# Who cooperates in standards consortia – rivals or complementors?

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Formal standard development is increasingly supplemented by standards consortia: informal and less inclusive alliances, in which firms coordinate standard-related R&D and streamline standard development. In order to cast light on the economic function of these consortia, this article provides empirical evidence for the driving factors of consortia existence and companies' decision to join. We find that consortia are more likely to be created for standards characterized by a fragmented ownership of IPR and a strong degree of technological rivalry. We also find that among the firms contributing to a standard, technological specialists are less inclined to join consortia. Companies are more likely to cooperate within consortia with companies specializing in R&D that is substitutable rather than complementary to their own patent portfolio. These findings suggest that a main benefit of standards consortia is to reduce the cost of standard development by eliminating wasteful R&D duplication and settling conflicts of interest upfront to formal standardization.

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# 1. Introduction

Information and communication technology (ICT) markets are subject to short product lifecycles and a rapid technology evolution. Competition takes place on several market levels where firms compete downstream on products and services and upstream on rivaling technologies. However, interoperability of products is a crucial factor for market success and firms evermore have to coordinate their innovation activities with other, often competing market participants. In the field of ICT, standard setting is no longer a sheer specification of compatibility standards, but in fact a joint development of sophisticated technologies. Thus, standardization often frames the process of simultaneous rivalry and coordination in the development of large systems of innovative technologies (GSM, UMTS, WiFi, DVD, Blue-Ray, MPEG, etc.). In this article, we analyze the driving factors of firm cooperation in the process of standardization. In particular, we analyze whether firms are more likely to coordinate their standard-related R&D programs with firms pursuing complementary or substitutable R&D. Analyzing membership of standard-related informal consortia, we find that firms are more likely to coordinate R&D with technological rivals.

Standards are described as de facto standards when they are sponsored by single firms or industry alliances. De facto standards emerge from consumer choices in a particular market. In comparison, standards are described as de jure standards when they are specified by formal standard developing organizations (SDOs). SDOs are voluntary and non-profit organizations which coordinate the specification of commonly accepted standards. These organizations are inclusive and attempt to gather all markets participants to reach consensus on technology specifications (Bekkers et al., 2011; Farrell et al., 2007). Especially in recent years SDOs increasingly gained importance. Firms are increasingly joining SDOs to value their often patented technology by having it approved as part of an industry-wide standard. Since technology selection in SDOs can be crucial for a firm’s future market position, competition also takes place within SDOs (Bekkers et al., 2002, DeLacey et al., 2006). As a result of this technological rivalry in standard development, the number of patents claimed on ICT standards has been increasing since the early nineties (Simcoe, 2007).

The fragmentation of R&D and critical inputs over many different standardization participants can induce coordination failures. Especially in the field of ICT, technological competition in formal standardization may generate costly R&D duplications and delays due to vested interests (Farrell & Simcoe, 2012; Simcoe, 2012). In other cases, the public good properties of a standard induce free-riding and underinvestment (Baron et al., 2012). As a response to the various coordination problems, firms rely on informal consortia to cooperate in the standard setting process (Cargill and Weiss, 1992; Lerner & Tirole, 2006). While some consortia substitute for SDOs and issue their own standards (e.g., Blu-Ray alliance or W3C for web protocols, also see Cargill and Weiss, 1992), most consortia actually follow up formal standardization and rather co-exist than compete (Blind and Gauch, 2008) with SDOs.[3]

For SDOs, the cooperation with consortia is of increasing importance. ISO for example explicitly states the goal to strengthen its cooperation with informal consortia "when such partnerships add value to and increase the efficiency of the development of International Standards"[4]. ISO and other SDOs cooperate with specific consortia ("Partner Standard Development Organizations") for instance through fast-tracking the specifications developed in such bodies. The increasingly active role of informal consortia bears the promise that formal standards be delivered more rapidly, and match more closely industry needs. On the other hand, there is also the risk that formal SDOs are captured by powerful special interest groups, bypassing the very inclusive and consensual decision making procedures of SDOs. Against the background of this strengthened recognition of consortia, it is important to deepen our understanding of the economic role of consortia in standardization. Baron et al. (2012) find that consortia increase the efficiency of R&D for standard development, and Delcamp and Leiponen (2012) show that consortia increase the propensity of their members to build upon each other's technology. There is however a lack of understanding and empirical evidence on the actual nature of this coordination and on the incentives to join.

This research project will fill this gap. We identify in the economic literature two very different conceptions of the role of informal consortia supplementing formal standard development. First, consortia can be a place to settle conflicts of interest. Companies with opposing stakes that nevertheless wish to decide on a standard have a clear incentive to select an appropriate venue to settle their dispute before engaging in the more inclusive and formal processes at the SDO. From this point of view, we would expect consortia to bring together

[3] There are formal statements on direct ties between standards consortia and formal standards bodies, e.g. the PAS (Publicly Available Specifications) fast track agreement or JTC1's Approved References Specifications (ARS) or the Partner Standards Development Organization (PSDO). Most standards consortia also enter liaison agreements, which is a rather broad statement of cooperation with formal standard bodies on specific topics. David and Shurmer (1996) describe the case of the DVB (Digital Video Broadcasting) Group, a private industry consortium which was responsible for drafting specifications that were approved by ETSI (European Telecommunications Standards Institute). Gauch (2008) shows how ECMA (European Computer Manufacturers Association) specified DVD technologies that were approved at ISO (International Organization for Standardization).

[4] http://www.iso.org/iso/iso_strategic_plan_2011-2015.pdf.

the fiercest technological rivals. In a different conception, consortia are alliances of firms joining forces in order to leverage their voting power in the SDO and obtain an advantage over rivaling firms that have not joined the consortium. Also in this case we would expect that consortia concentrate on standards experiencing strong fragmentation of R&D and fierce technological rivalry. We would however not expect rivaling firms to be members of the same consortium.

We thus hypothesize that consortia concentrate on standards characterized by strong technological rivalry. Furthermore, in order to test empirically the two different conceptions of the role of consortia, we analyze whether technological rivals are members of the same consortia or not. To this end, we first identify for each firm contributing technology to a particular standard its standard-related patents. We then construct empirical measures of the complementarity or substitutability between the standard-related patent portfolios of different firms. This analysis represents a major methodological innovation, building upon the analysis of the IPC classification of several millions of patents.

