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Flourish or Perish: The Influence of Interorganizational Networks and Flexibility on Technology Success in Winner-take-all Markets

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Abstract

This study focuses on cooperative standard setting. The empirical context is the home networking arena. This arena is characterized by rapid technological change and standards that are often supported by networks of actors. We hypothesize that the composition of these networks and the flexibility of these standards plays an important role in establishing dominance. Also, we hypothesize that network diversity, network size and standard flexibility reinforce each other. The study finds support for these hypotheses in a study of 137 consortia from 1990 to 2009.

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INTRODUCTION

Many industries are characterized by forces which lead to a single standard attaining dominance. In these industries positive direct network externalities arise where technology becomes more valuable when more people use it (Farrell *et al.*, 1985; Katz *et al.*, 1985). Most markets in which these effects exist are ‘two sided’ in that they consist of complementary goods for which the technology defines communication (Gallaughner *et al.*, 2002). Examples include the markets for VCRs (Cusumano *et al.*, 1992) and video game consoles (Gallagher *et al.*, 2002; Schilling, 2003). When more complementary goods are available for a technology, this has a positive effect on the installed base of that technology (Schilling, 2002). These “network markets” are often path dependent meaning that random historical events can determine the outcome of a technology battle (David, 1985; David *et al.*, 1990). Evolutionary economists place technology selection in the context of natural selection (Arthur, 1989). Technology evolves through periods of incremental change until, at some

point in time, a major breakthrough occurs in the industry. These so called technological discontinuities increase the uncertainty in the industry and usually change it considerably (Tushman *et al.*, 1986). As a result, a new technological paradigm emerges. Within a new paradigm, different technological paths can be developed, resulting in technologies that compete with each other for dominance (Utterback *et al.*, 1975). The technology that eventually achieves dominance is often referred to as the “dominant design” (Abernathy *et al.*, 1978; Utterback, 1994) or the “platform”.

Because the firm that establishes dominance with its technology can profit from a “winner-take-all” situation and can accrue monopoly rents with its technology (Shapiro *et al.*, 1999b) it is valuable for firms to understand which factors affect the outcome of technology battles. Scholars from various fields of research have endeavored to explain the outcome of technology battles (Lee *et al.*, 1995; Schilling, 1998; Suarez, 2004). Building on the resource based view of the firm (Penrose, 1959; Wernerfelt, 1984), scholars in the area of strategic management emphasized firm capabilities that are needed to successfully commercialize a technology. Teece (1986) uses the label complementary assets to describe factors including reputation, production capacity and distribution channels which can be exploited to reach a dominant standard (Suarez, 2004). Furthermore, firms that do not invest in knowledge acquisition run the risk of being locked out of the market (Schilling, 1998, 2002). Scholars have also focused on strategies that can be applied in network industries and that impact the expansion of an early installed base (McIntyre *et al.*, 2009). Willard and Cooper (1985) examine the influence of several strategic variables on survival in the TV industry and find that strategic factors influence market dominance, provided they are matched with the firm’s resources (including, its size and strength) and are effectively implemented. Various authors seem to agree on the significance of marketing communications to positively influence customer expectations regarding the standard (Besen *et al.*, 1994; Dranove *et al.*, 2003;

Farrell *et al.*, 1986; Gallagher *et al.*, 2002). Other authors focus on the price of a standard's implementation (Besen *et al.*, 1994; Farrell *et al.*, 1986), the availability of complementary goods (Hill, 1997; Schilling, 1999), appropriability strategies (Bekkers *et al.*, 2002; Brynjolfsson, 1996) and timing of entry (Schilling, 1998, 2002). Standardization scholars also emphasize technical characteristics including a standard's quality in terms of e.g. bandwidth capacity and the compatibility that it enables (Lee *et al.*, 2003). These scholars also focus on the importance of other stakeholders including standard development organizations. Moreover, government involvement in standardization may provide the standard with a certain degree of authority or legitimacy and is beneficial for its diffusion (Backhouse *et al.*, 2006). Also, governmental agencies may use their power to prescribe a standard (Greenstein, 1992). An example is the Federal Communications Commission which has exercised its power in the battle for a color television standard (Shapiro *et al.*, 1999b) and the battle for an HDTV standard (Farrell *et al.*, 1992).

In high technology markets, such as home networking, in which the pace of technological change is high, the uncertainty attached to choosing for a platform is high. When it becomes too great, firms are unwilling to take the risks which are attached to choosing a particular standard and postpone their decision (Jakobs, 2006; Leiponen, 2008; Schmidt *et al.*, 1998). To counteract uncertainty, inter-organizational relationships may be formed (Gulati *et al.*, 2000; Provan, 1982; Tushman *et al.*, 1992) which can decrease the risks considerably (Gulati *et al.*, 1999; Tidd, 1995). A selection of researchers has paid attention to the rationale for firms to establish joint ventures (Hamel *et al.*, 1989; Kogut, 1988). These scholars argue that from a strategy perspective firms establish relationships with the aim of decreasing transaction costs (Kogut, 1988), enhancing their competitive position (Eisenhardt *et al.*, 1996; Kogut, 1988; Porter *et al.*, 1986), and learning from each other (Hamel, 1991; Hamel *et al.*, 1989). These reasons will be further explored in the context of standardization.

