DOCUMENT RESUME

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|---|---|---|
| ED 305 058 | | IR 013 734 |

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| AUTHOR | Weiss, Martin B. H.; Sirbu, Marvin |
| TITLE | Technological Choice in Voluntary Standards Committees: An Empirical Analysis. |
| PUB DATE | 31 Oct 88 |
| NOTE | 17p.; Paper presented at the Telecommunications Policy Research Conference (16th, Arlie, VA, October 30-November 1, 1988). For other papers of this conference, see IR 013 715-735. |
| PUB TYPE | Reports - Research/Technical (143) -- Speeches/Conference Papers (150) |
| EDRS PRICE | MF01/PC01 Plus Postage. |
| DESCRIPTORS | *Advisory Committees; *Computer Networks; *Decision Making; Hypothesis Testing; Marketing; Regression (Statistics); *Standards; *Technology; Voluntary Agencies |


ABSTRACT

Vendors frequently compete to have their technology adopted as part of a voluntary consensus standard, and this paper reports the results of an empirical study of the factors that influence the choice of technologies by voluntary technical standards committees. Participation in standards committees is viewed as an aspect of the product development process of corporations involved in markets where network externalities are present. The factors hypothesized to affect the technology decision are: (1) the market power of the coalition sponsoring the technology; (2) the size of the firms that make up the coalition; (3) the promotional activities of the sponsors (such as technical contributions submitted); (4) the perceived superiority of the technology; (5) the political skills of the coalition; and (6) the installed base of the products containing the technology. These hypotheses were tested by collecting data on specific technical decisions that were made in several standards committees in the area of computer communications hardware. Logit regression was used to infer the importance of each factor in the adoption or non-adoption of the technology. The results suggest that the size of the firms in the coalition supporting the technology and the extent to which they support their positions through written contributions are significant determinants of technological choice in the standards decisions studied, although the market share or these firms was found to be only marginally significant. The proponents of both the adopted and non-adopted technologies were found to have equal belief in the technical superiority of their technical alternative, even after the decision. The installed base of a technology and the process skills of the sponsors were not found to be significant predictors of the committee outcome. The text is supplemented by three tables, and 28 references are provided. (Author/EW)

# Technological Choice in Voluntary Standards Committees: An Empirical Analysis

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October 31, 1988

Presented at the
Sixteenth Annual Telecommunications Policy Research Conference,
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This work was supported by grants from the NYNEX Corp. and the National Science Foundation (IST-8696054).

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## Abstract

Vendors frequently compete to have their technology adopted as part of a voluntary consensus standard. In this paper we report the results of an empirical study of the factors that influence the choice of technologies in voluntary technical standards committees.

Participation in standards committees is viewed as an aspect of the product development process of corporations involved in markets where network externalities are present. The factors hypothesized to affect the technology decision are: the market power of the coalition sponsoring the technology, the installed base of the products containing the technology, the size of the firms that make up the coalition, the promotional activities of the sponsors (such as technical contributions submitted), the perceived superiority of the technology, and the political skills of the coalition.

These hypotheses were tested by collecting data concerning specific technical decisions that were made in several standards committees in the area of computer communications hardware. Logit regression was used to infer the importance of each factor in predicting adoption or non-adoption of the technology.

The results suggest that the size of the firms in the coalition supporting a technology and the extent to which they support their position through written contributions are significant determinants of technological choice in the standards decisions studied. The market share of the firms in the coalition was found to be only marginally significant. The proponents of both the adopted and non-adopted technologies were found to have equal belief in the technical superiority of their technical alternative, even after the decision. The installed base of a technology and process skills of the sponsors were not found to be significant predictors of the committee outcome.

## 1. Introduction

In his 1985 paper, Brian Arthur [1] argued that when two technologies compete in a market with network externalities, the ultimately successful technology can be determined by essentially random historical small events. While Arthur did not specifically address voluntary standards committees, this characterization has been the only one proposed in the literature. Our underlying hypothesis is that, at least in the voluntary consensus standards process, the choice is not random, but is consistently affected by a set of economic, technical and behavioral factors. In this paper, we posit such a set of factors and test their influence with data collected from recent standards committee decisions.

This research presumes that standards are developed as a part of the competitive product development process. A firm's participation in the standards process is considered an extension of its product development function, since standards define product characteristics to ensure compatibility. By attempting to have its technology adopted, a firm can gain a competitive advantage in the market for compatible products. Thus, firms participate in an effort to have their technology adopted in order to gain a competitive advantage. In addition, they must prevent their competitors from gaining an advantage at their expense.

