R&D coordination in standard setting organizations: The role of consortia

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Abstract

We analyze R&D competition and cooperation between firms involved in the development of a technology standard. Our model captures the two counterweighting types of incentives these firms are subject to: free-riding due to the public good nature of the standard, and patent races in order to derive royalties from essential patents. As a consequence, R&D may be excessive or insufficient as compared to the collective optimum. Our purpose is to test empirically whether consortia can address any type of inefficiency, by either reducing or increasing collective R&D investment. We address this question empirically on a large dataset of ICT standards, by assessing the effect of consortia on the number of standard-related patents filed by companies. After sorting standards entailing over or underinvestment, our results confirm that in the first case consortia have a chilling effect on patent filings, while it has an inflating effect in the second case.

WORK IN PROGRESS, PRELIMINARY AND INCOMPLETE

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1 Introduction

Standard setting in the field of Information and Communication Technologies (ICT) has evolved from mere coordination on common specifications to the joint development of complex technology platforms. New generations of standards (e.g., 2G to 3G, or DVD to BluRay) tend to embody more components and functionalities. The rising number of essential patents claimed on standards (Simcoe, 2005) reflects this growing complexity. It also denotes the substantial licensing profits firms may derive from the large diffusion of their innovations if they are adopted in standard specifications.

Since formal standard setting organizations (SSOs) are opened to all interested parties, standard development can be seen as an original type of open innovation. However, SSOs are also perceived as slow and bureaucratic. In practice they are often supplemented by consortia, that is less formal alliances between sub-groups of firms. While some consortia may substitute for formal SSOs and issue their own standards, many of them accompany formal standardization taking place inside a SSO (Blind and Gauch). Leiponen (2008) has shown that consortia are efficient in leveraging their members' technology and increase their aptitude of influencing the outcome of formal standardization. Blind and Pohlmann (2011) argue that consortia membership increases the ability of a firm to introduce essential patents into a standard. Recent evidence also highlights that they are a way for their members to coordinate their R&D strategies (Delcamp & Leiponen, 2010).

In this paper, we asses the ability of consortia to improve the R&D efficiency of the standard development process. We first develop a theoretical framework highlighting the different types of R&D coordination failures that may arise in a standard setting environment. We use this setting to derive testable assumptions on the ability of consortia to address such coordination failures. We finally validate these assumptions empirical against a comprehensive database of contemporary ICT standards.

Our theoretical framework accounts for user-driven and royalty-driven incentives to invest in R&D. We show that, depending on the SSO IP policy, firms' contributions may lead to either insufficient or excessive R&D investment in equilibrium. Equilibria with excessive R&D occur when a too large share of the standard's value is appropriated by essential patent owners. Interestingly, they are also the only case in which pure R&D firms will engage in standard development.

Based on this model, we expect R&D coordination through consortia to either reduce or boost joint R&D depending on the type of inefficiency that prevails initially. We test these hypotheses against a comprehensive database of contemporary ICT standards. We identified firms' participation in standard development through the patent declaration database of the respective SSO. Furthermore, we matched our standards to a high number of informal consortia listed in the CEN standard consortia survey. We then in turn tracked back the information of consortium membership over up to 20 years. Using Patstat and the IPC classification of essential patents, we identified the patents filed by company by year in the technological field of the standard. These patents indicate the R&D effort undertaken by participating firms in view of obtaining essential patents. Our aim is thus to assess the effect of consortia on this variable.

Drawing on the theoretical framework, we use the participation of pure R&D firms to sort standards involving respectively insufficient and overinvestment. R&D coordination within consortia would then imply an R&D deflating effect of consortia for standards with pure R&D firms, and an R&D inflating effect for the rest. The econometric results largely confirm the coordination hypothesis. Controlling for the development stage of the standard and fixed effects for the firm-standard pair, firms that enter consortia significantly reduce patent files by firms in standards where pure R&D firms participate, while they increase patent files in the sample of other standards. At the aggregate level, the same effect is observed on total patent files when a firm joins the consortium.

Although standard-related consortia involve a weak form of coordination – based on information sharing rather than task sharing – these results can be related to other studies of consortia in other fields than standardization. The literature on R&D alliances (Katz 1986, Branstetter & Sakakibara, 2002) shows they internalize positive externalities due to spillovers or complementary capabilities, and can therefore induce an increase in their members' R&D. There is also case study evidence that some R&D alliances were beneficial to their members by reducing wasteful duplication of R&D investments (Irwin and Klenow, 1996).

The remainder of this article is organized as follows. Section 1 outlines the theoretical model and the empirical implications. Section 2 discusses the empirical strategy and the database. Section 3 presents descriptive findings and preliminary econometric results. Section 4 discusses shortcomings of this preliminary work, sketches ways for improvement and concludes.

2 Theoretical framework

We first develop a simple model describing collective investment to develop a standard. We consider a standard which implementation generated a profit market V in the industry. There are n firms investing in the standard. The R&D investment made by firm $i = 1,.,n$ is noted cx_i where c is a constant R&D cost parameter and x_i is the number of patented inventions developed by firm i. The total number of patents related to the standard is thus $X = \sum_{i=1}^{n} x_i$. The value V of the standard increases with the total R&D X dedicated to the standard development: $V'(X) > 0$. We also posit that the marginal benefit of R&D is decreasing $V''(X) < 0$.

