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R&D MANAGEMENT

Who's pulling the strings? The influence of network structure on standard dominance

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Innovative systems and infrastructures require generally accepted common compatibility standards to enable components of such systems to interoperate. In some cases, various standards are developed by competing standards organizations, often resulting in standards battles. This paper focuses on factors that affect the outcome of these standards battles, and, specifically, on the effect of the structure of the industry-wide standards networks on standard dominance. The empirical context is the consumer electronics, telecommunications, and ICT arenas. We conduct a study of 103 standards organizations from 2000 to 2011. We find support for the hypothesis that standards that are supported by standards organizations that have a central position in the industry-wide standards network have a high chance of achieving dominance.

1. Introduction

A market that is characterized by increasing returns to adoption often results in the establishment of a single dominant design. One important underlying reason for this is the existence of network effects, whereby products increase in value the more they are adopted by end users (Farrell and Saloner, 1985; Katz and Shapiro, 1985). Often, in these markets, battles among compatibility standards are waged resulting in a 'winner takes all' situation (Shapiro and Varian, 1999). When single dominant standards are established, innovations in the form of e.g. new systems or platforms may be achieved whereby the compatibility standards ensure the interoperability of the distinct components. Furthermore, new complementary products and services may be developed on top of the platform.

Examples of standards battles include the battle between AC versus DC current, VHS versus Betamax, Multimedia compact disc versus Super Density Disc, WiFi versus HomeRF, and the more recent Blu-ray versus HD-DVD case (Cusumano et al., 1992; Shapiro and Varian, 1999; Van den Ende et al., 2012; Van de Kaa and De Vries, 2015; Van de Kaa et al., 2015). Various scholars have assessed the outcome of these battles by discussing factors for standard dominance (Lee et al., 1995; Chiesa et al., 2002; Suarez, 2004). They argue that resources (e.g. financial resources or reputation) may enable a standard supporter to devise certain innovation strategies (e.g. timing of entry or marketing) to accumulate installed base of the standard. Then, under the influence of network effects this may lead to standard dominance (Suarez, 2004).

Although much research has focused on factors for standard dominance (Hill, 1997; Shapiro and Varian, 1999; Schilling, 2002; Suarez, 2004; Gallagher, 2012) and studies have illustrated and analyzed the effect of standards network composition on standard dominance (Cusumano et al., 1992; Van den Ende et al.,

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2012), little has been written about the role of the structural characteristics of standards networks on the chances that the standards achieve dominance [one exception includes (Afuah, 2013)]. We address this gap in the literature and propose that the actors that support the standard, and specifically, their structural position in an industry-wide standards network play an important role in whether this standard will reach dominance in the market. Research has shown that networks provide benefits to participants in the network. For example, a firm's competitive position may be enhanced by forming relationships within the network (Porter and Fuller, 1986; Eisenhardt and Schoonhoven, 1996). Networks can provide information and learning benefits to their members (Hamel et al., 1989; Hamel, 1991). We explore these benefits in the context of standardization. Specifically, we address the question: what is the influence of the structural network position of a standards organization in an industry-wide standards network on the chances that the standard that is promoted by the standards organization achieves dominance?

In this paper, we distinguish between two types of networks; standards organizations and industry-wide standards networks. A standards organization is defined as a collection of actors that develop and/or promote a particular standard. Examples of such standards organizations are standards consortia, standards alliances, and standards committees. An industry-wide standards network is the total set of standards organizations in a specific industry, and the relationships among these standards organizations. A relationship between standards organization X and Y is established if actor A is a member of both standards organizations.

2. Theory and hypotheses

The literature on social and inter-organizational networks mentions several benefits of establishing inter-organizational relationships in general. Firms can gain access to key assets, resources, and capabilities, and they can improve their strategic position through their relationships with other actors in the network (Porter and Fuller, 1986; Eisenhardt and Schoonhoven, 1996). These benefits may also apply to standards organizations. For example, a standard supporter can provide access to complementary assets (Teece, 1986) that are essential for establishing standard dominance (Suarez, 2004). Such complementary assets include reputation and financial resources (Shapiro and Varian, 1999). Moreover, by establishing relationships with manufacturers of (key) complementary goods (Cusumano et al., 1992), firms can gain control over the availability and supply of these goods. A large availability of complementary goods leads to an increase in installed base and to standard dominance (Schilling, 2002; Cenamor et al., 2013). Furthermore, inter-organizational relationships can lead to collective action and coordination of tasks (Provan et al., 2007; Van den Ende et al., 2012), both of which are required to create a successful standard. Inter-organizational relationships can provide access to novel information and facilitate learning among actors. In fact, research has indicated that firms participating in standards organizations more frequently use each other's patents (Delcamp and Leiponen, 2014) increasing innovation output. Firms can also gain access to tacit capabilities (Lane and Lubatkin, 1998) or inaccessible knowledge (Hamel, 1991) through their network partners.

