Innovating standards through informal consortia: The case of wireless telecommunications

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Abstract

We empirically examine the effects of industry consortia on the coordination of innovation strategies of the members. Our analyses utilize membership data from 32 consortia in variety of wireless telecommunications technology subfields from 2000 to 2005 and cross-citations between patents declared essential by the consortium participants in the context of the third-generation wireless telecommunication system UMTS and the members' earlier patents. Our results shed new light on the role of consortia in enabling the coordination of innovation in a network-technological industry. We find that co-membership of two firms in an informal technical consortium significantly increases the likelihood that they cite each other's patents in subsequent UMTS essential patents. In other words, inventions that are likely to become part of the UMTS telecommunication system tend to build on inventions by peers that were members in the same consortia, controlling for patent or firm fixed effects, technology class, and other characteristics.On one hand, consortia may enhance productivity of innovation and increase the incentives to invest in R&D by internalizing potential innovation externalities. On the other hand, our results are aligned with the interpretation that consortia structure and constrain the process of innovating standardized technologies. This growing role could be viewed as problematic, because the process may not be truly accessible for all the interested parties. Policymakers thus need to balance these two effects. For managers, the results show that participation in a variety of technical consortia enables influencing peers' innovation strategies related to the relevant compatibility standards.

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1. Introduction

This paper examines the effects of firms' participation in wireless telecommunications industry consortia on their subsequent innovations that become declared essential patents in the global UMTS standard for mobile communication. We explore the increasingly central role that these types of technical consortia play in coordinating technology development in many different technology fields and industries. Consortia are particularly closely related to, but not limited to, industries with compatibility standards.

Compatibility standards are common technology norms that ensure interoperability between communication products and services[3]. Information and Communication Technology (ICT) standards in particular embody an increasing number of patented elements. In many ICT fields, particularly in telecommunications, standards have traditionally been defined cooperatively by governments or industry actors within formal Standard Setting Organizations[4] (SSOs). However, these formal SSOs are often perceived to be slow and bureaucratic, particularly when intellectual property rights have become part of the negotiation (Simcoe, forthcoming; Bekkers et al. 2001). For instance, the 3G wireless telecom standard studied here contains around 16 000 essential patents and its development took most of a decade.

To accelerate the process, sub-groups of firms have increasingly begun to create less formal upstream alliances or consortia. These types of collaborative organizations offer opportunities to discuss, test, or promote certain technologies, or they can be used to actually develop new technical specifications that will subsequently be submitted to formal SSOs for official approval. The effects of these consortia have been debated in policy circles (e.g., Cargill, 2001) but there is little empirical research evidence. Leiponen (2008) suggests that ICT firms' participation in such consortia enhances their ability to influence formal standard-setting outcomes. However, there is no evidence to date about the broader implications of informal consortia for coordination of innovation. The purpose of this paper is to address this research gap and conduct an empirical analysis of the effects of ICT consortia on the coordination of R&D strategies of the participants.

[3] E.g., mobile phones, DVD content and players, and internet protocols.
[4] E.g., International Standard Organization, International Telecommunication Union, European Telecommunication Standards Institute.

The question of whether consortia facilitate coordination of subsequent innovations related to communication standards is interesting from both policy and managerial perspectives. From a policy standpoint, our results may inform competition policies. The economic literature on the subject (Katz and Ordover, 1990; Jorde and Teece, 1990; and Choi, 1993) often considers collaborative industry organizations as a potential threat to competition because of excessive market coordination. However, consortia can also be socially desirable if they reduce coordination problems around innovation. In this case, consortia might mitigate wasteful duplication of effort and increase incentives to invest in R&D by internalizing potential externalities (d'Aspremont and Jacquemin, 1988). These arguments could lead competition authorities to adopt a supportive policy with respect to standardization consortia,[5] because they might, overall, increase R&D efforts and productivity.

Our analyses of industry consortia in wireless telecommunications shed new light on the process through which communication standards are being created. Development of "open standards" through a process that is not truly accessible for all the interested parties may be viewed as problematic. To the degree that essential innovations that become incorporated in the formal standard are coordinated and agreed in informal and semi-private consortia, policymakers may find it worthwhile to better understand and provide rules of the game regarding meeting procedures, membership fees particularly for small firms, terms of access, and public release of relevant information. Indeed, if consortia are used to coordinate innovation in advance of formal standard setting, there is a trade-off between speed in the process work and representation of the different stakeholders. Monopolization of technologies underpinning a widely used standard is likely to lead to excessive royalties and potential holdup that can slow down technology adoption and reduce social welfare. This would be equivalent to monopolization of an upstream market in a long and complex value chain.

From a strategic viewpoint, participation in standardization consortia may offer a venue for firms to promote their technologies and become a central and hence powerful player in a technological field (Ballester et al. 2006). For instance, from a sociological perspective, Pfeffer (1981) suggests that consortium participation helps firms to access and control strategic knowledge. Nevertheless, there is little empirical evidence for this assertion. Our

[5] For instance, a balanced approach such as the one adopted on patent pools, cooperative agreements that also presents advantages in terms of innovation diffusion and drawbacks in terms of competition. On patent pools, competition authorities recognize their positive effects provided they meet certain strict rules of operation (for instance on the nature of patents included).

research aims to highlight strategies that firms may deploy to influence innovation by others – particularly that related to compatibility standards.

This paper utilizes a network-analytical approach and combines membership data from 32 ICT consortia to identify consortium network ties between firms involved in formal standardization through Third Generation Partnership Project, or 3GPP. 3GPP is the international standard-setting organization driving the specification development for the Universal Mobile Telecommunication System, UMTS, which is one of the third-generation mobile communication systems. Additionally, we compile and analyze citations of 16 000 essential patents filed by member firms in the 3GPP standardization process for UMTS. These data will be used to assess econometrically the effects of firms' participation in consortia on cross-citations of subsequent inventions. To properly empirically identify the causal relationship, we use a merger in the network of consortia as a natural experiment that exogenously changed consortium connections of dozens of member firms.

Our empirical analysis demonstrates that the patent holder's involvement in consortia has an impact on the likelihood that their patents are cited by other consortium members in subsequent patents that are declared essential for the UMTS standard. This result is particularly strong for consortia that are formally allied with and thus directly related to 3GPP. The result is weaker but still positive and statistically significant for consortia that are not allied with 3GPP. However, this relationship is significant only for informal consortia and does not hold for more formal organizations such as other formal standard-setting organizations (e.g., regional SSOs). Finally, a change in the network caused by a merger of several consortia had a significant impact on the strength of this coordination effect. Thus, our main results are supported by a difference-in-differences analysis utilizing this source of exogenous variation.

Our results highlight technical industry consortia as an organization form that enables sharing of knowledge and coordination of R&D efforts related to compatibility standards. The remainder of this paper is organized as follows. Section 2 presents a literature review of R&D consortia and discusses the conceptual foundations of our research. Section 3 explains the data collection process and the empirical methodology. Section 4 presents our main empirical results and section 5 concludes.

2. Literature on research and development consortia and the empirical contribution

Research and development consortia have been studied extensively in various strands of literature. The advantages and drawbacks of these organizations as well as their formation process and possible impact on future alliances are now relatively well understood. Here, we will review the benefits and costs of participation as discussed in earlier studies, and finish by discussing the distinct features and implications of consortia focused on standardization rather than just R&D.

