Innovating standards through informal consortia: The case of wireless telecommunications

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Abstract

We conduct an empirical analysis of the effects of technical industry consortia on the coordination of R&D strategies of the participants. Our analyses utilize membership data from 32 consortia in a variety of wireless telecommunications technology subfields from 2000 to 2005 and cross-citations between essential patents declared 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. 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, patent quality, and other characteristics. Thus, on one hand, consortia may increase incentives to invest in R&D by internalizing potential innovation externalities. On the other hand, our results highlight the growing role of consortia in the standardization process which 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 not only standard specifications, as shown in earlier research, but also peers' innovation strategies.

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1. Introduction

This paper examines the relationships between firms' participation in wireless telecommunications industry consortia and their subsequent innovations that become declared essential patents in the global UMTS standard for mobile communication. 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). For instance, the 3G wireless telecom standard studied here contains around 16000 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 industry consortia 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 evidence. Leiponen (2008) argues that ICT firms' participation in such consortia facilitates influencing formal standard-setting outcomes. However, there is no evidence to date about the implications of informal consortia for coordination of subsequent 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.

This 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 should inform competition policies. The economic literature on the subject (Katz and Ordover, 1990; Jorde and Teece, 1990; and Choi, 1993) often considers these collaborative organizations as a potential threat to competition because of excessive

[3] e.g., cell phones, DVD, internet protocols…
[4] Such as International Standard Organization, International Telecommunication Union, European Telecommunication Standard institute

market coordination. However, consortia can also be socially desirable if they reduce potential coordination problems around innovation. In this case, consortia might mitigate wasteful cost duplication 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] as they are also a way to increase overall efforts of R&D.

However, our analyses regarding the coordination of innovation through consortia also shed new light on the processes 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, open access, and public release of relevant information.

From a strategic viewpoint, participation in standardization consortia could be a way for firms to promote their technologies and become central and hence powerful in the technological field. For instance, from a sociological perspective, Pfeffer (1981) suggests that consortium participation helps firms to access and control strategic knowledge. Nevertheless, there is to date little empirical evidence for this assertion. Our research aims to highlight strategies that firms may deploy in the wireless telecom field to influence innovation by others.

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 mobile communication standardization through Third Generation Partnership Project, or 3GPP, that is the formal 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 16000 essential patents filed by these firms in the 3GPP standardization process of UMTS . These data will be used to assess econometrically the effect of firms' participation in consortia on the convergence (cross-citations) of subsequent inventions. We also use a merger

[5] For instance, the same kind of approach adopted for patent pools those also present drawbacks in terms of competition and advantages in terms of innovation diffusion

in the network of consortia as a natural experiment that, arguably, exogenously changed consortium connections of dozens of member firms to explore the robustness of our results.

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 consortia such as other formal standard-setting organizations (e.g., regional SSOs). We also find that this coordination effect is more important for firms with lesser technological capabilities than for those with more substantial capabilities, and that the change in the network of consortia caused by the merger had an impact on the strength of this coordination effect. In other words, our key results are supported by the difference-in-differences analysis utilizing this source of exogenous variation.

Our results highlight consortia as a form of organization to coordinate innovation strategies related to communication standards. Consortia thus seem to enable sharing of knowledge and coordination of R&D. Policy and managerial implications of these findings are discussed in the last section. 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 our targeted 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. We will discuss the benefits and costs of participation as viewed in extant studies.

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), d'Aspremont and Jacquemin (1988), among others, view consortia mainly as a way to share and reduce R&D expenses. These organizations are a way to realize scale economies among participants and to avoid project duplication. This stream of literature assumes symmetric contributions of consortia members in terms of R&D investments and competencies, and firms are assumed to manufacture substitutable products.

Complementary to this idea, another strand of literature discusses incentives to participate when firms do not have symmetric 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 are a way to internalize these spillover effects. This potentially positive effect of consortia has led some economists 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. This approach considers a firm as a bundle of competencies. Firms’ participation in consortia or other forms of cooperation can be viewed as a method to share skills and benefit from other members’ competencies. This argument implies that 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. 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 of 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.

The 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 expenditure by participants.

An organization-theoretic literature points out that participation in R&D consortia is a way to obtain 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 be help to orientate 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 R&D consortia significantly enhances firms' contributions to new standard specifications in 3GPP committees. Firms that are central in the consortium network are more able to ultimately influence the standard-setting outcome. From a social point of view, this result suggests that R&D consortia may also have adverse effects and are potentially a way to foreclose competition. This potential negative effect of consortia on competition (implicit collusion) was acknowledged in a series of papers[6] without causing significant reactions by competition authorities.

