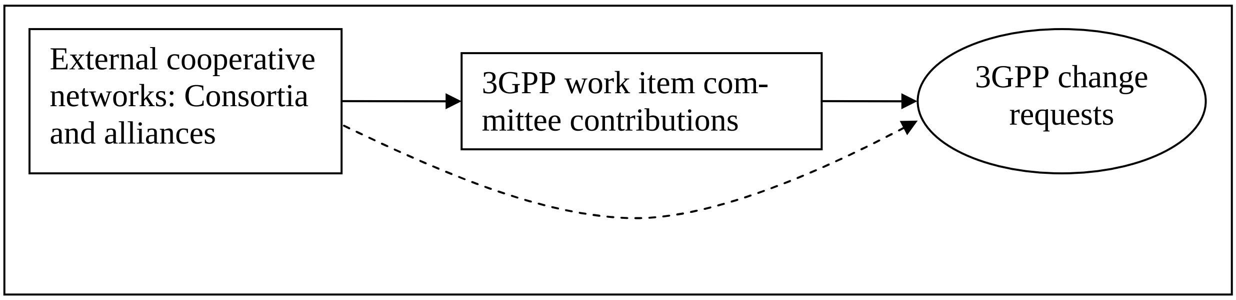

Figure 3: Effects of external networks on 3GPP standard setting

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 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 the networks of (projected) unipartite connections or the sheer number of bipartite affiliations best 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(work item committee contributions (+), 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; additionally, the data on patents, alliances, and consortia are 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 empirical variables and descrip-

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 Contacts	Number of unique contacts made in work item committees	4.132	9.732	0	63
	CR approvals	Number of approved sole authored change requests	2.164	12.416	0	145
	CR success rate	Approved divided by total sole authored change requests	0.069	0.220	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
	Essential IPR declarations	UMTS-related essential IPR declarations at ETSI	1.546	14.683	0	264
	Essential IPR dummy	Binary indicator for IPR declarations>0	0.129	0.335	0	1
External network variables	Private alliances	Number of alliances with other 3GPP members	0.403	1.132	0	10
	Alliance partners	Number of 3GPP member alliance partners	0.556	1.677	0	13
	Consortium memberships	Total CTO 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	Connections to other 3GPP members through the unipartite consortium network	151.768	185.872	0	887
	Related connections	Connections to other 3GPP members through the unipartite institutionally related consortium network	65.367	92.990	0	456
	Unrelated connections	Connections to other 3GPP members through the unipartite institutionally unrelated consortium network	86.401	117.729	0	595
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%			

tive statistics. Dependent variables measure the number of firms' contributions to work items and their success in change requests to existing work items in terms of the share of successful requests in all change requests made by each firm in each year. Additionally, to examine the robustness of these results we also estimate the key specifications with the number of approved change requests.

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 connections (unipartite degree) and the number of committees (bipartite 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 is argued to best reflect 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 privately-held firms, we define size classes in the way explained in table 3. Small private startup firms, for which these measures are typically lacking 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.

Table 3 Firm size classes

Size class	Number of employees	% of total observations
Size 1	0 – 100	3.4
Size 2	101 – 1000	10.2
Size 3	1001 – 10000	17.1
Size 4	10001 – 50000	16.2
Size 5	50001 – 100000	7.4
Size 6	100000 –	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) to measure firms' general technological assets. Alternative models included the patents from Japanese and European patent offices, too. These turned out to have little explanatory power beyond the US patents. Another concern is that the patents of certain firms in the sample may be related to technological fields that have little to do with wireless telecommunications. 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 the annual total US patents obtained: the marginal patent is assumed have a positive but declining effect.

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. IP declarations are highly sporadic, varying for individual companies between hundreds of declarations one year and none the next year. This can be problematic in the estimations. To remedy this data issue, we formed dummy variables for firms that made any declarations of essential IP over the period of study 1998-2003. In random effects models, it is possible to identify such time-invariant characteristics. The advantage of this variable is that it measures technological assets that are highly relevant from 3GPP's point of view.

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.[3] 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 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

[3] 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.