Scholars have found substantial positive effects of consortium participation on innovation by firms. For instance, an early stream of research analyzes R&D consortia from a theoretical standpoint and underlines financial incentives to participate therein. Katz (1986), Katz and Ordover (1990), and d'Aspremont and Jacquemin (1988) view consortia primarily as a means to share and reduce R&D expenses. Consortia may facilitate realization of scale economies among participants and avoidance of effort duplication. This stream of literature assumes symmetric contributions of consortium members in terms of R&D investments and competencies, and firms are assumed to sell substitutable products.

Complementary to this idea, another strand of literature discusses incentives to participate when firms have asymmetric contributions (e.g., Kamien, Muller and Zang, 1992). Here, the main idea is that R&D investments create knowledge spillovers. Spillovers are positive externalities that enhance the social benefits of R&D investments but they lead to socially suboptimal investments because private incentives do not take spillovers into account. Consortia may be a way to internalize these spillover effects. This potentially positive effect of consortia has led some scholars to support public funding of these organizations (Romer and Griliches, 1993).

The notion of consortia as a way to internalize R&D externalities is in line with the resource-based view of the firm in strategic management. For instance Chung, Singh and Lee (1999) analyze investment banking firms' syndication in underwriting corporate stock offerings during the 1980s and point out that that the likelihood of investment banks' alliance formation is positively related to the complementarity of their capabilities. Firms' participation in consortia or other forms of cooperation is then viewed as a method to share skills and benefit

from other members' competencies. This argument implies that the diversity of members enhances consortium efficiency, because it increases the potential for spillovers and ultimately has a positive effect on the level of R&D expenditures in the field.

Two empirical papers confirm that R&D consortia lead to increased R&D investments and productivity. First, Branstetter and Sakakibara (1998) analyze a sample of Japanese consortia and find that the marginal effect of consortium participation is about two percent increase in total R&D spending and between four and eight percent increase in patenting per R&D dollar (research productivity). In a subsequent paper, Sakakibara (2001) confirms an even more substantial effect of consortium participation on R&D expenses (around 9%) and also tests the hypothesis that diverse competencies of members enhance the efficiency of the consortium. Her paper examines a sample of publicly sponsored Japanese consortia involving 213 firms over 13 years and confirms that consortium diversity is associated with greater R&D expenditures by participants.

An organization-theoretic literature suggests that participation in R&D consortia facilitates obtaining a strategic advantage over competitors. In this view, consortia are not necessarily formed to share costs or reduce potential market failure but to create competitive advantages over other competitors. Pfeffer (1981) proposes that consortium participation helps firms to access and control strategic knowledge. Aldrich et al. (1998) also argue that R&D consortia could help to orient research in the industry in a way that supports the firm's strategy. This hypothesis is supported empirically by Leiponen (2008) who examines consortia around the Third Generation Partnership Project (3GPP), a formal standards-development organization. This study finds that participation in technical consortia significantly enhances firms' contributions to new standard specifications in 3GPP committees. Firms that are central in the consortium network are better able to ultimately influence the standard-setting outcome. From a social point of view, this result suggests that industry consortia may also have adverse effects and are potentially a way to foreclose competition. This potential negative effect of consortia on competition (implicit collusion) has also been discussed in a series of earlier papers (e.g. Brodley (1990), Katz and Ordover (1990), Jorde and Teece (1990) and Choi (1993).

Finally, a set of studies identifies consortia as a channel for signaling strategies within the industry. In a longitudinal study of 87 cellular service providers and equipment

manufacturers, Rosenkopf, Metiu and Georges (2001) show that participation in technical committees helps to identify potential alliance partners and opportunities for collaboration. The authors also find that the marginal effect of consortium participation on alliance formation is decreasing with the number of alliances already formed and varies according to interpersonal bonds. This importance of interpersonal bonds is also underlined by Dokko and Rosenkopf (2010), who examine how job mobility of individuals affects firms' abilities to influence others in a technical standard-setting committee for U.S. wireless telecommunications. The authors suggest that recruitment of employees with abundant social capital from consortium committees increases a firm's power to influence standard setting through such committees.

As described above, cooperative research arrangements can be very beneficial, but consortium participation may also be associated with risks and costs. First, firms have to support expenses such as membership fees, and travel, meeting, and human resource costs . Sakakibara's (2001) empirical analysis of Japanese consortia and Hawkins' study of ICT consortia (1999) present empirical evidence that consortium participation engenders substantial costs. Hawkins' estimate of membership fees for a typical technology firm in mid-1990s was in the order of 1.5 million US dollars. This number does not include the travel and human resource costs of participation. Moreover, in the years since this study, membership fees and the number of consortia have considerably increased.

Consortia can also present risks of technology leakage. Sharing R&D knowledge in technical meetings with other participants that have sufficient skills to understand and absorb these competencies strongly increases the risks of imitation. Indeed, Kodama (1986) suggests that firms participating in consortia may create internal research groups just to absorb knowledge from consortium work.

Consortium participation may also reduce the set of potential appropriation strategies available to firms. For consortium members, secrecy is no longer an effective protection method and therefore member firms may need to follow alternative appropriation strategies and define which competencies can be shared and which ones protected according to the firm's overall strategy. This idea is supported by empirical studies that analyze the means of protecting innovation in a cooperation context. For instance, Leiponen and Byma (2009) stress that small firms cooperating in innovation with horizontal partners (direct competitors)

tend to prefer speed to market over secrecy or patents to protect their innovations. However, in the wireless telecommunication context studied in this paper, patenting may be a prerequisite for innovative firms, independent of their size.

To conclude, extant literature on R&D consortia has identified many potential strategic benefits and drawbacks of participation, and their implications for competition policies. However, most of the work on consortia has examined general-purpose R&D consortia, whereas here the focus is on standardization-related consortia. These types of collaborative structures are increasingly common. We found dozens within wireless communications alone; computing is another field where pre-standardization is often organized through informal consortia. The well-known battle for high-definition DVD format dominance also featured competing consortia. However, the structures and functions of pre-standardization consortia are not well understood.

In particular, we do not know what kind of information exchange takes place in standards-related consortia. Whereas some technical consortia may primarily attempt to leverage and coordinate efforts in promoting a specific set of novel technologies with respect to the rest of the industry and the world, other consortia might be involved in more strategic knowledge sharing and alignment. It would be important for policymakers to understand when the latter is happening, because such activities may have long-term implications for an industry. Whereas regular R&D consortia also develop technologies for the participant firms to incorporate in new products or processes, pre-standardization consortia may develop technologies and make decisions that not only the participants but also the rest of the industry will have to abide by if they build products for the same compatibility standard. Early-stage standardization consortia may thus provide a somewhat opaque route to domination of a standard for a small subset of firms in the industry.

The focus of our empirical work is on the hypothesis that pre-standardization consortia facilitate coordination of subsequent R&D that results in essential innovations related to a compatibility standard. If this is true, then these types of consortia provide a structure for identifying which early-stage investments enable controlling the standard later on. Aldrich et al. (1998) and Hawkins (1999) have previously discussed closely related ideas. Hawkins notes that, in telecommunications, “an international system has evolved in which communication and co-ordination is achieved primarily through inter-organisational alliances[…]”. However,

systematic empirical evidence regarding firms' strategies and their implications remains scarce. Our paper targets this research gap by examining the role played by consortia as a vehicle for knowledge transfer and coordination of innovation in the context of standardization. Specifically, we are interested in the degree to which communication in early-stage technical consortia drives innovation that becomes incorporated in formal standard specifications in a later stage.