A share θ of the the value of teh standard is appropriated by the patent owners. This parameter θ reflects the friendliness of the IPR policy vis-à-vis the patent owners (we have in particular $\theta = 0$ if essential patents are licensed royalty free). The ability of firm $i = 1,.,n$ to appropriate part of the value θV depends on its share of the total R&D expense x_i/X. This ratio may be interpreted as the likelihood that firm i owns the single essential patent associated to the standard or (which is probably more realistic) as firm i's share of all the patents that are essential to the standard. Firms finally differ according to their share s_i of the market revenue θV generated by the standard, where $\sum s_i = 1$ and $s_i = 0$ denotes a pure R&D firm.

2.1 R&D coordination failure in equilibrium

We study as a first step the case where each firm makes its investment decision separately. We will use this case as a benchmark to highlight possible coordination failure in R&D investments. The investment decision x_i of firm i results from the program below:

$$\max_{x_i > 0} V(X) \left[s_i (1-\theta) + \frac{x_i}{X}\theta \right] - c x_i \tag{1}$$

where

$$X = \sum_{j=1}^{n} x_j$$

The R&D investment made by the other firms affects firm i' profit in two different ways. A large X first increases the chances $P(X)$ that the standard will be successfully developed, but it also reduces the share x_i/X firm obtains of the total licensing revenue. These two mechanisms are captured in two different terms of the FOC of program (1):

$$V'(X) \left[s_i (1-\theta) + \frac{x_i}{X}\theta \right] + V(X) \frac{X - x_i}{X^2}\theta = c \tag{2}$$

The term in brackets captures the public good nature of the standard. It implies in particular firm i's incentive to develop the standard is proportional to the share of the profit it can derive from it. The second term on the right hand side captures a patent race effect: To appropriate some part of the expected profit, firm i needs to invest more the higher the aggregate investments of its R&D competitors. While the first effect may induce underinvestment in R&D wrt to the optimal solution, the second effect plays in the opposite direction.

Solving the program of all firms $i = 1, n$, we can derive the joint R&D investment X^* in equilibrium. Comparing it with the outcome of the joint profit maximization program leads to the following proposition.

Proposition 1 *As compared with the collective optimum, there is overinvestment (underinvestment) in equilibrium when the total revenu from licensing is exceeds (does not exceed) the the total R&D cost. In any case, the discrepancy between total R&D at optimum and in equilibrium increases with the number of firms involved in the standard setting process.*

Proof. See Appendix ■

This Proposition firstly states that either free riding or patent race may prevail in equilibrium, coordination failure then resulting respectively in insufficient or excessive R&D spending. Which type of coordination failure depends on the value of the standard, V, the share θ of it that is appropriated by patent owners, and the unit R&D cost c. By contrast, the number n of firms investing in R&D does not determine the type of coordination failure that prevails, but simply its magnitude. The key result is that the condition for either type of failure to prevail is captured by the balance between total licensing profit and the total R&D cost in equilibrium:

$$\theta V\left(X^{*}\right)-X^{*}c \tag{3}$$

If this expression is positive, licensing essential patents is profitable per se. The patent race pattern then prevails in equilibrium, entailing excessive joint investment. By contrat, if expression (3) is negative, firms cannot count on licensing revenue only to recover their R&D costs. The free riding pattern is then dominant, entailing insufficient investment in equilibrium.

This simple condition provides us a simple and intuitive way to distinguish between two types of equilibria and coordination failure. It is especially interesting to observe that it can be disaggregated at the firm level. Indeed, we can derive directly from (3) that pure R&D firms are profitable only in a patent race equilibrium entailing excessive investment:

$$\theta V\left(X^{*}\right)-X^{*}c>0 \qquad \Leftrightarrow \qquad \theta\frac{x^{*}}{X^{*}}V\left(X^{*}\right)-x^{*}c>0 \tag{4}$$

We will thus use this corollary in our empirically strategy to infer the existence of a patent race equilibrium from the participation of one or more pure R&D firms.

Corollary 2 *The participation of pure R&D firms is profitable only in a situation of overinvestment.*

2.2 R&D coordination through a consortium

Our purpose is to test whether the formation of a consortium between a subset of the n firms involved in the standard development can improve the R&D efficiency of teh standard setting process. At this point it is important to keep in mind that consortia are not formal cooperation agreements between their members: There is in particular no contracting between members. Coordination is thus only based on voluntary information sharing between members, who make no binding commitment in the process. Since such interactions are akin to cheap-talk, it is questionnable whether they can effectively result in a better R&D coordination.

Rather than trying to explicitate the type of coordination mechanisms that may take place within consortium, our approach consists in testing whether the formation of a consortium amplifies or mitigates the R&D coordination failures associated to collective standard development. Based on the previous analysis of fully uncoordinated decisions, we have identified two possible patterns of coordination failures, from which we can induce the effect of a better coordination enabled by consortia. For this purpose, we first characterize R&D equilibria under the heroic assumption of a fully cooperative consortium. We can then infer from this extreme scenario several testable assumptions regarding a weaker coordination effect that should play in the same direction.