Our results show that consortia are more likely to be created for standards characterized by a high degree of technological rivalry. Furthermore, technological specialists are less likely to be consortium members than firms facing direct technological competitors on a standard. Regarding the two different conceptions of consortia, we find that firms specializing on the same technological components of the standard are very significantly more likely to jointly be member of the same consortium. This finding has interesting implications for the economic analysis of consortia. In their majority, informal consortia are not a device to coordinate the R&D programs of firms with complementary specializations. Rather, consortia appear to bring together firms specializing on the same standard components. These findings suggest that a major economic function of consortia is to reduce wars of attrition and the costs of technological rivalry through upfront coordination.

## 2. Theoretical Background

The economic literature discusses both incentives to cooperate on R&D with rivals and complementors. The economic analysis of R&D cooperation hereby traditionally identifies spillovers as the main incentive to cooperate on R&D (Katz and Ordover, 1990, D’Aspremont and Jacquemin, 1988). In presence of knowledge spillovers from private R&D, collaboration allows firms to internalize the positive learning externality of their R&D. Hence, R&D

collaboration increases both R&D efforts and productivity (Romer, 1993; Branstetter and Sakakibara, 2002). In order to best benefit from knowledge spillovers in R&D collaboration, firms predominantly cooperate with those firms whose focus of specialization is complementary, yet sufficiently similar to their own (Cantner and Meder, 2007).

Another important externality of private R&D is the competition externality. The R&D effort of each company decreases the profits of its competitors on the downstream product market (Schankerman et al.). Furthermore, in case of patent races, the R&D effort of a company reduces the chances of other firms to reap benefits from their own R&D. This rivalry spurs wasteful over-investment in R&D with respect to the collective interest of the firms and even with respect to social welfare (Reinganum, 1989). R&D collaboration among technological rivals can in this case efficiently reduce wasteful R&D duplication (Irwin and Klenow, 1996).

With respect to the well-studied Research Joint Ventures, standards consortia are different to several respects. First, these consortia usually do not imply any joint decision making or contracting on R&D investments, nor do firms share ownership of their technology. Second, while especially small companies and start-ups benefit from consortia meetings to get informed about the technological evolution (Fleming and Waguespack, 2008), knowledge spillovers and learning are not the main drivers of participation in standards consortia. Standards consortia are rather venues for limited groups of standardization participants to discuss on standard-related topics and to facilitate the emergence of a consensus regarding decision making in the more comprehensive standard body itself. This Axelrod et al. (1995) and Weiss and Sirbu (1990) describe consortia as venues of likeminded peers where firms jointly promote and develop a certain technology. However, the precise role of consortia in standard development differs substantially from standard to standard. For instance upstream consortia are active on the development of new technologies and the issuance of technical specifications, while downstream consortia deal with the promotion, maintenance or enforcement of existing standards. In spite of this heterogeneity, all consortia have in common that their objective is to coordinate their members' contribution to a shared technological standard.

Also regarding the more narrow type of R&D collaboration in standards consortia, the economic literature provides a rationale for both cooperating with rivals and complementors. According to one conception, consortia may improve a firm's bargaining power against external rivals in negotiations for technology selection (Rosenkopf et al., 2001). Leiponen

(2008) for instance shows that membership in a related consortium increases the capacity of a firm to influence the voting behavior of other companies in the SDO. Consortia may thus be means for members to forge alliances and to increase the chances of their patented technology to be selected for inclusion into a formal standard (Pohlmann and Blind, 2012). Such an alliance consists in firms favoring the same technologies for the standard, which precludes technological rivalry within the consortium and indicates a high degree of technological complementarity. Examples are for instance the alliances between companies specializing in as diverse industries as consumer electronics, software and media content in the development of the (rivaling) optical disc standards BluRay and HD-DVD. The members of these alliances forge a consensus on their preferred technological specifications, and align their R&D on the complementary R&D of other consortia participants (Delcamp and Leiponen, 2012).

On the other hand, companies also have an incentive to cooperate with their immediate technological rivals. First, companies often develop substitutable patented technologies for selection into technological standards. Only the selected technology benefits from a strong increase in its value (Rysman and Simcoe, 2008), while the non-selected alternatives are abandoned. Through upfront coordination, technological rivals can limit the extent of wasteful duplication in the development of technologies for selection into a standard. This way companies reduce their risk and make sure that their R&D corresponds to the future evolution of the standard (Aggarwal et al., 2011). Consistently, Baron et al. (2012) find that in cases of strong technological rivalry, consortia contribute to the efficiency of R&D by reducing the extent of related patenting. Second, inclusive SDOs are notoriously ill-equipped to settle conflicts of interest. Simcoe (2012) shows that companies with conflicting stakes in a technological standard can engage into wars of attrition. These costly hold-out games in the working groups of the SDO inefficiently slow down standard development. Practitioners interviewed for a EU study on patents and standards (Blind et al., 2012) also report cases in which standard development is substantially delayed or technological errors are introduced as a consequence of the vested interests of contributing firms. In order to avoid these costly adverse consequences of conflicts in SDOs, companies with conflicting stakes in a standard have the incentive to find an appropriate venue for solving their dispute. Companies can use forum shopping to select the standardization venue that best matches their needs (Lerner and Tirole, 2006; Chiao et al., 2007).

Consortia thus can be created either as a device to coordinate complementary R&D programs and to improve the position of their members against outside technological rivals, or to settle conflicts of interest and mitigate wasteful R&D duplication resulting from technological rivalry. The effects of consortia on innovation incentives and the technological evolution of the standard are likely to be very different in the two different cases. While coordination among technological rivals reduces R&D duplication and overinvestment, coordination among firms with complementary specializations reduces risk and increases R&D profitability (Baron et al., 2012). As a first step to increase our understanding of the economic role and effect of standards consortia, it is therefore very important to find out whether these alliances are predominantly composed of technological rivals or of companies with complementary specializations.