Also, technology management scholars have argued that in turbulent environments with high levels of uncertainty, firms should adopt a flexible new product development process (Iansiti, 1995; Thomke *et al.*, 1998). Similarly, in this paper, we argue that it is important for a standard to change along the way so that it can be adapted to enable communication between different products. This research goes beyond previous research by testing a model developed in our earlier work¹.

So, the objective of this study is to gain a better understanding of the influence of the characteristics of the *network of a standard* and the *flexibility of the standard* on the chances that standards achieve dominance. We define the network of a standard as the set of firms that are involved in a standards organization, which serves the objective of developing, maintaining, and/or promoting that standard. Examples of standards organizations include standards consortia (Hawkins, 1999) and standard development organizations (Dokko *et al.*, 2010).

THEORY AND HYPOTHESES

In this section, we place the study in the context of existing theoretical and empirical contributions that study the impact of business networks on standardization outcomes. Furthermore, drawing from the present literature, we develop testable hypotheses.

Standardization scholars have thoroughly emphasized the influence of other stakeholders in the standards battle. Often, stakeholders other than the group of standard supporters can be influential. Firms can establish cooperation with these stakeholders, thereby decreasing the uncertainty that exists for each of the firms (Gulati *et al.*, 1999). The influence of cooperation on the establishment of a dominant standard has been illustrated in multiple examples of standards battles. One form of cooperation is a licensing alliance

¹ The reference to this research is not included since it may influence the double blind character of the review process.

(Somaya *et al.*, 2010), which can help build an installed base quickly and can increase the acceptance of a firm's standard. This was one of the reasons behind the success of Matsushita in the video standards battle (Cusumano *et al.*, 1992) and Microsoft in the operating systems battle. Licensing agreements have also played a role in the workstations industry (Garud *et al.*, 1993) and the video game industry (Gallagher *et al.*, 2002). When firms license their technology to other firms, they can acquire additional distribution channels and thus increase their installed base (Bekkers *et al.*, 2002). Another form of cooperation are inter-organizational relationships. These includes vertical relationships between buyers and suppliers, horizontal relationships between competitors, and diagonal relationships between firms operating in different product markets (Nooteboom, 1998). In the case of digital recording technology, two competing standards existed: DCC (Philips) and Minidisc (Sony). Since the consumer waited for one of the standards to become dominant, neither standard has become dominant. In another situation, Philips and Sony worked together and developed one standard which achieved dominance: the compact disc (Hill, 1997). A special kind of inter-organizational relationship is that between a firm and a manufacturer of complementary goods (Cusumano *et al.*, 1992; Khazam *et al.*, 1994; Willard *et al.*, 1985). An advantage of inter-firm relationships is that firms can learn from the actors with which they are connected (Schmidt *et al.*, 1998). For complex systems, the advantage of cooperation is that firms can gain access to new product markets (Hagedoorn, 1993). They can obtain complementary resources from firms in different product market and learn from them. A disadvantage of joining a network is that the firm's influence on the standardization process may decrease.

Network size

Strategy scholars increasingly recognize that a source of competitive advantages may lie in a firm's inter-organizational relations (Dyer *et al.*, 1998; Kogut, 1988). These linkages can

provide firms access to needed assets (Harrigan, 1988; Nohria *et al.*, 1991; Porter *et al.*, 1986), new markets (Hagedoorn *et al.*, 1990), and installed base (Langlois, 1992) and can thus be a source of value-generating resources and capabilities (Afuah, 2000; Gulati *et al.*, 1999; Kogut, 2000; Mahmood *et al.*, 2011; Rothaermel, 2001; Van de Ven *et al.*, 1984). The relationships that a firm fosters can potentially improve its strategic position (Eisenhardt *et al.*, 1996; Kogut, 1988; Porter *et al.*, 1986). Moreover, Xia (2011) found that when local and foreign firms establish a cross border alliance, repeated partnerships between the firms creates mutual dependence and positively influences the survival of the cross border alliance. Some scholars perceive a firm's network as a resource of its own accord (Afuah, 2000; Gulati, 1999) which, in social network terms, is comparable to the concept of social capital (Burt, 1997). Other scholars use the term relational capital to emphasize that the value emanates from the partnerships and not from the firms alone (Kale *et al.*, 2000). Consequently, in the literature a move from a dyadic to a network level of analysis has been observed (Gulati *et al.*, 2000). Some scholars relate the characteristics of networks and the actors involved to firm-level outcomes (Hagedoorn *et al.*, 1994). It has been shown that by forming networks, firms may increase their financial performance (Baum *et al.*, 2000; Hagedoorn *et al.*, 1994; Stuart, 2000) and, ultimately their chances of survival (Baum *et al.*, 1991; Mitchell *et al.*, 1996; Mitsushu *et al.*, 2009).

Following this line of reasoning and applying it to standard selection, relations may give firms access to complementary assets (Teece, 1986) increasing the likelihood of standard dominance (Suarez, 2004). Examples of these assets include (brand) reputation (Gallagher *et al.*, 2002; Schilling, 2003; Shapiro *et al.*, 1999a), manufacturing capability (Suarez *et al.*, 2005), and additional distribution channels needed to distribute the complementary goods that implement the standard (Schilling, 2003). Furthermore, relations may create the collective action (Marwell *et al.*, 1984; Smith, 1976) required to create a

strong market position for a standard. If all members of a network adhere to a standard in the products they produce or apply, the installed base of that standard will grow. Ensuing this argument we posit that the more firms involved in a standards organization, the higher the chance that the standard achieves dominance.