We define a full coordination consortium as an R&D alliance between k firms undertaking R&D to develop the standard. For each firm $i = 1, .n$ we will note $\delta_i = 1$ if the firm is part of the alliance and $\delta_i = 0$ otherwise. The consortium then maximizes the following program, where x_k denotes the R&D investment of one of the k members:

$$\max_{X_k} V(X)\left[s_k(1-\theta) + \frac{X_k}{X}\theta\right] - X_k \tag{5}$$

By solving this program and combining the result with the other FOC as expressed in (2), we can derive the following Proposition:

Proposition 3 *Full cooperation between the members of a consortium induces an increase (respectively a decrease) in total R&D when the initial equilibrium involves insufficient (excessive) R&D. The type of coordination failure prevailing in absence of a consortium is mitigated but is not suppressed unless the consortium involves all n firms.*

Proof. See Appendix ■

The Proposition establishes that full cooperation between the $k \in [2, n]$ members of a consortium alleviates the coordination failure–be it free riding or patent race– at the aggregate level of total R&D performed by members and non-members. Hence the effect of perfect coordination within the consortium is either an increase or a decrease in total R&D depending on the type of R&D equilibrium prevailing initially. This result is quite intuitive: It can be understood as a decrease (from n to $n-k+1$) of the number of firms involved in the standard, entailing in turn a decrease thus of the magnitude of the coordination problem.

It is possible to go further in the analysis of R&D decision at firm level by specifying the relation between total R&D and the standard's value. We assume here that the standard's value is a Poisson function of total R&D, where the expected duration of the standard development process depends on the total R&D initially invested by the firms. Letting r and λ denote respectively the discount rate and the Poisson hit rate, and taking V as the exogenous market value of the standard, we have then:

$$V(X) = \frac{\lambda X V}{r + \lambda X}$$

Based on this specification, we can calculate how a firm would change its R&D strategy following entry of a new member in a consortium:

Proposition 4 *A new member of a full-cooperation consortium increases (respectively decreases) its R&D effort when the initial equilibrium involves insufficient (excessive) R&D. An outsider may either increase or decrease its R&D investment after entry of a new member in a consortium, whatever the type of coordination failure prevailing initially.*

Proof. See Appendix ■

This Proposition establishes that the R&D inflating or deflating effect of a consortium is chiefly borne by its members. In a situation of underinvestment, the members of the consortium will coordinate so as to increase their joint R&D effort, thereby increasing the likelihood that the standard be developed quickly. In the reverse situation of excessive investment, the members of the consortium will jointly reduce their R&D, thereby mitigating wasteful investments due to strategic patent race.

Although these results rely on the strong assumption of full cooperation between a coalition of firms, they point towards clear and simple effects of a better coordination between the members of the consortium. Indeed, the expected effect of better coordination is basically driven by the type of coordination failure that prevails initially, and it is borne by the subgroup of firms that coordinate with each other. It seems thus reasonable to use the full cooperation scenario as a reference point to derive a set of more general testable hypotheses about the expected effect of a weak coordination form within a consortium:

Hypothesys 1

1a: When standard development entails underinvestment, a firm joining a consortium will increase its R&D spending

1b: When standard development entails overinvestment, a firm joining a consortium will decrease its R&D spending

Hypothesys 2

2a: When standard development entails underinvestment, a larger consortium induces more total R&D.

2b: When standard development entails overinvestment, a larger consortium induces less total R&D.

3 Empirical analysis

3.1 Methodology

In order to test our theoretical model and to measure the effect of consortia on R&D investment in the standard setting context, we constructed a comprehensive dataset of technological standards including essential patents. Our sample includes all ICT standards complying with objective selection criteria: for instance, they are issued between 1992 and 2008, and they are issued by one of the major formal SSOs which operate on an international level: ISO, IEC, JTC1 – a joint committee of ISO and IEC – CEN/CENELEC, ITU-T, ITU-R, ETSI, and IEEE. We thereby exclude standards that are exclusively developed by informal consortia, such as BluRay. We restrict the analysis to formal standards, as our analysis deals with the interaction between formal standardization and R&D cooperation in a companion consortium. Furthermore, formal SSOs abide to comparable rules. This makes sure that no major bias results from different procedures for selecting technological components. Finally, restricting the analysis to the SSOs in our sample guarantees that we observe a type of standard development that is open in the sense of our model.

We furthermore restrict the analysis to standards including at least one essential patent. Companies that own IPRs which are essential to a standard, provide this information to the respective standard setting organization. We downloaded these patent declarations at the websites of the above-mentioned SSOs in March 2010. In total we identified over 1400 technological standards for which at least one essential patent has been declared. We concentrate upon these standards, as the prospect of royalty income from essential patents is a determinant driving factor of the model. As we can include only standards where at least two companies contribute, and as we can measure R&D investment only in the cases where the essential patents are clearly designated, the sample that is available for econometric analysis is limited to 578 standards.

In a next step, we identified for each standard in our sample the firms contributing relevant R&D. For our purposes, contributing firms are defined as the firms declaring essential patents. This definition yields a list of 242 different companies. These firms are observed over the whole period, we therefore do not assume that companies "enter" the R&D market for a specific standard at any specific point. We inform these firms by the amount of sales per year, R&D expenditure per year and employees per year. Using the specific sector code of the firm's main active industry (SIC), we are able to classify our sample by sector dummies[1]. In addition we classified each company with respect to its vertical integration[2]. Thus we distinguish between pure R&D firms, manufacturer and net provider.