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 negative binomial and tobit maximum likelihood models. The dependent variables are either count data or censored (corner solution outcome) variables. Regarding the count data models, tests for overdispersion indicated that negative binomial models are preferred to poisson. Additional tests suggested that constant dispersion is a more appropriate method than mean dispersion. The advantages of random effects negative binomial models include efficiency and ability to estimate the effects of time-invariant characteristics, but the underlying assumptions require that the unobserved effect is strictly independent of the explanatory variables. In contrast, the conditional fixed effect estimation relaxes this assumption and allows for arbitrary dependencies between the unobserved effect and the explanatory variables (Wooldridge 2002: 674). Unfortunately, this approach cannot utilize observations with zero outcomes, so we lose a large part of the sample. Because of this, we will report both random and fixed effect results.

Estimations of the change request success rates involve a continuous but limited dependent variable. For panel data, random effects tobit models are efficient and straightforward to estimate, but as above, they require strict exogeneity of the explanatory variables, conditional on the unobserved effect. To allow for a correlation between these two, we follow Wooldridge (2002: 540) and implement a Chamberlain-type model which includes the firm-level means of the time-varying explanatory variables as additional right-hand-side variables. Insignificance of the coefficients of these mean variables would imply that the correlations between the unobserved effects and the time-varying explanatory variables are insignificant, as well. This approach solves the unobserved heterogeneity issue in the panel data tobit model.

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 effect of external alliances and consortia. Table 4 shows the estimation results for work item committee contributions, i.e., empirical model (1). Overall, the results of random and fixed effects models are qualitatively aligned, but statistical significance and sometimes the magnitude of coefficients vary between the two methods. As expected, the random effects results are relatively more efficient, but a Hausman test rejects their consistency. Nevertheless, the results concerning the two main variables of interest, alliances and consortia, are very similar in the two types of models: consortia are very strongly positively related and alliances are negatively related to work item committee contributions. Industry consortia and formal standardization are thus strongly complementary strategies according to our data, 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 able to increase their formal work item committee contributions, holding all other firm and industry factors, including unobserved heterogeneity, constant. These results accord with the interpretation that industry consortia 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.

Regarding control variables, intellectual assets measured by patents granted in the United States are very important for making work item committee contributions. 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 probably is not a causal factor. Additionally, the random effects models indicate that firms that make a lot of work item contributions tend to be equipment vendors, operators, or software providers.

Specifications in table 5 introduce the different measures of external consortium activity. We only report the fixed effects models here. Specification 1 in table 5 that contains the consortium membership variable explains more in terms of log likelihood than the second specification in table 4 with consortium connections. The most variance in terms of maximizing log likelihood is explained by the

Table 4 Explaining participation in 3GPP work item committees: alliances and consortium connections

Estimation method	(1) Random effects			(2) Fixed effects			(3) Random effects			(4) Fixed effects		
	Coef.		SE	Coef.		SE	Coef.		SE	Coef.		SE
Constant	-4.641	***	0.874	-1.285		0.823	-4.620	***	0.874	-1.255		0.844
Size 3	0.436		0.385	-0.434		0.831	0.443		0.385	-0.421		0.841
Size 4	0.862	**	0.371	0.416		0.782	0.867	**	0.372	0.427		0.811
Size 5	0.541		0.372	0.107		0.782	0.549		0.372	0.129		0.804
Size 6	0.445		0.355	0.020		0.776	0.438		0.355	0.028		0.795
Log of USPTO patents	0.176	***	0.061	0.373	***	0.108	0.176	***	0.061	0.365	***	0.115
Essential IPR dummy	0.305		0.289				0.331		0.290			
3GPP alliances	-0.054		0.041	-0.054		0.041						
3GPP alliance partners							-0.022		0.029	-0.029		0.032
Consortium connections	0.0043	***	0.0007	0.0025	***	0.0007	0.0041	***	0.0007	0.0023	***	0.0006
R&D services	0.927		0.940				0.921		0.940			
Component	1.302		0.800				1.286		0.800			
Computer	0.766		0.871				0.717		0.870			
Equipment	2.415	***	0.814				2.393	***	0.814			
Operator	2.508	***	0.773				2.514	***	0.773			
Software	2.433	***	0.799				2.425	***	0.799			
North America	-0.085		0.220				-0.075		0.220			
Asia	-0.481		0.314				-0.460		0.317			
Year dummies	yes	***		yes	***		yes	***		yes	***	
Observations	772			436			772			436		
Groups	193			109			193			109		
Log likelihood	-796.89			-391.25			-797.47			-391.55		
Hausman test (d.f.), p	226.86(10)		0.000				82.28(10)		0.000			

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.