Much of the existing literature on standards views the process from the perspective of a user faced with the choice of selecting from among competing products conforming to different standards. While this view is necessary when examining the effects of network externalities or bandwagon effects, it is not the only view. Berg [3] considered standards from a product market point of view, for example.

In recent years, standards development has increasingly preceded product introduction [27]; consequently, standards committee participation has become more critical. Thus, it is of interest to consider factors that influence the choice of technologies in standards committees. Using such results, firms can adjust their participation strategies in standards committees to improve their effectiveness. This research examines eleven standards decisions in recent years and draws conclusions about the influence of various factors based on these decisions.

Systematic research into standardization has begun only recently. It is predominantly theoretical, although some empirical studies using highly aggregated data have been performed. In addition, much of the work has been oriented toward studies of the adoption by end user organizations of incompatible technologies already embodied in competing products. The following framework summarizes much of this work.

1. Theoretical work based on microeconomics and game theory. The work of Arthur [1], Katz and Shapiro [15, 16, 17], Farrell and Saloner [10, 11, 12], Braunstein [6], Berg [2, 3, 4], and David [8, 9] all fall into this category in most cases. Berg, Braunstein, and David, individually, have illustrated their hypotheses with prior cases in standardization.
2. Case study type of research, where the authors examine one or more case histories and draw conclusions from them. The work of Sirbu and Stewart [24], Sirbu and Hughes [25], Sirbu and Zwimpfer [23], and Besen and Johnson [5], and Crane [7] fall predominantly into this category. The approach taken by Sirbu and Stewart is to validate prior hypotheses with an examination of cases.
3. A macroeconomic approach that uses highly aggregated statistics to draw conclusions about the provisioning of standards. The works of Link [19, 20], Lecraw [18] and Grant [14], fall into this category.

## 2. Research Design

We began our research by developing a model of the committee-based standards development process from which we generated a number of research hypotheses concerning the factors which influence the committee's choice of technology for inclusion in the standard. The model was based on prior literature, anecdotal evidence obtained from interviews of standards committee members, and informal direct observation of the standards process. Once the hypotheses were developed, we attempted to develop a set of objective measures for each of the factors found in the hypotheses. Cases were then identified and research questionnaires developed to gather data on the measures. The questionnaires were mailed to the key proponents of the alternative technologies for the identified cases. The data from these questionnaires was combined with additional financial and market share data collected from various data sets to create a record for each case. These data were then used to test the research hypotheses using univariate t-tests and logit regression.

## 2.1. A Model of the Standards Process

A standards committee normally begins with a general project description that, in some respects, resembles a product proposal of a manufacturer. The members of the committee study the project and propose various alternative for achieving the objective. Argumentation and debate in standards committees occurs by presenting and discussing these technical proposals. In some cases, technologies may be designed in committee, in others they are brought into the committee by a sponsoring organization. If technologies are brought into a committee, they may be part of a portfolio of technologies that represent the approach of its sponsor. In some cases, the technology may immediately be acceptable to the majority of the participants, and so may be adopted without opposition. In other cases, alternative technologies may be brought into a committee by different participants, requiring a choice by the committee. Informal observation of standards committees indicates that most technologies are developed in committees or are adopted without opposition.

We conceptualize a compatibility standard as a collection of functional segments. Each of these functional segments defines an aspect of compatibility, and is implemented by a technology. In many cases, the choice of technology for a functional segment is independent of the choice for another functional segment of the same standard. For example, the choice of a connector may be made independently of the choice of a coding method in a data communications standard. In our study, we examine the choice of technologies for these functional segments when multiple technologies have been presented to the committee.

Each technology must be sponsored, meaning that a firm or coalition of firms must be willing to spend money to encourage the other members of the committee to adopt their technology. Since a technology must be introduced to a standards body by means of written contributions, this is inherent in the standards process; unsponsored technologies are simply not considered because no contributions are introduced on their behalf.

We hypothesize that each of the committee's technological decisions is influenced by a variety of factors, including the market power of the sponsors, the installed base of products containing the technology, the quality of the technology being considered, the activities undertaken by sponsors to promote the technology they are endorsing, and the ability of the sponsors to be effective in the standards development process. These factors are drawn from the standardization framework discussed above. They are based on product development guidelines [22, 26], the notions of power and politics [21], and the economics of standardization literature [16, 1C].