3. Data and Methods

Our main empirical test is whether consortium participation by a firm increases the likelihood that its patent is cited by another member of the same consortia in their patents that are declared as essential for the wireless telecommunication system UMTS. We thus analyze whether the likelihood that a patent is cited depends on the position and centrality of the patent holder in the network of consortia during the year in which the citing patent was applied, and particularly, whether the holders of the cited and citing patent were co-members of at least one consortium. We focus on citations by UMTS essential patents because we are interested in the ability of consortium participants to influence the set of technologies that become incorporated in the standard, but we will also test the effects on a broader set of patents by the same firms.

This paper relies on a combination of data on consortium co-membership links between firms involved in the third-generation mobile standards and cross-citations of patents filed by these participants. First of all, we gathered data on 16 000 patents declared essential for the UMTS standard[6]. We retrieved these data in October 2010 using the ETSI online patent database[7]. We then merged these data with information on citations using the 1976/2006 National Bureau of Economic Research database[8] and used the EPIP database to identify the patent holders of the cited patents[9]. Appendices 1 and 2 present some information about the timing of application and technological class of patents in our sample. As we can see, the citing patents are very concentrated in terms of technological class, whereas the cited patents are

[6] The projects included are : 3GPP, 3GPP release 7, 3GPP/AMR-WB+, UMTS, UMTS Release 5, UMTS Release 6, UMTS Release 7, UMTS Release 8, UMTS/CDMA
[7] Available at: http://ipr.etsi.org/
[8] Available at: http://www.nber.org/patents/
[9] Available at: http://www.epip.eu/datacentre.php

quite diverse. The cited patents were granted between 1976 and 2004 but the majority of them were granted in the late 1990s or early 2000s.

Next, we created a database on consortium membership links between firms involved in third-generation mobile standards. This database is partly based on Leiponen (2008). Using the website Internet Archive, we obtained data on the memberships of the patent holders (owners of the citing and the cited patents) in consortia in the ICT field from 2000 to 2005. Some of these consortia are formally allied with 3GPP and others are unrelated or even directly competing with 3GPP. A list of these consortia is presented in Appendix 3.

As we have information on participation in consortia from 2000 to 2005, we will restrict our analysis of citing patents applied in this period. We organize our database around the cited patents over six years. This database consists of 1021 patents that were cited at least once by a UMTS essential patent. These patents were held by 44 different firms[10]. The database connects the cited patents with 1962 citing patents.

Our main dependent variable is a binary indicator for whether a patent was cited by a patent application that was subsequently declared as "essential" for the UMTS wireless telecommunication system developed in 3GPP. We focus on citing patents held by members of 3GPP. We use three different explanatory variables to capture firms' participation in informal pre-standardization consortia. The first two measure the patent holder's general level of participation in consortia of the ICT field: the number of consortium memberships, (*total memberships*) and the number of unique connections to peers from consortia (*consortium connections*). A consortium connection is formed if two firms meet at least in one of the consortia during the year. In network-analytical terms these are two-mode and one-mode degree centrality measures, respectively. The last variable (*co-membership*) captures the direct connection between two firms, i.e., between the holders of citing and cited patents during the year in which the citing patent was applied.

We include a control variable to proxy for firms' standardization strategies with data on patent holders' participation in the relevant formal standards-development organization (3GPP). We trace patent holders' activities in formal standards-development committees[11] and create a variable *3GPP connections* that equals the number of unique connections (one-

[10] A list of the patent holders of the cited patents is presented in appendix 4.
[11] Using the website http://www.3gpp.org/

mode degree centrality) to other firms through work-item committees. This variable allows us to take into account the centrality of the firm in formal standard setting and thus to distinguish the effects of informal and formal standardization strategies on cross-citations. We also include patent age dummies to control for the evolution of citation patterns over time.

Table 1 describes the main estimation variables.

Table 1: Name and description of the main explanatory variables

Variable	Description	Mean	Std. dev.	Min	Max
Total membership$_{it}$	Number of cited firm's annual memberships (two-mode network degree) in consortia	8.27	6.96	0	24
Consortium connections$_{it}$	Number of cited firm's annual unique connections (one-mode network degree) through consortia	128.15	103.79	0	280
Co-membership$_{it}$	Dummy variable that equals 1 if the holder of the citing and the cited patent were in the same consortium during the year in which the citing patent was applied.	0.18	0.39	0	1
3GPP connections$_{it}$	Number of unique (one-mode degree) connections to other firms through 3GPP work-item (formal standardization) committees	16.05	18.50	0	63
Patent age dummies	Set of dummies for the age of the cited patent				

We thus work with a panel database of patents cited by (at least one) UMTS essential patents and estimate a fixed-effect conditional logit model with the likelihood to be cited at year y for a patent p as the dependent variable. We do not use a count data model but estimate the likelihood to be cited for a patent at year *t*. Table 2 presents the numbers of years in which our patents are cited over the six years of observation. The majority of the cited patents are not cited by UMTS essential patents during the years we analyze, but during the years before or after our period of study. We also have a small number of patents that are cited every year from 2000 to 2005. These observations will be excluded in a fixed-effect logit model, reducing our estimation sample.

Table 2: Number of years the patent is cited (2000-2005)

Number of years the patent is cited	Observations
0	657
1	78
2	102
3	76
4	48
5	49
6	13

Our main explanatory variables measure consortium participation, and we control for the patent holder's centrality in 3GPP and the patent's age. Other (permanent) patent characteristics are accounted for in the patent fixed effects. We thus estimate the following model:

$$\Pr(Citation_{pit}) = \alpha_0 + \alpha_1 Consortium_participation_{it} + \alpha_2 3GPP_connections_{it} + \alpha_3 Patent_age_{pt} + \varepsilon_{pt}$$

[1]

$\Pr(Citation_{pit})$ = Probability of patent p held by firm i being cited by another 3GPP participant's patent application in year t

Consortium participation$_{it}$ = Participation in consortia of firm *i*, using the variables *total membership*, *consortium connections*, and *co-membership* in year *t*

3GPP connections$_{it}$ = Firm *i*'s one-mode centrality in formal standardization in 3GPP committees in year t

Patent age$_{pt}$ = Set of dummies for the cited patent age

ε_{pt} = Error term

The main empirical issue is to disentangle the effects of participation in consortia and technological strategies of firms. A patent can be highly cited because of the patent holders' participation in consortia or because the patent is technologically central in the UMTS wireless system being standardized within 3GPP, for which reason its holder may participate in many consortia. In order to control for these confounding factors, we deploy a number of

empirical tactics: we include a control variable for firms' formal standardization strategies; we utilize panel-data methods to remove time-invariant unobserved heterogeneity; and we utilize an exogenous natural experiment to reduce potential time-variant unobserved heterogeneity. However, the last approach only works for our main result regarding whether industry consortia influence subsequent standards-related innovation, but for identification of the additional results on the types of consortia, we need to rely on the two former approaches.

