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STRATEGIC MANEUVERING OF TECHNOLOGICAL FACTORS AND EMERGENCE OF DE FACTO STANDARDS

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ABSTRACT

The emergence of a de facto standard in a product class depends on technological, competitive, and market factors. The question is whether or not a firm can strategically manipulate various factors to help determine the winner. To address this question, three factors, technological superiority, openness, and compatibility, are examined with regard to their influence on the emergence of de facto standards. Hypotheses are tested with an analysis of 78 historical cases in 39 market categories. Results indicate that in setting de facto standards, technological superiority is uniformly important, suggesting the logic of technological determinism. Moreover, results also suggest that the influence of technological openness may be contingent on the nature of competition. Thus, strategic managers may need to incorporate a contingency perspective into the selection of an appropriate strategy.

Keywords: competitive strategy, de facto standard, network externalities, open architecture

INTRODUCTION

De facto standards are those standards that achieve dominant position via economic or social factors, as opposed to de jure standards which are the mandate of an authority. Anderson and Tushman (1990: 613) define a de facto standard, or in their term dominant design, as "a single architecture that establishes dominance in a product class." Researchers point out that once de facto standards emerge, they regulate the fundamental technological rules and specifications used for the design of all related products in a product class (Besen & Farrell, 1994; Kristiansen, 1998; Srinivasan, Lilien, & Rangaswamt, 2006). Researchers suggest that the emergence of a de facto standard not only reflects the technical and socioeconomic evolution of the industry (Abernathy & Utterback, 1978; Tushman & Anderson, 1986; Utterback & Abernathy, 1975), but is also due to the strategic maneuvering of firms (Cusumano, Mylonadis, & Rosenbloom, 1992; Katz & Shapiro, 1994; Srinivasan et al., 2006). Since selecting the proper design and strategy is closely tied to firms' success, and ultimately their survival, (Christensen, Suarez, & Utterback, 1998; Suarez & Utterback, 1995; Tegarden, Hatfield, & Echols, 1999), understanding the factors driving the emergence of de facto standards is of critical importance to all firms (large and small) that exist within the ecosystem.

Indeed, various factors influence the emergence of a de facto standard in a given product class (market category). For instance, Pioneer's Laser Disk (LD) was able to defeat JVC's Video Disc (VHD) in the Japanese karaoke market because Pioneer's non-contact technology was critical to users such as restaurants and bars where dust and smoke tended to damage the VHD. However, Anderson and Tushman (1990) point out that the emergence of a de facto standard is not simply a function of technological superiority. Rather, a combination of product and technological strategic decisions intervene in the path toward the setting of such standards. For example, JVC established a de facto standard by actively licensing and cross licensing its VHS technologies to its rivals and suppliers of complementary products (Cusumano et al., 1992); Sun Microsystems established its workstation as a de facto standard via an open source strategy (Garud & Kumaraswamy, 1993). Thus, firms' decisions regarding their technological strategy may influence the emergence of de facto standards. However, understanding in this area is incomplete.

This paper attempts to shed light on how firms can strategically maneuver technological factors to help shape de facto standards. Specifically, using 78 cases from 39 Japanese and U.S. market categories in which firms competed to create de facto standards, this study examined how three of these factors – technological superiority, technological openness, and technological compatibility – may have influenced the emergence of such standards. Results from this study suggest the de facto standardization process to be more intriguing than previously shown in the literature. For instance, while ample literature suggests that the selection of a de facto standard involves more than simply a technical choice as technological superiority can sometimes be offset by other factors such as network effects (Anderson & Tushman, 1990; Barnett, 1990); this study concludes that technological superiority is indeed a major factor in choosing de facto standards. Moreover, while a number of studies emphasize the significance of an open architecture (Bonaccorsi & Rossi, 2003; Garud, Jain, & Kumaraswamy, 2002; Garud & Kumaraswamy, 1993), this study suggests that the effects of such a strategy on standardization may be contingent on the nature of competition. Based on these findings, this research makes two contributions to the literature. First, this study provides an examination of the effectiveness of three important technological factors related to firms' strategy in light of the moderating effects of competitive conditions. Second, a methodology was developed to investigate empirically the effectiveness of firms' technology strategies across various de facto standards from two countries and multiple market categories. Managerially, this research suggests that while alternative strategies to achieve de facto standard status exist, strategic managers may need to devise strategies based on a contingent perspective.

THEORY DEVELOPMENT AND HYPOTHESIS

The following discussion of de facto standards draws from a variety of studies under labels such as dominant design (Anderson & Tushman, 1990; Srinivasan et al., 2006; Suarez & Utterback, 1995; Tegarden et al., 1999), technological trajectories (Kim & Kogut, 1996; Lecraw, 1984; Zhu, Kraemer, Gurbaxani, & Xin Xu, 2006), technological standards (Besen & Farrell, 1994; Gandal, 1995; Ostrovsky & Schwarz, 2005), platforms (Cusumano & Gawer, 2002; Economides & Katsamakas, 2006; Parker & Van Alstyne, 2005), and others. The literature suggests that the overall value of a de facto standard comes from two disparate, relatively independent, sources: standalone value and network externalities. Standalone value refers to all advances in technology and consumer benefits except those derived from network effects (Sheremata, 2004; Srinivasan et al., 2006), also known as network externalities (Economides & Katsamakas, 2006; Garud & Kumaraswamy, 1993; Parker & Van Alstyne, 2005). Direct network externalities arise when a user's adoption of a product per se, confers a benefit on other users while indirect network externalities arise because of increased demand for complementary products or services (Farrell & Klemperer, 2006; Katz & Shapiro, 1986). Arthur (1989; 1996) points out that for markets involving significant network externalities, the increasing returns mechanism could eventually lead to the establishment of a de facto standard. Accordingly, a small lead in the installed base might decide the competitive outcome because an initially dominant technology may increase users' expected value of joining the network, and thus become more dominant as its number of users increase (Bonaccorsi, Giannangeli, & Rossi, 2006). In other words, for two technologies that compete in the same product category, a user's adoption of technology A instead of technology B, not only makes A more attractive to other users, but also makes B less so, resulting in a situation called winner-take-all (Schilling, 2002).