## 2.2. Research Hypotheses

This research developed and tested the hypotheses listed below. These hypotheses were developed in accordance with the process model described above. Where possible, we attempted to operationalize the factors with objectively observable measures. We were unable to discover a general means for objectively determining the technical quality of alternative proposals and were obliged to ask participants for a subjective assessment. The use of a subjective measure led to certain difficulties which are discussed further below.

**H1: The market power of the sponsors positively influences the adoption of the technology they endorse.** Market power is the ability to influence the choice of the market. A common measure of market power is market share [28], although installed base may also be an element of this phenomenon. Since standards may be developed in new product areas, it may not always be possible to directly measure the market share of the sponsor. Instead, it may be necessary to measure the market share of the sponsor in related product areas.

**H2: The installed base of products containing a technology positively influences the adoption of that technology.** Much of the economics of standardization literature [] refers to the importance of installed base. The network externality proposed by Katz and Shapiro [15, 16, 17] is a function of installed base. In addition, producers may be averse to "stranding" a large body of consumers who have already invested in a particular technology [10, 11, 13].

**H3: The financial resources of the sponsors positively influences the adoption of the technology they endorse.** The financial resources of a sponsor can be seen as an antecedent to the other, more proximate hypothesis. A sponsor with greater resources is able to:

- Increase their market power and installed base through below cost pricing,
- Conduct more research and tests to support their technology in the committee,
- Improve the viability of their technology by developing it, and
- Send more people if necessary, send technical experts, and occupy official committee positions. Since standards committee meetings take place at one to three month intervals at various locations throughout the country, participation is clearly costly.

**H4: The support and promotional activities of sponsors positively influences the adoption of the technology they endorse.** The sponsors may promote their technology with varying degrees of intensity. Their means of promotion include: conducting research on their technology and competing technologies, conducting tests and simulations on their technology and competing technologies, publishing the results of their tests and research in the committee and in the trade press, etc. Promotional aspects might also include below-cost pricing to buy installed base [16]. It is difficult, if not impossible, to detect if such a strategy is being used. However, the consequences of such a strategy should be reflected in our measure of installed base, and impact on H2.

**H5: The degree of superiority of a technology positively influences the adoption of that technology.** Technical superiority is the ability of one technology to achieve the intended results of the standardization effort at lower cost, with compatibility with previous standards, and/or with greater functionality than the alternative technologies. Additionally, this measures the perceived degree of "provenness" of the technology and the perceived time it would take to bring a standards compatible product to market with the technology.

**H6: The political skills of the sponsors of a technology positively influence the adoption of that technology.** Understanding the nature, formal, and informal features of the standardization process may be important. In voluntary consensus standards, this may mean detailed knowledge of, experience in, and credibility in the formal standards bodies and their procedures.

## 2.3. Operationalization of the Hypotheses

The research hypotheses were operationalized by selecting a set of variables to act as their proxies in the data analysis. To the extent possible, we used variables which could be objectively measured. The variables used in the analysis are described below.

*A* — A binary variable which identifies whether the data is associated with an adopted technology (1) or a non-adopted technology (0).

*MS* — The market share of the coalition supporting the technology in the market most closely related to the product being standardized. This corresponds to the market power hypothesis (H1). Market share data was obtained from International Data Corporation for each of the major sponsors.

*IB* — The number of units installed of products containing the technologies. In some cases, no prior products existed that contained the technologies considered by the committee. This variable corresponds to the installed base hypothesis (H2). The authors attempted to identify the types of products which embodied the technology, and used sales data from IDC to determine installed base.

*LNA* — The logarithm of the net assets of the coalition of firms supporting the technology was used as a proxy for the financial resources hypothesis (H3).

*PRT* — The total number of written contributions submitted in support of the technology. This is a proxy for the participation hypothesis (H4).

*TS* — This variable is the only variable that relies on subjective data. It was necessary to use a subjective variable for the technical superiority hypothesis (H5) because it depends on the specific application intended by the proponent as well as the experience of the firm in using both technologies. This variable represents the degree to which the adopted technology is believed to be superior to the non-adopted technology.

*PRS* — The number of individuals sent to the committee meetings by firms supporting the technology. This includes representatives, technical experts, and individuals in official positions. This is a proxy for process skills hypothesis (H6).