Finally, a set of studies identifies consortia as a way to signal strategies within the industry. In this framework (Rosenkopf, Metiu and Georges, 2001) consortium participation is a way to signal potential strengths to competitors or other actors of the technological field. In a longitudinal study of 87 cellular service providers and equipment manufacturers, the authors show that participation in technical committees help 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 Lorenkopf (2010). In this study of 186 firms over 7 years of participation in technical committees, the authors examine how job mobility of individuals affects firms' ability to influence others in a technical standards setting committee for U.S. wireless telecommunications. The authors point out that hiring individuals who are rich in

[6] For instance Brodley (1990), Katz and Ordover (1990), Jorde and Teece (1990) and Choi (1993)

social capital increases firms' power in technical standard-setting committees by increasing the hiring firm's social capital[7].

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 travel and meeting costs or loss of productivity due to engineers' participation to the reunions. 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 decade since, membership fees and the number of consortia have substantially increased.

Consortia can also represent an important risk 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) underlines 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 general strategy. This result 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.

To summarize, the extant literature on R&D consortia has identified many potential benefits and drawbacks of participation. However, systematic empirical evidence remains relatively scarce. The focus of our empirical work is on the hypothesis that consortia facilitate coordination of subsequent R&D. Aldrich et al. (1998) and Hawkins (1999) have previously discussed this idea. Hawkins argues that "[…]an international system has evolved in which

[7] In contrast, the loss of personnel does not affect a firm's social capital or influence over standards directly but it does have an effect on firm social capital and influence contingent on changes in the firm's business strategy.

communication and co-ordination is achieved primarily through inter-organisational alliances[…]". However, little systematic empirical evidence has been presented. Our paper targets this research gap by examining the role played by consortia as a vehicle for knowledge transfer and influence in the innovation context.

3. Data and Methods

The main research question that we empirically test in this paper is whether informal standardization bodies have facilitate the coordination of innovation strategies in terms of increasing the likelihood that a patent is cited by another consortium participant in a patent that is 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. We focus on citations by UMTS essential patents because we are interested in the ability of consortium participants to influence the set of technologies incorporated in the standard.

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[8]. We retrieved these data in October 2010 using the ETSI online patent database[9]. We then merged these data with information on citations using the 1976/2006 National Bureau of Economic Research database[10] and used the EPIP database to identify the patent holders of the cited patents[11]. 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 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.

[8] 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
[9] Available at: http://ipr.etsi.org/
[10] Available at: http://www.nber.org/patents/
[11] Available at: http://www.epip.eu/datacentre.php

Next, we created a database on consortium membership links between firms involved in the 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[12]. 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 of another member of 3GPP in the year after its application. In robustness analyses we also utilize a binary indicator at the firm level.

We use three different variables to capture firms’ participation in informal standardization bodies (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 membership*) and the number of connections to peers from consortia (*consortium connections*). A consortium connection is formed if two firms meet at least one time 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.

The main empirical issue is to disentangle the effects of participation in consortia and technological centrality of the firm in formal standards development. 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 this possibility, we use data on patent holders’ participation in the formal standards-development

[12] A list of the patent holders of the cited patents is presented in appendix 4.

organization (3GPP). We trace patent holders' activities in formal standards-development committees[13] from 2000 to 2005 and create a variable *3GPP connections* that equals the number of unique connections (one-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 enables us to distinguish the effects of informal and formal standardization on cross-citations.

Table 1 describes the main variables.

Table 1: Name and description of the main explanatory variables

Variable	Description	Mean	Std. dev.	Min	Max
Total membership	Number of cited firm's annual memberships (two-mode network degree) in consortia	8.27	6.96	0	24
Consortium connections	Number of cited firm's annual unique connections (one-mode network degree) through consortia	128.15	103.79	0	280
Co-membership	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	Number of unique (one-mode degree) connections to other firms through 3GPP work-item committees	16.05	18.50	0	63
Age cited	Age of the cited patent (since the grant year)	3.61	5.34	- 4	29
Patent quality	Stock of forward cites at t-1	32.87	56.29	1	920

[13] Using the website http://www.3gpp.org/

We work with a panel database of patents cited by UMTS essential patents and estimate a fixed-effect logit model with the likelihood to be cited at year y for a patent p as the dependent variable. Table 2 presents descriptive statistics (for the cited patents) regarding the number of citations by other 3GPP members. As we do not use a count data model but estimate the likelihood to be cited for a patent at year y, Table 3 presents the number of times (years) our patents are cited over the six years of observation. The majority of our cited patents are not cited during the years we analyze. 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 which significantly reduces our estimation sample[14].