We connected the firm level data to the specific standard information and

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

[2] 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)

built up a panel of company-standard pairs observed over a time span of 17 years (1992-2008). Thus we are able to work with 1081 company standard pairs and a maximum of 20.652 observations[3]. For each of these observations, we build up variables with specific information on company-standard pairs over time. For instance, these variables include the amount of patents filed by the respective company in the technological field of the respective standard, and a dummy variable indicating whether the company takes part in a consortium for this particular standard. We furthermore inform a large series of control variables relative to the company (overall R&D spending, sales) and the standard (age of the standard, releases, amendments, number of pages). Time-invariant factors affecting the firm, the standard or the relationship between both are captured by company-standard pair fixed effects.

As we are interested in measuring the R&D investment regarding a particular standard, we build up a standard-specific measure of firm R&D investment. We use patent files in the relevant technological field as our explained variable. The relevant technological field for each standard is identified using the 7-digit IPC classification of the declared essential patents. We are thereby able to identify the relevant technological classes (IPC) that are relevant for each standard at a very precise level. The distinct combination of IPCs per standard was then used to identify the patent filing behavior of each firm with respect to each standard.

We identified all ICT patents filed from 1992 to 2008 by the companies in our sample at the three major patent offices (USPTO, JPO and EPO), using the PatStat database and the merging methods of Thoma et al. (2010). This merging yields 13 million patent files. We aggregated these patents to INPADOC patent families and informed for each patent the IPC classification and the year of application. To create our explained variable, we computed for each company-standard pair and year the number of patents filed this year by this company in the relevant IPC classes.

This method is a novel way of measuring standard-specific R&D investment, and deserves robustness analyzsis proving that our methodology is successful in measuring R&D related to an important formal ICT standard. An important argument corroborating our measurement strategy is shown in Figure 1. We run Negative Binomail regressions on our proposed dependent variable, controlling for fixed effects and year dummies. Furthermore, we include dummies for each full six-month period since or up to first release of the standard. The figure plots the coefficients of these single values of periods before and after standard release. It can be seen in this figure that the coefficients are highest for the periods preceeding standard release, and decrease the further we move away from this period. This finding reassures us that our variable captures the innovation for a specific standard, which indeed is expected to culminate in the period immediately preceeding standard release.

[3] Due to data constraints, the actual number of observations for our econometric analysis is however limited to approximately 6.000 observations.

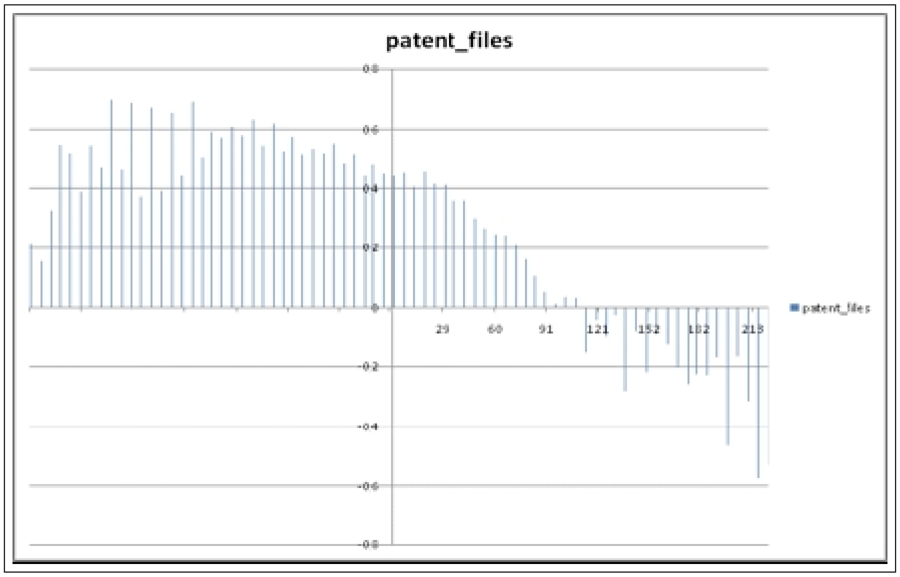

Figure 1.

In our model we assume that firms are able to join a R&D alliance to develop a standard. In the context of standard setting firms often participate in informal standards consortia that either produce standards that are later accredited by formal standard bodies, or follow up standards and later accomplish important contributions to standard setting. To identify consortia which are connected to the standards of our sample, we use data from the 15 editions of the CEN survey of ICT consortia, identifying 453 informal consortia since 1998. In a first step, we select appropriate consortia by informing the technological field in which they operate. The concrete connection to a standard in our sample is made using information from liaison agreements and information on the consortia and SSO web pages. For instance, a connection can be 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 14 consortia. The list of consortia and their linkage to formal standards is provided in Appendix. 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. We are thus able to connect the membership data of each consortium to the respective company standard pair of our sample.

3.2 Measurements of over and under investment

One basic contribution of our analysis is the comparison of over- and under investment in standardization. We assume that situations of overinvestment can be identified when pure R&D firms participate to a standard. These firms find it only profitable to invest in standards when they are able to generate returns, for instance royalties under RAND conditions. We use this prediction as identification strategy for our empirical sampling of standards.

