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To cite this version:

Justus Baron, Yann Ménière, Tim Pohlmann. Joint innovation in ICT standards: How consortia drive the volume of patent filings. 2012. hal-00707291

HAL Id: hal-00707291

https://hal-mines-paristech.archives-ouvertes.fr/hal-00707291

Preprint submitted on 12 Jun 2012

CERNA WORKING PAPER SERIES

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Working Paper 2012-03

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June 2012

Joint innovation in ICT standards: how consortia drive the volume of patent filings

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June 11, 2012

Abstract

The development of formal ICT standards is a loose form of collaborative innovation: firms first develop rival technologies, some of which are then eventually selected in the standard. Against this background, firms often use informal consortia to define a clearer technology roadmap ahead of the formal standard setting process. The paper aims to assess how such consortia influence the volume of patents filed around standards, and whether this is efficient. We show that their effect actually depends on the strength of firms' incentives to develop the standard. Consortium membership triggers a higher number of patent files when insufficient rewards for essential patents induce underinvestment in the standard. This effect is necessarily pro-efficient. In situations where excessive rewards induce patent races, consortium membership only moderately increases or even reduces their volume of patents. At least in the latter case, the effect of consortia membership is also pro-efficient.

We are grateful to Mark Schankerman, Andrew Updegrove and Stephan Gauch for helpful discussion and data. We furthermore acknowledge valuable comments from participants at the Asia Pacific Innovation Conference, the Telecom ParisTech Conference on Economics of ICT - in particular Tobias Kretschmer - as well as the European Policy for Intellectual Property and the Standardization and Innovation in Information Technologies Conferences.

1 Introduction

Over the past twenty years, the number of essential patents[1] claimed on ICT standards has strongly increased (Simcoe, 2007). This evolution firstly denotes the importance of these patents for firms: they can generate substantial licensing revenues, and be used as bargaining chips to obtain freedom to operate on rivals' patent portfolios (Rysman & Simcoe, 2008). Another explanation lies in the growing complexity of ICT standards. As compared with other sectors, standardization in ICT has indeed evolved from the definition of mere specifications enabling interoperability to the joint development of large technology platforms including critical technologies[2]. Consequently, they tend to embody a growing number of patented components.

While the conditions for licensing essential patents have been widely discussed (see e.g., Shapiro, 2001; Lerner & Tirole, 2004; Layne-Farrar & Lerner, 2011), the peculiar type of collaborative innovation they proceed from has received less attention so far. Formal ICT standards are developed in standard setting organizations (SSOs)–such as ETSI (telecommunications) or IEEE (electronics)–that are open to a broad range of stakeholders. Besides the large number of participants, the originality of this process is that it does not involve any ex ante contracting between the firms preparing to develop a standard (Ganglmair & Tarentino, 2011). The choice of standard specifications rather takes place ex post in ad hoc working groups, based on the merit of rival technologies available to solve a given technical problem. Firms thus compete in R&D ahead of the working group meetings, thereby generating a large volume of patented innovations of which only a fraction will eventually become essential.

This formal process generates costly R&D cost duplications and delays due to vested interests (Farrell & Simcoe, 2012; Simcoe, 2012). Firms therefore increasingly rely on informal consortia to take the lead in the standard setting process (Cargill, 2001; Lerner & Tirole, 2006). Such consortia are fora wherein a group of firms seek to agree on a common design that they will jointly push as a standard. While some of them substitute for the lack of formal SDOs and issue their own standards (e.g., Blu-Ray alliance or W3C for web protocols), most consortia actually accompany formal standardization[3]. They are then a means for members to better focus their R&D investments on a common roadmap (Delcamp & Leiponen, 2012), thereby saving useless development costs while enhancing their chances to obtain essential patents (Pohlmann and Blind, 2012). Leiponen (2008) furthermore shows that participation in a consortium improves

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[1] Patents are deemed essential to a standard if they cover technology that is necessary for any implementation of this standard.

[2] As an example, the number of functionnalities and formats (e.g., email, video, internet) supported by the late wireless comunication standards (3G and 4G) considerably exceed those of the second generation (GSM, CDMA) that are limited to voice communication.

[3] These consortia can submit the joint technological proposals of their member committees to the SDO for approval as part of a formal standard. ISO has for instance a formal fast track agreement, the PAS (Publicly Available Specifications), which allows sponsoring organization to receive a formal accreditation of their specification within six and nine months. JTC1 has a similar policy of featuring Approved References Specifications (ARS).

the capacity of firms to influence the technological decisions taken at the formal SSO.

This paper aims to assess how such consortia influence the volume of patents filed around formal standards, and whether this is efficient. We show that their effect actually depends on the strength of firms' incentives to develop the standard. Consortium membership induces a higher number of patent files in situations where insufficient rewards for essential patents induce underinvestment in the standard. This effect is necessarily pro-efficient. In situations where excessive rewards induce patent races, consortium membership only moderately increases or even reduces their volume of patents. At least in the latter case, the effect of consortia membership is also pro-efficient.

The implications of these results are twofold. They first highlight the cost entailed by the loose coordination of R&D investments in formal SSOs. In this context, they also suggest that the creation of informal consortia can be an efficient way to supplement formal SSOs. Consortia are indeed an effective means to unlock the development of standards when firms have insufficient incentives to contribute technology, while they do not significantly amplify the race for essential patents when these incentives are strong.

The paper proceeds in two steps. We first develop a theoretical model to analyse the efficiency of distributed innovation into a standard. We then assess empirically the actual impact of consortia over a large panel of ICT standards.

Our model allows for some degree of rivalry between the firms' innovations, so that only a fraction of their patents eventually become essential. We firstly establish that the level and efficiency of firms' investments depend on the share of the standard's value that accrues to owners of essential patents. A *public good* pattern involving sub-optimal investment prevails in equilibrium when the licensing revenue of essential patents holders is not sufficient to cover their R&D costs. Conversely, firms engage in a wasteful *patent race* when licensing profits exceed total R&D costs.

Against this background, we introduce consortia as a means to mitigate technology rivalry between member firms. By joining a consortium, a firm may thus deflate its volume of patents by cutting irrelevant R&D investments, or inflate it by seeking to develop more relevant innovations. We show that consortium membership is always pro-efficient if the first effect dominates. A patent-inflating consortium is also pro-efficient in a *public good* equilibrium, but it may actually harm efficiency in a patent race equilibrium if it induces an excessive inflation of patents around the standard.

Drawing on this framework, we use a large panel of ICT standards to assess the actual effect of consortia empirically, respectively for standards entailing over- and underinvestment. For this purpose, we have developed an original dataset of standard-related patent applications at firm level, which we use as a proxy for firms' R&D investments. We also use information on the participation of pure R&D firms in the standard development process in order to identify over-investment patterns. We find that firms entering a consortium strongly increase their patent files in most of the cases. This is however not true for standards featuring an over-investment pattern: in these cases, consortia membership has a smaller, and in some cases negative effect on firms' patent applications. These results thus suggest that consortia tend to enhance the efficiency of innovation in the development of standards.

The remainder of this article is organized as follows. We present the theoretical model and its implications in Section 2. Section 3 discusses the empirical strategy, the database and econometric results. We conclude in Section 4.

2 Theoretical framework

Value of the standard We consider a set $\mathcal{N}$ of n firms that take part in the development of a standard. The standard embodies $x = \sum_{i \in \mathcal{N}} x_i$ essential patents contributed by the firms, and its implementation is expected to generate aggregate profits $v(x)$ in the industry. These profits increase with the amount of embarked technology, but with decreasing returns: $v'(x) > 0$ and $v''(x) < 0$[4].

There are two ways in which firms can derive revenues from the standard. Patent holders firstly appropriate a share $r \in [0, 1]$ of the standard's value through the royalties they charge to implementors of the standards. Parameter r can thus be thought of as reflecting the IP licensing policy of the standard setting organisation ($r = 0$ denoting a royalty free policy). In line with common practices regarding ICT standard, we assume that the share of the licensing revenues that accrues to firm $i \in \mathcal{N}$ is proportionnal to its share of the essential patents (x_i/x).

The remaining part of the revenues, $(1 - r) v(x)$, accrue to the firms that implement the standard in their products. Let s_i denote firm i's share of these revenues, which can be thought of as its share of the market for standard-compliant products. We assume that all firms with $s_i > 0$ are involved in the standard setting process (so that $\sum s_i = 1$). Other firms ($s_j = 0$) may also contribute patented inventions provided they have appropriate R&D capabilities, but they will get a return only through royalty revenues.