Hypothesis 1: The higher the number of firms that adopt the standard, the more likely the standard will become dominant.

Market power

Relations can also provide firms with access to assets in the form of additional financial resources. When introducing a standard, financial resources can be used to compensate start-up losses (Ehrhardt, 2004); a group of standard supporters that has a higher financial strength than competitors can endure longer periods of low earnings due to low prices, as well as spend more on marketing (Schilling, 1999). Thus, we expect that the more powerful actors are involved in the network of a standard, the higher are the standard's chances of achieving dominance (Axelrod *et al.*, 1995). We therefore assume that the market power of the network positively influences the chances that a standard becomes dominant. We define the market power of a network as the sum of the market powers of the individual members of the network. We propose:

Hypothesis 2: The higher the market power of the network of a standard, the more likely the standard will become dominant.

Standard flexibility

Several technology management scholars have contended that in turbulent environments with high levels of uncertainty, firms should adopt a flexible new product development process (Garud et al., 2008; Iansiti et al., 1997; Iansiti, 1995; Kamoche et al., 2001; MacCormack et al., 2003; Moorman et al., 1998; Thomke et al., 1998). This may speed up development time (Eisenhardt et al., 1995), improve product quality (MacCormack et al., 2003) and project performance (MacCormack *et al.*, 2001; Thomke, 1997). Flexibility facilitates the adaptation of a product to customer requirements (Thomke, 1997). Ideally, a match with user requirements can be reached. For instance, in the internet software industry, product quality can be increased by incorporating customer feedback into the software early on in the product development process (MacCormack *et al.*, 2003). While most studies on flexibility in new product development focus on the point until market introduction we argue that it may still be important after that point. Presumably, users will preferably adopt a standard in which their requirements have been taken care of. Standardization literature addresses the topic of flexibility as well and implicitly assumes a more flexible standard adds to technological superiority and thus, *ceteris paribus*, to standard dominance (Hanseth *et al.*, 1996). The modification of the standard can result in an increase in technological superiority (for instance, in terms of functionality (Cusumano, 2011)). Ideally, the standard is adapted to the requirements of every product market involved. This can increase the installed base of the standard. Accordingly, we hypothesize that when a standard is more flexible, the chances that the standard will become dominant will increase.

Hypothesis 3: The higher the flexibility of the standard, the more likely the standard will become dominant.

Network diversity and reinforcing effects

First, networks of actors can provide information from diverse sources (Beckman *et al.*, 2002). This information can be used to adapt the standard to the requirements related to different applications of the standard, facilitating the growth of its installed base.

Many firms form inter-organizational relationships to learn tacit capabilities (Lane *et al.*, 1998) or obtain knowledge that is difficult to obtain by other means (Dyer *et al.*, 1998; Hamel, 1991; Kogut, 1988). One example can be found in the Canadian biotechnology industry where start-ups allied with different firms to access their capabilities and information; the resulting diverse network increased the start-ups performance considerably (Baum *et al.*, 2000). Some authors contend that the impact of network diversity on firm performance is positive due to the fact that in networks that are diverse, firms will have access to more diverse information (Beckman *et al.*, 2002; Gilsing *et al.*, 2005; Phelps, 2010), which leads to greater levels of learning (Dussauge *et al.*, 2000). In networks that are diverse, complementary technological capabilities can be matched (Hagedoorn, 1993). On the other hand, diversity can potentially lead to decreasing mutual understanding (Nooteboom *et al.*, 2007), a lack of trust, and unfamiliarity between actors in the network (Goerzen *et al.*, 2005). Jiang *et al.* (2010) find support for a U-shaped relation between network diversity and firm performance. Also, forming alliances with the aim of learning can involve considerable amounts of risk as firms might disband the alliance prematurely and apply their newly appropriated knowledge independently as was the case with many joint ventures between Japanese and US firms (Hamel *et al.*, 1989). In fact, some scholars have described alliances as ‘learning races’ in which each partner behaves opportunistically and wants to achieve its goal of learning first (Hamel, 1991; Hamel *et al.*, 1989). The potential opportunistic outcomes of organizational learning can be diminished if a certain amount of trust exists between the partners that are involved in the relationship (Kale *et al.*, 2000).

The diversity of the network of a standard can be defined as the amount of different industries that are represented in the network. Novel information can be gained from these different industries. By gaining access to novel information, actors may learn from each other and incorporate the novel information into the standard. As such the standard can be modified to realize communication with other systems; this may increase the compatibility that the standard enables. When a standard enables compatibility with multiple systems (from different industries), the actors that develop products for these systems may choose to support the standard. This will increase the diversity of the network of the standard. So, we theorize that a reinforcing relationship exists between network diversity and standard flexibility.

Hypothesis 4: standard flexibility and network diversity reinforce each other.

Also, when changes are incorporated in the standard, subsequently, other firms that endorse these changes may choose to adopt the (improved) standard and implement it in their products potentially increasing network size. In fact, sometimes, standards are even changed on purpose to realize communication with other systems, so to include representatives of those systems and increase network size. At the same time, when those actors choose to join the network of that standard, they will also try to change the standard to increase compatibility with products from their own market. For example the French company Thomson initially did not want to support the HDTV standard since it owned too little patents in this area and therefore could not guarantee profits on the long term. However, the group of HDTV standard supporters knew that with the support of Thomson the chances that the HDTV standard would achieve dominance would increase and therefore the group modified the standard and incorporated a French packetswitching system that was technically inferior to the existing British system. This was done with the goal of attracting Thomson to the

group of HDTV standard supporters (Simons *et al.*, 2002). By doing so the chances that the French would chose for the standard increased considerably and that would also have a positive effect on other southern European countries. We hypothesize that standard flexibility positively affects network size:

Hypothesis 5: standard flexibility positively affects network size.