Table 5 Explaining participation in 3GPP work item committees: consortium connections vs. memberships

	1		2		3		4	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Constant	-0.942	0.791	-0.786	0.784	-1.150	0.786	-1.194	0.831
Size 3	-0.488	0.821	-0.540	0.816	-0.452	0.810	-0.471	0.838
Size 4	0.401	0.769	0.323	0.764	0.441	0.758	0.377	0.790
Size 5	0.080	0.768	0.081	0.762	0.121	0.756	0.084	0.789
Size 6	0.118	0.763	0.089	0.757	0.166	0.752	0.013	0.784
Log of US patents	0.362***	0.118	0.369***	0.109	0.360***	0.121	0.366***	0.108
3GPP alliances	-0.091**	0.038	-0.066*	0.036	-0.111***	0.038	-0.049	0.041
Consortium memberships	0.135***	0.026						
Weighted memberships			0.268***	0.055				
Related consortium memberships					0.241***	0.057		0.061
Unrelated consortium memberships					0.107***	0.029		0.031
Related consortium connections							0.002*	0.001
Unrelated consortium connections							0.003***	0.001
Year dummies	yes***		yes***		yes***		yes***	
Log likelihood	-386.74		-388.41		-384.62		-390.67	

Notes: 436 observations and 109 groups. Dependent variable: WI committees. Conditional fixed effects negative binomial maximum likelihood estimation. *** implies significance at the 99% level of confidence, ** at the 95% level and * at the 90% level.

third specification in table 5 that includes memberships in institutionally related and unrelated consortia. Our evidence thus supports hypothesis H2b instead of H2a: consortium memberships are more significant than consortium connections. The evidence regarding H2c is mixed, however. In the third specification, the coefficient of related consortium memberships is larger than that of unrelated memberships, but, in the last specification, unrelated connections have a larger coefficient than do related connections. However, the coefficient of related consortium memberships is statistically significantly larger than the coefficient of unrelated memberships, while in the last specification there is no statistically significant difference. Evidence thus weakly supports H2c: institutionally related consortia generate the most impact in terms of 3GPP work item contributions. In contrast, the weighted membership variable in specification 2 that measures the technological relatedness of firms' memberships adds no explanatory power over the sheer number of memberships in specification 1.

Next we examine the second stage of the work item process: change requests to ongoing work items. Results in table 6 compare the random effects and fixed effects models with work item committee contacts, alliance partners, and either consortium connections or memberships as the key independent variables. The fixed effects models are estimated with the same tobit procedure as random effects models, but they include firm-level means of all time-varying independent variables, following the suggestion by Wooldridge (2002: 541). The means of these time-varying variables are not statistically significant as a group, but the means of consortium connections and memberships are individually highly significant, while the time varying portions of these variables are mostly insignificant in the fixed effects models. This suggests that there is a strong correlation between consortium activities and successful change requests, but it is driven by unobserved heterogeneity rather than a causal relationship.

In contrast, work item committee connections are highly significant in both fixed and random effects models. Hence, firms that increase their contacts through work item committees also improve their potential for change requests later on in the process. It thus helps to showcase the firm's expertise to as many standardization peers as possible. Also, the coefficient of alliance partners is now positive and marginally significant. We use lagged alliance variables here, assuming that the effect from external alliances only appears in standard-setting negotiations the following year. While alliances appeared to be a substitute for work item contributions, they nevertheless enhance firms' ability to influence later stages in the specification development process. Regarding the control variables, firm size has a weak positive effect, but only in the random effects models. Firm size alone thus does not make firms more powerful in standard setting. Similarly, intellectual assets play no causal role in change requests. In fact, according to the random effects results, firms that make successful change requests tend to have few patents, but the effect disappears in the fixed effects models. It is conceivable that firms with few patents choose to influence standardization through change requests rather than work item committees, but intellectual property positions as such do not help or hurt firms' change requests.

Additional specifications 5 and 6 in table 6 examine the effects of the number of work item committees as opposed to the connections formed therein and the number of alliances as opposed to the number of partners. Again, we focus on fixed effects results here. The lagged number of alliances has a positive but now statistically insignificant coefficient. Work item committees also turn out to be an insignificant factor in explaining change request success. Our evidence thus points to hypothesis H4a, whereby connections matter more than the number of technical contributions in the work item network. This can be interpreted as evidence for the social and political nature of the standard-setting process.