Taking into account both sources of profits, the expected benefit of firm $i \in \mathcal{N}$ is thus:

$$B_i = v(x) \left[r \frac{x_i}{x} + (1 - r) s_i \right]$$

R&D investments The definition of a standard is the outcome of an open innovation process wherein firms submit innovations, some of which only will be included in the standard specifications. Assuming constant and symmetric per unit R&D costs c, the R&D cost function of firm $i \in \mathcal{N}$ is proportional to y_i, the number of patents it develops for the standard:

$$C_i = c y_i$$

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[4] These assumptions account for various possible specifications. The standard's value $v(.)$ can in particular reflect a dynamic innovation process, if we define it as the expected outcome $\lambda x \pi / (\delta + \lambda x)$ of a Poisson process whith hit rate λx, discount rate δ, and aggregate profits π.

Equation (1) in turn posits that only a fraction of these patents enventually become essential.

$$\frac{x_i}{y_i} = \gamma_i \in (0,1) \tag{1}$$

Firm i's *selection rate* γ_i denotes the chance that one of its patented inventions be eventually included in the standard specifications. Conversely, γ_i^{-1} measures the number of patents that firm i must develop in order to obtain one essential patent. We define *technology rivalry* between the firms as follows:

$$m = \sum_{i \in \mathcal{N}} \gamma_i^{-1} \geq n \tag{2}$$

This parameter can be interpreted as a measure of the degree of complementarity or substituability between the firms' innovations. Setting $m = n$ implies in particular that the firms' innovations are perfect complements: each of them can be adopted without evicting another one. More generally, the ratio m/n provides us with a measure of the degree of rivalry between the different technology alternatives promoted by the firms. For instance, a ratio $m/n = 10$ means that only one out of ten innovations developed for the standard will become essential. At the firm level, observe finally that firm i has a relatively weak position vis-à-vis other firms if $\gamma_i < n/m$.

2.1 Public good or patent race

We first highlight that two types of coordination failure that may prevail in this context. Each firm $i \in \mathcal{N}$ defined by $\{\gamma_i, s_i\}$ makes its investment decision so as to maximize $B_i - cy_i$. Solving this problem over x_i yields the first order condition below:

$$v'(x)\left[r\frac{x_i}{x} + (1-r)\, s_i\right] + rv(x)\,\frac{x - x_i}{x^2} = \frac{c}{\gamma_i} \tag{3}$$

The term in brackets captures the public good nature of the standard. It implies that firm i's direct incentive to develop the standard is proportional to the share of the value it can appropriate. The second term captures a patent race effect: To appropriate part of the expected profit, firm i needs to invest more the higher the number of essential patents held by its R&D competitors. It is easy to check that the LHS of equation (3) is decreasing in x, so that the firms' decisions are strategic substitutes.

Summing the FOC of all firms $i = 1, n$, we derive the joint R&D investment x^* in equilibrium.

$$\frac{1}{n}\left[v'(x^*) + rv(x^*)\,\frac{n-1}{x^*}\right] = c\frac{m}{n} \tag{4}$$

The aggregate marginal profits (LHS) again combine the properties of a public good investment (marginal benefits are diluted when the number of firm increases) and a patent race (when $r > 0$, extra incentives are stronger the larger the number of competitors). On the RHS, the aggregate marginal cost of essential patents is higher when *technology rivalry* is strong (large m/n).

Observe also that the aggregate marginal cost does depend on the distribution of the γ_i between the firms, but only on the degree of technology rivalry at the aggregate level (m/n). We use this property to study how the structure of the incentives affects the efficiency of firms' investments. Let us consider a social program wherein a unique representative firm with *selection rate* $\overline{\gamma} = \left(\frac{m}{n}\right)^{-1}$ maximizes aggregate profits:

$$\max_x \Omega = v\left(x\right) - cx/\overline{\gamma}$$

Comparing the outcome of this program with the equilibrium outcome, we can establish the following result.

Proposition 1 *Aggregate investment in equilibrium is efficient if the licensing revenues* $rv\left(x^*\right)$ *equals the total R&D cost* $cx^*/\overline{\gamma}$*. Firms invest in excess if licensing revenues exceed total cost and they underinvest in the reverse case.*

Firms' incentices to innovate can induce either too much (patent race pattern) or too little (public good pattern) investment. Which one prevails in equilibrium depends on the balance between total licensing profit and the total R&D cost at equilibrium. Firms engage a patent race if

$$rv\left(x^*\right) > \frac{cx^*}{\overline{\gamma}} \tag{5}$$

Intuitively, a patent race takes place when licensing is profitable per se, so that firms will compete in R&D in order to preempt the essential patents. Conversely, the public good equilibrium emerges when firms' incentives are primarily driven by the possibility to use the standard.

Observe that condition (5) also implies that the participation of a pure R&D firm i ($s_i = 0$) with average sucess rate $\gamma_i = \overline{\gamma}$ is profitable only in a patent race equilibrium:

$$(5) \quad \Leftrightarrow \quad \frac{x_i^*}{x^*} rv\left(x^*\right) - c\overline{\gamma}x_i^* > 0 \tag{6}$$

Corollary 2 *The participation of pure R&D firms signals a patent race pattern in equilibrium.*

We will use this result in the empirical section to infer the existence of a patent race equilibrium from the participation of pure R&D firms. We can finally observe that the number of firms does not determine the type of equilibrium that prevails, but its magnitude. Hence Proposition 1 and its corrollary are robust to allowing free entry of firms in the standardisation game.

Corollary 3 *The inefficiency pattern prevailing in equilibrium does not depend on the number of firms, and is thus robust to free entry.*

2.2 Efficiency of consortium membership

Recall that the consortia we are interested in do not involve any formal contracting or joint R&D decisions. They rather function as fora wherein participating firms seek to agree on a mutually acceptable roadmap for specifications that they will jointly push in the SDO. Accordingly, we posit that consortium members can better focus their R&D effort, thereby saving useless investments and enhancing their chances of obtaining essential patents. Assuming that a subset of firms $\mathcal{K} \subset \mathcal{N}$ have created a consortium to support the standard setting process, members thus benefit from a higher selection rate[5]: $\gamma_{k\in\mathcal{K}} > \gamma_{k\in\mathcal{N}\backslash\mathcal{L}}$ where $\mathcal{L} = \mathcal{K}\backslash\{k\}$.

We focus on the consequences of firm k's decision to join the consortium[6]. Formally, this firstly translates into a positive shock on the new member's selection rate ($d\gamma_k > 0$). Since firm k can better screen irrelevant innovation opportunities, this in turn induces a fall in the degree technology rivalry at the aggregate level: $dm/d\gamma_k = -\gamma_k^{-2} < 0$. It thus follows directly from (4) that the number of essential patents embodied in the standard increases in equilibrium. Since the firm's decisions are strategic substitutes, it is moreover clear from (3) that firm k develops more essential patents while the other firms react by developing less of them. Lemma 4 summarizes these results.

Lemma 4 *Joining the consortium enables the new member to develop more essential patents in equilibrium, while the other firms develop less essential patents. The net effect is positive, and thus induces an increase of the equilibrium value of the standard* $v(x^*)$*.*

This result does not necessarily imply that an enlarged consortium coalition is efficient, since it does not take into account the induced variation of firms' R&D costs. Indeed, deriving firms' aggregate profits $\Omega = v(x^*) - c\sum_i x_i^*/\gamma_i$ wrt γ_k and rearranging makes it possible to highlight the following three effects:

$$\frac{\partial\Omega}{\partial\gamma_k} = \underbrace{\frac{cx_k^*}{\gamma_k^2}}_{A} + \underbrace{\frac{\partial x^*}{\partial\gamma_k}\left[v'(x^*) - \frac{c}{\bar{\gamma}}\right]}_{B} + \underbrace{c\sum_i \frac{\partial x_i^*}{\partial\gamma_k}\left[\frac{1}{\bar{\gamma}} - \frac{1}{\gamma_i}\right]}_{C} \tag{7}$$

The first effect corresponds to R&D costs savings induced by firm k's ability to reduce the volume of non-essential patents (A). It is clearly positive. The second one is the net (cost/benefit) value of adding new essential patents to the standard (B). It is clear from the term in brackets that it is positive in a *public*

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[5] We implicitely assume here that the size of the consortium coalition does not change the success rate of former members or consortium outsiders. In other words, the only effect of consortium membership is a better access to information of future specifications. The entry of a new member in the coalition nevertheless indirectly affects former members and outsiders through the new member's stronger ability to preempt essential patents in the standard.

[6] In practice, firms have to pay significant membership fees to join consortia, and therefore decide to do so only if they have significant stakes in the standard. The benefits in terms of information and influence strongly depend on idiosyncratic factors such as the degree of compatibility between the firms' technology profiles and strategic agenda.

good equilibrium. Indeed new patents can then mitigate firms' lack of investment in the standard. By contrast, developing more essential patents reduces joint profits in a *patent race* equilibrium. Finally, the third effect captures the cost or benefit of reallocating the development of essential patents between the firms (C). Its sign may be positive of negative, depending on the selection rate of firm k as compared with the other firms. Lemma 5 summarizes these findings.