Our hypotheses are shown in the research model in Figure 1.

Insert Figure 1 here

METHODOLOGY

Unit of analysis

Since consortia play an important role in the outcome of standards battles, this study focuses on their role. In consortia, all actors involved are expected to have a full commitment and we can thus measure ‘involvement’ in an unambiguous way. However, the group of active members in standards consortia can be much smaller than the total membership. What most of these consortia have in common is a group of actors that set the strategic objectives of the consortium. This is the highest organizational unit in the consortium (in most cases the board of directors). Organizations can be represented by their board of directors (see for instance Davis, 1991). Similarly, we represent consortia by their board of directors. We performed a separate study in which we assessed the member rights of actors sitting on consortium’s boards and it appears that these members have full rights with which they can completely influence the strategic direction of the standard. Usually, this unit decides about the final approval of the specifications that are drafted in the various committees and working

groups. Therefore, in most consortia, these actors are the most important actors when it comes to the adaptation of the standard. By representing the consortium with this group of actors, we take into account those actors that we expect to be actively involved in the standards process.

Data

For this study, we created a database that covers the time period from 1990 to 2009. In the database, each record represents one consortium. The database contains membership information on the consortia, the actors that are members of the consortia, and the standards that are being developed, maintained and/or promoted by the consortia. Data sources that were used to construct the database include the internet pages of the different consortia being studied as well as press releases both on these and other sites, the Lexis-Nexis archives, annual reports of companies, and the Thomson one banker database of company profiles. The data is collected by performing a retrospective search using the internet archive. The internet archive is an online library that consists of archived versions of web sites which can be freely used by researchers. In each year at multiple points in time the internet archive scans the websites for changes. By consulting the homepage of each consortium, the network could be reconstructed over time from the moment that it was founded until the moment that it was dissolved. For each year it was determined at which time the webpage was first updated and the members (of the board of directors) that were present in the network at that time were recorded in the database. When membership information from one year was not available, it was assumed that the membership did not change. We focus on the 137 consortia that promote home networking standards.

Context: the home networking market

This study focuses on the home networking market. Home networks combine components and technologies from different industries including consumer electronics (CE) (such as, TV, audio and gaming consoles), information technology (IT) (such as, personal computers), telecommunications (TE) (such as, smart phones), and home automation (HA) (such as thermostats and door chimes). Firms that are active in home networking come from different industries, making this an ideal research context.

Dependent variables

We define the *dominance* of a standard in terms of its survival. It is measured by assessing whether the consortium that supports the standard still exists or not in a particular year. Firm survival is frequently used in the literature to operationalize standard dominance (Christensen *et al.*, 1998; Suarez *et al.*, 1995; Willard *et al.*, 1985). Here, the dominance of the standard is determined by analyzing whether the organization (that promotes the standard) survives the standards battle or not. The consortium does not survive the battle when it was dissolved or when it was announced that the standard was withdrawn or was discontinued by the consortium. We treat mergers of consortia as censored exits. Also, when a consortium is dissolved because its objectives as stated at the establishment of the consortium have been fulfilled we treat this as a censored exit. For instance, some consortia solely develop a standard and leave promotion of the standard to other consortia. To determine the point in time that the exit occurs, we have analyzed secondary sources in which this information is communicated (in particular news archives).

Independent variables

Network diversity denotes the number of industries represented in the network. For each actor, we collect information regarding the industry in which it operates primarily. For each actor, we collect its (primary) standard industry code, which is a four digit number used to categorize actors according to the industry in which they primarily operate. This information is retrieved from the Thomson one banker database. In total, we categorized 1292 actors. Network diversity is measured by counting the number of different industries that are represented in each of the consortia that develop, maintain, and/or promote the standard.

Market power of the network is measured by counting the annual sales of the actors. This information is also retrieved from the Thomson one banker database. This variable not only measures market power in the home networking market, but in all markets that the firm is active in. The firm can use its power in other markets to establish a dominant standard in the home networking market. Intel, for instance, can use its power in the semiconductor market to try to establish a dominant standard in the home networking market.

Flexibility of the standard refers to the extent to which the standard is changed through time. One way to increase the flexibility of a design is by developing multiple iterations of the design that may be new and or build upon each other (Eisenhardt *et al.*, 1995). Flexibility of the standard is measured by counting the total number of times that a new version of the standard was released since the year that the first version of the standard was released. This has been done for the time period from 1990 to 2009. Whenever it was announced in the press that a new standard specification was released, we regard this as a new version.

Network size denotes the number of companies that supported the standard by, for example, adopting the standard in their products. By using the web archive, for each standards consortia, we analyzed the consortia's websites (most standards consortia present

their list of member on their website or announce their total number of members through press releases). The data was supplemented by consulting news archives.