Table 6 Explaining change request success: Work item committee connections, alliance partners, and consortium activity

Estimation method	(1) Random effects		(2) Fixed effects		(3) Random effects		(4) Fixed effects		(5) Fixed effects		(6) Fixed effects	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Constant	-2.091 ***	0.422	-1.989 ***	0.406	-1.930 ***	0.404	-1.886 ***	0.394	-2.191 ***	0.428	-2.059 ***	0.413
Size 3	0.013	0.231	-0.095	0.232	0.065	0.229	0.028	0.225	-0.161	0.239	-0.113	0.233
Size 4	0.170	0.238	0.074	0.237	0.238	0.237	0.191	0.234	0.050	0.242	0.066	0.238
Size 5	0.456 *	0.262	0.340	0.260	0.500 *	0.261	0.414	0.258	0.294	0.269	0.316	0.260
Size 6	-0.108	0.204	-0.124	0.201	-0.081	0.202	-0.103	0.198	-0.095	0.205	-0.112	0.202
Log of USPTO patents	-0.093 **	0.039	-0.150	0.153	-0.085 **	0.039	-0.112	0.148	-0.125	0.160	-0.159	0.154
Essential IPR dummy	-0.122	0.189	-0.206	0.196	-0.093	0.186	-0.192	0.190	-0.154	0.204	-0.194	0.195
WI connections	0.032 ***	0.007	0.026 **	0.009	0.033 ***	0.007	0.027 ***	0.009			0.026 ***	0.009
WI committees									0.011	0.010		
3GPP alliance partners (t-1)	0.066 *	0.035	0.090 *	0.050	0.077 **	0.034	0.087 *	0.048	0.063	0.050		
3GPP alliances (t-1)											0.140	0.086
Consortium connections	0.001 ***	0.001	-0.001	0.001					-0.001	0.001	-0.001	0.001
Consortium memberships					0.043 *	0.023	-0.083 *	0.050				
R&D services	-0.314	0.349	-0.369	0.347	-0.253	0.347	-0.269	0.340	-0.383	0.363	-0.384	0.349
Component	-0.139	0.285	-0.160	0.280	-0.130	0.284	-0.121	0.278	-0.179	0.291	-0.176	0.281
Computer	-0.932 **	0.389	-1.043 ***	0.395	-0.920 **	0.387	-0.953 **	0.387	-1.089 ***	0.407	-1.045 ***	0.399
Equipment	-0.498	0.322	-0.661 **	0.330	-0.531	0.328	-0.683 **	0.335	-0.634 *	0.344	-0.669 **	0.331
Operator	-0.269	0.275	-0.240	0.270	-0.259	0.274	-0.277	0.271	-0.064	0.267	-0.241	0.271
Software	-0.675 **	0.329	-0.703 **	0.327	-0.625 *	0.323	-0.627 **	0.317	-0.627 *	0.335	-0.707 **	0.328
North America	0.220	0.146	0.258 *	0.150	0.201	0.145	0.212	0.146	0.263 *	0.155	0.252 *	0.151
Asia	0.775 ***	0.189	0.871 ***	0.197	0.782 ***	0.189	0.849 ***	0.194	0.877 ***	0.207	0.913 ***	0.200
Mean variables												
Log of USPTO patents			0.034	0.159			0.009	0.156	0.009	0.168	0.051	0.161
WI connections			0.003	0.013			0.008	0.013			0.002	0.013
WI committees									0.010	0.014		
3GPP alliance partners			-0.070	0.074			-0.026	0.070	-0.050	0.075		
3GPP alliances											-0.159	0.126
Consortium connections			0.003 ***	0.001					0.004 ***	0.001	0.003 ***	0.001
Consortium memberships							0.149 **	0.059				
Year dummies	yes ***		yes ***		yes ***		yes ***		yes ***		yes ***	
Log likelihood	-213.06		-208.46		-211.47		-205.15		-211.96		-205.65	

Notes: 772 observations and 193 groups. Dependent variable: CR success rate. Panel tobit maximum likelihood estimation using Stata/SE 9.2. *** implies significance at the 99% level of confidence, ** at the 95% level and * at the 90% level.

The last set of estimations reported in table 7 uses the number of approved change requests as the dependent variable. The reason for using this alternative dependent variable is that the success rate may incorporate a lot of measurement error for firms with few change requests. Therefore, if the number of approved requests that measures the sheer "volume" of influence in the decisions of 3GPP yields similar results, we can be more confident regarding the statistical relationships that have been identified. However, with the number of approvals as the dependent variable, we would expect the effect of firm size be stronger: the number of approvals strongly correlates with firms' resources available for standard setting.