Table 2: Number of citations by other 3GPP members

	Mean	Std. Dev.	Min	Max
Total citations by other 3G members	2.97	7.24	0	79

Table 3: 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 quality and age. We thus estimate the following model:

$$\Pr(Citation_{py}) = \alpha_0 + \alpha_1 Consortium\_participation + \alpha_2 3GPP\_connections + \alpha_3 Patent\_quality + \alpha_4 Patent\_age + \varepsilon_{py} \quad [1]$$

[14] We also controlled that our results are not due to the patents that are cited only one time by other 3G participants, over the period, excluding these patents in one of our robustness tests. The results presented in the body of the paper remain robust even excluding these patents.

$\Pr(Citation_{py})$ = Probability of firm being cited by another 3GPP participant in year y for patent p

Consortium participation = Participation in consortia of the holder of the cited patent, using the variables *total membership*, *consortium connections,* and *co-membership*

3GPP connections = Cited patent holder's centrality in formal standardization in 3GPP committees

Patent age = Age of the patent

Patent quality = Patent stock of forward citations at year t-1

ε_{py} = Error term

Our primary estimation approach utilizes standard panel-data methods (fixed effects estimation) to control for time-invariant unobserved heterogeneity of firms and patents. We also disentangle the consortium participation effect according to the nature of the consortia and the size of the firm. As a fixed-effects estimation considerably reduces the number of observations, we also use a random-effects estimation taking into account the overall sample, using mean variables to control for intrinsic 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 5 and confirm the findings of the fixed-effects estimation.

We also 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 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[15] 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."[16] 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.

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 and its quality in terms of the stock of forward cites at time-1. The results of this model are presented in Table 4.

As we can see in Table 3, our three main explanatory variables all have statistically highly significant and positive effects on the likelihood to be cited by another consortium participant. Given the fact that our third explanatory variable, *co-membership*, presents a strong and very significant positive parameter, it is quite logical that our two other explanatory variables also have a positive impact. Marginal effects suggest that the total number of memberships has a stronger 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 0.02%. However, one needs to keep in mind that one additional membership tends to lead to 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 47%. We also

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

find that the control variable patent age does not have a clear impact on the likelihood to be cited. In contrast, patent quality (stock of forward cites at year – 1) has a significant negative impact on the likelihood to be cited[17]. However, the random-effects estimation presented in appendix 5 attenuate this finding. Nevertheless, the role of patent quality in formal and highly cumulative standardization should probably be further investigated.

Table 4: The effect of consortium participation on the likelihood of citation

	(1)		(2)		(3)	
	Coef.	Marginal effect	Coef.	Marginal effect	Coef.	Marginal effect
Total memberships	0.143***	0.0108*				
	(0.019)	(0.005)				
Consortium connections			0.00218***	0.0002*		
			(0.0001)	(0.0001)		
Co-membership					3.364***	0.4666***
					(0.193)	(0.006)
3GPP connections	0.00840	0.0006	0.021***	0.0018*	-0.00245	-0.0006
	(0.006)	0.272	(0.005)	(0.0010)	(0.006)	(0.002)
Patent age	0.0256	0.0019	0.053	0.0044**	-0.111	-0.0276
	(0.065)	0.715	(0.065)	(0.0065)	(0.089)	(0.022)
Patent quality	-0.0896***	-0.007**	-0.087***	-0.0072	-0.085***	-0.0212***
	(0.011)	0.042	(0.011)	(0.0035)	(0.012)	(0.003)
Dummy 0/3/6/9	Y		Y		Y	
Observations	2154		2154		2154	
Number of groups	352		352		352	
Chi2	434.56		428.34		924.69	
Prob > chi2	0		0		0	
Log Likelihood	-596.312		-599.424		-351.251	

Legend: * p<.05; ** p<.01; *** p<.001
(* p<.10; ** p<.05; *** p<.01 for marginal effects)

Notes: Dependent variable is an indicator for whether a patent was cited by an essential patent applied in year y. Estimation method is logit with fixed effects at the patent level. Dummies 0/3/6/9 are nonlinear effects for patent age. Standard errors are in parentheses under the coefficients.