The *TS* variable must be interpreted with some care. The principal advocates of the technologies being considered by the committee were asked to respond to the following question on a Likert scale, where 1="Strongly Disagree" and 5="Strongly Agree":

> *The <adopted> technology was superior to the <non-adopted> technology for the ______ decision in the _____ standard.*

Thus, it measures the intensity with which the sponsor believes its technology is best in comparison to the other, *post-facto*. Since the same statement was in the questionnaires of all respondents, one would not expect a significant difference between the adopted and non-adopted technologies in *TS* if there was general consensus among all participants as to the technical merits of the alternatives. If the adopted and non-adopted technologies differ significantly on this variable, it means that perceptions of the technologies are significantly different between the two sides. A response of "1" means that the respondent strongly disagrees with the statement that the adopted technology was superior. Since this is a paired comparison, one can infer that the respondent would strongly agree (i.e. respond with a "5") with the statement if the technologies listed in the statement were transposed.

## 2.4. Data Collection

Candidate cases were identified in the trade press, standards catalogs, and interviews. When a candidate was identified, it had to be qualified for the research. Qualification consisted of developing background on the context and technical detail of the standard, identifying a set of technical decisions that were made in the development of the standard, and establishing the date(s) of the decision(s). When a qualified technical decision was identified, questionnaires were mailed to the committee participants who were the principal advocates for each position on the decision and a participant who had been characterized as neutral and knowledgeable, if one existed.

A decision qualified for the research if the following criteria were met:

1. The standard had to be successful. In the cases where the standard preceded the market, the likelihood of success was judged by the model presented in Sirbu and Stewart [24].

2. It had to be generated by an on-going and approved standards committee.

3. Consensus on the decision had to be reached since 1985. The two decisions that were used as pilot cases for much of this research[1] were reached prior to this date. The pilot studies suggested we should focus on recent decisions where the recollections of the participants would be sharper. Notwithstanding the above observation, data from the pilot cases is included in our analysis.

4. It had to be independent of other decisions already included in the research.

5. Two technologies had to be competing for inclusion into the standard.

6. A single technology had to be chosen by the committee for inclusion into the standard[2].

After qualification, questionnaires were used to collect information on the historical and technical features of the decision, as well as the number and types of contributions and the number and types of participants for each technology. The market share and installed base data was provided by International Data Corporation. The financial information on the various firms was taken from the corporate annual reports of the firms supporting the technologies.

Data was collected on the following eleven decisions. Two additional decisions had beer identified and qualified, but the questionnaires were not returned prior to the cutoff date for this research.

- Optical Wavelength decision in Fiber Distributed Data Interface (FDDI). The committee chose an optical wavelength of approximately 1300nm for inclusion into the standard. The alternative that had been proposed was 850nm. At the time of this decision, devices capable of implementing 1300nm represented the state of the art although they were unproven. Prior optical systems for data communications used 850nm.
- Access Method decision in the IEEE 802.6 Metropolitan Area Network committee. The Distributed Queue Dual Bus (DQDB) approach was adopted in favor of the Multiplexed Slot and Token (MST) technique. An approach similar to MST has been considered in the discussions concerning FDDI-II, a version of FDDI that supports voice as well as data traffic.
- Error Detection and Correction (EDAC) in the standard optical disk (distinct from the CD/ROM). This debate centered around the adoption of an EDAC scheme based on a Degree-16 polynomial versus a Degree-32 polynomial. The Degree-16 polynomial was adopted, largely because the proponent of that technology gained the support of the leading computer disk controller manufacturers.
- Fiber Core Diameter in FDDI. This debate occurred after the optical wavelength decision. At the time of this debate, fibers with 62.5 and 85 micron core diameters were the critical contenders. The 62.5 micron fiber was successful primarily due to market considerations, although the 62.5 was more flexible with only slightly greater coupling loss.
- Line Powering decision in the DS1 interface. With the increased use of fiber in the telephone network, it became necessary to consider whether the common carriers should continue to supply the power to drive the interface devices. In the end, the committee adopted an unpowered approach (a so-called "dry" interface) over the powered approach (the "wet" interface). An unusual feature of this debate is that the standards committee adopted an approach that was at odds with an FCC requirement. The committee subsequently had to lobby the FCC to lift the line powering requirement.
- Frame Format decision in the Synchronous Optical Network (Sonet). Data bytes in Sonet were initially arranged in 13 rows of a variable number of columns that depended on the capacity of the link. An alternative proposal that arranged the data in 9 rows was adopted on the grounds that it was more consistent with both the CCITT (i.e. international and European) and North American digital hierarchies.