2.1. *Influential position*

When a standards battle is fought, it mostly occurs between rival standards organizations. For example, in the battle for a high density optical disk standard, Blu-ray battled against HD-DVD. Both standards were promoted by rival standards organizations. Eventually, Blu-ray won which spurred technological innovation in the form of Blu-ray disc players and gaming consoles, but also in the form of complementary goods (movies, games, etc.) (Gallagher, 2012). The presence of large powerful firms in a standards organization is often an incentive for smaller firms to join. They strengthen the organization by increasing available resources and knowledge (Teece, 1986; Axelrod et al., 1995). Hence, influential firms can convince other firms directly or indirectly to join standards organizations. However, besides being influential in (local) standards organizations, firms can also exert influence in an industry-wide standards network. They may have sufficient resources to participate in multiple standards organizations, and by doing so, assume an influential position in the industry-wide standards network.

First, by taking on an influential position in an industry-wide standards network, firms can gain access to knowledge and information faster and can access multiple short paths to other firms and standards organizations within the industry-wide network. As these members interact with more firms and participate in more organizations, they can also learn from actors and obtain external knowledge (Powel et al., 1996). Indeed, it has been argued that a firm's network position positively relates to its innovation output (Ahuja, 2000; Soh, 2010). As information diffuses through the network from actor to actor, it is important to keep the paths to other firms and organizations

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short as information is transmitted faster and with more integrity through a network with shorter paths (Powel et al., 1996; Soh and Roberts, 2003). The electronics market is characterized by rapid technological change and fast changing consumer preferences, and it is therefore important for standards organizations and firms to adapt their standards or products swiftly to keep up with the pace of technological progress and to satisfy consumer needs. Acquiring information before the competition can create a competitive advantage (Deeds and Hill, 1996). By implementing this information into the standard, the standard can be adapted to customer needs better and will therefore be more successful (Van den Ende et al., 2012).

Second, by taking on a central and influential position in the network, firms can exert more influence on other actors in the network (Soh, 2010) and can also spread information to other actors more easily (Provan et al., 2007). Potential partners can become interested if they receive information about the standard and the organization behind it through their network (Gulati, 1999). As the organization becomes a central point in an industry-wide network, its reach becomes larger, enabling actors to form more partnerships, and enhancing reputation and trust (Powel et al., 1996). Through this increased exposure, its actions become more visible, and the organization can better promote the supported standard. The promotion of the standard might persuade supporting firms in other (possibly competing) standards organizations to join the standards organization so that they can use the standard in their own products. These new member firms can implement the standard in their products, thereby increasing the installed base and the number of complementary products and positively influencing the chances of standard dominance (Cenamor et al., 2013). Hence, we posit that the influential position of the members of a standards organization can raise the level of influence of the standards organization, increasing the chances of success of the standard.

Hypothesis 1: *A standard that is supported by a standards organization that has a more influential position in an industry-wide standards network has a higher chance of achieving dominance.*

2.2. Structural holes

All ties can provide information, but ties can become redundant if the same information comes from different ties. Therefore non-redundant ties should be fostered, because they can provide different information more efficiently (Burt, 1992, 2004). Non-redundant ties exist when there are few connections between separate groups of actors. Due to the limited number of connections between the two groups of actors, the actors in the different groups possess different information. The separations between these groups are called structural holes (Burt, 1992). Structural holes can be bridged by actors that have ties with both groups. As the different sides of the structural hole hold different information, a bridging actor can create value by combining information (Burt, 2004). Firms that can successfully bridge these structure holes can serve as an obligatory passage point for information across the structural hole (Rosenkopf and Tushman, 1998). Firms active in different markets or niches will interact less often than firms active in the same market. Structural holes will therefore likely exist between different markets or niches.