[17] We cannot exclude that this effect is not due at least partially to an effect patent age not captured by our variable age. This effect could also confirm that the traditional indicators of patent quality do not work very well in a standardization context characterized by cumulative innovation.

These results lend support for our main hypothesis. The patent holder involvement in the consortium network increases the likelihood that the patent is cited by other participants. Thus, participation in informal standardization bodies helps firms coordinate subsequent research.

Next, we refine the result by analyzing whether the nature and size of the consortium and the cited patent holder influence the result. We distinguish between different types of consortia (formal or informal) and their relationship with 3GPP (related or unrelated to 3GPP)[18]. Formal consortia actually draft and certify standard specifications whereas informal ones simply discuss and test technological alternatives. Consortia can also be formally allied with 3GPP or completely unrelated to 3GPP. We would expect consortia that are allied with 3GPP to provide more fruitful venues for influencing peers' innovation activities related to technologies that 3GPP standardizes. Also, we would expect informal consortia to be more conducive for 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.

We also examine the interaction effect of the technological resources of the patent holder using an interaction variable, *consortium connections*patent apps,* between *consortium connections* and 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. These results are presented in Table 5.

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[18] See the data section.

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

	(1)		(2)		(3)	
	Coef.	Marginal effect	Coef.	Marginal effect	Coef.	Marginal effect
Informal consortium memberships	0.158*** (0.026)	0.0114* (0.006)				
Formal consortium memberships	0.0854 (0.048)	0.0061 (0.005)				
Related consortium memberships			0.267*** (0.046)	0.0216* (0.012)		
Unrelated consortium memberships			0.0843** (0.027)	0.0068* (0.004)		
Consortium connections					0.00278*** (0.0004)	0.0002* (0.0001)
Cons. connections* patent apps					-7.549e-07 (4.08e-07)	-5.59e-08 (0.000)
Patent apps					-0.00024 (0.0003)	-0.00001 (0.0002)
3GPP connections	0.00797 (0.006)	0.0006 (0.005)	0.0065 (0.006)	0.0005 (0.006)	0.0203*** (0.005)	0.0015 (0.0009)
Patent age	-0.00143 (0.064)	-0.0001 (0.005)	0.012 (0.066)	0.0010 (0.005)	0.0632 (0.067)	0.0047 (0.006)
Patent quality	-0.0879*** (0.011)	-0.0063 (0.003)	-0.089*** (0.011)	-0.0072 (0.004)	-0.0903*** (0.011)	-0.0067 (0.003)
Dummy 0/3/6/9	Y		Y		Y	
Observations	2154		2154		2154	
Number of groups	352		352		352	
LR chi2	427.34		443.35		410.89	
Prob > chi2	0		0		0	
Log Likelihood	-599.922		-591.919		-593.992	

Legend: * p<.05; ** p<.01; *** p<.001
(* p<.10; ** p<.05; *** p<.01 for marginal effects)

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 fixed effects at the patent level. Dummy 0/3/6/9 are nonlinear effects for patent age.

Regarding the types of consortia, the results confirm expectations. Both the formality and relationship with 3GPP of the consortium moderate the participation effect. We can see in Table 5 that the participation effect is positive and significant for informal consortia but insignificant for the formal standardization organizations of our sample. 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 directly 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 impact on the likelihood to have a patent cited by peers in subsequent innovation.

Perhaps contrary to expectations, the greater the firm's technological innovativeness (patent applications), the lower the consortium participation effect on the likelihood to be cited in subsequent research by peers (this result is significant at 10%). We speculate that representatives of firms with large technology portfolios may have a less accurate understanding of the potential of individual patents for peers to build on. However, we plan to investigate the size/technological resource effect in more detail.

Finally, we use a natural experiment, a merger of seven consortia in 2002 to examine the robustness of our results. When MGIF, UMTS Forum, Wap Forum, Wireless Village, SyncML Initiative, LIF and MWIF merged to form Open Mobile Alliance, the consortium connections of the members of the seven consortia were exogenously shifted. Using this exogenous event to identify the causal effect of 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 6.