A *platform* can be defined as a technological base that coordinates the synergy and interoperability between separately developed pieces of technologies (Cusumano & Gawer, 2002; Kim & Kogut, 1996; West, 2003). Important components of a platform include a modular architecture, interfaces by which modules interact, and protocols to which the design of modules must conform (Baldwin & Clark, 1997). When the technology of a platform is widely accepted and thus dominates the market, the platform becomes a de facto standard.

Most empirical work in the area consists of case studies. Gawer and Cusumano (2002) discuss how technology leaders such as Intel and Microsoft pursued a platform strategy, sharing key technologies with competitors to promote ecosystems. In another study, Windrum (2004) addresses the strategic bundling of Microsoft's browser with the operating system in the standards war against Netscape. Other case studies have provided valuable insights on the relationship between firms' platform strategy and technological dominance (Garud et al., 2002; Hargadon & Douglas, 2001). In spite of the abundance of work in this area, empirical studies to date have suffered a major limitation in terms of sample size, thus curtailing generalizability of the findings. The literature has a dearth of large scale empirical work that directly examines how a firm's technology strategies influence the establishment of a product or platform as a de facto standard. In the next section, hypotheses are developed to address this gap.

Hypotheses

Suarez (2004) points out that the emergence of a particular platform as a defacto standard depends substantially on its technological superiority. However, given the importance of network externalities, some researchers argue that technological superiority alone may not be sufficient to gain wide acceptance — a platform owner may need to pursue an open architecture strategy to include more manufacturers in the diffusion process (Bonaccorsi & Rossi, 2003; Economides & Katsamakas, 2006; Leibenstein, 1971). Furthermore, since the value of a platform often depends on interoperability across technologies, a related strategic choice for a platform involves its level of compatibility with other products (Sheremata, 2004). In the following pages, a discussion will take place of how each of these strategies relates to the establishment of de facto standards.

Technological superiority. Technological superiority is defined as the technological improvements a platform delivers to users. While this concept can be interpreted from a purely design point of view to capture the merits of a given technology in certain technical dimensions (Anderson & Tushman, 1990), one can also reflect on consumers' overall perception of the extent to which their desires for certain functionalities are satisfied. This perception-based view of technological superiority is particularly important as customers may have preexisting schemas and scripts for comparing the usefulness of technological alternatives (Hargadon & Douglas, 2001). In the innovation literature, a common belief is that superior technologies represent a competitive advantage over inferior ones (Schumpeter, 1950; Tushman & Anderson, 1986; Utterback & Abernathy, 1975), and Suarez (2004) argues that all else being equal, technologically advanced platforms have a higher probability of becoming de facto standards. However, research provides examples where better performing technologies failed to overtake inferior rivals. For instance, David (1985) found that switching costs prevented dethronement of the old QWERTY keyboards while Cusumano and colleagues (1992) studied the competitive war launched by Sony in promoting its Betamax product over JVC's VHS. In this case, results suggest that the advantage gained by JVC from possessing a large installed base might have offset Sony's advantage from having superior technology. Nevertheless, Sheremata (2004) argues that if the technological improvement is significant, the new platform may successfully challenge the competition, even if the current leader has a significant advantage due to a large installed base. In similar fashion, Katz and Shapiro (1992) present the idea that a platform (and its complementary products) with high technological superiority is likely to be attractive to users, especially early adopters. They further suggest that a platform providing really significant benefits will be able to attract enough adopters to satisfy later demands for network externalities. Mirroring this logic, Rohlfs (2001) reports that truly wonderful products may succeed in establishing de facto standards. In this regard, Shapiro and Varian (1998) quote

Intel CEO Andy Grove's rule of thumb that a product that is ten times better, will replace an existing standard. Thus, as established above, everything else being equal, a platform with a high level of technological superiority can and should establish a de facto standard.

Hypothesis 1: A platform offering a high level of technological superiority, within a market category, is more likely to emerge as the de facto standard.

Technological Openness. Technological openness is defined as the extent to which a platform owner shares, with other firms, the key technologies associated with the design of its platform (Bonaccorsi & Rossi, 2003; Leibenstein, 1971; West, 2003). Dahlander and Gann (2010) discuss two types, or directions, of openness: inbound openness to acquire technology from outside the firm and outbound openness to reveal or license the firm's technology. This research focuses on the outbound direction. A high degree of outbound technological openness encourages the involvement of multiple manufacturers in the diffusion process. In doing so, the platform owner extends the co-specialization network. Increased participation by manufactures should in turn lead to an enlarged installed base and increased network externalities (Farrell & Saloner, 1986; Schilling, 2002; Suarez, 2005). Strategies for technological openness include licensing, cross-licensing, and pre-market consortia formation. These strategies attempt to generate collaboration among firms and widespread adoption of a platform, thus leading to its successful establishment as a de facto standard (Bonaccorsi et al., 2006; Bonaccorsi & Rossi, 2003; West, 2003). For example, Palm Computing established a de facto standard in the USPDA market in the 90s by actively licensing its Palm OS to competitors. In this situation, an open architecture helped Palm Computing create competitive advantage by building a large installed base.