## 3. Empirical methodology

Our empirical analysis draws on a comprehensive dataset of technological standards which are subject to essential patents. Our sample includes all ICT standards issued between 1992 and 2009 by one of the major formal standard setting organizations or SDOs (ISO, IEC, JTC1 – a joint committee of ISO and IEC – CEN/CENELEC, ITU-T, ITU-R, ETSI, and IEEE) which operate on an international level. 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 four different companies, thereby limiting the sample to 121 standards. To retrieve information on patent declarations, we exploit publicly available data from all SDOs. SDOs suggest to firms to declare all IPR that is potentially essential to standards (Lemley, 2002). All of these SDOs provide lists of patent declarations, including information on the declaring firm, the date of declaration, the relevant standards and the patent number. In sum we retrieved over 64,000 patent declarations, which represent all essential patents that have been declared to formal SDOs (Blind et. al, 2011).

Nevertheless, essential patents only represent a very small fraction of the patents filed around standards (Bekkers et al., 2012). Indeed, especially in the case of standards characterized by strong technological rivalry, we expect that many companies have developed and patented competing technologies in view of inclusion into a standard. In this case, only one out of various rivaling technological solutions materializes in essential patents. To account for this effect, we build up a new measure of firms’ standard-specific patenting. 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 precise (4 digit) IPC classes in the relevant technological field of each standard, identified by using the IPC classification of declared essential patents[5]. We use the approach as in Baron et al. (2012) and conduct several measures to confirm this data method.

From the PERINORM database we retrieve information on the date of first release, releases of further versions and amendments, number of pages of the standard document and the technical classification of the standard. We then use the date of standard release to restrict our measure of standard-related patenting to patents filed between six and one year before the release of the first standard version. This way, we make sure that we measure the standard-related technological assets of the different standardization participants, which will eventually determine their likelihood to cooperate, but we do not capture any patent filings resulting from the effect of consortia or other standard-related coordination.

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[6]. These surveys cover a comprehensive sample of consortia responding to objective selection criteria, for instance openness and transparency. We identify approximately 250 active ICT consortia[7]. We categorize these consortia as to industry, function (e.g. spec producer or promoter) and years of activity. The connection to a standard in our sample is analyzed by using liaison agreements and information from consortia and SDO 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 SDO 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

[5]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 Baron et al. (2013).

[6] http://www.consortiuminfo.org/links/linksall.php

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

contribute to this specific standard (excluding pure promoting consortia)[8]. 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.

**Measuring complementarity**

We analyze whether firms participating in standard development contribute complementary or substitutable technology using the IPC classification of their standard-related patents. We identify the standard-relevant technology fields as being the main IPC classes (4 digit) of the declared essential patents. We then count all independent patent families filed by the companies declaring essential patents in the identified IPC classes. Following Benner and Waldfogel (2008), we use all IPC classes of the patents filed by the different firms, and rely upon a relatively aggregated level of technology (4 digit IPC). We weight the numbers of patent applications so that the relative weight of the different IPC classes in the count of related patents matches the weights in the group of declared essential patents. If patents from a relatively small patent class represent a large share of the declared essential patents, we give a particularly high importance to the patent files in these patent classes. This way we make sure that our analysis is not too strongly driven by very large and generic IPC classes which are present in almost all standards in our sample.

We then use the IPC classes of the identified patents in the related technological field to map the technological portfolio of the different firms. The following tables exemplify the procedure using two stylized hypothetical standards. Each field in the tables represents the weighted number of patents filed by the respective firm in the respective class.

| Standard 1 | | | |
|---|---|---|---|
| | IPC k1 | IPC k2 | IPC k3 |
| Firm A | 100 | 20 | 200 |
| Firm B | 200 | 100 | 300 |
| Firm C | 500 | 200 | 600 |

| Standard 2 | | | |
|---|---|---|---|
| | IPC k1 | IPC k2 | IPC k3 |
| Firm A | 70 | 500 | 100 |
| Firm B | 100 | 100 | 600 |
| Firm C | 300 | 80 | 100 |

**Table 1:** Numeric example of firms' technology overlap for standards.

8 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". Baron et al. (2012) provide a list of those consortia and standards for which a link could be established, as well as the narrower list of consortia contributing technologically.

For each firm and standard, we obtain a vector that shows how many patents *p* the firm has filed in each of the *k* relevant technological classes. We can then analyze the similarity of the standard-related firm portfolios by two different widely accepted measures based upon the firm standard vectors.

| Standard 1 | Standard 2 |
|---|---|
| $A_k = [100; 20; 200]$<br>$B_k = [200; 100; 300]$<br>$C_k = [500; 200; 600]$ | $A_k = [70; 500; 100]$<br>$B_k = [100; 100; 600]$<br>$C_k = [300; 80; 100]$ |

**Table 2:** Numeric example of technology vectors of firms' technology overlap for standards.

To compare firm i and firm j over technology classes k, we calculate the **angle *a*** and the **correlation coefficient *r*** between the respective vectors (*the similarity scores*):

$$\boldsymbol{a_{A,B}} = \frac{\sum_k p_{A,k} p_{B,k}}{\sqrt{\sum_k p_{A,k}^2 \, p_{B,k}^2}}$$

$$\boldsymbol{r_{A,B}} = \frac{\sum_k (p_{A,k} - \frac{p_{A,k} + p_{B,k}}{2})(p_{B,k} - \frac{p_{A,k} + p_{B,k}}{2})}{\sqrt{\sum_k (p_{A,k} - \frac{p_{A,k} + p_{B,k}}{2})^2} \sqrt{\sum_k (p_{B,k} - \frac{p_{A,k} + p_{B,k}}{2})^2}}$$

| Standard 1 | | | Standard 2 | | |
|---|---|---|---|---|---|
| | ***R*** | ***A*** | | ***R*** | ***a*** |
| $A_k \# B_k$ | 0,99794872 | 0,97619048 | $A_k \# B_k$ | -0,44491211 | 0,36876788 |
| $A_k \# C_k$ | 0,94104259 | 0,96134064 | $A_k \# C_k$ | -0,61974188 | 0,42290864 |
| $B_k \# C_k$ | 0,96076892 | 0,99449032 | $B_k \# C_k$ | -0,4271211 | 0,48737524 |

**Table 3:** Numeric example of correlation scores of firms' technology overlap for standards.

For our hypothetical examples, we can see that in Standard 1, Firms a, b, and c have highly correlated patent portfolios and a high angle. In Standard 2, firms have negatively correlated patent portfolios, and the angle is much lower. It thus becomes apparent that the Correlation Coefficient and the angle carry similar information on the similarity between firms.