Table 6: Impact of the OMA merger on subsequent citations

	(1)		(2)		(3)	
	Coef.	Marginal Effect	Coef.	Marginal effect	Coef.	Marginal effect
CTO_OMA	0.0178***	0.0026	0.0183***	0.0023	0.0239***	0.0060***
	(0.005)	(0.002)	(0.005)	(0.002)	(0.005)	(0.001)
CTO_not_OMA	0.00041	0.0001	0.00027	0.00003		
	(0.001)	(0.001)	(0.001)	(0.0001)		
CTO_not_OMA _formal					-0.00042	-0.0001
					(0.002)	(0.0004)
CTO_not_OMA _informal					0.00810*	0.0020**
					(0.004)	(0.0009)
CTO_OMA_after	0.00911*	0.0013	0.00941*	0.0012	0.0151**	0.0038***
	(0.004)	(0.001)	(0.004)	(0.001)	(0.005)	(0.001)
Dummy_after	-3.538***	-0.4562	-3.720***	-0.4232	-4.0422***	-0.7537
	(0.357)	(0.288)	(0.374)	(0.294)	(0.406)	(0.112)
3PP connections			-0.0149	-0.0018	-0.0148	-0.0037
			(0.009)	(0.002)	(0.009)	(0.002)
Patent age	1.128***	0.1646	1.160***	0.1439	1.378***	0.3442
	(0.161)	(0.143)	(0.163)	(0.137)	(0.192)	(0.056)
Patent quality	-0.177***	-0.0258	-0.179***	-0.0222	-0.184***	-0.0461
	(0.020)	(0.020)	(0.020)	(0.019)	(0.021)	(0.005)
Dummy 0/3/6/9	Y		Y		Y	
Number of obs	1731		1731		1731	
Number of groups	338		338		338	
LR chi2	667.35		670.33		675.34	
Prob > chi2	0.0000		0.0000		0.0000	
Log Likelihood	-330.306		-328.818		-326.314	

Legend: * p<.05; ** p<.01; *** p<.001
(* p<.10; ** p<.05; *** p<.01 for marginal effects)

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 fixed effects at the patent level. Dummy 0/3/6/9 are nonlinear effects for patent age.

CTO_OMA is a binary variable for membership in OMA or the seven component consortia. This variable has a strong 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 (CTO_not_OMA) is insignificant. However, when we separate informal and formal other consortia (CTO_not_OMA_formal and CTO_not_OMA_informal) we retain the positive and statistically significant effect of informal non_OMA connections. The most important coefficient in table 6 is that on the variable CTO_OMA_after that measures the additional effect of OMA-related connections after the merger. This effect is significant at the 95% level of confidence in all specifications, but it is particularly strong (and significant at the 99% level) when the non_OMA effect is separately estimated for formal and informal consortia. This natural experiment is useful to confirm and refine the robustness of our results. Using the creation of OMA consortium as a source of exogenous variation, the change in the network of consortia caused by the merger had an impact on the strength of the coordination effect.

To conclude, our main hypothesis that consortia participation facilitates coordination of firms' research policies is supported. The result is robust independent of the method or the variable to capture the participation used. But the magnitude of the effect substantially depends on the nature of the consortium and (technological) size of the patent holder. The coordination effect is insignificant for formal consortia and strongly positive and statistically significant for informal ones. Additionally, the effect is much greater when consortia are technologically or strategically related to 3GPP but it remains significant when consortia are unrelated to 3GPP. The impact is also lower when the technological innovation capacity of the firm increases. Finally, we note that a merger in the consortium network had a significant positive impact on the magnitude of the 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 the convergence of R&D strategies. In order to do that, we use data on participation in 32 ICT consortia and citations of essential patents filed by participants in the 3GPP standardization process. We also use a merger in the network of consortia as a quasi-experiment that exogenously changed consortium connections of members to explore the robustness of our results and refine our analysis.

Our empirical analysis underlines the impact of the patent holder’s involvement in the consortium network on the likelihood to have its patents cited by other participants in subsequent research. The higher the patent holder involvement in the consortium network, the higher the likelihood to be cited by other contributors in subsequent patents that are declared essential for the UMTS standard. This result is stronger for consortia that are formally allied or directly related to 3GPP, whereas the result is weaker but still positive and statistically significant for consortia unrelated to 3GPP. Our findings suggest that informal consortia are an effective vehicle to coordinate standards-related research. Indeed, while participation in informal consortia has a positive and statistically significant impact on the likelihood to be cited by subsequent research, this result does not hold for more formal consortia such as other standard-setting organizations. To finish, we also stress that an exogenous change in the consortium network had an impact on the strength of this coordination effect. Thus, our main findings are confirmed by a difference-in-difference analysis using a merger in the network of consortia as a source of exogenous variation.