Nevertheless, from a resource-based view, sharing key technological designs may allow competitors to imitate the firm's core competence, and therefore create undifferentiated rivals in the marketplace (Wernerfelt, 1984). For example, Bonaccorsi, et al (2006) suggests that the effectiveness of technological openness (open architecture) might be contingent on market conditions. Furthermore, Zhu et al. (2006) found that during periods of technological change, experience with older standards makes shifting to new technologies difficult for users even though the new technologies are open and potentially better. In addition, West (2003) argues that technological openness should be used situationally, with varying degrees of openness employed at different stages of the technology's lifecycle. Apparently, a platform's level of technological openness is not directly correlated with becoming a de facto standard.

Consider the possibility that the effect of a platform's degree of technological openness on the establishment of de facto standards is contingent on characteristics of the competition. According to the punctuated equilibrium model, two distinct types of competition may exist. On the one hand, two or more platforms may emerge in the same time frame and compete to establish a de facto standard. On the other hand, a new platform might compete to dislodge an entrenched platform (Anderson & Tushman, 1990; Tushman & Anderson, 1986). The following paragraphs will explain how technological openness should have different effects in each situation, starting with the competition between multiple new platforms.

When all competing platforms are new to customers, the scenario normally involves the creation of a new market category (Navis & Glynn, 2010). Navis and Glynn (2010) suggest that emerging markets, and their new platforms, have a liability of newness and need to establish legitimacy. They found that, in the case of satellite radio, the two platforms competed to legitimize their technologies by sharing core technologies with partnering automobile manufacturers. In another case, Sun Microsystems chose to enhance the legitimacy of their new technology by pursuing an open sources strategy (Garud & Kumaraswamy, 1993). By opening core technologies, a platform can theoretically attract more developers to advance supporting technologies and, at the same time, reduce the threshold of adopting the new technology. Some researchers argue that a key to winning a standards war is through the establishment of a large installed base by way of technological openness with other firms (Stango, 2004; Suarez, 2004). Anecdotal evidence, such as IBM's PC and the Blu-ray DVD, shows that technological openness may help diffuse a new technology and thus lead to establishment of de facto standards.

However, if the competition occurs in an existing market category with an embedded de facto standard, the role of technological openness may follow a different logic. Anderson and Tushman (1990) point to the difficulty of dislodging an established platform which has the advantage in distribution channels, reputation among consumers, price-performance ratios, and perhaps most importantly, availability of complementary products. However, they also point out that an older platform can be technologically inferior, and thus subject to replacement. Bonaccorsi et al. (2006) suggest that if the older platform imposes high switching costs, the size of the installed base embodies a significant competitive advantage. Hargadon and Dougla (2001) and Garud et al. (2002) further argue that standardized platforms are not only economically, but also socially, embedded and difficult to dislodge. Thus, an established standard has an advantage in their installed base.

While research suggests that the installed base advantage provides increasing returns to a platform, Katz and Shapiro (1994) suggest that a platform's surplus from networks is maximized if the marginal benefits of including a new user, including the added network externalities, equals the marginal costs. Furthermore, Swann (2002) points out that networks do not always generate increasing returns, proposing that after the network reaches a certain size, diminishing returns may occur. Based upon these studies, for an entrenched platform, an open architecture adds little in the way of benefits with regard to network size. Instead, opening a technology may bring in more competitors and remove some first mover advantages the firm derived from its innovation (Sheremata, 2004), possibly resulting in loss of market share.

In addition, employing a technology openness strategy seems to be a debatable solution to a new platform's installed base disadvantage. Some may argue that technological openness can reduce the relative advantage of an older standard. We, however, argue that this strategy has several drawbacks. First, new platforms represent the technological edge, and in order to recoup high initial expenses, new platform leaders must disequilibrate the market and seek high economic rents either through higher prices, and/or by quickly building economies of scale. Opening the platform architecture is the firms' tradeoff decision between appropriability and adoption to achieve these purposes (West, 2003). However, from a competitive point of view, the installed base of the entrenched platform works against new platforms due to first mover advantages, which in turn makes practicing such a strategy economically inefficient. In addition, Bonaccorsi et al. (2006) found that producers of complementary products are less willing to switch to new platforms if they are currently working with existing standards. For these firms, the adoption of a new platform is associated with switching costs related to production facilities, experience, customer relationships, and so on. The net effect is that a technological openness strategy will gain less industry support when attempting to overtake an entrenched standard. Furthermore, an open architecture will dissipate profits for all participating firms in the industry. However, profit levels may not be a problem if adequate adoption takes place due to the increasing returns mechanism. Nevertheless, if adoption by users is prohibited due to switching costs, competition among the various producers of complementary products (for the same platform) may reduce these producing firms' propensity for adoption, and thus strand early adopters. Finally, firms controlling the older standard may attempt to incorporate key technologies derived from the new open platform into their own product feature set, making displacement even more difficult. These arguments lead to the following hypotheses.

> *Hypothesis 2: The stage of the market category (emerging versus mature) in which the standard-based competition occurs will moderate the relationship between a platform's technological openness and its likelihood to emerge as the de facto standard.*

> *Hypothesis 2a: In an emerging market category, a platform offering a higher level of technological openness will have a higher likelihood to emerge as the de facto standard.*

> *Hypothesis 2b: In a mature market category, no relationship will exist between a platform's level of technological openness and its likelihood to emerge as the de facto standard.*

Technological Compatibility.

Technological compatibility is defined as the degree to which a platform owner allows other manufacturers' products to interoperate with its own (Garud et al., 2002; Sheremata, 2004). Technological compatibility is different from technological openness in two primary aspects. First, the design of compatible products does not necessarily require opening key technologies. For example, a software developer may introduce an application that runs on Microsoft's Windows operating system based on available published interfaces without knowing the underlying technologies. On the other hand, an open architecture does not necessarily ensure compatibility. For example, while JVC's VHS was technically open, VHS was incompatible with the competitor, Sony's Betamax. Thus, technological openness and compatibility represent disparate strategies.