In addition to the pairwise information on the similarity between firm portfolios, we analyze the technological position of a firm with respect to the remainder of the standard. For instance we wish to identify technological specialists and generalists. Therefore, for each standard and firm, we count the patents filed by all the other firms active on the standard. We can then calculate the angle and the correlation coefficient between each firm vector and the vector for the respective remainder of the standard (the *specialization scores*):

| Standard 1 | | | Standard 2 | | |
|---|---|---|---|---|---|
| | ***r*** | ***A*** | | ***R*** | ***A*** |
| $A_k\#A'_k$ | 0,96786784 | 0,96720225 | $A_k\#A'_k$ | -0,78088686 | 0,44217823 |
| $B_k\#B'_k$ | 0,98432414 | 0,99709339 | $B_k\#B'_k$ | -0,83409962 | 0,48681172 |
| $C_k\#C'_k$ | 0,95190175 | 0,98758573 | $C_k\#C'_k$ | -0,96618556 | 0,55264489 |

**Table 4:** Numeric example of rivalry scores of standards.

In Standard 1, Firms A, B and C have all very high correlation coefficients and very high angle scores. They are thus all technology generalists for Standard 1. In Standard 2, all the firms have negative correlation coefficients and low angle scores. In Standard 2, the three firms are technology specialists (each specializing on a different technological field).

Based upon the specialization scores, we can finally calculate the weighted average score of specialization for a standard. We weight the specialization score of each firm with the share of the firm in the patents in the standard-related field, and sum the weighted scores to obtain the weighted average score, or the *rivalry score* of the standard.

| Standard 1 | | | | Standard 2 | | | |
|---|---|---|---|---|---|---|---|
| | *Share* | ***r****share* | ***a****share* | | *share* | ***r****share* | ***a****share* |
| Firm A | 0,1441441 | 0,1395124 | 0,1394165 | Firm A | 0,3436 | -0,2683 | 0,1519 |
| Firm B | 0,2702702 | 0,2660335 | 0,2694847 | Firm B | 0,4103 | -0,3421 | 0,1997 |
| Firm C | 0,5855855 | 0,5574199 | 0,5783159 | Firm C | 0,2462 | -0,2378 | 0,1360 |
| Weighted Average | 1 | 0,9629659 | 0,9872172 | Weighted Average | 1 | -0,8483 | 0,4877 |

**Table 5:** Numeric example of rivalry scores of standards.

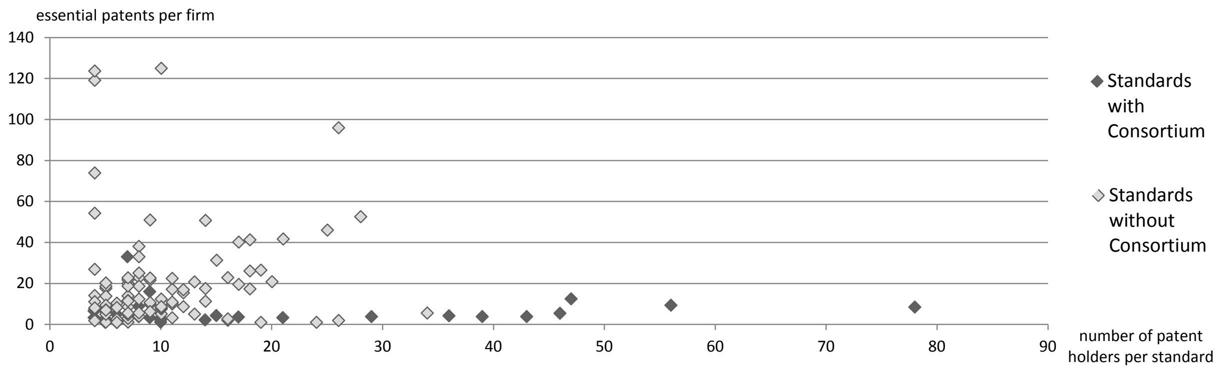
The *rivalry score* of Standard 1 is very high: all companies have their relative focus of specialization on the same technologies. There is thus potentially a very tough competition for including patented technologies into this standard. This pattern can induce patent races and wasteful excess patenting, as each firm does not take into account the negative effect of its R&D efforts on the profitability of the R&D of the other firms (Baron et al., 2012). Standard 2 however is characterized by a very low rivalry score. Each firm is specializing on a different technological field. There is thus less risk of wasteful patent races, but there might be free-riding problems: each firm benefits from the R&D investments of the other firms, investing in technologies which are complementary, but not competing with the technological portfolio of the firm. Therefore firms underinvest in R&D, as they do not take into account the positive effect of their own R&D upon the profitability of the R&D programs of other firms.

## 4. Empirical Analysis

In the following analysis we conduct several statistical tests, to identify factors of consortia formation and consortia membership. As mentioned in our methodological section we use pre sample data to ensure independence of the event of analysis.

### Fragmentation of patent holders and the existence of standards consortia

In our theoretical section we have discussed that the fragmentation of IPR ownership may result in coordination failures. To overcome these obstacles, firms may form standards consortia to solve conflicts of interest. We use two variables to test situations of fragmentation IPR ownership among standard setting firms. First, we count the number of essential patent owning firms; second we relate the number of standard essential patents to the number of firms. Graph 1 illustrates the distribution of standards with and without consortia. Consortia have been formed for all standards with an unusually high number of patent holders. Furthermore for these standards the concentration of patents per firm is remarkably low. In comparison standards where we could not identify a consortium show in some cases a very strong concentration of patents per firm, while the number of patent holders is lower.




**Graph1:** Comparison of standards with and without consortia in a matrix of essential patents per firm and the number of patent holding firms.

The distribution graph indicates that consortia are particularly relevant to standards in situations of fragmented ownership of IPR. However, we seek to further test if these are also situations of technological rivalry.