Our initial estimation approach utilizes standard panel-data methods (fixed effects estimation).. We then explore whether a natural experiment occurring in the data allows us to isolate sufficient exogenous variation in the main explanatory variables to control for possible time-varying unobserved effects and estimate a differences-in-differences type model. Our concern is that innovations emerging during the period of study might make firms more likely to both attend certain consortia and cite their central members. This event is the merger of a set of industry consortia of mobile services that, we argue, exogenously shifted the consortium contacts of some but not all firms in our dataset. In late 2002, seven of the consortia in our database[12] merged to create the Open Mobile Alliance (OMA). OMA was formed by nearly 200 companies including mobile operators, device and network suppliers, information technology companies and content and service providers. Therefore we argue that individual firms were unlikely to have substantial influence in the merger. The stated reasons for the merger were increasing interactions and synergies between the technology fields of the seven component consortia: "The purpose of OMA is to address areas that previously fell outside the scope of any existing organizations, as well as streamline work that may have been previously duplicated by multiple organizations."[13] As a result of the merger, consortium connections of some firms increased and those of other firms decreased. We use this merger to estimate a diff-in-diff model and examine the robustness of our fixed-effects results.

[12] Wap Forum, Wireless Village, SyncML Initiative, MGIF, LIF, MWIF, and UMTS Forum.
[13] http://www.openmobilealliance.org/AboutOMA/FAQ.aspx, retrieved 8/2/2002.

4. Estimation results

We first run a fixed-effect model estimating the likelihood of a patent to be cited by a patent that was declared as essential for the UMTS standard, held by another consortium participant. We control for the age of the cited patent. The results of this model are presented in Table 3.

Table 3: The effect of consortium participation on the likelihood of citation

	(1)		(2)		(3)	
	Coef. (SE)	Marginal effect	Coef. (SE)	Marginal effect	Coef. (SE)	Marginal effect
Total memberships	0.1045***	0.0108**				
	(0.016)	(0.005)				
Consortium connections			0.0049***	0.0005*		
			(0.001)	(0.0002)		
Co-membership					3.2022***	0.3403***
					(0.149)	(0.056)
3GPP connections	0.0109	0.0006	0.0187***	0.0013*	-0.0014	-0.00008
	(0.006)	(0.001)	(0.005)	(0.0007)	(0.005)	(0.0003)
Patent age dummies	Y		Y		Y	
Observations	2154		2154		2154	
Groups	352		352		352	
Chi^2	366.64		366.75		564.11	
Prob > chi^2	0		0		0	
Log Likelihood	-596.31		-587.824		-391.11	
Cited firms	33		33		33	

Notes: Dependent variable is an indicator for whether a patent was cited by an essential patent applied in year t. Estimation method is conditional logit with fixed effects at the patent level. Unit of analysis is the cited patent. Standard errors, clustered on patents, in parentheses under the coefficients. * p<.05; ** p<.01; *** p<.001

According to the basic fixed-effects results at the level of the cited patent as shown in table 3, the three main explanatory variables, the cited patent holder's *total number of memberships* in wireless industry consortia, their *unique connections* to peers in those consortia, and *co-memberships* in consortia with firms citing their patents, all have statistically highly significant and positive effects on the likelihood of a patent to be cited by another consortium participant. Marginal effects suggest that the total number of memberships has a stronger and statistically more significant impact than the number of cited firm's annual unique connections (one-mode network degree) through consortia. One additional consortium membership increases the likelihood of citation by 1%, whereas an additional connection increases it by 0.05%. However, one additional membership may generate dozens of new connections. Meanwhile, *co-membership* has the strongest positive marginal effect on the likelihood to be cited by other 3GPP members in subsequent innovations. If two firms are

both members of the same consortium, the likelihood of citation goes up by 34%. We also find that the patent age dummies (included in all specifications but not reported in the table) do not have a significant impact on the likelihood to be cited.

Next, we use a natural experiment, a merger of seven consortia in 2002 to examine the robustness of our results. When Mobile Games Interoperability Forum (MGIF), UMTS Forum, WAP Forum, Wireless Village, SyncML Initiative, Location Interoperability Forum (LIF) and Mobile Wireless Internet Forum (MWIF) merged to form Open Mobile Alliance, the *consortium connections* of the members of the seven consortia were exogenously shifted[14]. Using this exogenous event to identify the causal effect of firms' consortium connections on patent citations, we dissect the participation effect according to the timing, the consortia affected by the merger, and their nature. The results are presented in table 4.

The variable *OMA connections* (number of unique connections through OMA or its constituent consortia) has a positive and statistically significant effect on citations. OMA and the component consortia were thus probably central venues for discussing ongoing innovation. In fact, the effect of connections from other consortia (*other connections*) is statistically insignificant. The most relevant coefficient in table 4 is that on the variable *OMA connections after* that measures the additional effect of OMA-related connections after the merger. This effect is statistically borderline significant at the 5% level in the first two specifications, but becomes more strongly significant when the connections from other consortia are separately estimated for formal and informal consortia in specification 3.

In specification 4 we utilize the co-membership variable that indicates whether a cited and citing firm were in the same consortium, and split this variable into dummies for co-memberships in other consortia and co-memberships in OMA constituent consortia before the merger (*old OMA co-membership*) and after the merger (*new OMA co-membership*). The coefficient on new OMA co-memberships is statistically very strong, but the marginal effect indicates that merger-induced co-membership in OMA increased the probability of cross-citation only by 0.2%. Nevertheless, these results reinforce the earlier sets of results.

[14] A list of the firms included in the control group, non-participant in one of the consortia concerned by the merger, is available in appendix 5

Table 4: Impact of the OMA merger on subsequent citations

	(1)		(2)		(3)		(4)	
	Coef. (SE)	Marginal Effect	Coef. (SE)	Marginal effect	Coef. (SE)	Marginal effect	Coef. (SE)	Marginal effect
OMA connections	0.0163***	0.0026	0.0167***	0.0023	0.0190***	0.0036**		
	(0.005)	(0.002)	(0.005)	(0.002)	(0.005)	(0.002)		
Other consortia connections	-0.0005	0.0001	-0.0008	0.00003				
	(0.001)	(0.001)	(0.001)	(0.0001)				
Formal consortia connections					-0.0011	-0.0002		
					(0.001)	(0.001)		
Informal consortia connections					0.0026	0.0005		
					(0.003)	(0.001)		
OMA connections after	0.0078*	0.0013	0.0082	0.0012	0.0104*	0.0020**		
	(0.004)	(0.002)	(0.005)	(0.002)	(0.005)	(0.0009)		
New OMA co-membership							0.0112**	0.0025**
							(0.004)	(0.001)
Old OMA co-membership							0.0043	0.0009
							(0.004)	(0.0001)
Co-membership							5.0506***	0.7909***
							(0.687)	(0.235)
Dummy after	-2.9259***	-0.4562	-3.088***	-0.4232	-3.1792***	-0.6076***	-1.9371***	-0.4323***
	(0.347)	(0.308)	(0.353)	(0.315)	(0.363)	(0.137)	(0.490)	(0.159)
3GPP connections			-0.0138	-0.0018	-0.0107	-0.0021	0.0037	0.0008
			(0.008)	(0.002)	(0.008)	(0.002)	(0.012)	(0.003)
Dummy Cited Age	Y		Y		Y		Y	
Observations	1731		1731		1731		2154	
Groups	338		338		338		352	
Chi 2	357.51		401.51		288.18		192.59	
Prob > chi2	0.0000		0.0000		0.0000		0.0000	
Log Likelihood	-376.65		-375.24		-386.76		-182.62	
Cited firms	33		33		33		33	

Notes: Dependent variable is an indicator for whether a patent was cited by an essential patent applied in year t. Estimation method is conditional logit with fixed effects at the patent level. Standard errors, clustered on patents, are in parentheses under the coefficients. * p<.05; ** p<.01; *** p<.001.