Table 7 Explaining the number of successful change requests

Estimation method	Random effects		Fixed effects		Random effects		Fixed effects	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Constant	-5.094***	1.199	-5.047***	0.983	-5.053***	1.278	-5.127***	0.983
Size 3	0.271	0.709	2.484**	1.019	0.327	0.740	2.484**	1.028
Size 4	0.645	0.673	1.768**	0.895	0.738	0.707	1.857**	0.903
Size 5	1.530**	0.668	2.707***	0.900	1.523**	0.694	2.750***	0.904
Size 6	0.215	0.606	1.580*	0.832	0.369	0.636	1.691**	0.834
Log of USPTO patents	-0.220*	0.116	-0.151	0.150	-0.223*	0.122	-0.141	0.151
Essential IPR dummy	0.251	0.535			0.397	0.572		
WI connections	0.044***	0.012	0.041***	0.012	0.041***	0.012	0.039***	0.012
Alliance partners (t-1)	0.124**	0.060	0.120*	0.065				
Alliances(t-1)					0.227**	0.105	0.256**	0.107
Consortium connections	0.003**	0.001	0.000	0.002	0.003**	0.001	0.000	0.002
R&D services	-1.319	1.207			-1.660	1.339		
Component	-0.405	0.989			-0.610	1.084		
Computer	-2.120*	1.245			-2.405*	1.380		
Equipment	-0.835	1.094			-1.031	1.221		
Operator	-0.598	0.956			-0.704	1.056		
Software	-2.079*	1.133			-2.246*	1.238		
North America	0.463	0.482			0.524	0.508		
Asia	1.168*	0.622			1.439**	0.676		
Year dummies	Yes***		Yes***		Yes***		Yes***	
Log likelihood	-432.61		-173.57		-432.18		-172.53	
Observations	772		164		772		164	
Groups	193		41		193		41	

Indeed, according to the results in table 7, firm size becomes a more consistently significant factor. However, it has to be emphasized that the fixed effects method drops all firms without successful change requests, which in our case means that only 41 firms and 164 observations remain. Nevertheless, intellectual asset measures remain insignificant. In contrast, alliance variables now become statistically more significant. The coefficient of alliance partners is positive and marginally significant in both random and fixed effects models, while the number of alliances becomes significant at the 95% level in both models. This provides additional weak support for H3a: alliances may be a vehicle for developing capabilities that are relevant in the later stages of formal standard-setting negotiations.

To summarize the empirical results, our empirical 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, and alliances may facilitate making successful change requests to ongoing work item projects. Regarding the competing hypotheses H2a and H2b, the results suggest that consortium memberships are more important than consortium connections for work item contributions. 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. Evidence for H2c regarding the effects of related vs. unrelated consortia weakly 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 a negative relationship with work item contributions, which we interpret to suggest that firms tend to choose either alliances or formal standards development organizations as their standardization strategy, but, in attempting to influence specifications in progress, the number of alliances has a positive and weakly significant effect. We thus have partial support for H3b—knowledge created and obtained in different alliances appears to facilitate influencing formal standards negotiations. Finally, the evidence on the fourth set of hypotheses that studied the effects of committee activities within 3GPP is quite clear: supporting work items where firms can obtain new committee contacts is a more successful strategy than maximizing the quantity of contributions. Committee connections positively and very significantly explain both the success rate and 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 success, but in fixed effects models (apart from the number of approvals which is highly scale-dependent) the effect disappears. Influential firms thus tend to be large but this does not appear to be a causal factor. In contrast, intellectual assets as measured by patents obtained in the US 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 tend to have relatively weak intellectual property portfolios, but these results are driven by correlation with unobserved characteristics—their significance disappears in fixed effects models. We interpret this to mean that intellectual property holders usually 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) tend 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 very 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, and alliances are important for the number of approved change requests—one of the measures of the ability to influence specifications in progress.

In trying to understand why external consortia and alliances 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, 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, we have evidence of the social and political nature of formal standardization: it doesn't matter 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, the numbers of affiliations matter more for standard setting than the numbers of connections. Thus, we argue that the ability to contribute to formal standardization depends on the learning 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 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 of the affiliation network.

For managers, the results obtained underline the importance of a multipronged cooperation strategy. Having access to 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-constraint 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 enable 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 resource bases.