Structural holes may also exist in industry-wide standards networks. The presence of structural holes means that only a few connections between the groups on different sides of the holes exist. Therefore, valuable consumer preference information is not available to other standards organizations, but only to the standards organization that bridges the structural hole. Consequently, this information can result in a competitive advantage for the standards organization that bridges the structural hole as to launch a standard successfully in a new market or niche, information about consumer preferences and the market environment is needed to determine the successful innovation strategy. Indeed, Afuah (2013) shows that structural holes and ties within a network positively affects its value. Furthermore, standards organizations that bridge structural holes and have access to valuable consumer preference information from different markets can use this information to adapt the properties of the standard to consumer demand in multiple markets. This would enable successful launching of the standards in multiple industries, which would increase the potential market size of the standard. Furthermore, by adapting standards to user requirements, more diverse firms will adopt the standard (Van den Ende et al., 2012). Launching products implementing the standard in different markets increases the installed base and the number and variety of complementary products, and consequently increases the chances of standard dominance (Cenamor et al., 2013). Therefore we posit:

Hypothesis 2: *A standard that is supported by a standards organization that can successfully bridge structural holes in the industry-wide standards network has a higher chance of achieving dominance.*

3. Method

This study uses data on standards, standards organizations, and firms (members) participating in the

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information technology, consumer electronics, and telecommunications market in the period from 2000 to 2011. The unit of analysis is the individual standards organization. We represent the standards organizations by the members that participate at the highest strategic level of the organization. These members can actually influence the strategic direction of the organization and the standard as they formally approve the specifications of the standard. In most standards organizations, this is the board of directors. In other standards organizations, it is the equivalent highest organizational level which has the power to vote. The board consists of people representing their respective firms. This study looks at the firms which these people represent and takes these firms to be board members.

To arrive at our sample of standards organizations we conducted a secondary data analysis in which we analyzed various websites that provide information on standards consortia (such as consortiuminfo.org). Furthermore, we analyzed academic literature that focus on standards in the industries involved. Each standards consortium that we found was analyzed to what extent dynamic membership data was available. Each consortium for which this data was available was included in the dataset. The data was collected using archived websites, press archives, and information from databases such as the Lexis–Nexis and Thomson One Banker. Examples of the standards organizations include the 1394 trade association and the USB implementers forum and examples of board members include Apple, Microsoft, and Motorola.

This study uses a sample of 103 standards organizations, which in total constitutes 644 complete observations (one observation constitutes a specific standards organization in a specific year). As the number of standards organizations is relatively large compared to the average number of observations per standards organizations, the results from this analysis will be efficient and consistent.

Using board membership data, we created a bipartite network of standards organizations and firms. Connections between standards organizations and firms are created through board memberships. We analyzed this network using the program UCInet. As the mathematics used to analyze social networks require square matrices, we converted the rectangular affiliation data matrices to square matrices by calculating the biadjacency matrix; a square matrix of dimensions $M X N$ (Scott, 2000). One dimension stands for the standards organizations and the other dimension stands for the firms.

The network characteristics are operationalized using measures for centrality [betweenness centrality (Burt, 1992; Provan et al., 2007; Gilsing et al., 2008) and eigenvector centrality (Mintz and Schwartz, 1981; Mariolis and Jones, 1982; Bonacich, 1987; Faust, 1997)] which are normalized to enable comparison between the networks.

The data in the database is sorted in long format; every standards organization has multiple entries in the database, namely one for every year for which data is available. Due to these repeated measurements ordinary regression cannot be used, as this would treat every entry as an independent measurement (Liang and Zeger, 1986). Hence generalized estimating equations (GEE) has been applied. GEEs are commonly used for analysis of longitudinal data in biostatistics and in medicine to estimate population-averaged responses, but the method has been used in strategic and management literature as well (Liang and Zeger, 1986; Katila and Ahuja, 2002). GEE accounts for repeated measurements by determining the average effect of the predictor variables on the response variables and allows specification of a correlation structure between the error terms.