Lemma 5 *A firm's entry in the consortium deflates the volume of non-essential patents, which is clearly efficient. By contrast, the inflated volume of essential patents may be inefficient if i) a patent race pattern prevails in equilibrium and/or ii) it entails a reallocation of R&D effort from efficient to inefficient firms.*

In order to carry further the analysis, we now focus on the direct effects of firm k's patenting strategy on joint profits, aside from the other firms' reactions[7]. We are especially interested in relating joint profits with the (empirically obervable) total volume of patents filed by firm k. Assuming that firm k has average selection rate ($\gamma_k = \overline{\gamma}$), we can establish that

$$\frac{cx_k^*}{\gamma_k^2} + \frac{\partial x_k^*}{\partial \gamma_k}\left[v'\left(x^*\right) - \frac{c}{\overline{\gamma}}\right] > 0 \quad \Leftrightarrow \quad dy_k^* < \Delta \frac{dx_k^*}{\overline{\gamma}} \tag{8}$$

where

$$dy_k^* = \frac{dx_k^*}{\overline{\gamma}} - x_k^* \frac{d\overline{\gamma}}{\overline{\gamma}^2}$$

is the variation of the total number of patents filed by firm k (that is, the difference between the volumes of spared patents and new essential patents) and $\Delta = \overline{\gamma} v'\left(x^*\right)/c$. Since $\Delta > 0$, condition (8) clearly holds if the total volume of firm k's patents is deflated. This is quite intuitive, since firm k then develops more essential patents and saves at the same time the R&D cost of an even larger volume of useless patents.

The effect of firm k's move is more ambiguous if joining the standard has a patent inflating effect. Indeed the benefit of enhancing the standard's value must then be balanced with the cost of a larger volume of patents. As stated in Proposition 6, the new member still invests more efficiently provided the *public good* pattern prevails in equilibrium. Indeed, it thereby provides more of the missing essential patents, and it does so at a lower cost thanks to consortium membership. By contrast, and inflated volume of patents filed by the new member may harm efficiency in a *patent race* pattern, unless the volume of extra non-essential patents remains sufficiently small to be compensated by the benefit of new essential patents.

Proposition 6 *Assume that a firm with average success rate joins the consortium:*

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[7] This can also be interpreted as an approximation of the full effects when the reactions of the other firms are negligible. We will see in the next section that this interpretation is actually supported by empirical evidence.

- *A deflated volume of patents filed by the new member is efficient whatever the inefficiency pattern prevailing in equilibium.*

- *A inflated volume of patents filed by the new member is efficient in a public good equilibirum. It becomes inefficient in a patent race equilibrium when it exceeds a positive threshold* $T \in (0, dx_k^*/\overline{\gamma})$.

Proof. Observe also that $\Delta > 1 \Leftrightarrow v'(x^*) - v'(x^*) - c/\overline{\gamma} > 0$, which is the condition for the *public good* pattern to prevail in equilibrium. Since $dy_k^* < dx_k^*/\overline{\gamma}$, it directly follows that condition (8) is also verified in a *public good* equilibrium when firm k inflates its volume of patents. By contrast, the *patent race* pattern prevails when $0 < \Delta < 1$. Hence joint profits can increase only if the inflation of firm k's patents remains moderate, that is if $dy_k^* < T \in (0, dx_k^*/\overline{\gamma})$. Otherwise, a strong inflating effects induces a fall of joint profits. ■

3 Empirical analysis

This section in turn presents an empirical analysis of patent filings around a large panel of ICT standards. Our purpose is to assess whether joining a consortium changes the volume of patents filed by firms involved in standard development, and what is the direction of this change. Drawing on the results of our theoretical analysis, we assess this effect separately for standards corresponding respectively to a *public good* or *patent race* pattern.

3.1 Data and indicators

Our empirical analysis draws on a comprehensive dataset of technological standards including essential patents[8]. Our sample includes all ICT standards issued between 1992 and 2009 by one of the major formal SSOs which operate on an international level[9]. Since we aim to focus on the interaction between formal standardization and companion consortia, we exclude standards that are exclusively developed by informal standards consortia (e.g. BluRay).

We furthermore restrict the analysis to standards including essential patents of at least two different companies, thereby limiting the sample to 578 standards. Companies that own IPRs which are essential to a standard provide this information to the respective SSO. We downloaded these patent declarations at the websites of the above-mentioned SSOs in March 2010. From the PERINORM[10] database we retrieve information on the date of first release, releases of further versions and amendments, number of pages from the standard document such as the technical classification of the standard.

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[8] A summary of all relevant variables with description and sample statistics can be consulted in Appendix 1

[9] ISO, IEC, JTC1 - a joint committee of ISO and IEC -, CEN/CENELEC, ITU-T, ITU-R, ETSI, and IEEE.

[10] PERINORM is the world's biggest standard database with bibliographic information on formal standards and is regularly updated by the SDOs DIN, BSI and AFNOR.

Our sample includes 242 different companies declaring essential patents, observed over the whole period. For each firm, we collect yearly information on the amount of sales, R&D expenditure, employees and market to book ratio (Tobin's Q[11]). In addition we distinguish between pure R&D firms, manufacturer and net provider[12] and classify our sample by main active industry using SIC codes.

We connect the firm level data to the specific standard information and built up a panel of 1,720 company-standard pairs observed over a time span of 18 years (1992-2009). For each company-standard pair, we observe the amount of patents filed by the respective company in the technological field for the respective standard, and include a dummy variable indicating whether the company takes part in a consortium supporting the development of this standard. Other time-variant control variables are either company- or standard-specific. Time-invariant factors affecting the firm, the standard or the relationship between both are captured by company-standard pair fixed effects.

Matching between informal consortia and formal standards To identify informal consortia accompanying the formal standardization process, we use data from 15 editions of the CEN survey of ICT consortia and a list of consortia provided by Andrew Updegrove. We identify approximately 250 active ICT consortia[13]. We categorize these consortia as to industry, function (spec producer, promoter) and years of activity (see Appendix 1). The connection to a standard in our sample is analyzed by using liaison agreements and information from consortia and SSO web pages. For instance, a connection was identified, when a consortium explicitly references a formal standard, or when a standard has been submitted to the formal SSO by an informal consortium. We are conservative in establishing the connections, resulting in a narrow list of 54 consortia. We use supplementary information for the selected consortia and further restrict the list to 21 consortia that technologically (spec producer) and significantly contribute to this specific standard (excluding pure promoting consortia)[14]. Using information on the websites of the consortia as well as internet archives (www.archive.org) and internet databases (www.consortiuminfo.org), we inform consortium membership over time and connect this information with the company standard pairs of our sample.

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[11] We used the Thomson one Banker database to match the respective firm level data.

[12] We used the extended business model description in the Thomson One Banker database and compared our classification to the list of companies identified by Layne-Farrar and Lerner (2010).

[13] This is coherent with the identification of the CEN survey which reports approximately 250 standards consortia in ICT.

[14] Assisting this rather broad distinction we conduct a word count analysis on the consortia self-description abstracts, kindly provided by Andrew Updegrove. We use keywords such as "developing", "creates", "set standard" or "standardizes". Appendix 1 provides a list of those consortia and standards for which a link could be established, as well as the narrower list of consortia contributing technologically.

Standard-specific patents The most intuitive approach to track firms' R&D investments in standards is to count the patent declarations they state for these standards. However, former empirical analyses have shown that the timing of declaration is not connected to the dynamics of standardization (Baron and Pohlmann, 2010). Moroever essential patents only represent a very small amount of patenting around standards (Bekkers et al., 2012). To avoid these shortcomings, we thus build up a new measure of firms' standard-specific R&D investment. In a first step we count patents filed from 1992 to 2009 by the companies in our sample at the three major patent offices (USPTO, JPO and EPO), using the PatStat database and the company assignee merging methods of Thoma et al. (2010). We restrict the count of patent files to IPC classes in the relevant technological field of each standard, identified by using the IPC classification of declared essential patents[15]. We measure the dynamics of patenting over the standard lifecycle (details can be consulted in Appendix 3). Our mean value analysis shows a patenting increase before standard release and a decrease thereafter. This finding reassures us that our variable captures the innovation for a specific standard, which indeed is expected to culminate in the period immediately preceding standard release.

Public good **and** ***patent race*** **patterns** One contribution of our analysis is the comparison of over- and under investment in standardization. As shown in the theroretical model, the *patent rac*e pattern can be identified when pure R&D firms take part in the standard development. We use this prediction as our identification strategy for the empirical sampling of standards. By labeling over- and underinvestment as to the classification above, we compare the residual results of a regression of standard related patent files against technical characteristics of the standards(details can be consulted in Appendix 4). A t-test analysis suggests that our classification of overinvestment is an appropriate measure. Results show that residual values of the regression are in average positive for standards where pure R&D firms participate to a standard and in average negative for those where pure R&D firms are not involved.