Control variables

Timing of entry can be essential for achieving dominance in a market (Kristiansen, 1998; Lieberman *et al.*, 1998; Mitchell, 1991). Some agree that it is better to enter early with the goal of quickly building up an initial installed base and preempting the market (Katz *et al.*, 1985; Lieberman *et al.*, 1988; Suarez *et al.*, 1995). On the other hand, early entrants are hindered by a lack of market information and have to make a comparatively higher initial investment (Lieberman *et al.*, 1988; Schilling, 2002). We follow Christensen *et al.* (1998) who speak of a ‘window of opportunity’ within which it is ideal to enter the market, and, Schilling (1998, 2002), who postulate and find the existence of an inverted U-shaped relationship between timing of entry and technology dominance. We measure timing of entry by looking at the year that the standard was introduced in the market.

Failure to invest in learning can increase the likelihood of a standard being locked out (Schilling, 2002). Learning from experience can increase the chances that standard dominance will be reached. For instance, in the television industry, firms that were also producing radios survived longer and had higher market share than those that did not: they were able to make use of their prior experiences in the radio industry (Klepper *et al.*, 2000). Hence, we control for the learning orientation of the group of standard supporters. Following previous studies we measure the extent of learning by the standards consortium’s average *R&D intensity* (R&D/sales) (Lane *et al.*, 1998; Srinivasan *et al.*, 2006).

If actors in standards consortia are of different nationalities, problems related to cultural differences could occur potentially leading to a lack of trust, and unfamiliarity between actors in the network (Goerzen *et al.*, 2005). This could affect the chances that

standards consortia break up. Contrariwise, it could be argued that wider international exposure of a standard positively affects its survival chances. Accordingly, we controlled for *geographic diversity* which was operationalized by counting the number of countries that are represented in each consortium.

Standards can be sent to formal standards development organizations (such as ISO or IEEE) in hopes of gaining formal approval of the standard (Backhouse *et al.*, 2006). It may be argued that formal approval of a standard increases its reputation and awareness among potential adopters which in turn may positively affect its chances of survival. Therefore, we included the ‘*Approved as formal standard*’ dummy to control for significant differences between standards that were formally approved and standards that were not formally approved.

Method

To test the first three hypotheses, we use logistic regression on the likelihood that a standard will exit the home networking industry in any given year. We regress the event indicator on the time indicators (D1 through D20) and the predictor variables. For every record in the dataset, the event indicator takes on either the value 0 (the standard still survives in that year) or 1 (the standard did not survive in that year). In the first year of the existence of the consortium the time indicator D1 is set to 1 and the other time indicators are set to 0; in the second year of its existence, the time indicator D2 is set to 1 and the other time indicators are set to 0, and so on. The general model used can be written as:

$$\text{logit } h(t_j) = [\alpha_1 D_1 + \alpha_2 D_2 + \dots + \alpha_{20} D_{20}] + \beta_1 \text{Market Power of the network} + \beta_2 \text{Flexibility of the standard} + \beta_3 \text{Network size} + \gamma C$$

where $h(t_j)$ is the hazard at time t_j , D_1 to D_{20} are dummy variables which refer to the time period (there are 20 time periods in the dataset), *Market power of the network*, *Flexibility of the standard* and *Network size* are time varying predictor variables, C is a vector of control variables, and α_i , β_k and γ are the parameters that are estimated. This model can be fitted using logistic regression (Singer *et al.*, 2003).

RESULTS

To test Hypothesis 4 and 5, we created one year lag variables for the network diversity variable (network diversity lag), the flexibility of the standard variable (Flexibility of the standard lag) and the network size variable (Network size lag). Table 1 contains the means, standard deviations, samples size, and correlations of the variables. We took the natural logarithm of network size, sales and standard flexibility. We have mean-centered the timing of entry variable. SPSS linear regression collinearity diagnostics were used as a means to assess multi-collinearity between independent variables. Variance inflation factor (VIF) values for each predictor variable were below 1.71, indicating that none of the variables demonstrated problematic collinearity.

Insert Table 1 here

In table 2 we present first order partial correlations between standard flexibility, network diversity and network size. The relation between network diversity and flexibility of the standard was highly correlated. Network diversity was significantly related to flexibility of the standard lag ($r=.181$, $p<.0001$) and flexibility of the standard was significantly related to network diversity lag ($r=.214$, $p<.000001$). Thus, we accept hypothesis 4. Also, flexibility

of the standard was significantly related to network size lag ($r=.160$, $p<.001$) indicating support for hypothesis 5.

Insert Table 2 here

To test hypotheses 1, 2, and 3, we performed a discrete time-event analysis. In Block 1, we enter the time dummy variables together with the control variables. In blocks 2 to 4, we enter the predictor variables. This results in the four models as presented in Table 3. The likelihood-ratio test shows that the addition of the independent variables provides a better fit to the data than the base model of controls. Model 4 has the highest deviance, indicating that model 4 is the best fit when compared to the other models. Also, the variables in the model explain a lot of the variance in the data ($R^2 = .721$) signifying a good fit. Therefore, we interpreted our results based on the full model.