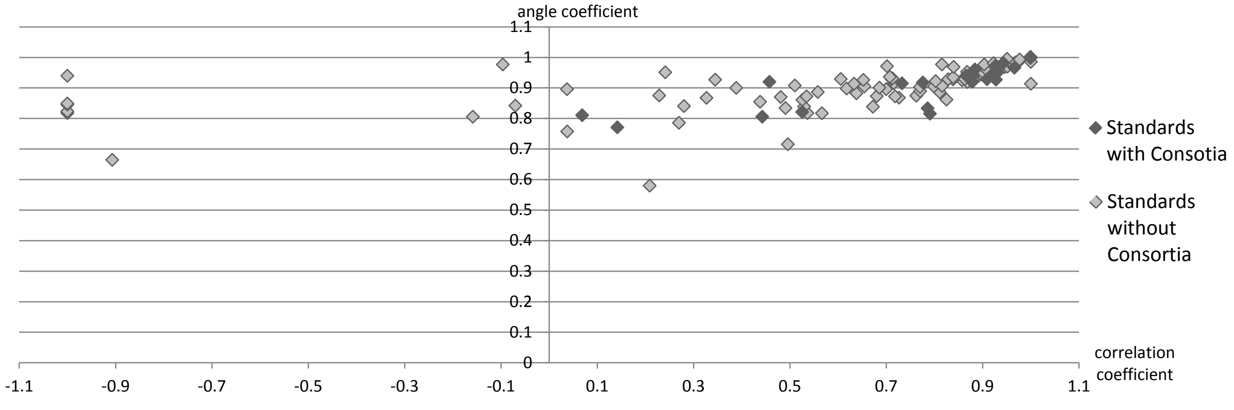
### Rivalry scores and the existence of standards consortia

We compare the rivalry scores of standards that can be related to consortia with other standards for which no consortium could be identified. For calculating the rivalry scores per standard we use the approach described in our previous methodological section. High rivalry scores indicate a high technological overlap among all firms that contribute to a particular standard. Table 7 shows the results of t-tests comparing the mean rivalry scores between standards with and without consortia.

| **Rivalry Scores** | | **Angle Coefficient** | **Correlation Coefficient** |
|---|---|---|---|
| Standards with Consortia | Mean | 0.9269 | 0.7575 |
| | Obs. | 28 | 22 |
| Standards without Consortia | Mean | 0.9102 | 0.5544 |
| | Obs. | 97 | 86 |
| t-statistics | T | 1.0726 | 1.8364 |
| | Pr(T < t) | 0.8572 | 0.9654 |
| | Pr(T > t) | 0.1428 | 0.0346 |

**Table 5:** Mean rivalry scores for standards with and without consortia.

The rivalry scores are successively calculated using the angle and the correlation coefficient. While the comparison of the rivalry scores using the angle coefficient does not reveal significant differences, we can see that the correlation-based rivalry scores of standards related to consortia are significantly higher than the scores of other standards. We further graph the distribution of rivalry scores per standard in a matrix of correlation and angle coefficients. Graph 2 shows that correlation and angle coefficients strongly correlate. The angle coefficient shows just a slight different distribution for standards with and without consortia. However, in comparison the correlation coefficient rivalry scores show no negative values when standards are subject to consortia and concentrate on higher values.




**Graph2:** Comparison of the rivalry score distribution of standards with and without consortia in a matrix of correlation and angle coefficients.

Results of our t-statistics as well as our distribution graph indicate that consortia are more likely to accrue in situations of high technological rivalry and fragmented ownership of IPR. We further test our descriptive findings and count the number of consortia in several intervals of coefficients for the two rivalry scores. In addition we conduct a pair wise correlation analysis (results can be consulted in appendix 1). Both analyses again confirm our previous results. Standards consortia are more frequent in higher intervals of rivalry scores. The correlation matrix indicates a significant positive connection of consortia existence with our rivalry scores and with the number of patent holders. In comparison, consortia formation and the number of essential patents per firm negatively correlate.

### Specialization scores and consortia membership

In a next step, we compare consortia members and other companies as to their specialization scores. A high angle or correlation coefficient indicates that a firm's standard-specific patent portfolio is very similar to the portfolio of other firms, whereas a low score characterizes strong technological specialization. The following table compares consortia member with firms that contribute to standards without consortia (firms that contribute to standards where we do not identify a consortium) and consortia outsiders (firms contributing to a standard for which at least one consortium exists, but which are not member).

| **Specialization Scores** | | **Angle** | **Correlation Coefficient** | **Angle** | **Correlation Coefficient** |
|---|---|---|---|---|---|
| Consortia Members | Mean | 0.918 | 0.876 | 0.918 | 0.876 |
| | Obs. | 118 | 118 | 118 | 118 |
| Firms on Standards without Consortia | Mean | 0.875 | 0.598 | | |
| | Obs. | 746 | 716 | | |
| Consortia Outsiders | Mean | | | 0.854 | 0.664 |
| | Obs. | | | 163 | 163 |
| t-statistics | T | 2.4945 | 4.5940 | 3.1991 | 4.311 |
| | Pr(T < t) | 0.9936 | 1.0000 | 0.9985 | 1.0000 |
| | Pr(T > t) | 0.0064 | 0.0000 | 0.0015 | 0.0000 |

**Table 6:** Mean specialization scores for consortia members and non-members.

The comparison of both, the calculated angle and the correlation coefficient indicates that technological specialists are less likely to be consortium members. Furthermore we show that firms that contribute to standards where we do not identify consortia are more specialized and thus have less technological overlap to other standard setting firms.