It is the aim of this section to provide evidence that our methodology is successful in identifying different situations of investment behavior. Therefore we label our observations of company standard pairs with overinvestment when pure R&D firms participate in the respective standard. We apply the same method for underinvestment vice versa. We measure participation in a standard with our database of co-declaring companies. We thus observe only firms that declare patents on a respective standard to be participants. The classification of pure R&D firms is grounded on the extended business description of the Thomson One Banker database and the list of companies identified by Layne-Farrar and Lerner (2010). To further validate and extend this classification we plot residual values of two regression results (Figure 2). We first run a cross section poisson regression of the mean number of patent files from 2000 until 2009. We connect our firm specific variables (sales, employees, R&D expenditure, sector) with the information of our standards (number of pages, cumulative number of version releases, standard age, technological standard classes) to create explanatory variables and controls. We use these same independent variables for our second regression to explain the mean number of patent declarations (regression results in appendix1). Using the label of over- and underinvestment as to the classification discussed above, we plot the residual results of both regression in a graph (figure 2). The X values are residuals from the patent files regression; the Y values represent residuals from the patent declaration regression.

We assume negative residuals to be an indicator of underinvestment, whereas positive results represent the opposite. This visual sampling further differentiates our classification of over- and underinvestment. When comparing residuals of patent files, our first labeling of over- and underinvestment apparently proves to be a sufficient classification, but lacks to exclusively identify all standards with overinvestment. Residuals of patent declarations however illustrate ambiguous results. We interpret results from our second regression to less likely measure standard specific R&D investment, but rather a strategic interest in declaring essential patents (Baron and Pohlmann, 2011).

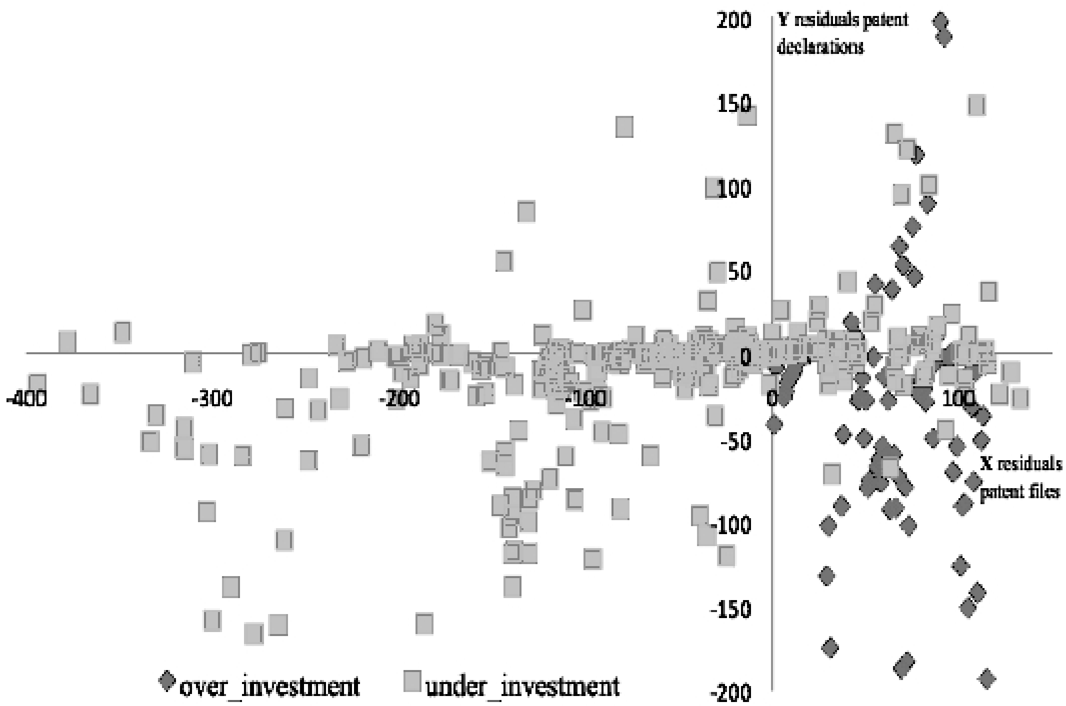

Figure 2. Scatter plot of residual values labeled with over- and underinvestment

Our results verify our classification of overinvestment, since all residual values of the patent file regression are positive (positive X values). The classification of underinvestment seems to be not yet sufficient. The majority of labeled underinvestment standards have negative residuals (negative X values), but we still find a group of observations with positive residual values. To further test the robustness of our regressions, we can apply the classification as to residual values of the patent files regression.

3.3 Empirical results

We run panel regressions to test the empirical implications of our theoretical model. As explained, we have constructed a panel of company-standard pairs for a time-span covering 17 years from 1992 to 2008. Our explained variable is patent files per year, per company and per standard. We only count patent files of one company when they touch the technical classes that are relevant for the respective standard in question. Since our explained variable is over-dispersed with respect to a poisson distribution, we are using a negative binominal estimator. We run a fixed-effects regression to control for time-invariant company and standard characteristics. The baseline investment scenario over the life-cycle of the standard is controlled for using the standard age variable, i.e. the difference between the year of observation and the year of standard release. As discussed, patent files peak close to the year of standard release. In order to control for this inverted U-shape, we include both standard age and its square. We furthermore include year dummies to control for policy and other shocks affecting the overall number of patent files.

We measure two different effects of consortia on the number of patent files. First, we measure a direct coordination effect on the patenting strategies of consortia members. Therefore, a first model is tested with a dummy variable for consortia membership. This dummy variable is time-variant, and we can exploit substantial variation in the data resulting from entries and exits observed over time. Second, we measure the overall coordination effect of consortia on the patenting strategies of all firms. We assume that this effect depends upon the degree of coordination among firms. We therefore propose a second model, in which the effect of consortia is tested using a variable indicating the share of consortia members among firms contributing patents to a standard. This variable is equal for all companies on the same standard and in the same year.