This research utilized a panel dataset of wireless telecommunications firms, which alleviated issues of unobserved heterogeneity. However, 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. It would also be interesting to study other standards development organizations in different fields of technology to gauge how specific our results are to the empirical context.

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 consortia and alliances. In particular, interactions with other 3GPP members through multiple external consortia are important in explaining success in contributing 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 unobserved heterogeneity. Cooperative activities were found to be at least as relevant as intellectual assets in explaining firms' influence on standard setting. Joint research and development, as well as social and political capabilities, appear to be 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

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

Borgatti SP, Everett MG. 1997. Network analysis of 2-mode data. *Social Networks* **19**: 243-269.

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

Davis A, Gardner BB, Gardner MR. 1941. *Deep South*. University of Chicago Press: Chicago.

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

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

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

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

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

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

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

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

Funk JL, Methe DT. 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, Marsden PV. 1978. Interorganizational Resource Networks: Formal Patterns of Overlap. *Social Science Research* **7**: 89-107.

Katz ML, Shapiro C. 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.

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

Newman MEJ, Watts DJ, Strogatz SH. 2002. Random graph models of social networks. *Proceedings of the National Academy of Sciences* **99**(supplement 1): 2566-2572.

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

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

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

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

Schmidt SK, Werle R. 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.

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

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

E L I N K E I N O E L Ä M Ä N   T U T K I M U S L A I T O S   (ETLA)
THE RESEARCH INSTITUTE OF THE FINNISH ECONOMY
LÖNNROTINKATU 4 B, FIN-00120 HELSINKI

Puh./Tel. (09) 609 900
Int. 358-9-609 900
http://www.etla.fi

Telefax (09) 601753
Int. 358-9-601 753

KESKUSTELUAIHEITA - DISCUSSION PAPERS ISSN 0781-6847

Julkaisut ovat saatavissa elektronisessa muodossa internet-osoitteessa:
http://www.etla.fi/finnish/research/publications/searchengine

No 1024 KARI E.O. ALHO, Climate Policies and Economic Growth. 31.05.2006. 23 p.

No 1025 JYRKI ALI-YRKKÖ, Technology Sourcing through Acquisitions – Do High Quality Patents Attract Acquirers? 14.06.2006. 16 p.

No 1026 DEREK C. JONES – PANU KALMI – MIKKO MÄKINEN, The Productivity Effects of Stock Option Schemes: Evidence from Finnish Panel Data. 15.06.2006. 36 p.

No 1027 MIKKO MÄKINEN – PANU KALMI, Henkilöstöjohtaminen, henkilöstönn osallistuminen ja organisaatiomuutokset teollisuusyrityksissä. Aineistokuvaus puhelinkyselyn tuloksista. 16.06.2006. 27 s.

No 1028 OLAVI RANTALA, T&K-panostusten kansantaloudelliset vaikutukset. 22.06.2006. 44 s.

No 1029 ARI HYYTINEN – OLLI-PEKKA RUUSKANEN, What Makes an Entrepreneur Independent? Evidence from Time Use Survey. 22.06.2006. 23 p.

No 1030 MARI MAUNULA, The Perceived Value-added of Venture Capital Investors. Evidence from Finnish Biotechnology Industry. 03.07.2006. 86 p.

No 1031 JYRKI ALI-YRKKÖ – MIKA MALIRANTA, Impact of R&D on Productivity – Firm-level Evidence from Finland. 07.08.2006. 20 p.

No 1032 TERTTU LUUKKONEN – MARI MAUNULA, ‘Coaching’ Small Biotech Companies into Success: The Value-adding Function of VC. 22.08.2006. 33 p.

No 1033 LAURA VALKONEN, Perhevapaiden vaikutukset naisten ura- ja palkkakehitykseen – Kirjallisuuskatsaus. 30.08.2006. 38 s.

No 1034 MIKA WIDGRÉN, Trade Potential, Intra-Industry Trade and Factor Content of Revealed Comparative Advantage in the Baltic Sea Region. 01.09.2006. 26 p.

No 1035 RAIMO LOVIO – JARI JÄÄSKELÄINEN – JUHA LAURILA – KARI LILJA, Globalisaatio Suomen vanhojen teollisuuspaikkakuntien kehityksen muovaajana – Tapaustutkimus Varkauden kaupungista. 06.09.2006. 16 s.