3.2 Descriptive Statistics

Pairwise correlations In the following Table 1, we provide pairwise correlations of firm-specific, standard-specific and firm-standard-specific variables at the company-standard-pair level.

Insert Table 1 about here

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[15] This method is a novel way of measuring standard-specific R&D investment. We apply tests of timing, estimate technological positions of standards as well several test of size measures to prove our proposed variable to be a sufficient indicator of standard-related R&D investment. The methodology and the various tests have been presented at the Patent Statistics for Decision Makers Conference 2011 at the USPTO and can be reviewed in Appendix 3.

The volume of patents around standards is negatively correlated with both consortium membership and the existence of a consortium on the standard. This could indicate that consortia attract companies with smaller standard-related patent portfolios. On the other hand, consortium membership is positively correlated with the value of sales and the number of employees. The existence of consortia is positively correlated with the number of firms per standard and with standard age. As to the correlation analysis effects are yet not strong enough to derive conclusive interpretations.

Difference in means In the following Table 2, we present differences in the volume of patents, the number of employees, the value of sales and the book-to-market ratio between consortia member observations and the rest. Membership observation is associated with a lower volume of standard-specific patents, but a higher number of employees and a higher value of sales.

Insert Table 2 about here

3.3 Multivariate Analyses

Estimation methodology We use our panel dataset to estimate how consortium membership affects the volume of patents filed around the related standard. Our dependent variable is the number of patent priority filings by firm i for standard j in year t. Our first key explanatory variable, $member_{ijt}$, is a dummy equal to one for years where the firm i participates in a consortium supporting standard j. Following the theoretical model, we expect its effect to depend upon whether the standard is initially characterized by over- or underinvestment. We therefore also interact the consortium membership dummy with the $over\_investment_j$ variable, denoting the share of pure R&D firms involved in the develoment of standard j.

To account for unobserved heterogeneity of standards and companies, we systematically include fixed effects for company-standard pairs. As our dependant variable is a count variable with overdispersion with respect to a poisson distribution, we will use a poisson estimator with robust standard errors unless explicitly stated otherwise[16]. We furthermore cluster standard errors by companies in order to exclude that unobserved shocks to a company's patenting level bias the standard errors and lead to an insufficiently restrictive confidence interval[17]. Unsurprisingly, we found strong evidence for persistent effects of transitory shocks to our explained variable, as indicated by positive autocorrelation of standard errors. We therefore include the lagged dependent variable as explanatory variable in all models.

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[16] We prefer the poisson estimator with robust standard errors over a negative binomial estimator with fixed effects, because the negative binomial estimator cannot totally control for fixed effects and thus account for unobserved heterogeneity.

[17] All presented results are robust to clustering standard errors by standard instead of by company.

Our basic regression model has the following specification:

$$\begin{aligned} st\_patents_{ijt} &= \exp\big(\alpha_1.st\_patents_{ijt-1} \\ &\quad +\beta_1.member_{ijt} \\ &\quad +\beta_2.member_{ijt} * over\_investment_j \\ &\quad +\beta_3.st\_activity_{jt-1} \\ &\quad +F'_{it-1}\beta_4 + X'_t\beta_5 + c_{jt} + \varepsilon_{ijt}\big) \end{aligned}$$

where $st\_activity_{jt-1}$ counts version releases and amendments per year, F_{it-1} is a vector of firms specific change such as a measure of Sales and Tobins's Q, X_{jt-1} denotes other control variables for time trends such as the overall ICT patent files and the count of patent declarations, c_{jt} are standard age dummies and ε_{ijt} is an idiosyncratic error term.

We use the standard age dummies, each indicating a one year period in the standard lifetime, to control for the timing of standardization. Downstream innovation and patenting (taking place after the first release of the standard) is indeed likely to peak around periodical revisions of standards. The release of new standard versions or amendments to existing versions is labeled as standard activity and included as a control variable. In order to exclude immediate feedback (amendments or version releases explained by prior innovation), we include this control variable with a one-year lag.

We furthermore wish to account for external shocks such as the business cycle or technology-related policy. As we already control for standard fixed effects and standard age, it is impossible to include year dummies as a further control because of a collinearity problem. We therefore control for external shocks by including the overall number of triadic patent priorities filed per year in the relevant technological category (respectively IPC class G for telecom and IPC class H for IT standards) and the overall number of patent declarations made to any formal ICT standard per year in order to capture policy shocks that are more specifically relevant to essential patents.

Models 1-4 Consortia are more likely to be created for important or technologically complex standardization projects. Furthermore, the organization of R&D can be different if a consortium is created for a standard. For these reasons, the timing of standardization is likely to be affected by the existence of consortia. It is thus preferable to estimate all coefficients, including controls for standard timing, only on the sample of standards related to an informal consortium. This strategy could however bias downwards the estimated effects of consortia, if some of these effects are systematically captured by control variables. We therefore present results based upon the whole sample in model M1. As expected, the coefficients on consortia variables are higher in the larger sample, but the fit of the model is much lower. This indicates that heterogeneity between standards with consortia and other standards is large. We therefore only estimate standard with accompanying consortia in all following models (M2-M4), while acknowledging a potential downward bias on our consortia coefficients.

In our second model (M2), consortium membership has a significant positive effect on the volume of standard-specific patents, but the level of this effect decreases with the level of overinvestment. This result is however potentially subject to an endogeneity bias. Unobservable variables, such as changes in the strategic importance of the standard for the specific company, may have an impact on both standard specific patents and consortium membership. External factors jointly affecting consortium membership and related patenting are particularly likely to occur in periods of turmoil, like the internet bubble in 2001. While desirable in order to reduce within-groups bias on weakly endogenous variables (Nickell, 1981; Bloom et al., 2005), the long period of observation (relatively to the fast-evolving world of ICT standards) increases the vulnerability to this type of biases.

Insert Table 3 about here

In order to deal with these concerns we restrict the observation period to 8 years from 2002 to 2009. Furthermore, we also reduce the cross-section dimension of the panel, by restricting the sample to stock-market listed companies. These companies are more likely to react in a similar fashion to external events. Finally, we identify positive or negative shocks to the number of employees in a one year period[18], indicating mergers, acquisitions, restructuring etc. If this shock takes place after 2005, all observations after the shock are dropped for this company, if the shock takes place earlier, we drop all previous observations. Companies with more than one shock are dropped altogether for our third model (M3), reducing the sample to 174 groups and 999 observations.

In our last model M4 we furthermore tackle endogeneity more directly by including time-varying firm characteristics as control variables. We choose to include the value of sales, and Tobin's Q as a measure of expected profits (both lagged by one year to exclude immediate feedback). We opt for not including employees, which is highly correlated with sales in the within dimension (both reflecting company growth). Furthermore, the number of employees, with respect to the value of sales, is likely to be more important for determining whether a company has the possibility to participate in a consortium, but less important in independently determining the evolution of patenting[19]. By including the value of sales as a control, we nevertheless face the risk to bias downwards the estimates of the consortia effects for smaller companies refraining from joining an expensive consortium. We therefore divide the level of consortia member fees[20] by the value of sales of the company at the time of consortium creation. The first percentile of observations according to this value (the companies-standard pairs characterized by the highest consortia fees relative to the value of sales) is

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[18] distribution, the lower 5% are labeld as negative shocks.

[19] The primary cost of consortium participation is workload, while the cost of patenting is primarily financial

[20] Since our goal is to estimate the financial burden to join a consortium we use the low range of membership fees (find an overview of highest and lowest membership fees in the appendix 1).

most at risk to be affected by this effect. We therefore decide to exclude these observations, leaving us with 158 company-standard pairs and 884 observations in model 4.

M1-M4 show robust results. The magnitude of the coefficients decreases but the effects are yet more significant, and the signs of the coefficients are unchanged.

Further robustness checks We check for robustness of our results to a correlation of our main explanatory variables with past outcomes of the dependent variable. It is plausible that a company's decision to join a consortium depends upon its stock of related patents. In this case, the regressors are predetermined, and the poisson fixed effect estimator yields inconsistent results (Blundell et al., 1999). In order to account for this problem, we take advantage of the fact that we have information on pre-sample levels of our dependent variable and adopt the methodology suggested in Blundell et al. (1999), substituting pre-sample means for fixed effects. The results displayed in Appendix 5 are mainly consistent with the results from the fixed effect analysis.

Effect of consortium member share So far we have estimated the effect of consortium membership on the volume of patents of the respective company. In this section, we will estimate the effect of the consortium member share (indicating how many of the firms contributing to the standard are member of the consortium) on the volume of patents filed by members and outsiders. Finally, by estimating the effect of consortium member share on patents filed by all companies, we obtain a measure of the net effect of consortia.