Insert Table 3 here

A negative sign for a parameter indicates that the higher the parameter, the lower the risk of event occurrence. Its magnitude estimates the size of the vertical differential in logit hazard corresponding to a 1-unit difference in the parameter. The network size parameter is negatively related to the risk of event occurrence ($p < .01$). The Wald based chi square hypothesis test for network size provides a value of 8.718 which is significant at the .01 level. Thus, the network size estimate is significantly related to standard survival (meaning that higher values of network size will result in decreased hazard of event occurrence, thereby increasing the chances of survival). So, in every year from 1990 to 2009, standards that are

supported by more actors are less likely to leave the industry than standards that are supported by fewer actors. Antilogging the network size estimate yields an estimated odds ratio of .293 with a confidence interval of .129 to .662. Hence, for every one unit increase in network size, the estimated odds that a standard leaves the market are 70.7 percent lower. This provides strong support for Hypothesis 1. The market power parameter is negative and significant (Wald based chi square hypothesis test is 6.809, $p < .01$). The market power of the network parameter is also quite strong since antilogging yields an estimated odds ratio of .506, with a confidence interval of between .303 and .844. Thus, we find strong support for Hypothesis 2. Finally, the flexibility of the standard parameter is negative and significant (Wald based chi square hypothesis test is 7.106, $p < .01$). The effect is also quite strong since antilogging yields an estimated odds ratio of .112, with a confidence interval of between .022 and .560. Thus, we find strong support for Hypothesis 3.

CONCLUSION AND DISCUSSION

In this study, we developed a model for the influence of the characteristics of the networks of firms and the flexibility of the standard, on the chances that it becomes dominant. We have studied the dynamics of the network of actors per standard. We have tested our hypotheses by developing a database using secondary sources. Our study bridges the literature on firm networks and standardization processes. We have found that the market power of the network of the standard has a significant positive effect on the chances that the standard achieves dominance. Thus, it appears that standards that are supported by more powerful consortia are less likely to leave the industry than standards that are supported by less powerful consortia. Further, it appears that if the standard is more frequently adapted to user requirements the chances that it will become dominant increase. It would seem that a standard should not be too 'standard', but should be flexible enough so that it can be changed

to realize communication with other systems, resulting in a higher chance that the standard achieves dominance. Also, we provide a first indication that the size of the network of a standard positively influences its chances of survival. Finally, it appears that standard flexibility and network diversity reinforce each other and that standard flexibility positively affects network size. So, in line with Weick (1979), in standardization, network members enact and socially construct their environment. We show that co-evolution between the network of a standard and its institutional environment (Koza *et al.*, 1999; Lewin *et al.*, 1999) may occur in standards battles.

Limitations and areas for further research

One limitation concerns the operationalization of some variables. For example, we operationalized standard dominance in terms of the survival of the SO. In literature, standard dominance is often operationalised by market share per standard (Majumdar *et al.*, 1998; Mitchell, 1991; Tegarden *et al.*, 1999; Wade, 1995). To measure market share one could count the number of products that adhere to the standard and divide this by the total number of products in the applicable product category. However, in many cases, we do not know in which context the products are used. Consider a company that is active in the consumer electronics industry and supports the WIFI standard. It could use this standard in its TV sets in order to realize communication with PCs in the home. Alternatively it could use this standard in its DVD player to realize communication with the TV set. In the first situation, the company uses the standard to realize a home network; whereas in the latter situation, the company does not. Another difficulty with respect to market share is that it is difficult to measure, since the list of companies that supports the standard is not always available. We measured flexibility by counting the number of new versions of the standard that were released. It should be noted that when a new version of a standard is released, this does not

always mean that the contents of the standard have been changed. Therefore, one should look at whether changes have actually been incorporated into the standards. However, since most of the time specifications are not freely accessible, this was impossible to do. However, we have systematically analyzed a sample of the specifications that were available and in most cases the different versions of the standard differed considerably. This analysis is available upon request.

Relationships can differ with respect to their degree of formality (Van de Ven, 1976) where personal relations are less formal than corporate relations for instance (Burt, 1997; Marsden *et al.*, 1984). A limitation of this research is the fact that those relations that have a small amount of formality tend to be difficult to measure whereas these relations could play a prominent role in reaching a standard for complex systems. An example is the battle for the standard for next generation DVDs, where Microsoft Chairman Bill Gates met with Sony's CEO Howard Stringer and discussed Microsoft's possible adoption of the Blu-ray standard for high definition DVD (Porto, 2005).

Another area for further research is the importance of the power of individual actors over other actors within the network. This can be either in the form of mere influence to domination of one actor over another (Knoke, 1990). Sometimes in networks supporting standards one actor controls the other actors. The advantage here is that decisions can be taken quickly. It would be interesting to study whether this situation is preferred over a situation where actors have more equal roles. Future research could fruitfully examine this subject.

Finally, we have focused in this study on home networking standards. Further research could try to replicate these findings in other areas where standards compete for dominance. As such the generalizability of our findings can be assessed.

Theoretical and practical contributions

Multiple studies address the relationship between network structure and innovation adoption (Davis, 1991). Some studies focus on the impact of a firm's position in a network on its market share (Bekkers *et al.*, 2002), while other studies link a firm's network position to its innovation output (Ahuja, 2000; Soh, 2010). Here, it is argued that a firm can learn from actors and obtain external knowledge, increasing its innovation output (Powel *et al.*, 1996). The studies that apply network literature to standardization mostly study the impact of networks of end users on standard diffusion. For example, Weitzel (2006) studies the impact of network topology and density on standard diffusion. Other authors study the diffusion of standards among actors by drawing upon social network literature and network economics (Abrahamson *et al.*, 1997; Suarez, 2005). These researchers have in common that they focus on the social network of end users that may adopt a certain standard. Some authors also focus on the formation of standard setting alliances. For instance, Vanhaverbeke (2001) has studied the formation of inter-organizational networks around proprietary RISC designs and Axelrod (1995) relates a firm's incentive to join a standard setting alliance to the size and composition of the alliance. Other authors study the influence of a firm's position in a network on its formal standard setting influence (Leiponen, 2008).