Prior research posits that the extent to which a platform is compatible with complementary products is a key decision for a platform leader in the quest to establish a de facto standard (Garud & Kumaraswamy, 1993; Katz & Shapiro, 1992; Xie & Sirbu, 1995). Sheremata (2004) suggests that technological compatibility is an important source of a platform's network value. The more compatible a platform is with complementary products, the more indirect network externalities the platform offers for users. Increasing network externalities should in turn increase demand for the platform and ultimately the user base. For instance, the increased installed base of VHS video recorders led to an increased number and variety of videos available, which in turn increased demand for VHS recorders (Cusumano et al., 1992; Sheremata, 2004).

The value of a platform's compatibility design can be assessed from both the demand and supply sides. Demand-side compatibility provides users benefits such as ease of communication, interchangeability of complementary products, and transaction cost savings (Farrell & Saloner, 1986). Benefits for supply-side compatibility provides manufacturers with increased revenues from proportionally larger installed bases (Gabel, 1991), increased sales of complementary products (Lecraw, 1984), and economies of scale (Katz & Shapiro, 1986). Thus, platform leaders may strategically design compatibility into their platforms in an attempt to establish a de facto standard (Farrell & Saloner, 1985; Katz & Shapiro, 1992; Shibata, 1993). For instance, WordPerfect, a de facto standard in word processing software in the 1980s, sought file compatibility with files produced by previous standard, WordStar, and then fought against similar file compatibility with its challengers after achieving de facto standard status. Similarly, when Microsoft introduced the Windows XP operating system, most application software written for the older Windows 98 could run on Windows XP, but software written for XP could not run on the older system. In these cases, compatibility permitted the continued use of products purchased for alternative platforms; as a result, users were faced with less switching costs, which in turn made adoption more likely. Based on these arguments, the final hypothesis is as follows.

Hypothesis 3: A platform offering a higher level of technological compatibility, within a market category, is more likely to emerge as the de facto standard.

While compatibility may increase a platform's likelihood of becoming a de facto standard, its influence on firms' profitability is uncertain, and a host of factors may moderate the relationship. Sheremata (2004) suggests that rivals may be better off if their platforms are compatible with rivals to avoid an R&D race; however, this compatibility logic is only applicable for platforms that have not already emerged as standards (Garud & Kumaraswamy, 1993). After a firm's platform wins dominance, compatibility with rivals may remove some first mover advantages from the equation. Therefore, challengers should prefer a strategy of compatible innovation to increase overall market size, whereas dominant firms should not as compatibility with competitors might be correlated with lower profits (Sheremata, 2004).

METHODOLOGY

Data and Sample. The population for this research involves platforms that attempted to establish de facto standards. A key characteristic of these platforms is that they work (to some degree) with compatible complementary products—that is, platforms for which users can transfer or exchange data or files through compatible or complementary products with other users. Since this type of architecture is utilized in both hardware and software, the population includes both.

In order to construct an appropriate sample, the following procedure was utilized. First, platforms that attempted to set a de facto standard were identified – platform As. Two major sources were used to find candidates for A: 1) previous research papers that discussed de facto standards or dominant designs; and 2) the LexisNexis database with the search terms: standard, de facto standard, de jure standard, standardization, competing standards, and winner-take-all. By doing so, a list of platforms that attempted to establish de facto standards was established. Examples of these platforms included VCRs, 3.5-inch floppy disk drives, Palm's PDA, Microsoft's MS DOS operating system, and HTML markup language.

Then, each platform A was matched with a competing platform, B. The criteria for selecting B included: 1) B should be a platform that attempted to establish a de facto standard in the same product category as A; and 2) B competed with A. Using the same sources mentioned above, and with the exception of two cases, a platform B was found for each A. Xerox's copy machine (with special compatible paper) and Polaroid's instant camera (with special compatible film) were excluded because of difficulties in finding apparent challengers. Furthermore, in the event more than one competitor was identified, the competitor with the largest installed base was chosen as the primary competitor of A. Thus, the selection process produced sets of paired cases that permitted benchmarking the characteristics of competing platforms. The sample covered the period 1972 to 2004 and included: 1) both the competition between new and established (mature) regimes and the competition between dual emerging technologies; 2) both Information Technology (IT) and Audio-Visual (AV) related products; 3) standards observed both in the US and Japanese markets; and 4) both hardware and software platforms. The initial sample consisted of 46 pair-wise cases (92 cases). Seven pairs (14 cases) were subsequently dropped from the sample for two reasons: 1) only experts seemed familiar with the standards, and/or 2) some cases had very limited relevant data available. Consultation took place with several experts in both IT and AV-related fields, and in both the US and Japanese markets, to confirm the validity of the remaining 78 cases as a representative sample of de facto standards in the US and Japan.

Next, the method suggested by Srinivasan and colleagues (2003) was utilized to collect data on each case. The process started with the product's entry to the market and concerned its survival, competitive strategies, and technological attributes. Source data were obtained from 1) news article databases such as LexisNexis, which include all the popular business journals such as Business Week, Fortune, etc.; 2) Trade journal such as Computer World; and 3) Japanese newspapers and business journals such as Nikkei and Nikkei Business Weekly for Japanese cases.

Two authors and a graduate student (each with an academic engineering background) collected published data and documents on each case separately and then combined the collected data and documents. In some cases, interviews and phone calls with managers and engineers in charge of each standard were conducted in order to access data and gain insight on cases. Data were collected for the period prior to a platform, A or B, winning the competition in order to examine the effect of the independent variables on the outcome. Although great effort was used to collect as much objective data as possible, some data were not available, for example, information on licensing agreements. Thus, a coding sheet with a 7-point Likert-type scale was developed for use in the evaluation. Overall, data collection took about one and a half years to complete.