As discussed, we predict that the effect of consortia on patenting depends upon whether the standard is initially characterized by over- or underinvestment. We have proposed and discussed an identification strategy for standards characterized by overinvestment. For this purpose, we will rely upon the presence of pure R&D firms among the contributors of essential patents. We acknowledge that the presence of pure R&D firms is a sufficient, but not a necessary indicator for an equilibrium of overinvestment. However, this strategy should in principle be reliable in identifying a sample of standards all characterized by overinvestment.

We therefore estimate the two econometric models separately in the two samples of standards. Table 2 presents the results of the regressions on the sample of standards classified in the sample of overinvestment. As predicted by the theory, consortia membership significantly reduces patent files related to the standard in this sample. This finding is coherent with our hypothesis on the effects of consortia in cases of overinvestment. However, we do not find a significant effect of the share consortia members in the number of patent holding companies. The standard age controls show once again the strongly significant link of our explained variable to the standard life cycle.

Dependent variable: Annual patent files per company-standard pair

	Model 1	**Model 2**
Consortia membership	-.3372597***	
Share of firms in consortia		.1471959
Standard age	.008687***	.0384031***
Standard age (squared)	-.0000162***	-.0000449***
Year dummies	Yes	Yes

Notes: Fixed effect estimation by negative binomial on firm-consortia pairs.
2,729 observation, 152 groups.

Table 2: Standards with pure R&D firms

Table 3 presents the results on the sample of standards with no pure R&D firms. These results are fully in line with our theoretical model. As predicted, we find that consortia membership has a positive and significant effect on patent files in this sample. Furthermore, also the share of consortia members in the number of participating firms has a positive and significant effect. This finding corroborates the theoretical proposition on the role of consortia in a case of free riding. Also in this sample the standard age controls provide significant support to our claim that we measure innovation related to the standard setting process.

Dependent variable: Annual patent files per company-standard pair

	Model 1	**Model 2**
Consortia membership	.1422048**	
Share of firms in consortia		.1471959*
Standard age	.0040118***	.0117448***
Standard age (squared)	-6.78e-06***	-.0000153***
Year dummies	Yes	Yes

Notes: Fixed effect estimation by negative binomial on firm-consortia pairs. 2,729 observation, 152 groups.

Table 3: Standards without pure R&D firms

4 Conclusion

This paper investigates the role of consortia in coordinating the R&D investments of firms involved in the development of new standards. Based on a theoretical model capturing the firms' incentives to invest in R&D for standards, we have highlighted two possible coordination failures of such joint innovation. When the licensing revenue from essential patents is low, R&D for standards is mainly driven by market incentives for future producers of standard-compliant products. In this case standards are a form public good, and their R&D development is subject to free-riding, entailing inefficiently low R&D investments. By contrast, some standards also give firms an opportunity to derive substantial licensing revenue from their essential patents. The equilibrium may then involve a patent race for preempting the essential patents, and therefore socially wasteful investment. We also show that pure R&D firms will participate in the standard setting development process only in the latter type of equilibrium.

We test empirically the capability of consortia to address these two types of inefficiency by improving R&D coordination. More precisely, our theoretical setting suggests that a firm joing a consortia will increase (respectively) decrease its R&D effort when standard development is subject to a free-riding (respectively a patent race) problem. We also expect to observe the relative size of the consortia to have same effect at the aggregate R&D level (including non-member firms). Our empirical analysis is based on a rich dataset of 242 firms claiming patents on 578 ICT standards. We use essential patents declarations to identify firms those firms, and the technology fields (as defined by their IPC classes) that are closely related to the standard. Drawing on this information, we can then use the number of patents filed by the firms in these technology fields as a proxy of their R&D output related to the standard. We finally use the participation of pure R&D firms as a filter to identify the subset of standards that are subject to a patent race equilibrium. We use the remaining standards to test results about free riding, although the sample may also include false negatives.

Controlling for the development stages of the standard, we find significant effects of consortia that are broadly consistent with our theoretical model. Joining a consortia has a positive (respectively negative) effect on the new member's patent filing when pure R&D firms are (not) involved in the standard setting process. The relative size of the standard has a significant effect only for standards that do not involve pure R&D firms, and as expected this effect is positive. These results thus seem to confirm both the existence of two opposite types of coordination failure (free riding or patent race) depending on the standards, and the capability of consortia to alliviates those failures.

References

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

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

[4] 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.

[5] Katz, M. (1986): An Analysis of Cooperative Research and Development, RAND Journal of Economics, The RAND Corporation, vol. 17(4), pages 527-543, Winter.

[6] 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.

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

[8] Scotchmer, S. (2004): Innovation and Incentives, MIT Press.

[9] 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.

[10] 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.