[1] These cases are the V.22bis modem modulation decision and the V.32 modem coding decision.

[2] This excluded situations such as the IEEE 802 Committee which, unable to agree on a single local area network standard, has to date approved three different technologies as standards [25].

- Modulation Decision in the V.22bis modem standard. One approach that was proposed for this decision was to have an 8 point QAM constellation in which each symbol transmitted on the data channel would represent 3 data bits. The other, and successful, technology, was a 16 point QAM constellation, where each symbol represented 4 data bits.
- Coding Decision in the V.32 modem standard. A Trellis channel code was adopted by the committee as opposed to a block channel code. Block codes had been one of the traditional channel coding techniques for forward error correction until the development of Trellis coding technology in the late 1970's.
- Primary Bit Rate decision in Sonet. Early in the development of Sonet, a debate took place surrounding the basic bit rate. The initial proposal, which prevailed, was a data rate of approximately 50Mb/s, and the other proposal argued for a data rate of approximately 150Mb/s.
- System Architecture decision in the twisted pair version of IEEE 802.3 standard. An approach that consisted of linked stars of twisted pair cable was adopted over an approach that replaced the coaxial cable with twisted pair. The former approach was generally considered to be more consistent with other development efforts undertaken previously by the same committee.
- Connector decision in FDDI. A connector that had a fixed shroud protecting the ends of the optical fibers was adopted over a connector that had a removable shroud performing the same function.

Note that two decisions in Sonet and three from FDDI are included in this research. In each decision, the coalitions supporting each of the technologies were different. For example, in the FDDI wavelength decision, the coalition supporting the adopted technology had as its most prominent members AT&T and DEC, while the coalition supporting the non-adopted technology consisted of primarily of Sperry (later merged with Burroughs to become Unisys) and Plessey. In the FDDI connector decision, the adopted technology was supported by DEC and AMP, Inc. in large part, and the non-adopted technology by AT&T and IBM. In the other decisions, the coalition members change in similar fashion. The fact that the coalitions were different for the various technologies suggest that the technical choices involved were sufficiently independent that they can each be used in the analysis.

Each of the cases described above is represented by two data points, one for the adopted technology and one for the non-adopted technology. All respondents were asked to provide information on the composition of and levels of participation by both sponsoring coalitions. These responses were combined to prepare the estimate of participation for each coalition, *PRT* A similar procedure was used for constructing the measure of process skills, *PRS*. Subjective evaluations of the technical quality were obtained separately from a representative of each coalition.

## 3. Results

The objective of the analysis was to test the research hypotheses described above. Each of our measures is associated with a specific factor hypothesized to be important in determining the outcome of the standards process. Two statistical procedures were used to test the association of the various measures with the decision to adopt or not to adopt a technology. First, partial means for each measure were constructed for the adopted and the non-adopted technologies. A univariate t-test was used to test for a significant difference in the sample means.

Second, a logit regression was used to adduce the importance and significance of each factor in predicting adoption or non-adoption of a technology.

### 3.1. Data Characteristics

The basic summary statistics for the data variables are shown in Table 3-1. These statistics include the data associated with the adopted and non-adopted technologies. In section 3.2, these groups will be separated and compared using a t-test. Table 3-2 is the correlation matrix associated with the variables. As with Table 3-1, this matrix does not distinguish between the data associated with adopted or non-adopted technologies. Note that the variable *TTS* is included in these tables; the reason for this is discussed in more detail in Section 3.3.

| | *MEAN* | *MEDIAN* | *STDEV* | *SE* | *MIN* | *MAX* | *Q1* | *Q3* |
|---|---|---|---|---|---|---|---|---|
| *MS* | 23.55 | 10.00 | 29.68 | 6.33 | 0.00 | 100.00 | 0.00 | 50.00 |
| *IB* | 6.32 | 0.00 | 11.64 | 2.48 | 0.00 | 32.00 | 0.00 | 6.25 |
| *LNA* | 23.83 | 24.49 | 1.75 | 0.37 | 18.42 | 25.61 | 22.78 | 25.13 |
| *TTS* | 4.05 | 4.00 | 1.17 | 0.25 | 1.00 | 5.00 | 3.75 | 5.00 |
| *PRT* | 18.86 | 18.00 | 8.64 | 1.84 | 7.00 | 37.00 | 10.75 | 24.50 |
| *PRS* | 17.07 | 14.50 | 13.07 | 2.79 | 2.00 | 43.00 | 6.00 | 25.25 |