The separation of "other consortia" into formal and informal ones in specification 3 of table 4 is intended to highlight what types of consortia are useful for knowledge sharing and coordination related to standardization. In the diff-in-diff estimation the results are not very significant, as most of the connection effect is driven by OMA itself, which is an informal consortium.

In table 5 we return to the fixed-effect approach to further distinguish the effects of different types of consortia, which we cannot examine with the diff-in-diff method. We distinguish between formal and informal consortia and between consortia that are related and unrelated to 3GPP. Formal consortia draft and certify standard specifications whereas informal ones typically discuss and test technological alternatives. We expect informal consortia to be more conducive to influencing peers, because their fundamental purpose is usually to discuss and promote a set of technologies, hence these discussions can be more easily used to promote the members' technologies that might be utilized or built on in the standard-setting context of 3GPP. Consortia can also be formally allied (related) with 3GPP or unrelated with 3GPP. We expect consortia that are allied with 3GPP to provide more fruitful venues for influencing peers' innovation activities related to technologies that 3GPP standardizes.

We also examine the interaction effect of the technological resources of the patent holder using an interaction variable, *consortium connections*patent apps,* that is, *consortium connections* multiplied the number of patents applied by the cited firm during the year. This variable allows us to assess the potential moderating impact of the (technological) size of the patent holder on the consortium participation effect. We expect that larger technology firms are more effective at translating consortium connections into opportunities to influence others' innovation activities.

Table 5: Effects of different types of consortia and the moderating effect of technological resources

	(1)		(2)		(3)	
	Coef. (SE)	Marginal Effect	Coef. (SE)	Marginal effect	Coef. (SE)	Marginal effect
Informal consortium memberships	0.1102*** (0.023)	0.0114* (0.006)				
Formal consortium memberships	0.0806 (0.041)	0.0061 (0.005)				
Related consortium memberships			0.2372*** (0.042)	0.0216* (0.012)		
Unrelated consortium memberships			0.0376 (0.023)	0.0068* (0.004)		
Consortium connections					0.0019*** (0.0003)	0.0002* (0.0001)
Cons. connections* patent apps					-4.813e-07 (3.05e-07)	-5.59e-08 (0.000)
Patent apps					-0.0004 (0.002)	-0.00001 (0.000)
3GPP connections	0.0109 (0.007)	0.0006 (0.005)	0.0094 (0.006)	0.0005 (0.006)	0.0212*** (0.005)	0.0015* (0.0009)
Patent age dummies	Y		Y		Y	
Observations	2154		2154		2154	
Groups	352		352		352	
LR chi^2	391.05		433.97		349.68	
Prob > chi^2	0		0		0	
Log Likelihood	-599.922		-591.919		-593.992	
Cited firms	33		33		33	

Notes: Dependent variable is an indicator for whether a patent was cited by an essential patent applied in year t. Estimation method is conditional logit with fixed effects at the patent level. Unit of analysis is cited patent. Standard errors, clustered on patents, are in parentheses under the coefficients. * p<.05; ** p<.01; *** p<.001.

Regarding the types of consortia, the results confirm expectations. When OMA consortia are included in the informal group of consortia, memberships in these organizations are driving the effect. The coefficient of memberships in formal standardization organizations is insignificant. The strategic and technological scope of the consortium also has an impact on the intensity of the effect. The consortium participation effect is much stronger for consortia that are related to 3GPP, and the difference is statistically significant at 0.01%. However, even though the coefficient is substantially lower, participation in unrelated consortia also has a positive and statistically significant marginal effect on the likelihood of having a patent cited by peers in subsequent innovation.

The firm's technological innovativeness (patent applications) do not seem to have any significant moderating effect on the consortium participation effect on the likelihood to be cited in subsequent research by peers. Thus, our hypothesis that larger technology firms are more effective at translating consortium connections into opportunities to influence others' innovation activities is not supported. To further explore implications of firm heterogeneity, in appendix 6, we explore the impact of a set of leading patent holders in 3GPP. The companies analyzed include Ericsson, Qualcomm, Panasonic and InterDigital. In these regressions, *co-membership_firm* is a variable that captures the participation in the same consortium during the same year with the firm analyzed. The idea behind this model is that the capacity and willingness of firms to influence others may vary significantly.

Indeed, the results are different depending on the patent holder's identity. For example, co-membership with Qualcomm is very unlikely to lead to cross-citations. Similarly, although patents held by Panasonic and InterDigital are generally more likely to be cited in essential patents, this does not seem to be driven by consortium co-memberships, whereas Ericsson's received citations strongly correlated its consortium activities. These results can be compared with the observable strategies of these firms, where Ericsson is an equipment vendor that manufactures whole telecommunication networks and systems, whereas Qualcomm and InterDigital are only providing intellectual property for such communication systems. Panasonic is primarily a handset manufacturer. This appendix suggests that deepening the analyses by type and nature of firms (and not only nature of consortia and firms' technological assets) could be an interesting research path.

In other robustness analyses, we implemented a firm-pair level panel, following the methodology of Agrawal and Goldfarb (2009). The results, presented in appendix 7, confirm the main insights from fixed-effects analyses in tables 3 and 5. We also tested whether the consortium coordination effect matters for 3GPP members' patents that are not declared as essential for the UMTS standard. We found no significant effect on non-essential patents, even though we focused on patents in the same wireless technology classes. Thus, our results concern pre-standardization consortia are an effective way to coordinate R&D around the relevant compatibility standard but not more generally to influence innovation in the same technological classes.

As fixed-effects estimation considerably reduces the number of observations, we also estimated with a random-effects specification taking into account the overall sample and using mean variables to control for permanent characteristics (Wooldridge, 2002, pp. 487-488, 679). This Chamberlain-style procedure includes the means of the time-varying explanatory variables as additional regressors in the random-effects procedure, assuming that the permanent characteristics are normally distributed conditional on the explanatory variables. According to Wooldridge (2002), this method is less robust but more efficient than the conditional fixed-effects approach. The results are presented in appendix 8 and confirm the findings of the fixed-effects estimation. We also checked the robustness of our results using a linear probability model. These results are presented in appendix 9 and confirm the findings presented in the body of the paper, with one exception: according to the linear probability model, formal consortia are more important for subsequent innovation than are informal consortia. The sources of this discrepancy will need to be further analyzed.

Finally, we checked whether our results are driven by patents that are cited only once over the study period by other 3G participants. Excluding these patents in a robustness tests did not change our results.