Appendix:

Proof of Proposition 1

Optimal R&D investment. Since R&D costs are linear, a social planner would choose the total investment $X = \sum_{i=1}^{n} x$ according to the program below:

$$\max_{X} V(X) - cX$$

The first order condition is straightforward:

$$V'\left(\widehat{X}\right) = c \tag{6}$$

R&D investment in equilibrium. By summing the FOC for all firms, we can obtain an implicit definition of the total R&D effort X^* at equilibrium. Taking into account the participation constraint of pure R&D firms, we obtain two different cases

$$\frac{1}{n}\left[V'(X^*) + V(X^*)\frac{n-1}{X^*}\theta\right] = c \tag{7}$$

From equations (7) and (2), we define the private and social marginal benefits of R&D such that $MR(X) = c/V$:

$$\begin{aligned} MR_n(X) &= \frac{1}{n}\left[V'(X) + V(X)\frac{n-1}{X}\theta\right] \\ MR_w(X) &= V'(X) \end{aligned}$$

By comparing them it comes easily that

$$\begin{aligned} MR_w &> MR_{\widetilde{n}} \\ &\Leftrightarrow \\ \theta V(X) - XV'(X) &< 0 \end{aligned} \tag{8}$$

From (7) it comes in turn that:

$$\theta V(X^*) - X^* V'(X^*) = \frac{n}{V}\left[V(X^*)\theta - X^* c\right]$$

Hence:

$$\begin{aligned} MR_w &> MR_{\widetilde{n}} \\ &\Leftrightarrow \\ \theta V(X^*) - X^* c &< \theta \end{aligned}$$

Effect of the number of firms.By applying the envelop theorem to (7) we can identify the effect of n:

$$\frac{dX^*}{dn} = -\frac{\theta V(X^*) - cX^*}{X^* V''(X^*) V + \frac{X^* V'(X^*) - V(X^*)}{X^*}(n-1)\theta}$$

It can be checked easily that denominator of this expression is always negative. Hence

$$sign \frac{dX^*}{dn} = sign\left[V(X^*)\theta - cX^*\right]$$

Proof of Proposition 3

The FOC of program (5) is:

$$V'(X)\left[s_k(1-\theta) + \frac{X^k}{X}\theta\right] + V(X)\frac{X - X^k}{X^2}\theta = c$$

where $X^k = \sum x_k$ and $X^{-k} = X - X^k$. Summing this condition with the $(n-k)$ individual FOC of the remaining firms (as given by equation (2)) and simplifying gives the total R&D at equilibrium as an implicit function of the size of the coalition:

$$V'(X^*) + (n-k)\frac{V(X^*)}{X^*}\theta = (n-k+1)c$$

By implicit differentiation of X^* with respect to k, we can establish the following result:

$$\frac{dX^*}{dk} = \frac{\theta V(X^*) - cX^*}{X^* V''(X^*) + \frac{X^* V'(X^*) - V(X^*)}{X^*}(n-k)\theta}$$

The denominator of expression (**??**) is clearly negative. Hence:

$$sign \frac{dX^*}{dk} = sign - \left[\theta V(X^*) - cX^*\right]$$

We then know from the previous section that the effect of an R&D alliance depends on the comparison beween total investment at equilibrium and the social optimum.

Proof of Proposition 4

In equilibrium, the FOC of a firm within and outside the consortia are:

$$\begin{cases} V'(X^*)\left[s_k(1-\theta) + \frac{X_k^*}{X^*}\theta\right] + V(X^*)\frac{X^* - X_k^*}{X^{*2}}\theta = c \\ V'(X^*)\left[s_i(1-\theta) + \frac{x_i^*}{X^*}\theta\right] + V(X^*)\frac{X - x_i^*}{X^{*2}}\theta = c \end{cases}$$

where x_k^* and x_i^* denote respectively the individual investment of a consortium member and outsider in equilibrium. By rearranging these expressions, we can obtain:

$$\begin{cases} V(X^*)\frac{X_k^*}{X^*}\theta - X^*V'(X^*)\left[s_k(1-\theta)+\frac{X_k^*}{X^*}\theta\right] = \theta V(X^*) - cX^* \\ V(X^*)\frac{x_i^*}{X^*}\theta - X^*V'(X^*)\left[s_i(1-\theta)+\frac{x_i^*}{X^*}\theta\right] = \theta V(X^*) - cX^* \end{cases}$$

and consequently (the terms on the right hand sides being equal):

$$(s_k - s_i)(1-\theta)X^*V'(X^*) + \theta\left[X^*V'(X^*) - V(X^*)\right]\left[\frac{X_k^* - x_i^*}{X^*}\right] = 0$$

When can then obtain a measure of the firms' contribution to the total R&D investment:

$$\frac{x_i^* - X_k^*}{X^*} = (s_i - s_k)\frac{1-\theta}{\theta}\frac{X^*V'(X^*)}{V(X^*) - X^*V'(X^*)}$$

and

$$x_i^* = (s_i - s_k)A + X_k^*$$

where

$$\begin{aligned} A &\equiv \frac{1-\theta}{\theta}\frac{(X^*)^2 V'(X^*)}{V(X^*) - X^*V'(X^*)} > 0 \\ &= \frac{1-\theta}{\theta}\frac{r}{\lambda}\ \text{(Poisson)} \end{aligned}$$