Measures.

Dependent Variable. The dependent variable (Winner) is dichotomous and denotes whether a platform won or lost the competition with its primary rival in the establishment of a de facto standard. The variable was operationalized in general accordance with the definition of Anderson and Tushman (1990). Essentially, a platform was considered a winner by satisfying two conditions. First, the platform should consist of a single configuration, or a narrow range of configurations, that occupied in excess of 50 percent of new product/process sales and maintained the 50 plus percent market share for approximately four years. Second, the market share should be measured in the period in which the pair-wise platforms were competing. Unfortunately, in some cases, strictly objective data was not available regarding market share data. Subjective data then needed to be incorporate into the calculation by consulting with experts in the appropriate field (depending on the platform). The value of Winner was coded 1 if the platform won and 0 if the platform lost.

Independent Variables. Technological superiority was estimated by joint assessment of the three evaluators. Using 7-point Likert scales (1= do not agree at all to 7= strongly agree), two evaluators first separately evaluated the following five items: Technological superiority of the platform, technological superiority of complements, technological superiority of the platform/complement synergetic system, relative benefits of using the platform, and relative benefits of using complementary products, for all cases.[1] The archival data used in the evaluation contained historical information about how users of each platform assessed the functionalities of the aforementioned technology. Therefore, two coders used this accumulated information as the basis to formulate their assessments. The third evaluator reviewed the scores recorded by the first two evaluators, and in the event of disagreement, coordinated a discussion to thoroughly discuss the differences and reach consensus.

Technological openness was assessed with the same procedure mentioned above. Using 7-point Likert scales (1= do not agree at all to 7= strongly agree), two evaluators first separately evaluated the following four items: rivals' participation in the standard-setting process,

[1] A sad and unfortunate event happened. The author who coordinated the data evaluation process died prior to completion of this paper. Hence, many of the original coding sheets used by the two evaluators were lost. However, data analysis was based on the full set of final evaluations reported by the consensus of the three evaluators.

technological openness with other manufacturers, technological openness with complementary suppliers, and technological openness with major customers, for all cases. The third evaluator reviewed the scores recorded by the first two evaluators, and in the event of disagreement, coordinated a discussion to thoroughly discuss the differences and reach consensus. Hence, agreement was achieved among the three evaluators and the final scores determined.

Technological compatibility was likewise measured with the same procedure. Using the same 7-point Likert scale, two evaluators first separately evaluated two items: platform's compatibility with complementary products from the same platform families and compatibility with complementary products from different platform families, for all cases. The third evaluator reviewed the scores recorded by the first two evaluators, and in the event of disagreement, coordinated a discussion to thoroughly discuss the differences and reach consensus. Therefore, agreement was achieved among the three evaluators.

Because technological superiority, technological openness, and technological compatibility were each measured with multiple items, a confirmatory factor analysis was conducted to validate the convergent and discriminate validity of the a priori groupings. Composite measures of each latent variable were derived by computing an average for the items (Degree of freedom =51, Chi-Square = 155, $p<0.001$, Comparative Fit Index=0.863). The Cronbach alpha for these composite variables is as follows: technological superiority = 0.88, technological openness = 0.85, and technological compatibility = 0.76, thus confirming the constructs internal consistency.

Type of competition is a dichotomous variable. When a de facto standard had previously emerged in the market category, competition was designated mature, and coded 1; otherwise, competition was designated as an emerging market and coded 0.

Control Variables. Objective measures that are consistent across fields and technologies are not readily available; therefore, a number of control variables which focus on the technological specifications of the platform were employed. To develop these control variables, the two authors and graduate student read extensively the related articles in order to understand the technology, and then used 7-point Likert scales to determine the value for each control variable. The assessment included the following questions: 1) To what extent is the platform related to audio-video? (As audio-video products themselves are often useless without accompanying contents such as movies); 2) To what extent is the platform a system product? (As system products may require multiple complementary products); 3) To what extent is the platform related to IT? (Especially strong network effects are expect with IT products); 4) To what extent is the platform modularly designed? (As modular products may allow higher levels of compatibility); 5) To what extent does the platform perform as an interface? (Interface platforms are more likely to be embedded in subsystems); 6) To what extent is the platform related to communications? (Communication products are expected to have high levels of direct network externalities); 7) To what extent is the platform an end user product?

(As platforms used by OEMs may be different from those used by end users); 8) To what extent should the platform be considered hardware as opposed to software? (Hardware may requires more sunk investments); 9) To what extent should the platform be considered a killer application? (As a killer application may demonstrate a different diffusion path); 10) To what extent is the price/performance ratio of the platform high? (The demand curve is expected to influence the diffusion path); 11) To what extent does the platform charge high licensing fees? (As licensing threshold may influence the diffusion of platforms); 12) To what extent does the platform generate lock-in? (As lock-in reflects the switching costs of a platform); 13) To what extent does the platform appear to be a first mover? (First-movers may have a diffusion advantage).

Analysis. In selecting statistical methods to test the hypotheses, two primary considerations needed to be considered. First, the test needed to relax assumptions of normality due to the use of purposely paired cases. Second, the test should provide enough power to consider thoroughly the contingencies of competition. For these purposes, a logistic regression analysis was conducted using SAS. Results are detailed in Tables 2 and 3.

In using logistic regression, concern focused on the matched pair research design because of possible dependence within these pairs, which could lead to bias in the standard error estimates. Therefore, the CLASS option of the PROC GENMOD statement in SAS was chosen (Allison, 2001, p. 200). Results were compared with those from using the PROC LOGISTIC statement, and similar results observed.