Our main result, that consortium participation facilitates coordination of firms’ R&D activities lends support for an earlier literature on the effects of R&D cooperation on managing knowledge transfer between rivals. Thus, cooperation potentially improves incentives for R&D because it enables the internalization of knowledge-creation externalities. However, in the standard-setting context our findings also raise questions. Our results demonstrate that standardization is no longer practiced only in formal standard-setting organizations but also in informal upstream consortia.

First, transparency and openness of consortium activities is currently not ensured. Thus, it can be difficult for an entrant to understand who makes decisions about standardization, where, and through what process. 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 tend to have few (if any) technical experts who are able to travel to standards meetings, and with dozens of potentially relevant consortia, this may simply not be possible. Finally, major firms have motivated consortia as a method of speeding up standards development. While this is an acceptable goal for any industry, the actual reason for accelerated outcomes from consortia may be exactly that smaller firms and those who disagree with industry leader(s) are not participating.

We suggest that these novel results potentially call for a rethinking of standard-setting policies. Innovation policymakers should no longer be interested only in formal standard-setting organizations but also pay attention to activities in informal upstream consortia in which much of the coordination work is actually done. Similarly, our results show that innovating firms that want to commercialize new products or technologies in network industries must design a standard-setting strategy that involves not only formal SSOs but also active participation and influencing peers within informal consortia.

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Appendix 1: Description cited patents