**Table 3-1:** Descriptive Statistics of the Data

| | *MS* | *IB* | *LNA* | *TTS* | *PRT* |
|---|---|---|---|---|---|
| *IB* | -0.211 | | | | |
| *LNA* | 0.286 | -0.003 | | | |
| *TTS* | 0.206 | -0.507 | -0.040 | | |
| *PRT* | -0.060 | 0.011 | 0.219 | 0.184 | |
| *PRS* | 0.500 | -0.112 | 0.296 | 0.099 | 0.098 |

**Table 3-2:** Correlation Matrix

In Section 2.2, it was indicated that the financial strength of the coalition was an antecedent to the other hypothesis. Given that, a significant correlation with the all of the other variables could have been predicted. Table 3-2 indicates that *LNA*, representing this hypothesis, has a significant correlation only with *TTS*.

### 3.2. T-Tests

The collected data were separated into the categories of "adopted" and "non-adopted", and two-sided t-tests were performed comparing each of the categories by variable. The results of this analysis are contained in Table 3-3.

The t-tests compare the means of the data associated with adopted technologies with those associated with non-adopted technologies for each of the variables. A two-sided t-test is used to decide whether the difference in sample means is significantly different from zero. The results in the table indicate the probability that the difference in sample means is in fact zero, and thus the factors do not differ as between adopted and non-adopted technologies. The results of this t-test provide some evidence for accepting or rejecting the research hypotheses described previously. This analysis indicates that the means of the adopted data differ significantly from the means of the non-adopted data for the *MS*, *LNA*, *TS* and *PRT* variables.

### 3.3. Technical Quality

The large difference in partial means for the TS variable indicates that sponsors are far apart in their perception of the technical merits of the two technologies -- our informant for each group continues to believe his technology is best, even *after* the decision. This suggests that we cannot use the TS measure as a widely agreed to objective indicator of technical quality in a regression designed to measure the relative importance of technical quality versus other factors.

| *Variable* | *Total Mean* | *Adopted Mean* | *Non-Adopted Mean* | *Significance* |
|---|---|---|---|---|
| MS | 23.55 | 36.5<br>(10.5) | 10.6<br>(4.93) | p=.043 |
| IB | 6.32 | 6.5<br>(3.76) | 6.1<br>(3.43) | p=.93 |
| LNA | 26.14 | 24.78<br>(.262) | 22.8<br>(.581) | p=.011 |
| TS | 3.13 | 4.18<br>(.263) | 2.1<br>(.436) | p=.0008 |
| PRT | 18.86 | 23.64<br>(9.08) | 14.1<br>(4.91) | p=.0078 |
| PRS | 43.55 | 48.3<br>(21.5) | 38.8<br>(6.06) | p=.30 |
| TTS | 4.04 | 4.18<br>(.26) | 3.91<br>(.44) | p=.60 |

**Table 3-3:** Univariate T-Tests

The variable TS measures the subjective perception of the informants as to the preferability of their technology. Thus, to measure the difference in strength of perception, the values associated with the non-adopted technologies must be transformed. This is done by letting $TTS = 6 - TS$ for the non-adopted technologies only. The values for the adopted technologies remain the same. Now, if the means of the adopted and non-adopted technologies in the *TTS* variable are significantly different, it means that the participants differ in the *intensity* of their belief in their respective technology *post facto*. A t-test on the transformed variable TTS does not suggest that we will find intensity of the advocates' belief in his technology to be a significant predictor of adoption versus non-adoption.

## 3.4. Regression Analysis

While the t-test results show that some factors, on their own, are significant, they do not indicate the relative explanatory power of the variables. A logit regression was performed on the variables for this purpose. The result of the regression on the full model is contained in Table 3-4.

The results of the full model indicate that not all variables are significant; this is best shown by the F-to-remove column ($F_R$). $F_R$ compares the full model with a model without that variable; small values of $F_R$ imply that the model without that variable is indistinguishable from the full model[3]. Using this criterion, the *MS*, *IB*, *TTS*, and *PRS* variables can be removed without significantly reducing the explanatory power of the model. When this was done, the "minimum sufficient" model, shown in Table 3-5 was obtained. An F-test comparing this model to the full model indicates that they are not significantly different at the 0.05 level. Thus, the "minimal" model is statistically identical to the "full" model. This implies that the removed variables are insignificant in explaining the data.