As compared to the previous analysis, this method is less prone to endogeneity biases, as the decisions of other companies to join a consortium are probably relatively unrelated to a firm's own current or expected future R&D efforts. We are therefore less restrictive regarding the sample, and only drop observations for 2001 or earlier and of standards with no consortium within the observation period. On the other hand, the member share is sensitive to the membership decision of the firm itself, especially if the number of firms on the standard is low[21]. In order to check for robustness to this sensitivity, we present all results for a narrower subsample of standards including at least 6 contributing firms.

We estimate the effects of consortium member share separately for consortium members and non-members and for both. For the purpose of this analysis, a firm is labeled as a member over the whole period of observation, if it is consortium member at least once within this period. It is labeled consortium outsider if it has never been consortium member over the period of observation. We control for time-variant firm characteristics, standard-company fixed effects, the lagged dependent variable and external shocks. Results are displayed in Table 4.

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[21] If we substracted the company itself from the consortium size variable, this count would be nevertheless sensitive to company membership, as we estimate the effects separately for consortium members and non-members.

Consortium members react to increasing consortium member share by inflating their patent filings, but this effect decreases with the level of overinvestment (model 5). Consortium outsiders do not react in a statistically significant way to changes in consortium member share (model 6). The overall effect (the effect indistinctly for members or outsiders) of increasing consortium member share on the volume of standard-specific patents is positive and significant, but this effect decreases significantly with the level of over-investment (model 7).

Insert Table 4 about here

Net effects Our results suggest that nearly all effects of consortia depend upon the initial level of overinvestment. In order to be able to discuss the effect of consortia on patenting, one should therefore relate the estimated coefficients to the sample values of the overinvestment indicator. We calculate the net effects from the results of model 5 (for the effect of consortium membership) and model 7 (the overall effect of consortium member share in the whole sample). We find that the effect of consortia membership is positive for any share of non-practicing entities not exceeding 6 %. This is the case for 92,12% of the observations. The effect of consortia member share on overall volume of patents is positive for any share of non-practicing entities below 9 %. This is the case for 94,13% of the observations. These results indicate that the effects of consortia membership and consortia member share on standard-specific R&D are positive in a broad majority of standards[22]. However, they also suggest that consortia can have a deflating effect in a minority of standards that are characterized by a particularly strong patent race pattern.

4 Conclusion

The purpose of the paper is to assess how consortia influence the volume of patents filed around formal standards, and whether this is efficient. In the first theory section, we defined consortia as a means to reduce the degree of rivalry between the firms' innovations. Accordingly, consortium members can obtain essential patents at a lower average cost, by better targeting R&D investments. The effect on the volume of patents filed around the standard is however ambiguous. By joining a consortium, a firm may indeed file less patents by cutting irrelevant R&D investments, or more of them if it seeks to develop more technology inputs for the standard. We have established that consortium membership is always pro-efficient if the first effect dominates. A patent-inflating consortium is also pro-efficient in a *public good* equilibrium, but it may actually harm efficiency in a patent race equilibrium if it induces an excessive inflation of patents around the standard.

Our empirical analysis makes it possible to assess which effect actually dominates, depending on the investment pattern – *public good* or *patent race* –

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[22] The negative effect of consortia membership and relative consortia size on R&D investment in situations of overinvestment is however stronger than this positive effect.

prevailing for a given standard. When joint investments are suboptimal (*public good* pattern), the observed rise in patent files indicates that consortium membership induces firms to develop more innovations, rather than saving R&D costs. Since royalty-based incentives are weak in this case, this suggests that their reaction is chiefly driven by the opportunity of enhancing the value of the standard by developing more essential components. Consortia are thus an efficient way to supplement the lack of R&D investments when incentives to develop the standards ar not sufficient.

Empirical results differ when the *patent race* pattern prevails. For most standards, new consortium members still increase their patent applications, but in significantly lesser proportions than in the *public good* cases. Since firms have strong strategic incentives to develop essential patents, this suggests that there are few opportunities left for developing innovations that are relevant to the standard. For some standards featuring strong overinvestment, we even oberve that consortium members reduce their investments – consortia being then used to save R&D costs by eliminating irrelevant R&D investments. These results thus indicate that the creation of consortia does not significantly accentuate patent races, and rather has a proefficient deflating effect for at least a minority of standards around which overinvestment is particularly strong.

References

[1] Baron, J., Pohlmann, T. (2010) "Patent Pools and Patent Inflation – The effects of patent pools on the number of essential patents in standards", Cerna working paper

[2] Bekkers,R., Catalini, C., Martinelli, A., Simcoe, T. (2012) "Standardizing Intellectual Property Disclosure Data", NBER Working Paper Series.

[3] Benner, M., Waldfogel, J. (2008) "Close to you? Bias and precision in patent-based measures of technological position", Research Policy, 37: 1556-1567.

[4] Blind, K., Gauch, S. (2008) "Trends in ICT standards: The relationship between European standardization bodies and standards consortia", Telecommunications Policy 32 (2008) 503– 513.

[5] Bloom, N., Schankerman, M., Van Reenen, J. (2005) Identifying technology spillovers and product market rivalry, Proceedings, Federal Reserve Bank of San Francisco

[6] Blundell, R., Griffith, R., Windmeijer, F. (2002) Individual Effects and Dynamic Feedback in Count Data Models. Journal of Econometrics, 87, pp. 115-143

[7] Branstetter, L., Sakakibara, M. (2002) "When Do Research Consortia Work Well and Why? Evidence from Japanese Panel Data", American Economic Review, vol. 92, no. 1, March 2002, pp. 143-159.

[8] Cargill, C., Weiss, M. (1992) "Consortia in the Standards Development Process", Journal of the American Society for Information Science, Volume 43 Issue 8, 559 – 565.

[9] Cargill, C. (2002) "Intellectual Property Rights and Standards Setting Organizations: An Overview of failed evolution", A Report Issued By the U.S. Department of Justice and the Federal Trade Commission, March 2002.

[10] Chiao, B., Lerner, J., Tirole, J. (2007) "The Rules of Standard Setting Organizations: an Empirical Analysis" RAND Journal of Economics, 38:4, pp. 905-930.

[11] David, Paul A, Shurmer, Mark (1996) "Formal standards-setting for global telecommunications and information services. Towards an institutional regime transformation?", Telecommunications Policy, Volume 20, Issue 10, December 1996, Pages 789-815.

[12] Delcamp, H., Leiponen, A. (2012) "Innovating Standards Through Informal Consortia: The Case of Wireless Telecommunications" NBER Working Paper Series.

[13] Egyedi, T.M. (2003) "Consortium Problem Redefined: Negotiating 'Democracy' in the Actor Network on Standardization", International Journal of IT Standards & Standardization Research, 1(2), 22-38.

[14] Farrell, J., Simcoe, T. (2012) "Choosing the Rules for Consensus Standardization" RAND Journal of Economics (forthcoming).

[15] Fleming, L., Waguespack. D (2009) "Evidence on the Benefits to Startups Participating in Open Standards Development". Management Science, 55(2), pp. 210-223

[16] Ganglmair, B., Tarentino, E. (2011) "Patent Disclosure in Standard Setting" NET Institute Working Paper #11-15

[17] Gauch, Stephan (2008) "Dynamics and effects of competing standards of recordable DVD-media Author(s)" Gauch, S. Source Egyedi, T.M. ; Blind, K.: The dynamics of standards Cheltenham: Elgar, 2008 ISBN: 978-1-84720-486-8 ISBN: 1-84720-486-4 pp.47-67.

[18] Hawkins, Richard (1999) "The rise of consortia in the information and communication technology industries: emerging implications for policy" Telecommunications Policy, Volume 23, Issue 2, March 1999, Pages 159-173.

[19] Layne-Farrar, A., Lerner, J. (2011) "To join or not to join: Examining patent pool participation and rent sharing rules," International Journal of Industrial Organization, 29:2, pp. 294-303.

[20] Leiponen A. E. (2008) "Competing Through Cooperation: The Organization of Standard Setting in Wireless Telecommunications", Management Science Vol. 54, No. 11, November 2008, pp. 1904–1919.

[21] Lerner, J, Tirole, J. (2004) "Efficient Patent Pools". American Economic Review, 94:3, pp. 691-711.

[22] Lerner, J, Tirole, J. (2006) "A Model of Forum Shopping". American Economic Review, 96, pp. 1091-1113.