We further test these findings by calculation a logit regression:

| | M1-A | M1-B | M2-A | M2_B | M3-A | M3-B |
|---|---|---|---|---|---|---|
| DV=Consortium Member | Coef. (SE) | Coef. (SE) | Coef. (SE) | Coef. (SE) | Coef. (SE) | Coef. (SE) |
| Correlation Coefficient | 2.170** (0.902) | | 2.016** (0.959) | | 2.272** (1.002) | |
| Angle Coefficient | | 4.380*** (1.666) | | 4.093** (1.839) | | 4.382** (1.804) |
| Rel. Patent Portfolio | | | 0.105 (0.119) | 0.095 (0.118) | 0.106 (0.139) | 0.097 (0.133) |
| Rel. Patent Declaration | | | -1.231 (2.824) | -1.272 (2.711) | -1.71 (3.049) | -1.782 (2.947) |
| Relative Employee | 0.319*** (0.113) | 0.270** (0.117) | 0.284*** (0.108) | 0.244** (0.106) | 0.354*** (0.115) | 0.300*** (0.115) |
| Relative R&D Expenditure | 0.067 (0.291) | 0.11 (0.277) | 0.016 (0.310) | 0.061 (0.300) | 0.001 (0.314) | 0.042 (0.301) |
| Firms on Standard | 0.150*** (0.034) | 0.153*** (0.031) | 0.147*** (0.034) | 0.150*** (0.031) | 0.096*** (0.023) | 0.106*** (0.021) |
| Cons | -5.670*** (1.064) | -7.920*** (1.631) | -5.448*** (1.004) | -7.562*** (1.642) | -4.186*** (0.842) | -6.559*** (1.444) |
| Standard Dummies | YES | YES | YES | YES | YES | YES |
| Consortia Exists Restriction | **NO** | **NO** | **NO** | **NO** | **YES** | **YES** |
| N_clust | 108 | 108 | 108 | 108 | 15 | 15 |
| N | 816 | 816 | 816 | 816 | 196 | 196 |
| Pseudolikelihood | -95.924 | -96.215 | -95.493 | -95.833 | -82.382 | -83.551 |
| Pseudo R2 | 0.717 | 0.716 | 0.718 | 0.717 | 0.373 | 0.364 |

Note: All models apply a Logit-analysis with clustered robust standard errors (in parenthesis). Standard errors are robust to arbitrary heteroskedacity and allow for serial correlation through clustering by firm pair. ***,**,and * imply significance at the 99%, 95%, and 90% levels of confidence, respectively.

**Table 7:** Logit regression models explaining consortia membership.

We run estimations on two different samples, successively estimating the likelihood of consortium membership in general and consortium membership conditional upon the existence of at least one consortium (M1-M2 and M3). We control for firm characteristics relative to the average characteristics of firms active on the specific standard (firm size in terms of employees; R&D expenditures, patent portfolio, number of declared essential patents), and for the fragmentation of IPR ownership (Firms on standard). Variable descriptions and summary statistics can be consulted in Appendix 2.

Results of the logit model confirm our previous descriptive findings. Technological specialists – firms with a low angle and correlation coefficient with respect to the remainder of the standard – are less likely to be consortium members. In all models, the number of firms that hold patents on the standard has a positive influence on joining a consortium. This again confirms that situations of fragmented IPR ownership increase incentives to coordinate. We furthermore find that firms with a higher number of employees than the average of the firms contributing to the same standard are more likely to be consortium members for this standard.

**Similarity scores and joint consortia membership**

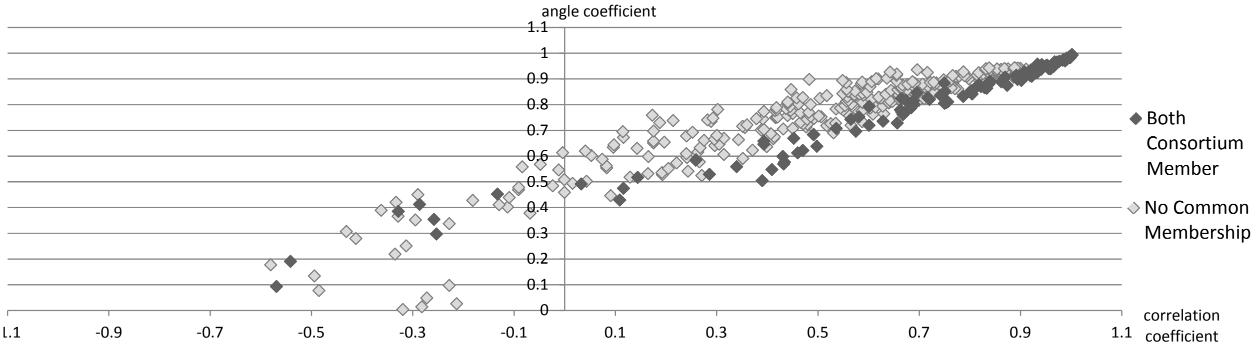
In a final step, we compare pairs of companies contributing the same standard and analyze the similarity scores of the standard-specific patent portfolios on the likelihood to be member of the same consortium. The following table compares the similarity scores (calculated using the angle and the correlation coefficient) of company-pairs where both companies are members of the same consortium with other pairs of companies contributing to the same standard.

| **Similarity Scores** | | **Angle** | **Correlation Coefficient** |
|---|---|---|---|
| Pairs of companies which are member of the same consortium | Mean | 0.8472 | 0.7844 |
| | Obs. | 1,954 | 1,954 |
| Remaining pairs of companies active in the same standard | Mean | 0.7887 | 0.5994 |
| | Obs. | 5,028 | 5,028 |
| t-statistics | T | 11.4342 | 18.5344 |
| | Pr(T < t) | 1.0000 | 1.0000 |
| | Pr(T > t) | 0.0000 | 0.0000 |

**Table 8:** Mean similarity scores for consortia co-members and non-members.

The t-test mean comparison indicates that companies with similar patent portfolios have a significant higher likelihood to be members of the same consortium.  Technological overlap between firms' patent portfolios for a particular standard thus seems to increase their incentives to become co-members in standards consortia. To better illustrate the distribution of our estimated coefficients we graph a scatter plot.

Graph 3 plots the scores of our similarity measure in a matrix of correlation and angle coefficients. In situations where both firms are member, the scores seem to rather concentrate on higher levels, compared to situations where firms are not co-members. However, the distribution also shows cases where the similarity score of co-members are rather low.