The main limitation of our study is the well-known issue related to inference drawn from patent cross-citations (Alcacer and Gittelman, 2006 ; Thompson and Fox Kean, 2004). In particular, it is not clear whether the consortium effect actually demonstrates knowledge flows and coordination of innovation, or whether participation in consortia simply makes firms aware of each other's patents and, by courtesy, include citations to peers' earlier patents.

To conclude, our main hypothesis that participation in technical consortia facilitates coordination of firms' innovation policies is supported. This result is robust to the choice of method, level of analysis, and variable used to capture the participation effect. However, the magnitude of the effect depends on the nature of the consortium. In the logit estimations, the coordination effect is insignificant for formal consortia and positive and statistically significant for informal consortia, but this result is not robust to estimation method, as in the linear probability models the effect is stronger for formal consortia and weaker for informal ones. Additionally, the coordination effect is greater when consortia are technologically and strategically related to 3GPP, although it remains significant also when consortia are unrelated to 3GPP. This result is robust to the method of estimation. Finally, we exploited a merger in the set of consortia to statistically identify the main coordination effect. Exogenous changes in

consortium connections caused by the merger positively and statistically significantly influenced subsequent citations by peers.

5. Conclusion

This paper analyzes the impact of firms' participation in ICT consortia on knowledge sharing and coordination of innovation strategies related to compatibility standards. We use data on participation in 32 ICT consortia and prior art citations in essential patents filed by participants in the 3GPP standardization process. To empirically identify the effect of consortium connections, we exploit a merger in the network of consortia as a quasi-experiment that exogenously changed consortium connections of members.

Our empirical analysis highlights the impact of the patent holder's position in the consortium network on the likelihood of having its patents cited by other participants in subsequent research. The more central the firm is in the consortium network, the greater the likelihood of its patents being cited by other firms in subsequent patents that are declared essential for the UMTS standard. This result is stronger for consortia that are formally allied with (related to) 3GPP, whereas the result is weaker but still positive and statistically significant for consortia unrelated to 3GPP. Our findings also suggest that informal consortia are a more effective vehicle for coordinating standards-related innovation. Whereas participation in informal consortia has a positive and statistically significant impact on the likelihood to be cited by subsequent research, the same does not hold for more formal consortia such as other standard-setting organizations, although this result is not completely robust to different estimation methods.

The main result that consortium participation facilitates coordination of firms' innovation activities is confirmed by a difference-in-difference analysis using a merger in the network of consortia as a source of exogenous variation. It lends support for an earlier literature on the effects of R&D cooperation on managing knowledge transfer between rivals. Thus, consortia potentially improve incentives for R&D because they enable the internalization of knowledge-creation externalities. However, in the standard-setting context our findings also raise questions. Our results demonstrate that standardization takes place not only in the marketplace and in formal standard-setting organizations, but also in informal upstream consortia.

First, transparency and openness of informal consortia may be an issue for less prominent innovators. It can be difficult for an entrant to understand who makes decisions about standardization, where, and through what process. During and preceding the period of study, many consortia were formed by a small group of industry leaders, and the consortia tended to have a pre-set agenda and a two-tiered membership structure where the founding firms had a more powerful position than latecomers.

Second, when standard setting is effectively distributed to dozens of consortia, each with substantial membership fees and frequent meeting schedules, participation can become prohibitively costly for smaller firms. Small firms are likely to have few (if any) technical experts who are able to travel to consortium meetings, and with dozens of potentially relevant consortia, this may simply not be possible.

Finally, major firms have justified consortia as a method of speeding up standards development. Whereas this is a laudable goal for any industry, the actual cause of accelerated outcomes from consortia may be exactly that smaller firms and those who disagree with industry leaders are not participating. Further research would need to be conducted to properly understand the welfare implications of the effect of upstream consortia in potentially narrowing down the pool of innovations that are subsequently incorporated in the compatibility standard.

We suggest that these novel results on the organization of compatibility standardization call for a rethinking of standard-setting policies. Innovation and competition policymakers might include informal upstream consortia in their frameworks for standardization policy, because this is where a significant part of coordination is done. By the same token, our results show that innovating firms who want to commercialize new products or technologies in network industries must design a standard-setting strategy that involves participation not only in formal standard-setting organizations but also in informal consortia to optimize opportunities to influence and align strategies with peers.

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Appendix 1: Description cited patents