For all models, the dependent variable is a dichotomous variable (Winner), which indicates whether a platform won the competition. A formal presentation of the models is as follows:

$$LN = \alpha 0 + \alpha 1X1 + \alpha 2X2 \ldots + \alpha nXn + e ,$$

Where

LN=likelihood of becoming a de facto standard,
Xn= independent variables (for interaction terms $Xn = Xl \times Xm$),
e = the error term.

RESULTS

Table 1 reports the mean, standard deviation and correlations for all variables used in the analysis while Table 2 summarizes the study's results. Model 1 reports how the control variables influence the likelihood of establishing de facto standards. In general, results were consistent with expectation. For instance, lock-in effects were expected to provide a platform competitive advantage due to an increasing returns mechanism (Auriol & Benaim, 2000; Liebowitz & Margolis, 1995; Witt, 1997), and the positive sign confirmed expectations. Furthermore, results suggest that end user platforms were typically difficult to standardize. Interestingly, the results suggested that platforms having the characteristics of an interface were less likely to become a standard. Perhaps, because in spite of the network externalities generated, an interface by itself may not provide high value.

Table 1: Descriptive Statistics and Correlations

		Mean	Std Dev	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Winner	0.50	0.50																	
2	Audio-Video	3.23	2.48	0.02																
3	IT Standard	5.82	2.13	0.01	-.76***															
4	System Product	4.12	2.08	-0.06	-0.04	-0.18														
5	Modular System	4.97	1.57	-0.01	-.45***	0.62***	-.32***													
6	Interface	3.34	2.34	-0.01	-0.14	0.40***	-.60***	0.41***												
7	Communication Product	3.26	2.05	0.01	-0.21	0.40***	-.34***	0.31*	0.72***											
8	Earlier Entrant	3.15	1.77	0	0.05	0.02	-0.13	0.05	0.13	0.19										
9	End User Product	6.12	1.39	-0.01	0.21¶	-0.23¶	0.30*	-0.30*	-.44***	-0.06	-0.11									
10	Hardware	3.83	2.35	0.02	0.34***	-0.44***	0.14	-0.30*	0.02	-0.11	-0.1	0.11								
11	Killer Application	4.22	1.64	0.04	-0.25*	0.44***	-0.09	0.12	0	-0.09	0.08	-0.03	-0.05							
12	Price /Performance	5.35	1.13	0.24*	0.01	0.14	-0.25*	0.12	0.15	0.09	-0.12	0.19	0.15	0.33***						
13	Licensing Fee	4.12	1.60	0.1	0.17	-0.06	-.33***	0.18	0.18	0.03	0.03	-0.08	-0.21¶	0.09	-0.08					
14	Lock-in Effect	5.13	1.36	0.36***	-0.03	0.14	0.03	-0.01	-0.02	0.02	-0.04	0.18	-0.16	0.15	0.28*	0.11				
15	Mature Market	0.46	0.50	0	-0.09	0.26*	-.34***	0.16	0.24*	0.15	0.01	-0.02	-0.16	0.14	0.22¶	0.15	0.13			
16	Tech Superiority	5.42	1.05	0.33***	-0.1	0.25*	-0.25*	0.15	0.17	0.03	-0.18	-0.09	-0.07	0.36***	0.43***	0.15	0.20¶	0.06		
17	Tech Openness	4.63	1.73	0.07	-0.23*	0.32***	-.34***	0.30*	0.37***	0.19¶	0.12	-.33***	-0.02	0.44***	0.09	0.30**	-0.02	-0.01	0.54***	
18	Tech Compatibility	4.57	1.20	0.17	-0.38***	0.48***	-0.17	0.37***	0.19¶	0.27*	-0.05	0.02	-.33***	0.22*	0.31**	0.1	0.21*	0.35***	0.39***	0.27*

N= 78, p<.10, *p<.05, **p<.01, ***p<.001

Table 2. Logistic Regression of Standard Setting Firms' Strategies

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Intercept	-0.239		-0.754		-0.336		-9.250	**	-4.124		-1.365	**
Audio-Video	0.006		0.002		0.011		0.083		0.042		0.005	
IT Standard	0.045		0.034		0.054		0.325		0.174		0.031	
System Product	-0.023		-0.018		-0.026		-0.203	¶	-0.124		-0.031	¶
Modular System	-0.027		-0.021		-0.032		-0.232		-0.137		-0.010	
Interface	-0.098	**	-0.099	**	-0.098	**	-0.672	**	-0.462	¶	-0.099	**
Communication Product	0.051	¶	0.054	¶	0.047		0.375	*	0.228		0.053	¶
Earlier Entrant	0.013		0.029		0.013		0.112		0.063		0.046	
End User Product	-0.099	***	-0.085	**	-0.091	***	-0.707	***	-0.504	¶	-0.097	***
Hardware	0.040	**	0.043	**	0.037	*	0.387	**	0.216		0.072	***
Killer Application	-0.055	¶	-0.071	*	-0.067	¶	-0.339		-0.268		-0.052	
Price/Performance	0.114	*	0.067		0.119	*	0.873	*	0.499		0.064	
Licensing Fee	0.056	¶	0.045		0.053	¶	0.591	**	0.254		0.078	*
Lock-in Effect	0.126	***	0.120	***	0.128	***	0.801	***	0.642	**	0.114	***
Tech Superiority			0.145	**							0.146	*
Tech Openness					0.023		0.676	***			0.030	
Mature Market					-0.066		4.793	***			0.784	*
Openness*Previous Standard							-1.193	***			-0.160	**
Tech Compatibility									0.242		0.059	
Compatibility*Previous Standard											-0.027	
Degree of Freedom	64		63		62		61		63		61	
Chi-Square	15.19		76.51		72.47		68.62		73.04		68.99	
Log Likelihood	-46.87		-41.39		-43.97		-39.14		-44.02		-42.64	