Little research has been conducted on the influence of a network of actors that develops and or promotes a standard on the chances that the standard will become dominant in the market. One exception is the qualitative study performed by Markus (2006) who studied vertical information systems standards which connect information systems from user organizations of different structural types and proposes that collective participation of representative members is necessary to reach a standard that will meet the needs of each of these organizations.

Another factor that has received limited theoretical and empirical attention in standardization research is the role of flexibility. The technology management literature indicates that flexibility facilitates the adaptation of a product to customer requirements, and thus has a positive influence on the installed base (Thomke, 1997). Although standardization literature addresses the topic of flexibility (Hanseth *et al.*, 1996), it does not link it directly to standard dominance. We contribute to the standardization literature by studying the influence between the flexibility of a standard and standard dominance.

Furthermore, we add to the literature by concentrating on cross industry networks. Although some authors have explored the relationship between firms representing multiple industries (Hagedoorn *et al.*, 1992), most empirical research in the area of inter-organizational networks concentrates on networks in specific industries (Ahuja, 2000)

While most studies that examine networks of actors focus on only one point in time, there are exceptions. A good example is the qualitative work done by Soh and Roberts (2003) who studied alliances of firms in the US data communications industry from 1985 to 1996 at three points in time. By analyzing the network at multiple points in time, we could study the network dynamically and analyze how changes in both the composition of the network of actors supporting the standard and the flexibility of the standard influence standard dominance and reinforce each other.

Thus, this research adds to both standardization and interorganizational network literature in three ways: first, by focusing on the influence of networks of actors and standard flexibility on standard survival; second, by studying networks of actors at multiple points in time; and third, by studying cross industry networks of actors.

A clear recommendation to practitioners in the home networking industry is to try to increase the number of members adopting the standard. One way to accomplish this is by cooperating across product markets (increasing network diversity). Also, firms should try to

frequently adapt the standard to changing user requirements. This not only increases the chances of standard survival but also positively impacts network size.