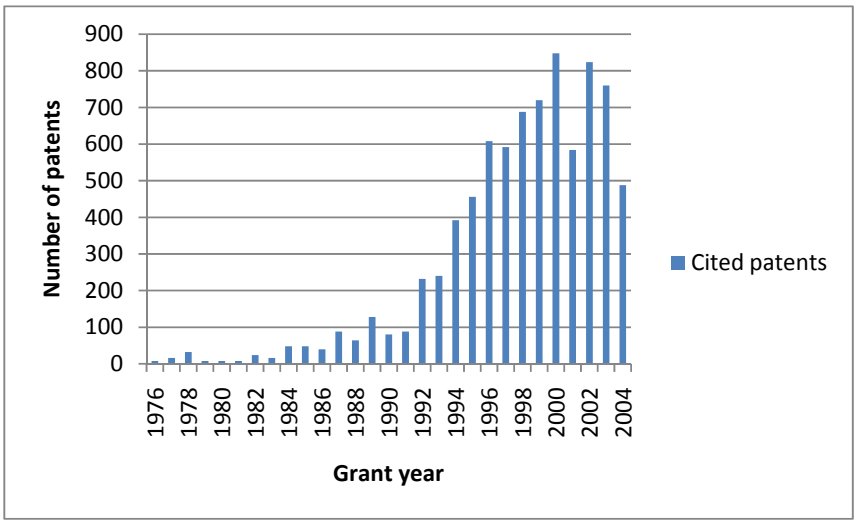


Figure 1: Grant year of the cited patents

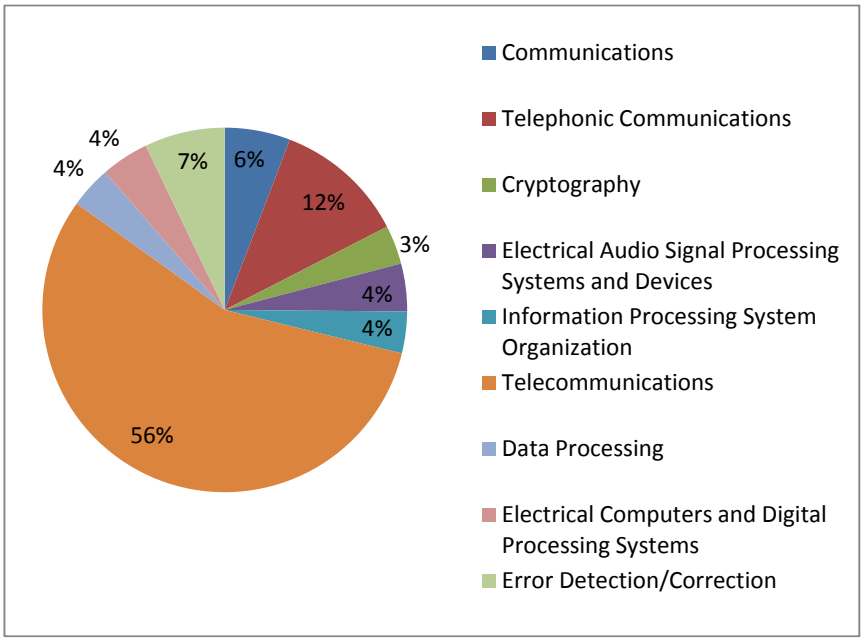


Figure 2: Technological class of the cited patents

Appendix 2 : Description citing patents

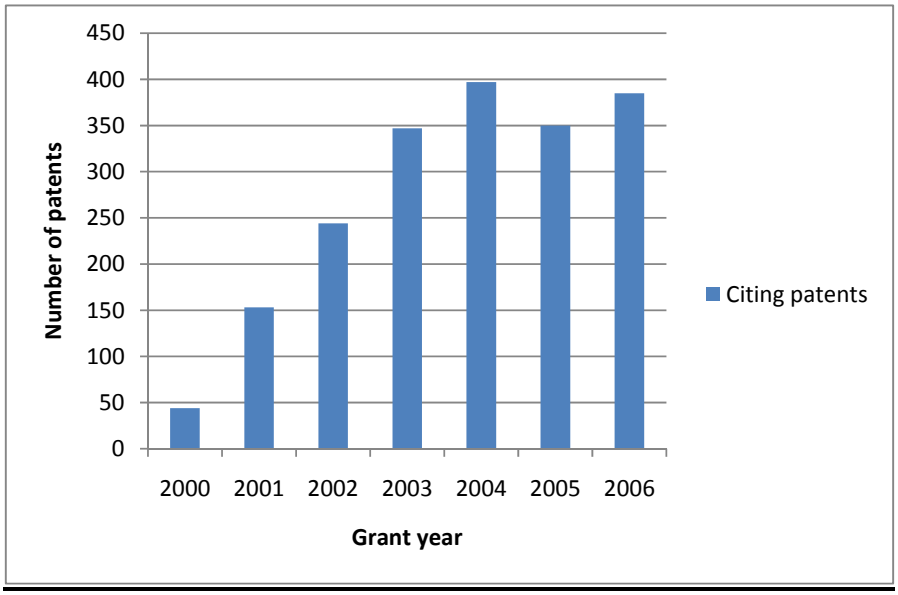


Figure 3: Grant year of the citing patents

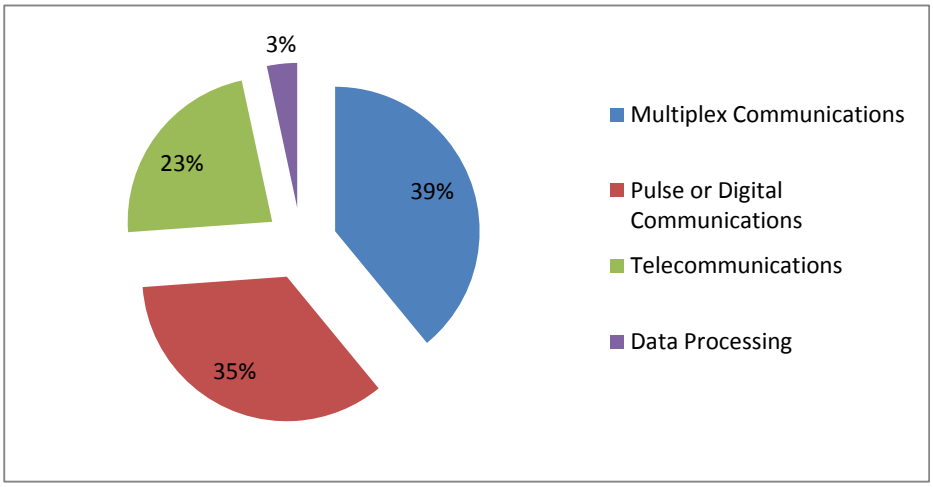


Figure 4: Technological class of the citing patents

Appendix 3 : List of consortia

Consortium Name	3GPP related	Affected by the OMA merger
MET	No	No
WLANA	No	No
SA Forum	No	No
ATIS	No	No
3G Americas	No	No
CDG	No	No
VoiceXML	No	No
IPv6 Forum	Yes	No
Hiperlan 2	No	No
WiFi Alliance	No	No
GSA	Yes	No
TTC	Yes	No
Bluetooth	No	No
GPP 2	No	No
UMTS Forum	Yes	Yes
T1	Yes	No
SyncML	No	Yes
TTA	No	No
UWCC	Yes	No
WAP Forum	No	Yes
Wireless Village	No	Yes
3GIP	No	No
ARIB	Yes	No
BWIF	No	No
CWTS	No	No
ETSI	Yes	No
GSM Association	Yes	No
MGIF	No	Yes
MWIF	No	Yes
OMA Alliance	No	No
Symbian	No	No
WECA	No	No

Appendix 4 : Cited patent holders

ID	Company Name
50020	Agere
50040	Alcatel
50100	ArrayComm
50120	AT&T Wireless
50180	Bell South
50220	BT (British Telecom)
50250	BULL S.A.
50360	Cisco Systems
50411	3Com
50421	Infineon Technology
50520	Ericsson
50580	France Telecom
50590	Fujitsu Limited
50630	Golden Bridge Technology
50640	Hewlett Packard
50670	Hughes Network
50710	ICO Global
50750	Intel
50760	InterDigital
50860	LG Electronics
50880	Lucent
50940	Matsushita
50950	Matra
51000	Microsoft
51010	Mitsubishi
51060	Motorola
51090	NEC
51130	Nokia
51140	Nortel Networks
51200	OKI Electrics
51280	Panasonic
51340	Qualcomm
51360	Racal Instruments
51400	Rogers Wireless
51440	Samsung
51490	Seiko Epson
51540	Sharp
51560	Siemens
51640	Sony
51880	Texas Instruments
51900	Thomson
51920	Toshiba

Appendix 5 : Control group for the OMA merger

Company Name
Hughes network
Agere
ArrayComm
BT (British Telecom)
Bull S.A.
Comneon
Golden Bridge technology
ICO Global
Matra
Racal Instruments
Rogers Wireless
Shanghai Bell

Appendix 6: Firm heterogeneity in the coordination effect (fixed-effects estimation)

	Coef.	Coef.	Coef.	Coef.
co_membership	3.366***			
	(0.194)			
co_membership_Ericsson	10.498			
	(956.892)			
dummy_Ericsson	1.651			
	(1.311)			
co_membership		2.762***		
		(0.252)		
co_membership_Interdigital		-0.386		
		(0.382)		
dummy_interdigital		3.379***		
		(0.390)		
co_membership			3.398***	
			(0.197)	
co_membership_Panasonic			-1.812*	
			(1.101)	
dummy_Panasonic			1.466	
			(1.033)	
co_membership				4.005***
				(0.251)
co_membership_Qualcomm				-2.931***
				(0.417)
dummy_Qualcomm				1.699***
				(0.364)
3GPP connections	Y	Y	Y	Y
Patent age and quality	Y	Y	Y	Y
Dummy 0/3/6/9	Y	Y	Y	Y
Number of obs	2154	2154	2154	2154
Number of groups	352	352	352	352
chi2	926.51	1059.89	927.52	976.76
Log likelihood	-350.338	-283.651	-349.835	-325.211
Legend: * p<.05; ** p<.01; *** p<.001				