No 1036 HANNU PIEKKOLA, Are Individuals who are Active and Doing Household Work Prone to Retire Earlier: Evidence from Time Use Survey of Older Finns. 08.09.2006. 30 p.

No 1037 MARTTI KULVIK – ISMO LINNOSMAA – RAINE HERMANS, Adoption of New Technologies and Costs of Health Care. 15.09.2006. 40 p.

No 1038 PETRI BÖCKERMAN – MIKA MALIRANTA, The Micro-Level Dynamics of Regional Productivity Growth: The Source of Divergence in Finland Revised. 12.09.2006. 38 p.

No 1039 HANNU HERNESNIEMI – ESA VIITAMO, Pääomasijoitukset ympäristöalalla ja tilastollisen seurannan kehittäminen. 22.09.2006. 42 s.

No 1040 MARKKU KOTILAINEN, Finland's Experiences and Challenges in the Euro Zone. 20.09.2006. 34 p.

No 1041 HANNU PIEKKOLA, Tax Cuts and Employment: Evidence from Finnish Linked Employer-Employee Data. 23.10.2006. 32 p.

No 1042 ELAD HARISON – HELI KOSKI, Innovative Software Business Strategies: Evidence from Finnish Firms. 02.10.2006. 28 p.

No 1043 VILLE KAITILA – REIJO MANKINEN – NUUTTI NIKULA, Yksityisten palvelualojen kansainvälinen tuottavuusvertailu. 13.10.2006. 50 s.

No 1044 SAMI NAPARI, Perhevapaiden palkkavaikutukset: Katsaus kirjallisuuteen. 09.10.2006. 18 s.

No 1045 MIKA PAJARINEN – PETRI ROUVINEN – PEKKA YLÄ-ANTTILA, T&K:n verokannustimien mahdollisia vaikutuksia suomalaisten yrityskyselyjen valossa. 13.10.2006. 29 s.

No 1046 LAURA VALKONEN, Verokannustimet innovaatiopolitiikan välineenä – Katsaus verokannustimien käyttöön OECD-maissa. 13.10.2006. 26 s.

No 1047 ALBERTO DI MININ – CHRISTOPHER PALMBERG, A Case for Non-Globalisation? – The Organisation of R&D in the Wireless Telecommunications Industry. 23.10.2006. 28 p.

No 1048 TUOMO NIKULAINEN – RAINE HERMANS – MARTTI KULVIK, Patent Citations Indicating Present Value of the Biotechnology Business. 25.10.2006. 21 p.

No 1049 TOMI KYYRÄ – MIKA MALIRANTA, The Micro-Level Dynamics of Declining Labour Share: Lessons from the Finnish Great Leap. 02.11.2006. 35 p.

No 1050 KARI E.O. ALHO, Structural Reforms in the EU and The Political Myopia in Economic Policies. 03.11.2006. 30 p.

No 1051 MIKKO KETOKIVI, When Does Co-Location of Manufacturing and R&D Matter? 03.11.2006. 22 p.

No 1052 MIKA PAJARINEN – PETRI ROUVINEN – PEKKA YLÄ-ANTTILA, Uusyrittäjien kasvuhakuisuus. 03.11.2006. 77 s.

No 1053 RAIMO LOVIO, Sijainti seuraa strategiaa: Kokonaiskuva suomalaisten monikansallisten yritysten globaalien karttojen muutoksista 2000 – 2005. 03.11.2006. 30 s.

No 1054 KARI E.O. ALHO – NUUTTI NIKULA, Productivity, Employment and Taxes – Evidence on the Potential Trade-offs and Impacts in the EU. 10.11.2006. 24 p.

No 1055 JUSTIN BYMA – AIJA LEIPONEN, Can't Block, Must Run: Small Firms and Appropriability. 11.11.2006. 30 p.

No 1056 AIJA LEIPONEN, Competing Through Cooperation: Standard Setting in Wireless Telecommunications. 11.11.2006. 30 p.

Elinkeinoelämän Tutkimuslaitoksen julkaisemat "Keskusteluaiheet" ovat raportteja alustavista tutkimustuloksista ja väliraportteja tekeillä olevista tutkimuksista. Tässä sarjassa julkaistuja monisteita on mahdollista ostaa Taloustieto Oy:stä kopiointi- ja toimituskuluja vastaavaan hintaan.

Papers in this series are reports on preliminary research results and on studies in progress. They are sold by Taloustieto Oy for a nominal fee covering copying and postage costs.