The repeated measurements of the network characteristics of the standards organizations are correlated. The resulting autocorrelation could cause interdependence of the error terms, violating the assumptions of regression (Hair et al., 2005). Using GEEs with a specified correlation structure reduces these autocorrelation problems (Liang and Zeger, 1986).

3.1. Dependent variable

3.1.1. Standard dominance

Standard dominance was operationalized by determining the number of firms supporting the standard. To determine the number of supporting firms, we collected the total number of members which we have termed *network size*. Network size is measured by either counting the firms that are mentioned as being an adopter firm on the homepage of the standards organization in a specific year or, when that data is not available, gathering the data from announcements that are made on these pages or in e.g. press releases.

We considered only corporate members and ignored individual members, as the focus of this project is on firms and standards organizations. As network characteristics are not expected to influence network size immediately, the effects of these variables have been lagged by one year. This also partially corrects for standards organizations that have just been founded and have not had time to gain members. As the number of members in standards organizations can differ considerably, the distribution of organization size is nonnormal and positively skewed. We therefore transformed the data by taking the logarithm of network size to make the data approximately normal.

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3.2. Independent variables

3.2.1. Influential position

To measure the value of the connections to the board members, we used eigenvector centrality which accounts for both direct and indirect ties. This measure of centrality is positively related to social capital and has been used to estimate the influence of an actor (Bonacich, 2007). Eigenvector centrality in bipartite graphs has often been used in studies of interlocking corporate boards to measure the centrality of the actors (Mintz and Schwartz, 1981; Mariolis and Jones, 1982; Bonacich, 1987; Faust, 1997).

3.2.2. Structural holes

To measure the bridging of structural holes for Hypothesis 2, we used betweenness centrality. To calculate betweenness centrality, we calculated all possible shortest paths between nodes. Betweenness centrality measures how many of these shortest paths pass through a node (Freeman, 1979). In the bipartite graph, the theoretical maximum number of shortest paths differs from the one-mode case, hence a different normalization is required. A node that connects structural holes will lie on many of the shortest paths connecting the two sides of the hole; consequently this node will have a high betweenness centrality (Scott, 2000). Betweenness centrality is highly correlated with structural holes (Burt, 1992) and has been used to measure access to structural holes (Provan et al., 2007; Gilsing et al., 2008).

3.3. Control variables

3.3.1. Year

The goal of this study has been to determine the influence of network characteristics on standard dominance. The tested model is not a complete model as other factors have also been shown to affect the chances of standard dominance. Although these factors have not been incorporated into the model the intercept for every year is flexible. These flexible intercepts have been fitted using a categorical year variable. This procedure aided in accounting for exogenous effects such as market or environmental factors. As standards organizations experience similar events and a similar environment in the same year, the year could affect the network size in a certain years.

3.3.2. Years active

Another important characteristic of a standards consortium is the years that it is active. The more years it is active, the more time it will have to increase the number of standard supporters. Furthermore, in each year that it is active it can build up reputation and credibility among potential users which has been shown to be an important aspect that determines their choice for the standard and thus standards dominance (Van de Kaa et al., 2011). Also, the more years, the more time it will have to improve the standard according to the requirements of potential users which is also an important aspect that positively affects network size (Van den Ende et al., 2012). The years that the consortium is active is measured by subtracting the last year that the consortium was active from the first year that it was active.

3.3.3. Consortium size

One important characteristic of a standards consortium is the number of actors that are promoting the standard. The more actors, the more assets, resources, and capabilities that are available. For example, the more promoting actors, the more financial resources are available to e.g. fund marketing campaigns which can positively influence expectation toward the standard (Suarez, 2004). This has a positive effect on the chances that additional firms will support the standard. The size of the consortium is measured by counting the number of firms represented in the board of directors of the consortium.

4. Results

Table 1 shows the descriptive statistics and the correlations between the variables. Although the variables

Table 1. Descriptive statistics and correlations

Variable	Mean	SD	Min	Max	1	2	3	4
1. Standard dominance	4.51	1.19	1.61	7.00				
2. Structural holes	0.026	0.021	0.000	0.117	0.206**			
3. Influential position	0.089	0.070	0.000	0.312	0.412**	0.328**		
4. Years active	9.31	10.90	0	94	0.197**	0.417**	0.050	
5. Consortium size	10.7	5.4	2	30	−0.762**	0.060	−0.162**	0.099

$n = 644$.
**$P < 0.01$ (two-tailed).