**Graph 3:** Comparison of the similarity score distribution of situations of co-membership and no membership in a matrix of correlation and angle coefficients

Once again, we test these results using a logit regression model. We control for measures of firm similarity or dissimilarity, such as variables indicating whether the companies are active in the same industry, or whether the companies have the same business model (classified by manufacturer, network provider or non-practicing entity). In addition, we control for the difference in firm size, in R&D expenditures, in the size of the patent portfolio and in the number of declared essential patents. These measures are constructed by dividing the larger value by the lower value. We furthermore include the full list of standard dummies to control for standard fixed effects, restrict the sample to standards with at least one consortium, and cluster standard errors by standards and firms. Variable descriptions and summary statistics can be consulted in Appendix 3.

Regression results are consistent with the mean comparison. The similarity score (calculated with the angle and correlation coefficient) has a positive effect on the likelihood of membership in the same consortium. Even though we have identified situations where co-members' patent portfolios are less similar compared to non-members, our statistical estimations conform a higher likelihood of joint membership when similarity scores are high.

Our control variables show that companies with the same business model are more likely to be members of the same consortium. Differences in the amount of R&D expenditure or the total number of the firms' patents are negatively correlated with co-membership.

| | M1-A | M1-B | M2-A | M2_B | M3-A | M3-B |
|---|---|---|---|---|---|---|
| DV = Both Member | Coef. (SE) | Coef. (SE) | Coef. (SE) | Coef. (SE) | Coef. (SE) | Coef. (SE) |
| Correlation Coefficient | 1.350*** (0.182) | | 1.286*** (0.188) | | 0.709*** (0.181) | |
| Angle Coefficient | | 2.704*** (0.364) | | 2.611*** (0.381) | | 1.184*** (0.385) |
| Diff. Employee | -0.001 (0.001) | -0.001 (0.001) | -0.001 (0.001) | -0.001 (0.001) | 0 (0.001) | 0 (0.001) |
| Diff. R&D Exp. | -0.014*** (0.003) | -0.014*** (0.003) | -0.015*** (0.003) | -0.015*** (0.003) | -0.014*** (0.003) | -0.014*** (0.003) |
| Same Business Model | | | 0.796*** (0.239) | 0.835*** (0.24) | 1.082*** (0.258) | 1.127*** (0.257) |
| Same Industry | | | 0.155 (0.6) | 0.178 (0.572) | 0.189 (0.637) | 0.184 (0.608) |
| Diff. Patent Portfolio | | | | | -0.002*** (0.001) | -0.002*** (0.001) |
| Diff. Patent Declaration | | | | | 0.004 (0.007) | 0.005 (0.007) |
| Cons | -0.017 (0.192) | -1.392*** (0.308) | -0.430* (0.247) | -1.798*** (0.376) | 0.133 (0.278) | -0.371 (0.422) |
| N Clustered | 675 | 675 | 675 | 675 | 675 | 675 |
| N | 1256 | 1256 | 1256 | 1256 | 1256 | 1256 |
| Log Pseudolikelihood | -445.927 | -449.125 | -435.661 | -437.721 | -407.567 | -410.171 |
| Pseudo R2 | 0.3023 | 0.2973 | 0.3184 | 0.3152 | 0.3623 | 0.3583 |

Note: All models apply a Logit-analysis with clustered robust standard errors (in parenthesis). Standard errors are robust to arbitrary heteroskedacity and allow for serial correlation through clustering by firm pair. ∗∗∗,∗∗,and ∗ imply significance at the 99%, 95%, and 90% levels of confidence, respectively.

**Table 9:** Logit regression models explaining consortia co-membership.

## 5. Discussion and outlook

In this article we provide novel empirical evidence on standards consortia accompanying formal standard development. While the earlier literature has discussed standards consortia as an alternative to formal standardization, more recent research has revealed many examples of complementarity between consortia and formal standard development. Nevertheless, until now, our understanding of the precise role of standards consortia in the standardization process is limited. For instance, an important limitation is the lack of empirical analysis of the incentives to join or not to join these consortia. In this article, we have for the first time used a large database to analyze the driving factors of consortia membership. In particular, we construct and compare measures of complementarity and substitutability of patent portfolios. The motivation for this analysis is the expectation that the effect and the very nature of R&D coordination among technological competitors differs from R&D coordination among firms specializing in rather different, complementary technological fields.

Recent research indicates that coordination in standard setting is especially difficult to accomplish, when the ownership of IPR is fragmented and when firms have vested interests in a particular standard (Farrell & Simcoe, 2012; Simcoe, 2012). Standards consortia may be a means to solve coordination failures and regulate conflicting interests. However, standards consortia may also be a venue where firms coordinate their R&D decisions to strengthen their positions against outside competitors (Leiponen, 2008). In both cases standard consortia are formed in situations where the ownership of IPR is fragmented among several market participants and when the level of technology rivalry among firms is high. Results of our estimations confirm both theoretical implications. We show that standards consortia are especially created when a high number of firms hold a comparable even number of patents. Furthermore our results indicate that in situations of higher technological overlap among standard setting firms, consortia formation is more likely.

Literature findings so far identified two reasons for joining standards consortia. First, consortia may solve coordination failures and reduce wasteful duplication of R&D investments. Thus, we would expect that firms with a high technological overlap join the same standards consortia. Second, firms participate in standards consortia to increase their influence on standard developing against outside solutions (Leiponen, 2008; Pohlmann and Blind, 2012). This may be especially beneficial when joining consortia with firms that have a rather complementary patent portfolio.

Our results indicate that firms with substitutable R&D programs are more likely to be members of the same consortium. A potential explanation for this finding is that consortia regulate upstream conflicts of interest, thus avoiding wars of attrition in the formal SDO. Another explanation, analogous to examples of research alliances (Irwin and Klenow, 1996), could be that a major benefit of consortia for their members is to save the costs of wasteful R&D duplication. Indeed, through upfront R&D coordination, companies with substitutable research capacities can better anticipate technology selection decisions in SDO working groups, evaluate the strength of rivaling technological proposals and dissuade potential competitors from entering into patent races.