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Figure 1: Research model

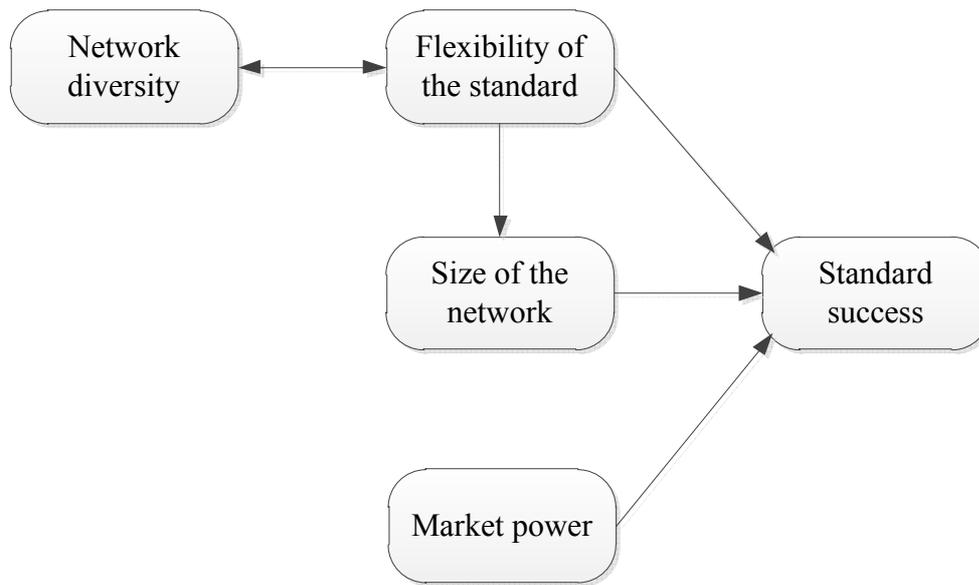


Figure 2: Estimated survivor functions

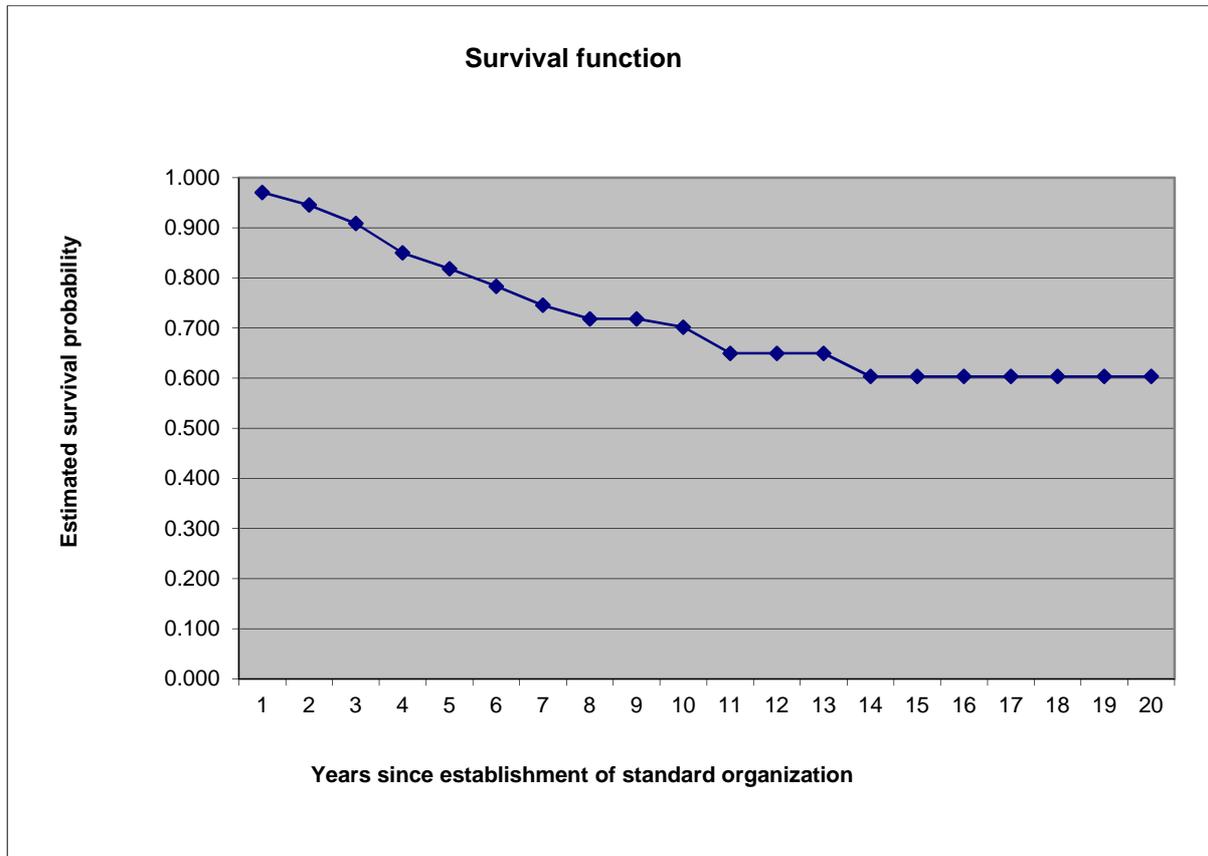


Table 1: Descriptive Statistics and Correlation Matrix

variable	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12
1. Network size	4.535	1.423	1											
2. Network size lag	4.584	1.408	.938**	1										
3. Flexibility of the standard	1.262	0.96	.195**	.176**	1									
4. Flexibility of the standard lag	1.231	0.953	.108*	.182**	.947**	1								
5. Network diversity	6.723	3.52	.178**	.171**	.194**	.177**	1							
6. Network diversity lag	6.819	3.556	.173**	.179**	.227**	.200**	.923**	1						
7. Market power of the network	13.436	4.078	.083*	.093*	.104**	.085*	.273**	.237**	1					
8. Timing of entry	19.629	6.951	-.061	-.071	-.072*	-.109**	.053	.084*	.156**	1				
9. Timing of entry squared	433.537	248.175	-.201**	-.187**	-.208**	-.200**	-.111**	-.190**	.162**	-.509**	1			
10. R&D intensity	2.265	0.671	.039	.058	-.044	-.051	.047	.059	.009	-.024	-.009	1		
11. Approved as formal standard	0.333	0.472	.063	.065	-.117**	-.115**	.074*	.093*	-.034	.064	.052	-.008	1	
12. Geographic diversity	3.516	2.222	.258**	.245**	.085*	.067	.464**	.423**	.170**	.098**	.083*	-.129**	.137**	1

*. $p < 0.05$; **. $p < 0.01$

Table 2: first order partial correlations

Partial correlations between flexibility of the standard and network size

	1	2
1. Flexibility of the standard	1	
2. Network size lag	.160 ^{***}	1

Partial correlations between network diversity and standard flexibility controlling for network size

	1	2
1. Network diversity	1	
2. Flexibility of the standard lag	.181 ^{****}	1

	1	2
1. Flexibility of the standard	1	
2. Network diversity lag	.214 ^{****}	1

*. $p < 0.05$; ***. $p < 0.001$; ****. $p < 0.0001$

Table 3: Results of fitting four discrete-time hazard models to the data

Parameters^a	Model 1	Model 2	Model 3	Model 4
Timing of entry	-.033 (.051)	-.053 (.062)	-.039 (.060)	-.123 (.079)
Timing of entry squared	.004 (.004)	-.007 (.006)	-.012 (.006)	-.017* (.007)
R&D intensity	.865* (.370)	.718 (.376)	.736 (.392)	.691 (.394)
Approved as formal standard	.087 (.596)	.463 (.654)	.380 (.673)	.592 (.714)
Geographic diversity	-.359 (.203)	-.037 (.188)	.075 (.153)	.142 (.222)
Market power of the network		-.652** (.212)	-.748** (.234)	-.681** (.261)
Flexibility of the standard			-2.034** (.761)	-2.187** (.820)
Network size				-1.229** (.416)
Goodness of fit				
Sample size	797	861	638	530
Deviance (-2 Log-likelihood)	105.472	91.868	82.293	70.707
# parameters ¹	25	26	27	28
Overall Chi-square	629.264***	642.868***	652.442***	664.028***
Cox & Snell R Square	0.695	0.703	0.708	0.714
Wald Based Hypothesis Test				
H ₀ : $\beta_{\text{Market power of the network}} = 0$				6.808**
H ₀ : $\beta_{\text{Flexibility of the standard}} = 0$				7.106**
H ₀ : $\beta_{\text{Network size}} = 0$				8.718**

* p < .05; ** p<.01; *** p<.001

¹ In these models the 20 time dummies were included

^a Standard errors are in parentheses