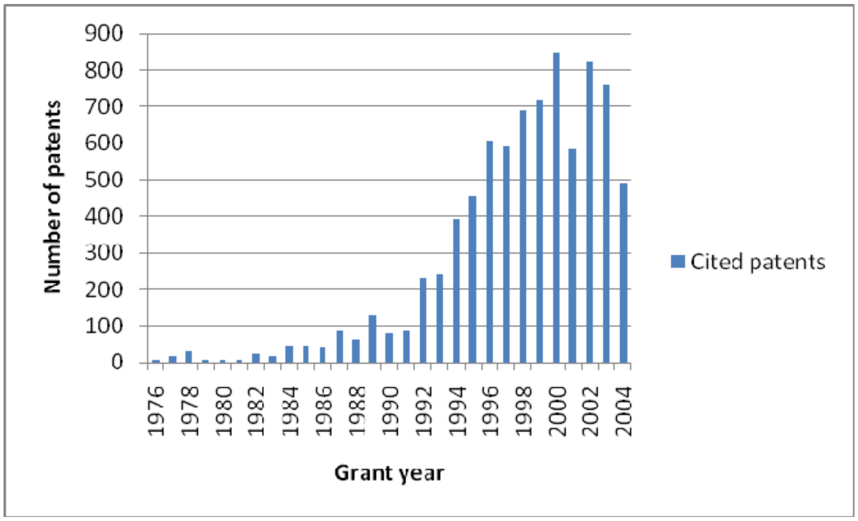

Figure 1: Grant year of the cited patents

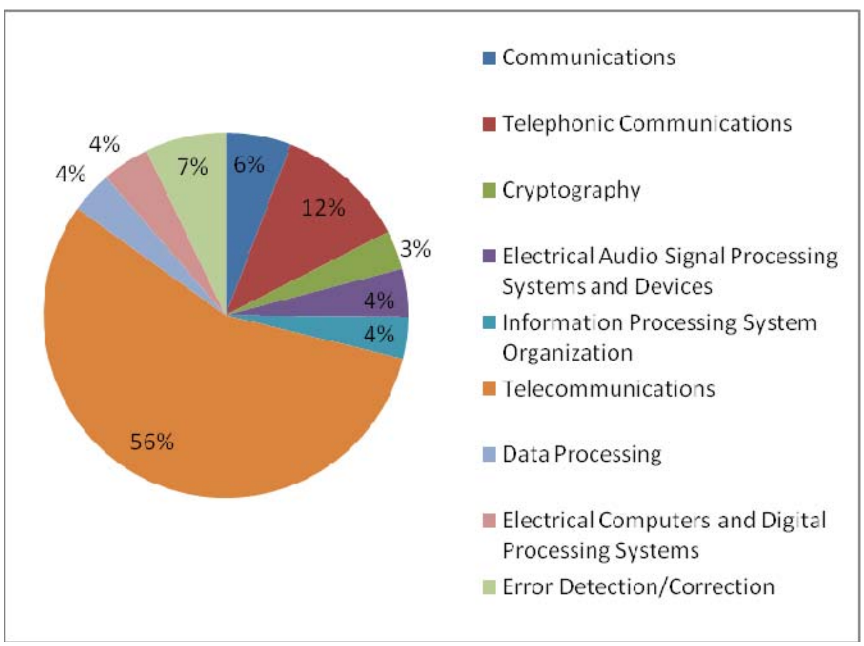

Figure 2: Technological class of the cited patents

Appendix 2 : Description citing patents

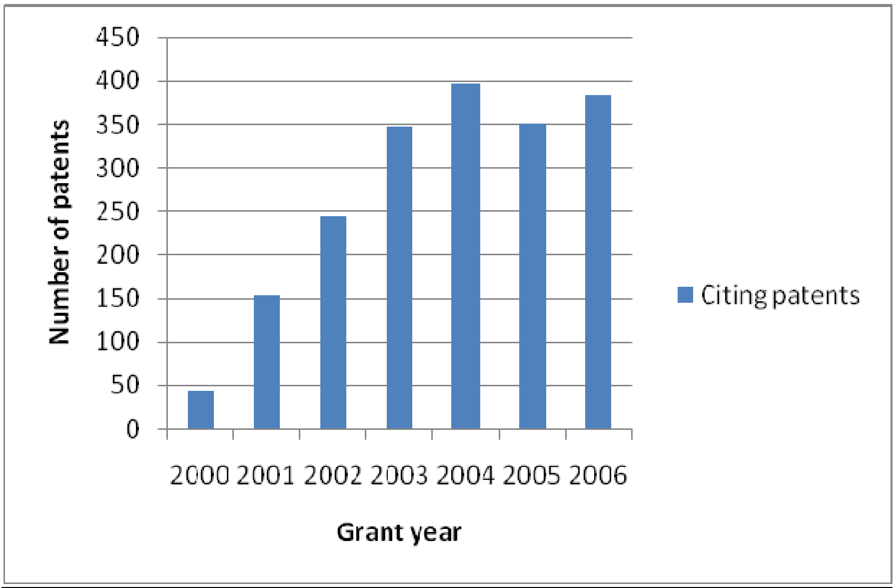

Figure 3: Grant year of the citing patents

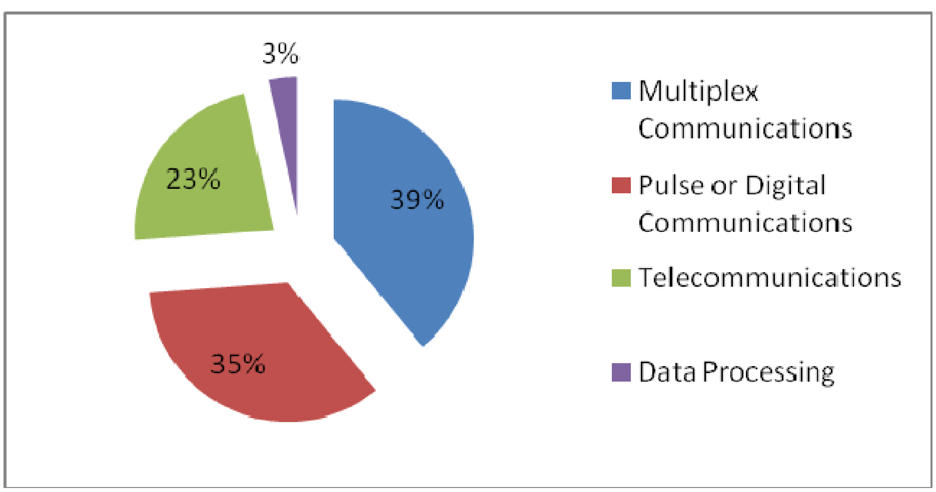

Figure 4: Technological class of the citing patents

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 : List of cited patent holders

id2_cited	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 : Results using a random effects estimation

	(1)		(2)		(3)	
	Coef.	Odds ratios	Coef.	Odds ratios	Coef.	Odds ratios
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 connections			-0.002	0.998		
			(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	

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.