Appendix 7: Regression results with firm pairs

This estimation utilizes the method developed by Agrawal and Goldfarb (2008). In this case, we work with a panel database organized around pairs of cited and citing firms (rather than patents) and estimate a fixed-effect logit model with the likelihood for firm *i* to be cited by an essential patent held by firm *j* at year *t* as the dependent variable. Our main explanatory variables again measure consortium participation, and we control for the patent holder's centrality in formal standardization (3GPP). We thus estimate the following model:

$$\Pr(Citation_{ijt}) = \alpha_0 + \alpha_1 Consortium_participation_{it} + \alpha_2 3GPP_connections_{it} + \varepsilon_{it}$$

With:

$\Pr(Citation_{ijt})$ = Probability of firm i being cited by firm j in year t

Consortium participation$_{it}$ = Participation in consortia of firm *i*, using the variables *total membership, consortium connections,* and *co-membership* in year *t*

3GPP connections$_{it}$ = Firm *i*'s one-mode centrality in formal standardization in 3GPP committees in year t

The results are presented in the following table

	(1)	(2)	(3)
	Coef. (SE)	Coef. (SE)	Coef. (SE)
Total memberships	0.5842 (0.368)		
Consortium connections		0.0140 (0.013)	
Co-membership			1.6525*** (0.266)
3GPP connections	-0.1882 (0.167)	-0.1882 (0.167)	0.00004 (0.035)
Observations	535	535	535
Number of firm pairs	79	79	79
Chi 2	54.16	57.42	43.13
Prob > chi2	0	0	0
Log likelihood	-251.89	-237.46	-143.55
Legend: * p<.05; ** p<.01; *** p<.001			

ε_{it} = Error term

Notes: Standard errors, clustered on patents, in parentheses under the coefficients.

Appendix 8: Results using a random effects estimation

	(1)		(2)		(3)	
	Coef. (SE)	Odds ratios (SE)	Coef. (SE)	Odds ratios (SE)	Coef. (SE)	Odds ratios (SE)
	DV= Dummy patent cited/year					
Total memberships	0.139***	1.149***				
	(0.018)	(0.021)				
Mean memberships	-0.215***	0.806***				
	(0.061)	(0.049)				
Consortium connections			0.002***	1.002***		
			(0.0002)	(0.0002)		
Mean consortium			-0.002	0.998		
Connections			(0.001)	(0.001)		
Co-membership					3.162***	23.610***
					(0.168)	(3.976)
Mean Co-membership					6.463***	640.071***
					(0.645)	(412.579)
3GPP connections	0.007	1.007	0.021***	1.021***	-0.002	0.998
	(0.006)	(0.006)	(0.005)	(0.005)	(0.006)	(0.006)
Mean 3GPPconnections	-0.037	0.964	-0.081***	0.922***	-0.035***	0.965***
	(0.023)	(0.022)	(0.016)	(0.015)	(0.010)	(0.010)
Patent age	-0.109*	0.896*	-0.076	0.926	-0.039	0.962
	(0.053)	(0.048)	(0.053)	(0.049)	(0.064)	(0.062)
Mean patent age	0.305***	1.357***	0.276***	1.318***	0.199**	1.220***
	(0.052)	(0.070)	(0.051)	(0.068)	(0.062)	(0.075)
Patent quality	-0.068***	0.934***	-0.067***	0.935***	-0.074***	0.929***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.008)	(0.007)
Mean patent quality	0.080***	1.083***	0.079***	1.082***	0.079***	1.082***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.009)
Dummy 0/3/6/9	Y		Y		Y	
Observations	6276		6276		6276	
Number of groups	1021		1021		1021	
Chi2	418.96		421.75		539.77	
Prob > chi2	0		0		0	
Log Likelihood	-1554.269		-1558.675		-1142.618	
Unit of analysis	Cited patent		Cited patent		Cited patent	
Number of cited firms	44		44		44	
Legend: * p<.05; ** p<.01; *** p<.001						

Notes: Dependent variable is an indicator for whether a patent was cited by an essential patent applied in year t. Estimation method is logit with random effects. Dummy 0/3/6/9 are nonlinear effects for patent age. Means are computed at the cited patent level.

Appendix 9: Regression results with a linear probability model

Table 9.1 Main results

	(1)	(2)	(3)
	Coef. (SE)	Coef. (SE)	Coef. (SE)
Total memberships	0.0050***		
	(0.0007)		
Consortium connections		0.0002***	
		(0.00004)	
Co-membership			0.2307***
			(0.013)
3GPP connections	0.0003	0.0007**	-0.0005**
	(0.0003)	(0.0002)	(0.0002)
Dummy Age Cited	Y	Y	Y
Observations	7297	6276	6276
Number of groups	1021	1021	1021
R-sq	0.1071	0.0975	0.1969
Unit of analysis	Cited patent	Cited patent	Cited patent
Number of cited firms	44	44	44
Legend: * p<.05; ** p<.01; *** p<.001			

Notes: Standard errors, clustered on patents, in parentheses under the coefficients.

Table 9.2 Types of consortia

	(1)	(2)	(3)
	Coef. (SE)	Coef. (SE)	Coef. (SE)
Informal consortium memberships	0.0022* (0.0008)		
Formal consortium memberships	0.0172*** (0.0032)		
Related consortium memberships		0.0191*** (0.0022)	
Unrelated consortium memberships		-0.0013 (0.0008)	
Consortium Connections			0.0002* (0.00009)
Cons. connections* patent apps			-1.237e-07 (9.86e-08)
Patent apps			-0.0001*** (0.00003)
3GPP connections	0.0006 (0.0003)	0.0001 (0.0003)	0.0075*** (0.0013)
Dummy Cited Age	Y	Y	Y
Observations	6276	6276	6276
Number of groups	1021	1021	1021
R-sq	0.0516	0.1049	0.0821
Unit of analysis	Cited patent	Cited patent	Cited patent
Number of cited firms	44	44	44
Legend: * p<.05; ** p<.01; *** p<.001			

Notes: Standard errors, clustered on patents, in parentheses under the coefficients.

Table 9.3 Differences-in-differences estimation of the effects of OMA merger

	(1)	(2)	(3)
	Coef.	Coef.	Coef.
OMA connections	0.0007***	0.0006***	
	(0.0001)	(0.0001)	
Other consortia connections	-0.0001*		
	(0.00005)		
Formal consortia connections		-0.00009	
		(0.00005)	
Informal consortia connections		0.0014**	
		(0.0005)	
OMA connections after	0.0005***	0.0005**	
	(0.0001)	(0.0001)	
New OMA co membership			0.0004*
			(0.0002)
Old_OMA_co_membership			-0.0066***
			(0.0006)
Co membership			
Dummy after	-0.1831***	-0.1811***	1.7505***
	(0.018)	(0.018)	(0.116)
3GPP connections	-0.0014***	-0.0014***	-0.5576***
	(0.0003)	(0.0003)	(0.087)
Dummy Cited Age	Y	Y	Y
Number of obs	6276	6276	6276
Number of groups	1021	1021	1021
R-sq	0.1109	0.1169	0.2555
Unit of analysis	Cited patent	Cited patent	Cited patent
Number of cited firms	44	44	44
Legend: * p<.05; ** p<.01; *** p<.001			

Notes: Standard errors, clustered on patents, in parentheses under the coefficients.