[3]The significance of $F_R$ can be determined by examining an F-statistic table with (1,15) degrees of freedom.

| *Variable* | *Coefficient* | *S.E.* | *Significance* | $F_R$ |
|---|---|---|---|---|
| *Constant* | -44.91 | 15.82 | 0.05 | 8.31 |
| *MS* | 0.04 | 0.03 | 0.10 | 2.46 |
| *IB* | -0.04 | 0.04 | -- | 0.03 |
| *LNA* | 1.77 | 0.64 | 0.05 | 8.41 |
| *TTS* | -0.73 | 0.66 | -- | 1.87 |
| *PRT* | 0.25 | 0.08 | 0.01 | 12.38 |
| *PRS* | -0.03 | 0.0[illegible] | -- | 0.31 |

**Table 3-4:** Logit Regression - Full Model

Finally, all of the t-scores of the coefficients of the minimal model indicate that the likelihood that they are zero is less than 0.05. Note that the coefficients in Tables 3-4 and 3-5 estimate the value of ln[*P*/*1*-*P*], where *P* is the probability of adoption. The appropriate transformation on the equation must be performed to compute *P* directly.

| *Variable* | *Coefficient* | *S.E.* | *Significance* | $F_R$ |
|---|---|---|---|---|
| *Constant* | -90.70 | 49.39 | 0.05 | 11.08 |
| *LNA* | 3.43 | 1.85 | 0.05 | 8.41 |
| *PRT* | 0.404 | 0.21 | 0.05 | 12.38 |

**Table 3-5:** Logit Regression - Best Fit Model

## 3.5. Tests of the Research Hypotheses

**Hypothesis 1 (Market Power)**

This hypothesis is represented by the *MS* variable in the analysis. In the t-test, the difference between the means of the adopted and non-adopted variables was significant; in the regression analysis, including this variable did not contribute to the explanatory power of the model. We are unable to reject the negative hypothesis, that Market Share is not significant.

**Hypothesis 2 (Installed Base)**

The collected data provides no support for the hypothesis that Installed Base is a significant factor in predicting adoption. Since, for several of the cases examined, standardization preceded products, a dummy variable was included in the analysis to account for these cases. The dummy variable identified those cases in which the standard preceded the product from those where the product preceded the standard. If the precedence of standards versus products had been significant, the dummy variable would have been significant in the analysis. The data provides no support for this hypothesis either.

**Hypothesis 3 (Financial Resources)**

The logarithm of the net assets (*LNA*) variable was used to represent this hypothesis in the analysis. The logarithm of the net assets was used instead of the value of net assets itself to reduce the marginal effect of very large firms or coalitions. The results indicate that the influence of the larger coalition is significant and the sign is positive, so hypothesis H3 can be accepted.

**Hypothesis 4 (Promotion)**

The t-tests on the variable (*PRT*) indicate that the means of the adopted data and non-adopted data are significantly different. In addition, the regression analysis indicates that it is useful in modelling the outcome, and the sign is positive, as expected. Thus, this hypothesis can be accepted.

**Hypothesis 5 (Technical Superiority)**

As noted earlier, TS cannot be considered an operationalized measure of technical quality. The measure TTS reflects only relative strengths of *perception* of technical quality by proponents for each side. The analysis using the transformed variable, *TTS*, is not significant in the t-test or in the regression analysis. Thus we cannot support the (revised) hypothesis that strength of belief in the technology by the proponent is a predictor of eventual success.

**Hypothesis 6 (Process Skills)**

The *PRS* variable, representing this hypothesis, was not significant in either of the analyses. Thus, the data provide no support for this hypothesis.

## 4. Discussion

The implications of this research are numerous, particularly for participants of the standards process. In the cases studied for this research, one can conclude that the coalition with the largest firms, possibly with superior market power, are more likely to be successful in having their technology adopted in a standards committee, especially if they support their effort vigorously through contributions.

*Installed Base*

One of the interesting results is that, for the technology decisions examined, installed base had no significant influence. Prior research [10, 11, 15, 16] strongly supported the hypothesis that installed base would be influential. There are some explanations for this result. Perhaps the most significant explanation lies in the data itself. Even in those cases where products containing the technologies proposed in the standards committees existed prior to the development of the standard, the markets were often new and the installed base small. Thus, we have a relatively weak test of the importance of installed base. Further research needs to be conducted where the installed base at the time of standardization is larger.