Since $X_k^* = X^* - \sum x_i^*$ we have:

$$\begin{aligned} X_k^* &= X^* - \sum(s_i - s_k)A - (n-k)X_k^* \\ &= X^* - A\left[1-(n-k+1)s_k\right] - (n-k)X_k^* \\ &\Leftrightarrow \\ X_k^* &= \frac{X^*}{n-k+1} + A\left[s_k - \frac{1}{n-k+1}\right] \end{aligned}$$

and thus

$$\begin{aligned} x_i^* &= (s_i - s_k)A + X_k^* \\ &= \frac{X^*}{n-k+1} + A\left[s_i - \frac{1}{n-k+1}\right] \end{aligned}$$

using the poisson specification and rearranging, this becomes:

$$\begin{aligned} X_k^* &= \frac{X^*}{n-k+1} + \frac{1-\theta}{\theta}\frac{r}{\lambda}\left[s_k - \frac{1}{n-k+1}\right] \\ x_i^* &= \frac{X^*}{n-k+1} + \frac{1-\theta}{\theta}\frac{r}{\lambda}\left[s_i - \frac{1}{n-k+1}\right] \end{aligned}$$

Effect of a firm joining the consortium on this firm's R&D: Noting $s_i = \frac{s_k}{k} = \frac{1}{n}$ we have:

$$\begin{aligned}
\frac{X_{k+1}^*}{k+1} &> x_{i,k}^* \Leftrightarrow X_{k+1}^* - X_k^* > \frac{k(n-k)-1}{n-k+1}\left(X_k^* - \frac{1-\theta}{\theta}\frac{r}{\lambda}\right) \\
x_{i,k+1}^* &> x_{i,k}^* \Leftrightarrow X_{k+1}^* - X_k^* > \frac{1}{n-k+1}\left(\frac{1-\theta}{\theta}\frac{r}{\lambda} - X_k^*\right)
\end{aligned}$$

Noting that

$$\frac{X_k^* P'(X_k^*)}{P(X_k^*)} < \theta \Leftrightarrow \frac{1-\theta}{\theta}\frac{r}{\lambda} < X_k^*$$

The effet on outsiders is ambiguous. Let us try the effect on their market share:

$$\begin{aligned}
\frac{x_{i,k+1}^*}{X+\Delta} &> \frac{x_{i,k}^*}{X} \Leftrightarrow X_{k+1}^* - X_k^* > \frac{1}{n-k+1}\left(\frac{1-\theta}{\theta}\frac{r}{\lambda} - X_k^*\right) \\
\Delta &> \left[\frac{1-\theta}{\theta}\frac{r}{\lambda} - X\right] - \frac{1-\theta}{\theta}\frac{r}{\lambda}\frac{(k-1)(n-k)}{n}\frac{\Delta}{X}
\end{aligned}$$

Effect of a firm joining the consortia when the coordination failure results in free-riding ($\theta < r$)

Consortia and their linkage to formal standards

Standard	Consortia	Members
IEEE1394	1394 Trade Association	61
IEEE1800/IEC62530	ACCELLERA	27
IEEE1801	ACCELLERA	27
ISO/IEC 18092	ECMA	23
ISO/IEC 18000-6	EPCglobal	
IEEE802.21	IETF	125
H.323	IMTC	41
ISO/IEC 14496-10/ITU H.264	ISMA	18
ISO/IEC 14496-2	ISMA	18
ISO/IEC 14496-1	MPEGIF	53
ISO/IEC 14496-10/ITU H.264	MPEGIF	53
ISO/IEC 14496-12	MPEGIF	53
ISO/IEC 14496-14	MPEGIF	53
ISO/IEC 14496-15	MPEGIF	53
ISO/IEC 14496-16	MPEGIF	53
ISO/IEC 14496-18	MPEGIF	53
ISO/IEC 14496-19	MPEGIF	53
ISO/IEC 14496-2	MPEGIF	53
ISO/IEC 14496-20	MPEGIF	53
ISO/IEC 14496-3	MPEGIF	53
ISO/IEC 14496-4	MPEGIF	53
ISO/IEC 14496-5	MPEGIF	53
ISO/IEC 14496-6	MPEGIF	53
ISO/IEC 14443-1	NFC Forum	150
ISO/IEC 14443-2	NFC Forum	150
ISO/IEC 14443-3	NFC Forum	150
ISO/IEC 14443-4	NFC Forum	150
ISO/IEC 18092	NFC Forum	150
IEEE1003.1/ ISO/IEC9945	TOG (The Open Group)	254
ISO/IEC DIS29341	UPnP Forum	891
IEEE802.11/ ISO/IEC8802-11	Wi-Fi Alliance	309
IEEE802.16	WiMax	462
IEEE802.15.3	WiMedia Alliance	374

Cross section regression of the mean number of patent files and patent declarations

	poisson regression of the mean number of patent files	poisson regression of the mean number of patent declarations
number pages	0.0002292**	-.0002408
	(0.0000995)	(.0004423)
version releases	-0.0059018	-.1395566
	(0.0139882)	(.1035427)
standard age	-0.0288434	.3278869*
	(0.0224759)	(.1737296)
standard age sq	0.0000249	-.0002868**
	(0.000019)	(.0001487)
Sales (mean)	-0.000021**	-.0000538**
	(3.25E-06)	(.0000215)
Employees (mean)	5.55E-06**	7.85e-06**
	(7.10E-07)	(4.41e-06)
R&D expense (mean)	0.0002431***	.0003204***
	(0.0000168)	(.0001217)
cons	12.92451	-92.75688**
	(6.591821)	(50.37273)
observations	504	505
Pseudo R2	0.4333	0.3297
Log pseudolikelihood	-25784.352	-1587.5084

* represents the level of significance: * = 10%-level; ** = 5%-level; *** = 1%-level, robust standard errors in brackets

note: note: control variables for industry SIC codes and technical classes (ICS) are not displayed in the results