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Table 2. Generalized estimating equations results

Variable	Model 1	Model 2	Model 3	Model 4
Intercept	3.78***	3.58***	3.58***	3.66***
	(0.26)	(0.25)	(0.26)	(0.24)
Year 2000	0.06	0.15	0.03	−0.02
	(0.18)	(0.18)	(0.19)	(0.19)
Year 2001	−0.04	0.04	−0.05	−0.09
	(0.17)	(0.17)	(0.17)	(0.17)
Year 2002	−0.07	−0.04	−0.07	−0.08
	(0.16)	(0.16)	(0.16)	−0.08
Year 2003	0.00	0.05	0.04	0.02
	(0.14)	(0.15)	(0.15)	(0.15)
Year 2004	0.03	0.06	0.05	0.04
	(0.14)	(0.14)	(0.14)	(0.14)
Year 2005	0.01	0.00	0.01	0.01
	(0.13)	(0.13)	(0.14)	(0.14)
Year 2006	−0.02	−0.04	−0.03	−0.02
	(0.12)	(0.12)	(0.12)	(0.12)
Year 2007	0.07	0.09	0.07	0.06
	(0.10)	(0.10)	(0.10)	(0.10)
Year 2008	0.00	0.07	0.00	−0.03
	(0.10)	(0.10)	(0.11)	(0.10)
Year 2009	−0.03	0.03	0.01	−0.01
	(0.05)	(0.06)	(0.06)	(0.05)
Years active	0.01	0.01	0.02*	0.02*
	(0.01)	(0.01)	(0.01)	(0.01)
Consortium size	0.06**	0.12***	0.04	0.01
	(0.02)	(0.03)	(0.05)	(0.03)
Structural holes		−17.26*	−7.92	
		(7.36)	(7.82)	
Influential position			6.08***	6.41***
			(2.04)	(1.94)
QIC	861.5	847.4	786.2	784.5
Difference in QIC	−69.5	−83.6	−144.8	−146.5
QICC	845.0	828.3	751.4	753.1
Difference in QICC	−86.1	−102.8	−179.7	−178.0

103 standards organizations, 644 valid observations.
Two-tailed test for controls, one-tailed tests for hypothesized variables.
$*P < 0.05$.
$**P < 0.01$.
$***P < 0.001$.

correlate we have checked the variance inflation factors and they are within normal limits.

The resulting regression coefficients with the standard errors are reported in Table 2. In the lower part of this table, two goodness-of-fit indicators have been added. As GEE estimates the parameters under unknown correlation structures, the normal goodness-of-fit indices cannot be used. Instead, the Quasi Likelihood under Independence Model Criterion (QIC) and the Corrected Quasi Likelihood under Independence Model Criterion (QICC) are used. Both these fit indices are extensions of Akaike Information Criterion. Smaller QIC and QICC indicate better model fit.

Model 2, which includes structural holes but without influential position, resulted in a positive and significant regression weight for structural holes. However, adding influential position removed this significant effect. This change in regression weight could be a sign of multicollinearity. This is also suggested by the correlations in Table 1, which show that influential position and structural holes are significantly correlated. We also tested a fourth model, which does not include structural holes. This model resulted in positive and significant regression weight for influential position at a lower QIC score but at a higher QICC score.

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Therefore, it cannot be indisputably determined whether this model is an improvement over Model 3.

All models that include influential position result in positive and significant regression weights, even at a very high significance level. Furthermore, we can conclude from the QIC and QICC scores that adding influential position results in a better fitting model than the variable intercept baseline model.

Therefore, we find support for the positive effects of the influential position of the standards organization in the network on the success of the standards organization and find support for Hypothesis 1. This implies that an increase in influential network position is associated with being a successful standards organization. This position is likely attained through their board members who are in an influential position in this network as well. These firms are very influential because they are industry leaders, hence their choice for a standard can influence the choice of other firms. Comparing the firms in this network indicated that the more renowned firms scored high on eigenvector centrality, which was used to operationalize influential position. Therefore, these firms have an influential position in the network.