[23] Pohlmann, T. (2010) "Attributes and Dynamic Development Phases of Informal ICT Standards Consortia", Working Paper

[24] Rysman, M., Simcoe, T. (2008) "Patents and the Performance of Voluntary Standard Setting Organizations", Management Science, 54:11, pp. 1920-1934,

[25] Shapiro, C. (2001) "Navigating the Patent Thicket: Cross Licences, Patents Pools, and Standard Setting", in A. Jaffe, J. Lerner et S. Stern (Ed.), Innovation Policy and the Economy, Vol 1, MIT Press.

[26] Simcoe, T. (2007) "Explaining the Increase in Intellectual Property Disclosure", Pages 260-295, in Standards Edge: The Golden Mean. Bolin Group, 2007.

[27] Simcoe, T. (2012) "Standard Setting Committees: Consensus Governance for Shared Technology Platforms", American Economic Review, 102:1, pp. 305-336.

[28] Thoma G., S. Torrisi, Gambardella, A., Guellec, D., Hall, B. H., Harhoff, D. (2010) "Harmonizing and Combining Large Datasets – An Application to Firm-Level Patent and Accounting Data", NBER Working Paper No. 15851, March 2010.

[29] Updegrove, A. (1995) "Consortia and the Role of the Government in Standard Setting", in B. Kahin & J. Abbate (Eds.). Standards Policy for Information Infrastructure, Cambridge: MIT Press, 321-348.

APPENDIX

Table 1: *Pairwise correlations on the company-standard level*

		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	St. R&D Invest.	1.00							
2	Member	-0.10 ***	1.00						
3	Consortia Exists	-0.14 ***	0.67 ***	1.00					
4	Standard Event	-0.07 ***	0.39 ***	0.58 ***	1.00				
5	Tobin's Q	0.02	0.01	-0.04 *	-0.05 *	1.00			
6	Sales	0.11 ***	0.06 ***	0.01	-0.01	-0.25 ***	1.00		
7	Employees	0.10 ***	0.06 **	0.01	0.02	-0.33 ***	0.87 ***	1.00	
8	Number of Firms	0.05 **	0.34 ***	0.60 ***	0.62 ***	-0.09 ***	-0.02	0.00	1.00
9	Standard Age	-0.07 ***	0.17 ***	0.29 ***	0.32 ***	-0.20 ***	0.00	0.05 **	0.25 **

Table 2: *Differences in variable means between consortia members and others*

t = 4.1256 **Standard Specific Patent Files**

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
consortium members	261	2,238.6	190.8	3,081.9	1,862.9	2,614.2
not consortium members	1,571	12,092.8	972.8	38,559.2	10,184.6	14,001.0

t = -2.4585 **Employees**

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
consortium members	272	125,635.0	6,929.8	114,289.8	111,991.9	139,278.2
not consortium members	1,645	106,528.7	2,945.1	119,448.5	100,752.2	112,305.2

t = -2.6035 **Sales**

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
consortium members	272	40,119.1	1,774.0	29,257.4	36,626.5	43,611.6
not consortium members	1,644	35,211.2	708.4	28,721.6	33,821.8	36,600.6

t = -0.2502 **Book-To-Market Ratio**

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
consortium members	243	1.7	0.1	1.5	1.5	1.9
not consortium members	1,240	1.7	0.0	1.4	1.6	1.8

Table 3: *Results of the multivariate analysis – testing consortia membership (firm level)*

Unit of Observation = Company Standard Pair DV = Standard Specific R&D Investment (Patent Files)

	M1		M2		M3		M4		M5	
	Coef.		Coef.		Coef.		Coef.		Coef.	
Member	0.470	***	0.208	**	0.188	*	0.193	**	0.194	**
	(0.175)		(0.108)		(0.105)		(0.098)		(0.077)	
Member * Over Investment	-1.746	***	-1.135	*	-1.172	*	-1.203	*	-1.349	***
	(0.981)		(0.636)		(0.705)		(0.685)		(0.506)	
Lag1 Standard Activity	-0.061	*			-0.022	***	-0.022		-0.021	**
	(0.032)				(0.008)		(0.008)	**	(0.009)	
Lag1 Patent Files[1]	0.002	***	0.072	***	0.044	**	0.04	*	0.022	**
	(0.001)		(0.017)		(0.021)		(0.022)		(0.004)	
ICT Patent Files[1]	0.003	**	0.007	***	0.006	**	0.007	**	0.008	***
	(0.002)		(0.001)		(0.003)		(0.003)		(0.003)	
Patent Declarations[1]	-0.001		-0.003		0.002	***	0.004		0.008	
	(0.006)		(0.006)		(0.009)		(0.01)		(0.009)	
Lag1 Tobin's Q									0.088	
									(0.059)	
Lag1 Sales[1]									-0.011	***
									(0.003)	
Standard Year Dummies	Incl.		Incl.		Incl.		Incl.		Incl.	
Log Likelihood [2]	-17,820		-490.82		-68.55		-59.35		-114.06	
AIC [2]	35,600		981		137		118		228	
BIC [2]	35,600		981		138		118		228	
Observations	16,390		4,181		999		884		884	
Groups	1,046		298		174		158		158	

Note: All models are estimated with the conditional fixed-effects poisson estimator with robust clustered standard errors (reported in parentheses). Standard errors are robust to arbitrary heteroskedacity and allow for serial correlation through clustering by firm. Model 2-4 are restricted to a limited time period 2002-2009. ∗∗∗, ∗∗,and ∗ imply significance at the 99%, 95%, and 90% levels of confidence, respectively. [1]Coefficient multiplied by 1,000 to make effects visible. [2] Values are reported in thousand.

Table 4: *Results of the multivariate analysis – testing consortia member share (consortia net effect)*

Unit of Observation = Year DV = Standard Specific R&D Investment (Patent Files)

	M6				M7				M8			
	Coef.		Marg. Effekt		Coef.		Marg. Effekt		Coef.		Marg. Effekt	
Member_share	0.884	***	0.884	***	0.337		0.337		0.903	***	0.903	***
	(0.328)		(0.328)		(0.445)		(0.445)		(0.233)		(0.233)	
	-5.489	***	-5.489	***	-3.65		-3.65		-5.532	***	-5.532	***
Member_share * Over Investment	(1.923)		(1.923)		(2.177)		(2.177)		(1.346)		(1.346)	
	-0.022	**	-0.022	**	-0.035	**	-0.035	**	-0.027	***	-0.027	***
Lag1 Standard Activity	(0.011)		(0.011)		(0.012)		(0.012)		(0.009)		(0.009)	
Lag1 Patent Files [1]	0.013		0.013		0.078	***	0.078	***	0.022		0.022	
	(0.018)		(0.018)		(0.028)		(0.028)		(0.021)		(0.021)	
ICT Patent Files [1]	0.008	***	0.008	***	0.004		0.004		0.007	***	0.007	***
	(0.002)		(0.002)		(0.003)		(0.003)		(0.002)		(0.002)	
	0.009	*	0.009	*	0.008		0.009		0.007		0.007	
Patent Declarations[1]	(0.005)		(0.005)		(0.017)		(0.017)		(0.005)		(0.005)	
	-0.003		-0.003		0.003		0.003		-0.002		-0.002	
Lag1 Sales [1]	(0.004)		(0.004)		(0.003)		(0.003)		(0.003)		(0.003)	
Standard Year Dummies	Incl.				Incl.				Incl.			
Consortium	Member				Outsider				Both			
Log Likelihood [2]	-140.39				-29				-175			
AIC [2]	280				58				351			
BIC [2]	281				57				352			
Observations	1,288				735				2041			
Groups	169				107				276			

*Notes: All models are estimated with the conditional fixed-effects poisson estimator with robust clustered standard errors (reported in parentheses). Standard errors are robust to arbitrary heteroskedacity and allow for serial correlation through clustering by firm. ***, **,and * imply significance at the 99%, 95%, and 90% levels of confidence, respectively. [1]Coefficient multiplied by 1,000 to make effects visible. [2] Values are reported in thousand.*

Appendix 1: *Summary of relevant variables*

Variable	Description	Level of Obs.	Obs	Mean	Std. Dev.	Min	Max
Standard Specific R&D	Triadic Patent Priority Filings by this firm in the standard-related IPC classes	Firm-Standard-Year	31,020	1,072	4,022	0	91,121
Member	Membership of this Company in the Consortium related to this standard	Firm-Standard-Year	39,816	0.058	0.234	0	1
Over Investment	The share of non-producing entities for this standard	Standard	31,312	0.120	0.138	0	1
Standard Event	Sum of Amendments and version Releases	Standard-Year	36,918	0.292	0.979	1	37
ICT Patent Files	Triadic patent priority filings by all firms in either Telecom or IT	Standard-Year	37,621	223,320	52,748	132,721	301,890
Patent Declarations	Number of patent declarations to all formal standards	Year	39,834	3,538	4,038	78	13,938
Tobin's Q	Market-to-book ratio of the firm	Firm-Year	11,740	1.702	1.598	0.076	8.257
Sales	Value of sales per year in Million USD	Firm-Year	17,780	35,694	30,172	895	199,925