This finding is likely to fuel further debates regarding the welfare implications of the increasing role of standards consortia in the process of standard development. On the one hand, Baron et al. (2012) point out that standards consortia in the cases of strong technological rivalry improve the efficiency of R&D, resulting in a reduction of wasteful R&D investments. On the other hand, consumers and other standard users may often benefit from the technological competition among standard setting participants. If the major economic function of consortia is to chill down technological rivalry, SDO cooperation with standards consortia should be monitored carefully by competition authorities. This is especially important as several large SDOs currently develop more permissive policies to encourage a larger role of consortia in the upfront coordination of R&D for standards (see for instance the ISO Strategic Plan 2011-2015)[9]. In contrast to the great interest for patent pools, the competitive effects of standards consortia have received so far only limited attention from economic researchers. In spite of these concerns, our findings alone do however not justify advocating for a restrictive stance with respect to standards consortia. Further empirical research is warranted, in particular because in this article we do not directly analyze the effects of consortia or of consortium membership.

[9] http://www.iso.org/iso/iso_strategic_plan_2011-2015.pdf

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**Appendix 1**

| Rivalry Score: **correlation** coefficient (interval) | | Number of Standards in Interval | Consortia connected to Standards |
|---|---|---|---|
| -1 | 0.344745 | 20 | 4 |
| 0.388332 | 0.652659 | 20 | 3 |
| 0.654504 | 0.798965 | 20 | 5 |
| 0.802343 | 0.885222 | 20 | 7 |
| 0.887512 | 0.950764 | 20 | 13 |
| 0.950764 | 1 | 10 | 9 |

**Table 10:** Intervals of correlation coefficients and the existence of consortia

| Rivalry Score: **angle** coefficient (interval) | | Number of Standards in Interval | Consortia connected to Standards |
|---|---|---|---|
| 0.579933 | 0.840531 | 20 | 8 |
| 0.841466 | 0.895696 | 20 | 0 |
| 0.897691 | 0.926574 | 20 | 4 |
| 0.927145 | 0.944235 | 20 | 12 |
| 0.945642 | 0.976391 | 20 | 6 |
| 0.976691 | 1 | 20 | 12 |

**Table 11:** Intervals of angle coefficients and the existence of consortia

| Pairwise correlation analysis | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | **1** | **2** | **3** | **4** | **5** | **6** |
| **1** | consortia formation | 1 | | | | | |
| **2** | correlation coefficient | 0.162* | 1 | | | | |
| **3** | angle coefficient | 0.096 | 0.562*** | 1 | | | |
| **4** | number of standard essential patents | -0.117 | 0.149 | -0.034 | 1 | | |
| **5** | number of patent holders per st. | 0.372*** | 0.314*** | 0.217** | 0.381*** | 1 | |
| **6** | essential patents per firm | -0.259*** | -0.042 | -0.176 | 0.700*** | -0.042 | 1 |

Note: ***,**,and * imply significance at the 99%, 95%, and 90% levels of confidence, respectively.

**Table 12:** Pairwise correlation analysis on the formation of consortia

## Appendix 2

| Variable | Description | Obs. | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|---|
| Consortium Member | Denotes one if firm is member of the consortium, 0 if not. | 971 | 0.153 | 0.361 | 0.000 | 1.000 |
| Correlation Coefficient | Correlation of a firm's patent portfolio compared to all other firms' patent portfolios contributing to the particular standard. Calculated as described in the method section. | 867 | 0.649 | 0.473 | -1.000 | 1.000 |
| Angle Coefficient | Correlation of a firm's patent portfolio compared to all other firms' patent portfolios contributing to the particular standard. Calculated as described in the method section. | 970 | 0.893 | 0.138 | 0.039 | 1.000 |
| Relative Patent Portfolio | Relation of the number of a firm's patents to the mean number of firms' patents on the same standard. | 971 | 1.000 | 1.172 | 0.000 | 9.107 |
| Relative Patent Declaration | Relation of the number of a firm's essential patents to the mean number of firms' essential patents on the same standard. | 942 | 0.099 | 0.148 | 0.000 | 0.981 |
| Relative Employee | Relation of the number of a firm's employees to the mean number of firms' employees on the same standard. | 953 | 1.018 | 1.031 | 0.002 | 5.590 |
| Relative R&D Expenditure | Relation of the amount of a firm's R&D expenditure to the mean amount of firms' R&D expenditure on the same standard. | 944 | 1.028 | 0.720 | 0.001 | 3.786 |
| Firms on Standard | Number of firms that hold essential patents for the particular standard. | 970 | 13.769 | 10.521 | 4.000 | 49.000 |

**Table 13:** Variable description comparing firm participation in a standard consortium and characteristics to mean values of other participating firms.

## Appendix 3

| Variable | Description | Obs. | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|---|
| Both Member | Denotes one if both firms are member of the same consortium, 0 if not. | 5,138 | 0.248 | 0.432 | 0.000 | 1.000 |
| Correlation Coefficient | Correlation of the firm's patent portfolio compared to the other firm's patent portfolio. Calculated as described in the method section. | 4,636 | 0.617 | 0.423 | -1.000 | 1.000 |
| Angle Coefficient | Correlation of the firm's patent portfolio compared to the other firm's patent portfolio. Calculated as described in the method section. | 5,138 | 0.827 | 0.191 | 0.000 | 1.000 |
| Diff. Patent Portfolio | Relation of the number of a firm's patents to number of the other firm's patents on the same standard. | 5,138 | 59.715 | 256.143 | 1.000 | 7,320.140 |
| Diff. Patent Declaration | Relation of the number of a firm's essential patents to the number of the other firm's essential patents on the same standard. | 5,138 | 10.144 | 15.739 | 1.000 | 190.000 |
| Diff. Employee | Relation of the number of a firm's employees to the number of the other firm's employees on the same standard. | 4,884 | 50.529 | 161.379 | 1.015 | 1,349.333 |
| Diff. R&D Exp. | Relation of the amount of a firm's R&D expenditure to the amount of the other firm's R&D expenditure on the same standard. | 4,790 | 36.961 | 202.037 | 1.000 | 3,665.503 |
| Same Business Model | Denotes one if both firms have the same business model, 0 if not. | 5,138 | 0.563 | 0.496 | 0.000 | 1.000 |
| Same Industry | Denotes one if both firms are active in the same industry, 0 if not. | 5,138 | 0.053 | 0.223 | 0.000 | 1.000 |

**Table 14:** Variable description of firm pairs comparing joint participation in a standard consortium and firm characteristics.