For Hypothesis 2, the effect of structural holes in the industry-wide standards network on standard dominance, we found insufficient support. It should be remarked that the literature on structural holes has reached no consensus on the effects of structural holes. One school of thought formed by Burt and others proposes that value can be created if structural holes are bridged (Burt, 1992, 2004). Another school of thought emphasizes the trust generation function of networks. A network without structural holes facilitates the generation of trust. As all actors are connected to each other, opportunistic behavior can be punished through collective action (Coleman, 1988). Following this line of thought, one would assume that a network with structural holes would be less efficient in sharing information. Standards organizations that bridge structural holes may be faced with members that do not trust each other, which would negatively affect the performance of the standard. Ahuja (2000) also finds evidence for the negative effects of structural holes. As evidence for both schools of thought has been found, it is possible that bridging structural holes might affect the standards organization both positively and negatively. Hence, the total effect of bridging structural holes may indeed be zero. To check whether there may exist a non-linear relationship between the existence of structural holes and success we have included both the normalized betweenness centrality and its squared variant but this does not result in a model with a better fit and in the model both variables were not significant.

5. Discussion and conclusion

This paper focuses on factors that affect the outcome of standards battles. We have studied the influence of structural aspects of industry-wide standards networks on standard dominance. We have analyzed data from a dataset consisting of standards, standards organizations, and firms participating in these organizations, covering the period from 2000 to 2011. We found that a standards organization's influential position in an industry-wide standards network positively affects the chances that its standard achieves dominance. This is one of the first studies that relates structural network characteristics to standard dominance.

This research contributes to the theory on innovation management in general and standards and dominant designs in particular in several ways. First, although the effect of the composition of standards networks in relation to standard dominance has been researched in several case studies of standards battles (Cusumano et al., 1992; Van den Ende et al., 2012), we focus on the effect of network structure on standard dominance; a topic that has been scarcely studied. Second, longitudinal studies of innovation networks in general and standards networks in particular are lacking (one exception is Soh, 2010). Our study covers the period 2000–2011 and takes into account the various changes that took place in the industry-wide standards network during this period. Third, the effect of a standards organization's influential position in an industry-wide standards network on standard dominance has not been studied before. We show that a standards organization's influential position in an industry-wide network positively affects the chances that its standard achieves dominance. Finally, this study provides additional support for the notion that the outcome of standards battles is not fully characterized by path dependency, but that standard supporters can influence the outcome. This is in line with results from prior studies (Schilling, 2002).

This research also has managerial implications. Our results imply that support from influential firms is needed to achieve a successful standard. Earlier research has already indicated that firms with good reputation and sales affect the success of standards (Suarez and Utterback, 1995). Our study indicates that besides these static resources, it is important for a standards organization to have members that are active in an industry-wide network. To a certain extent, these effects will accompany each other as powerful and influential firms produce many products and therefore have incentives to join many standards organizations.

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In our findings, we see that the firms scoring the highest on eigenvector centrality, used to measure influential position, are well-known companies who are industry leaders (examples are Dell, Intel, Microsoft, Samsung, and Sony). Firms that develop standards should actively involve these industry leaders early in the standardization process as they can exert influence in an industry-wide standards network.

Operationalizing standard dominance through network size has two limitations. First, the size of the firm may also affect standard dominance since larger firms may have access to a larger potential installed base. However, firm size of the adopter firms is not taken into account because this data is mostly unavailable. Also, network size may be dependent on the potential number of adopters in a specific product category. However, again, that data is mostly unavailable. Another limitation is that all ties of the industry-wide network have been modeled as being equally strong. Although all firms in the board can participate in the decision making of the standards organization, some firms might be more influential in this process. Large firms or firms with specific capabilities and assets might be able to exert more influence on the development of the standard. Firms may participate in the board of multiple standards organizations, but their activity in these boards could differ. For example, firms might be more actively involved in a standards organization when the standard is more important to the firm. Future research could attempt to model these ties as ties of different strength. This information, however, is often not available. Even if this information was available, it would be difficult to use as many network measures do not exist for valued networks (Scott, 2000). Furthermore, we focus on firms and standards organizations that are active in the telecommunications, information technology, and consumer electronics industry. The question arises whether the results of our study are specific for these particular industries or whether similar results might apply for other industries. Future research could explore this in more depth. A final limitation is that we applied convenience sampling, and, therefore, our sample is not fully random and might not be completely representative of the full population of standards consortia.

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