Appendix 2: *Linkages between standards and informal consortia*

Consortia Name	MatchStandard	Incl	Consortia Name	MatchStandard	Incl	Consortia Name	MatchStandard	Incl
EPCglobal	EN300220	No	WiMax	IEEE802.16	Yes	MPEGIF	ISO/IEC14496-14	Yes
DVB	EN300468	No	Cable Laboratories	IEEE802.1Q	Yes	MPEGIF	ISO/IEC14496-15	Yes
DVB	EN301192	No	FCIA - Fibre Channel Industry Association	IEEE802.1Q	No	MPEGIF	ISO/IEC14496-16	No
DVB	EN301199	Yes	MEF	IEEE802.1X	No	MPEGIF	ISO/IEC14496-18	Yes
DVB	EN301790	No	IETF	IEEE802.21	Yes	MPEGIF	ISO/IEC14496-19	No
DVB	EN301958	Yes	(GEA	IEEE802.3	No	ISMA	ISO/IEC14496-2	Yes
EPCglobal	EN302208	No	AUTOSAR	IEEE802.3/ISOIEC8802-3	No	MPEGIF	ISO/IEC14496-2	No
DVB	EN302304	No	FCIA	IEEE802.3/ISOIEC8802-3	No	MPEGIF	ISO/IEC14496-20	No
DVB	EN302307	No	HGI	IEEE802.3/ISOIEC8802-3	No	ISMA	ISO/IEC14496-3	Yes
DVB	EN302583	No	IETF	IEEE802.3/ISOIEC8802-3	Yes	MPEGIF	ISO/IEC14496-3	Yes
DVB	EN302755	No	MEF	IEEE802.3/ISOIEC8802-3	No	MPEGIF	ISO/IEC14496-4	Yes
DVB	ES200800	Yes	ODVA	IEEE802.3/ISOIEC8802-3	No	MPEGIF	ISO/IEC14496-5	Yes
IETF	ES201108	Yes	OIF	IEEE802.3/ISOIEC8802-3	No	MPEGIF	ISO/IEC14496-6	Yes
IETF	ES202050	Yes	Rapidio	IEEE802.3/ISOIEC8802-3	No	TAHI	ISO/IEC14543-2-1	No
IETF	ES202212	Yes	IETF	IEEE802.5/ISOIEC8802-5	No	IETF	ISO/IEC15444-1	No
WORLDDAB FORUM	ETS300401	Yes	INCITS	ISO/IEC10118-2	No	IETF	ISO/IEC15444-12	No
DVB	ETS300814	Yes	INCITS	ISO/IEC10118-3	Yes	IETF	ISO/IEC15444-2	No
DVD	ETSIEN300468	No	INCITS	ISO/IEC10536-3	No	IETF	ISO/IEC15444-3	Yes
IETF	G.711	Yes	INCITS	ISO/IEC10918-1/ITU-TT.81	Yes	IETF	ISO/IEC15444-5	No
IETF	G.722	Yes	TOG	ISO/IEC10918-1/ITU-TT.81	No	EPCglobal	ISO/IEC15693-2	No
IETF	H.263	Yes	INCITS	ISO/IEC11172-1	No	EPCglobal	ISO/IEC15693-3	No
IMTC	H.323	Yes	DVD	ISO/IEC11172-2	No	EPCglobal	ISO/IEC18000-1	No
IMTC	H.324	No	INCITS	ISO/IEC11172-2	No	EPCglobal	ISO/IEC18000-2	No
IETF	IEC6183411	No	DVD	ISO/IEC11172-3	No	EPCglobal	ISO/IEC18000-3	No
TOG	IEEE1003.1/ISOIEC9945	Yes	INCITS	ISO/IEC11172-3	Yes	EPCglobal	ISO/IEC18000-4	No
PICMG	IEEE1101.1	Yes	INCITS	ISO/IEC11693	No	EPCglobal	ISO/IEC18000-6	Yes
OCP-IP	IEEE1149.1	Yes	INCITS	ISO/IEC11694-1	No	AIM	ISO/IEC18000-6	No
BPMI	IEEE1226.5	No	INCITS	ISO/IEC11770-3	No	AIM	ISO/IEC18000-7	No
OMG	IEEE1226.5	No	INCITS	ISO/IEC11889-1	Yes	EPCglobal	ISO/IEC18000-7	Yes
PWG	IEEE1284	Yes	INCITS	ISO/IEC11889-2	Yes	ECMA	ISO/IEC18092	No
1355 Association	IEEE1355	No	INCITS	ISO/IEC11889-3	Yes	EUROSMART	ISO/IEC18092	No
1394TA	IEEE1394	Yes	INCITS	ISO/IEC11889-4	Yes	NFC Forum	ISO/IEC18092	Yes
AUTOSAR	IEEE1394	No	DMPF	ISO/IEC13818-1/ITU-TH.220.0	No	INCITS	ISO/IEC19794-3	No
DVD	IEEE1394	No	DVD	ISO/IEC13818-1/ITU-TH.220.0	No	INCITS	ISO/IEC19794-6	Yes
HAVi	IEEE1394	No	INCITS	ISO/IEC13818-1/ITU-TH.220.0	Yes	ECMA	ISO/IEC23651	No
PWG	IEEE1394	No	DVD	ISO/IEC13818-2/ITU-TH.262	No	GS1 – (Formerly EAN)	ISO/IEC24730-2	No
ODVA	IEEE1588/IEC61588	Yes	INCITS	ISO/IEC13818-2/ITU-TH.262	Yes	ECMA	ISO/IEC28361	No
ACCELLERA	IEEE1800/IEC62530	No	TOG	ISO/IEC13818-2/ITU-TH.262	No	TAHI	ISO/IECDIS29341	No

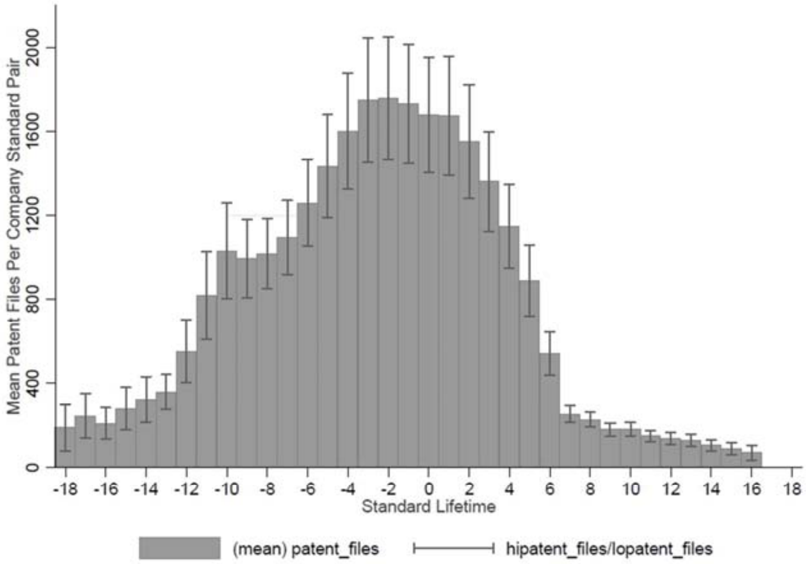
ACCELLERA	IEEE1801	Yes	DVD	ISO/IEC13818-3	No	UPnP Forum	ISO/IECDIS29341	Yes
Homeplug	IEEE1901	No	INCITS	ISO/IEC13818-3	Yes	ECMA	ISO/IECDIS29500	No
IVI	IEEE488.1/IEC60488-1	No	INCITS	ISO/IEC13818-7	No	3GPP2	Q.703	No
ASTM	IEEE802.11/ISOIEC8802-11	No	EUROSMART	ISO/IEC14443-1	No	DVB	TS102474	No
Bluetooth	IEEE802.11/ISOIEC8802-11	No	INCITS	ISO/IEC14443-1	No	DECT Forum	TS102527	No
DLNA	IEEE802.11/ISOIEC8802-11	No	NFC Forum	ISO/IEC14443-1	No	DVB	TS102584	No
ewc	IEEE802.11/ISOIEC8802-11	No	EUROSMART	ISO/IEC14443-2	No	DVB	TS102611	No
HGI	IEEE802.11/ISOIEC8802-11	No	INCITS	ISO/IEC14443-2	Yes	TV Anytime Forum	TS102822	No
IETF	IEEE802.11/ISOIEC8802-11	No	NFC Forum	ISO/IEC14443-2	No	DVB	TS102825	No
Wi-Fi Alliance	IEEE802.11/ISOIEC8802-11	Yes	EUROSMART	ISO/IEC14443-3	No	IMS FORUM	TS123002	No
100VG-Anylan Forum	IEEE802.12	No	INCITS	ISO/IEC14443-3	Yes	3GPP2	TS123401	No
IETF	IEEE802.12/ISOIEC8802-12	No	NFC Forum	ISO/IEC14443-3	No	3GPP2	TS123402	No
Bluetooth	IEEE802.15.1	No	EUROSMART	ISO/IEC14443-4	No	3GPP2	TS133402	No
WiMedia Alliance	IEEE802.15.3	Yes	INCITS	ISO/IEC14443-4	Yes	DRM	TS201980	No
DISA	IEEE802.15.4	No	NFC Forum	ISO/IEC14443-4	No	IETF	V.44	No
IETF	IEEE802.15.4	No	ISMA	ISO/IEC14496-1	Yes	3GPP2	X.509	No
TAHI	IEEE802.15.4	No	MPEGIF	ISO/IEC14496-1	No	ASTM	X.509	No
ZigBee	IEEE802.15.4	No	ISMA	ISO/IEC14496-10	Yes	Cable Laboratories	X.509	Yes
IETF	IEEE802.16	No	MPEGIF	ISO/IEC14496-10	No	ISMA	ISO/IEC14496-10/ITUH.264	Yes
			MPEGIF	ISO/IEC14496-12	Yes			