N= 78, p<.10, *p<.05, **p<.01, ***p<.001

Model 2 provides a test of the first hypothesis. The significant and positive sign (b=0.12, P<.001) suggests, as expected, that technological superiority has a strong positive effect on a platform's likelihood to emerge as a de facto standard, thus providing strong support for Hypothesis 1.

$$\frac{\partial(LN)}{\partial\,(Tech\ Openness)} = 0.676 - 1.193\ \times Previous\ Standard$$

In Models 3 and 4, Hypotheses 2, 2a and 2b, regarding technological openness, were tested. Hypothesis 2 asserts that the stage of a market category will moderate the relationship between a platform's technological openness and its likelihood of achieving de facto standard status. In Model 3, the main effect of technological openness was tested. No statistically significant association between technological openness and the dependent variable was found. Next, an interaction term (Tech Openness × Mature Market Category) was added to the model (Model 4). A statistically significant relationship between the interaction term and the dependent variable was found, demonstrating that the stage of market category moderates the relationship between a platform's technological openness and its likelihood to emerge as a de facto standard. More importantly, a partial differentiation with respect to Tech Openness suggests that Mature Market Category reverses the relationship between Tech Openness and the likelihood of becoming a de facto standard.

The slopes are calculated as 0.676 for Mature Market = 0 and -0.517 for Mature Market = 1 . A graphic presentation of the equation (Figure 1) clearly suggests that when rivalry is in an emerging market category, technological openness enhances the focal platform's chance for becoming a de facto standard, supporting Hypothesis 2a. However, for 2b, while no relationship between technological openness and emergence of a standard was expected, when the rivalry occurs in a mature market category, a negative impact was found. Therefore, by jointly considering the effects of Tech Openness and Previous Standard, strong support is found for the role of market stage as a moderator, thus supporting Hypothesis 2.

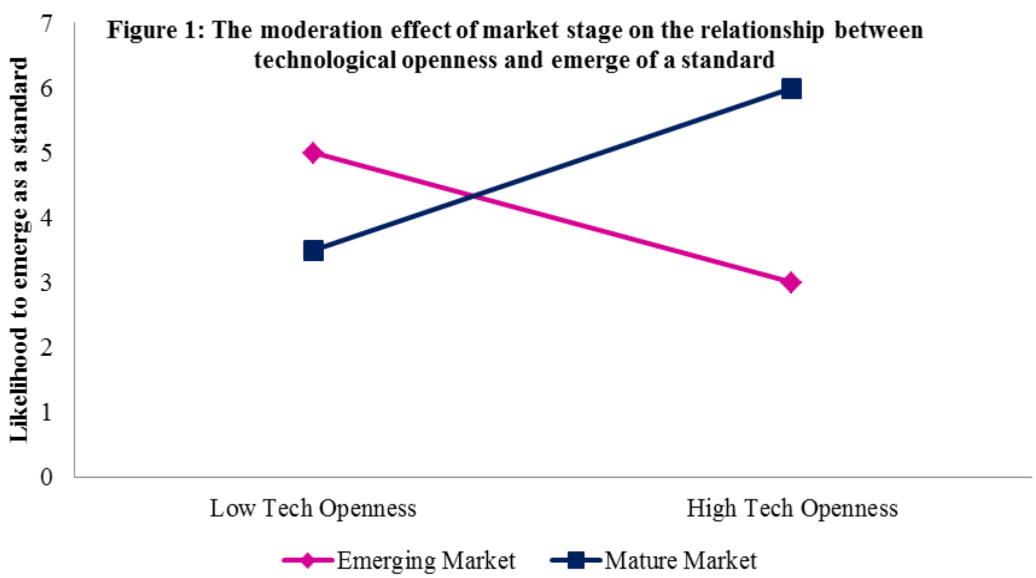

Figure 1: The moderation effect of market stage on the relationship between technological openness and emerge of a standard

Hypothesis 3 states that platforms with higher levels of technological compatibilities are more likely to establish a de facto standard. In Model 5, a positive but not statistically significant association exists. Suspecting that the situation might be akin to technological openness (contingency based upon type of competition), an interaction term (Tech Compatibility × Mature Market) was added to the model (model 6) as an exploratory test. Still, no statistical support for Hypothesis 3 was found.

DISCUSSION

Standard setting is a dynamic process involving a number of strategic factors. Although researchers have endeavored to explore the topic, few, if any, large-scale empirical studies have been conducted, perhaps due to limited access to historical, in-depth data. This paper contributes to the literature by using data from 78 cases, from a variety of industries, and from two countries. Through painstaking effort, this study contributes to the literature in the following regards.

First, the study's results confirm the notion that technological superiority is a strong factor in setting de facto standards, despite the intricacies incurred by increasing returns mechanism, network externalities, and types of competition. For managers, investing in superior technologies should always be considered a key strategy.

Second, the results suggest the role of technological openness is intriguing. On the one hand, an open architecture pulls in additional manufacturers from the technological community. While technological openness helps to diffuse the technology, this strategy also allows competitors to dissipate the focal firm's technological superiority and thus may ultimately reduce technology-based differentiation. While this debate has attracted researchers' attention (Bonaccorsi & Rossi, 2003; Economides & Katsamakas, 2006; West, 2003), this study's findings suggest the successful outcome of technological openness to be contingent on the type of competition. Specifically, for competition in emerging market categories, technological openness was significant, meaning that the platform providing a higher level of technological openness was more likely to win the competition. Interestingly, for competition in mature market categories, while the expectation was for little effect of technological openness, the evidence suggests that technological openness exhibited a negative effect. Perhaps this negative effect happens because in mature markets, a challenger's opening of core technologies effectively permits the standard bearer to incorporate desirable features or technologies of the new platform and thus provide little or no window of opportunity for the new platform. No direct significant relationship between technological compatibility and the establishment of a de facto standard was found. However, the possibility of some joint effect with openness, technological superiority, or some other combination of factors remains, perhaps an area of future research.