Appendix 3: *Empirical Methodology for measuring standard-related R&D*

We identified the relevant technological field for each standard by using the 7-digit IPC[1] classification of the declared standard essential patents, to then count patents filed by each company in the identified IPC classes. We counted all patents filed from 1992 to 2009 by the companies in our sample at the three major patent offices (USPTO, JPO and EPO), using the PatStat database and company assignee merging methods of Thoma et al. (2010). This merging yields 13 million patent files. We aggregated these patents to INPADOC patent families and informed the IPC classification and the year of priority. To create our explained variable, we computed for each company-standard pair and year the number of patents filed in the relevant IPC classes for the standard of observation.

This method is a novel way of measuring standard-specific R&D investment, and we therefore have to conduct a reliability analysis. We compute for each company-standard pair the mean number of patents filed in one year periods before and after standard release (t=0) and report the standard derivation for high and low values (figure1). The resulting pattern is a convincing description of the innovation process around standardization: the number of patents filed is highest in the years immediately preceding standard release, and sharply decreases after the release of the standard. The further we move away from the development phase of the standard, the lower are the calculated numbers of relevant patents. We believe that these findings are important arguments corroborating our methodology.

Figure1: *mean number of patents filed in years before and after standard release*



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[1] International Patent Classification

Appendix 4: Empirical Methodology for sorting standards into cases of over- and underinvestment

Based upon the theoretical model, we use the contribution of pure R&D firms to indicate overinvestment in a standard. We observe contribution of pure R&D firms in a standard using our database of companies that declare patents. Only firms that declare at least one patent on a standard are considered as contributors. Firms are classified as pure R&D firms using the business description database of Thomson One Banker and the companies identified by Layne-Farrar and Lerner (2011).

Using this classification, we create two sub samples, one where pure R&D firms contribute to the standard and one where pure R&D firms are not at place. We test over- and underinvestment by predicting the residual values of our specification. We run a linear fixed effect regression of our firm-standard pairs explaining patent files per year, controlling for standard dynamics and year trends and estimate the linear residual values[2]. We then compare the means of our residual values in both subsamples (pure R&D firms participate or not) conducting a t-test analysis.

The result of the t-test analysis in table 5 shows that in the case of overinvestment (pure R&D firms contribute), the mean residual value is positive and significantly higher compared to the subsample of underinvestment (pure R&D firms do not contribute). The estimated residual values indicate the level of patenting predicted upon our estimation equation. The differences of residual values among our observations thus reflect the heterogeneity of patent behavior among observations and help us to find proof for different outcomes of patenting when pure R&D firms contribute to a standard or not. Our findings indicate to confirm predictions from our theoretical model that pure R&D firms would only participate in standardization, when the licensing of the standard is characterized by a situation of overinvestment (positive residual values).

Table5: *T-test of residual values from a fixed effect regression on patent files controlled for standard dynamics and year trends*

T-test of linear residual values by pure R&D firms contribution

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
pure R&D firms do not contribute	16,121	-0.2435	0.0193	2.4512	-0.2814	-0.2057
pure R&D firms contribute	11,441	0.1145	0.0237	2.5347	0.0680	0.1609
combined	27,562	-0.0949	0.0150	2.4924	-0.1244	-0.0655
diff		-0.3580	0.0304		-0.4176	-0.2984

t = -11.7797
degrees of freedom = 27560
Ha: diff != 0 Pr(|T| > |t|) = 0.0000

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[2] We change our poisson specification to a liner regression, since residual values of poisson estimators will not produce conclusive results. We log transform our count variable of patent files and run a linear OLS fixed effect regression model to then predict the linear residual values in a post estimation analysis.

Appendix 5: *Robustness check substituting pre-sample means for fixed effects*

We apply the methodology developed by Blundell et al. (1999) to control for predetermined regressors. The authors suggest substituting the pre-sample averages of the dependent variable for the group fixed effect. While the fixed effects are estimated over the sample period, and are thus affected by the feedback of predetermined regressors, the pre-sample means are exogenous to the sample period values of the regressors. Analogous to our previous analysis, we set the period of observation from 2002 to 2009. In choosing the appropriate pre-sample period (1982-1992 or 1992-2001), we have to trade off endogeneity (several consortia memberships observed in the sample period have already existed in the period from 1992 to 2001) against heterogeneity (closer pre-sample values are a better approximation of the sample fixed effect than more remote pre sample information). As this model is intended to complement a fixed effect analysis, we choose the average of the period from 1982 to 1992 as pre-sample values[3]. We control for the same variables and operate the same sample restrictions as in the main models of our empirical tests. As our dependent variable is over-dispersed with respect to a poisson distribution and we no longer include group fixed effects, we now opt for a negative binomial regression. This allows us to further add standard dummies. The results are displayed in table 6. The coefficients of the consortia membership variables of models 11-1 and 11-2 as well as 12-1 and 12-2 are similar to our previous poisson fixed effect analysis with clustered standard errors. Models 11-1 and 11-2 estimate the firm level membership effect, while models 12-1 and 12-2 estimate the overall membership net effect. We run two models including and excluding the lagged sales variable and restricting the observations to 2002-2009. Our estimations provide significant results for the consortia variables in all models. Furthermore the coefficients of the pre-sample means are positive and significant in all specifications, which indicates that controlling for unobserved heterogeneity of the patent behavior is important.

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[3] Additionally including the closer pre-sample information (1992 to 2002) does not alter significantly the reported results.

Table 6: *Robustness analysis with mean scaling and negative binominal estimation*

	M11-1	M11-2	M12-1	M12-2
	Coef. (SE)	Coef. (SE)	Coef. (SE)	Coef. (SE)
Member	0.474***	0.186*		
	(0.094)	(0.101)		
Member *	-1.969***	-1.273**		
Over Investment	(0.62)	(0.635)		
Member_share			1.162***	1.947***
			(0.212)	(0.269)
Member_share *			-5.931***	-12.757***
Over Investment			(1.418)	(1.823)
Lag1 Patent Files^{1}	0.117***	0.105***	0.117***	0.103***
	(0.006)	(0.007)	(0.005)	(0.006)
ICT Patent Files^{1}	0.002***	0.006***	0.002***	0.006***
	(0.001)	(0.001)	(0.001)	(0.001)
Patent Declarations^{1}	0.001	0.011***	0.006	0.011***
	(0.001)	(0.003)	(0.001)	(0.003)
Pre Sample Means	0.162***	0.427***	0.173***	0.457***
(1982-1992)	(0.055)	(0.089)	(0.052)	(0.081)
Lag1 Sales^{1}		-0.007***		-0.007***
		(0.001)		(0.001)
Constant	-0.730***	-1.014***	-0.908***	-1.277***
	(0.158)	(0.298)	(0.162)	(0.297)
Standard Dummies	Incl.	Incl.	Incl.	Incl.
Standard Age Dummies	Incl.	Incl.	Incl.	Incl.
Log Likelihood	-26,487.9	-13,642.7	-26,492.5	-13,622.5
AIC	53,071.9	27,383.5	53,081	27,343.1
BIC	53,369.9	27,653.3	53,379	27,612.8
Observations	3,671	1,819	3,671	1,819
Groups	262	246	262	246

Notes: All models estimated with the conditional fixed-effects negative binominal estimator. Model 11-2,12-2 are restricted to a limited time period 2002-2009. ∗∗∗, ∗∗,and ∗ imply significance at the 99%, 95%, and 90% levels of confidence, respectively. [1]Coefficient multiplied by 1,000 to make effects visible.