How do these findings affect the many small and medium size enterprises (SMEs) that are either part of the ecosystem of de facto standard competitors or competitors themselves? When large competitors enter existing markets, or when new markets are uncovered, uncertainty arises as to who or what products and services will reign. A study of SMEs in emerging markets

(Droege & Marvel, 2009) found that SMEs lean toward planned versus emergent strategies when faced with perceived environmental uncertainty with regard to what actions competitors will take and also with regard to technology. Large businesses have sufficient resources to hedge their bets in multiple markets or in developing multiple products or services to see which ones pan out (Barton, 1988), while small companies often lack the slack resources necessary to play in multiple markets (Nohria & Gulati, 1996). Droege and Marvel (2009) claim a critical issue is often the investment in the production equipment needed to revamp product lines. With SMEs electing to stick to a plan, whether by choice or necessity, it is critical to understand the factors affecting who wins standards wars so as to get on the winning side.

Changes in our global society with regard to communications and transportation, combined with rapid technological change and the need for significant investment in new products and services, have forced many SMEs to let go of their go-it-alone strategy and instead, implement cooperative strategies with domestic or international partners (Park, Chinta, Lee, & Yi, 2010). Interestingly enough, some of these partners may also be competitors in one or more markets. When firms engage in both competition and cooperation in a given relationship, a situation that may occur when part of a consortium, or otherwise working with open systems architecture, the situation is referred to as coopetition (Morris, Koçak, & Özer, 2007). Supply chains now reach around the world and many SMEs find themselves linking up with foreign partners, many in Asia, to develop new products or services. Asian countries such as Japan, Korea, and China have a unique culture and way of doing business that affects management practices. For example, a recent study of SMEs in the U.S. and Korea with regard to new product development projects, found significant differences in strategic decision criteria implemented in such projects. In this study, Park et. al. (2010) found that Koreans (as opposed to U.S. managers) focused more on the competency of the team as opposed to the manager. Koreans focused on client involvement and good communications, whereas U.S. managers focused more on monitoring and feedback, using the appropriate technology, risk analysis, and safety management. In addition, research from Hitt, Dacin, Tyler and Park (1997) claims that Korean managers focus on growth opportunities, while U.S. managers focus on profitability and that many U.S. executives fail to understand these differences and how they may impact the viability of international joint projects.

This study has limitations. First, the research design assumes that competition for de facto standards occurs mainly between two major competitors (the de facto standard and its number one challenger) and that the industry will eventually choose one. While these two major competitor assumptions may be reasonable, competition may actually occur among three or more platforms. In this sense, the paired cases design might not fully capture the diversity in terms of the actual competition. In addition, only cases where a standard emerged were included, precluding situations where no standard ever emerged, which might have created bias in the sampling strategy. Cases were also excluded in the event clear challengers could not be identified, or sufficient information was unavailable, which again may have introduced bias into the study's findings. Finally, the data were not wholly objective. Although painstaking efforts took place in searching for objective data, the limited availability of data forced us to utilize a subjective evaluation process. However, the data was carefully considered independently by multiple parties, and a high degree of uniformity was arrived at in evaluating the various factors. While believing that the depth and breadth of the qualitative evaluation allowed us to arrive at relatively objective judgments, caution against overgeneralizing results from this study must be taken as they are potentially subject to bias.

FUTURE RESEARCH

In future research, we should endeavor to develop methodologies that are more rigorous in order to study complex factors such as network externalities. Let's say users are queried about their reasons for buying, for example, VHS-based VCRs. Could they determine, with any confidence, the degree to which they desire network externalities and/or technological superiority or reputation? Another issue is that measuring direct network externalities and indirect network externalities separately is difficult because users are likely to enjoy the two simultaneously. For instance, VCRs have no value for users without cassette tapes, and cassette tapes have no value for users without VCRs.

Further research should also develop models to address the fundamental structure of network markets. These markets are characterized by two-sidedness with platforms as the mediator to bridge the demand-side and supply-side networks. For example, Toshiba's decision to join JVC's VHS group, rather than Sony's Beta group, was primarily based on the larger number of participants in JVC's group. One may argue that supply-side networks not only include a manufacturer's competitors, but all players in its ecosystem such as suppliers of complementary products and/or services (e.g., TDK, a cassette manufacture), suppliers of key parts, and distributors. Such supply-side network externalities are very important in promoting de facto standards. Indeed, NEC's success in the Japanese PC market in the 1980s had much to do with its licensing strategy to involve in-group manufactures, key part suppliers, and complementary product suppliers such as software developers.

With regard to which factors were key to determining the winner of the de facto standards wars, results point to the type of competition (emerging markets versus mature) as a boundary condition. Future research should delve more deeply into types of competition as boundary conditions for these (and other) factors for their ability to effect outcomes in standards wars and other types of competition. As this paper suggests, pre-standard issues may be studied with post-standard issues from a comparison point of view to reveal the possible change of competitive dynamics related to technological cycles.

CONCLUSION

Overall, this paper provides several important insights to the study of de facto standards. First, the results suggest that the technological superiority of a platform has a strong influence on the outcome of competition across markets. These results also suggest that whether or not a standard setting firm should open its architecture in an attempt to derive competitive advantage from a somewhat larger installed base depends on the characteristics of the competition. Specifically, when competition occurs in emerging markets, technological openness is an effective strategy; however, such effect does not exist in mature markets where technological openness may negatively influence the outcome. The study's findings also provide implications with regard to firms' strategy regarding compatibility.

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