Another possible explanation is that the previous research discussed the adoption of technologies and standards by user organizations. In this research, it was assumed that firms participate in the standards process as a part of their product development process. It is possible that a different theoretical model underlies the adoption process in this case.

*Technology Preference*

Some interesting conclusions can be drawn about the subjective variable, *TS*. It indicates that the supporters of the non-adopted technologies still feel strongly, in general, that the technology they supported was best, *post facto*. While it is impossible to measure their preferences before the decision, it is rational to conclude that they believed the same way. The strength of this result indicates that technology is indeed an important factor in the decision, and that people do not significantly change their perception, regardless of the committee outcome.

In addition to the overall technology preference data collected for the *TS* variable, the components of technical superiority were examined. In this section, the respondents were asked to compare the two technologies in terms of their

- compatibility with previous standards
- ability to meet future requirements (growth)
- ability to meet the performance requirements of the standard being developed (performance)
- "provenness"
- the estimated time required to bring a compatible product to market (time)
- the estimated cost of producing a compatible product (cost).

In addition, the respondents were asked to weight each of these in terms of their importance to the standard. When the weighted sum of these components were calculated and compared to the overall judgement of the technology (i.e. the *TS* variable), they were found to be highly correlated[4]. Thus, the respondents differing perceptions of the overall merits of the technologies was supported by their differing perceptions of the various components of technical quality.

*Process Skills*

Finally, sending large numbers of people to standards committees does not appear to make a difference. In most committees, firms have only one vote, so sending multiple participants does not in general influence the voting process[5]. That a "brute force" approach of sending many warm bodies is ineffective is intellectually and socially satisfying.

Some secondary data that was collected bring further insight into the effectiveness of participation. They indicate that heavy standards participants, *i.e.* those members participating in other committees at the time of the decision being studied, had no particular influence when they acted as proponents for a technology. Secondly, there was no significant difference in the numbers of official committee positions held by individuals belong to either to firms supporting adopted or non-adopted technologies. This either implies that the official positions lend no particular influence to the outcome, or that the firms that participate in standards committees are sufficiently sophisticated to realize the importance of these positions, thus attempting to balance the committee leadership with a broad spectrum of individuals. Since the lifetime of the discussions of a technical decision is considerably shorter than the tenure of the committee leadership, the former is likely true.

The use of outside experts is not significantly different in the adopted and non-adopted technologies for the cases studied. Pfeffer [21] suggests that the use of outside experts is a means of exercising power in organization. In the case of the standards decisions studied, successful firms, in general, sent no more experts than the firms supporting alternate technologies. As above, this implies one of two possibilities. First, that the use of experts does not significantly influence the committee's decision, or, second, that the firms participating in standards committees have not yet discovered the value of using experts.

Finally, it should be pointed out that the numbers of participants in various categories may not be a complete proxy for the process skills of the individuals participating in the committee. It is difficult to objectively measure, *post facto*, the ability of the individuals involved to persuade other committee members or to use the official and unofficial organizational processes to their best advantage.

[4]The correlation coefficient of these two variables was 0.780.

[5]An exception to this are IEEE standards committees, where the committee members participate as individuals, not as representatives of firms. Thus, it would be possible to bias the voting by sending multiple committee members to meetings from the same firm.

## 5. Summary

A study was performed to assess the factors that influence technological choice in voluntary compatibility standards committees. In this study, hypotheses were developed and tested with data collected from eleven standard decisions. We were able to establish that the financial strength of the coalitions supporting the technologies and the extent to which they supported their technology in the committee through written contributions are significant predictors of the probability of adoption. The market power of the firms was found to be a weak indicator of the success of the technology in the committee.

We were unable to conclude that the installed base of products containing the technology being debated, and the number of participants attending committee meetings in support of the technologies were significant predictors of the probability of adoption for the cases we examined. Data collected on the proponents' perceptions of the technologies indicate that their strength of conviction about the superiority of the technology they supported is identical, even in retrospect. Thus, it could not be concluded that the adopted technology was unanimously perceived to be superior.

Due to the technical difficulties associated in measuring technological superiority, it is not possible to resolve one of the important debates discussed by standards committee participants. This debate surrounds the question of whether technological factors are more important in these technical standards committees than non-technological ones. In this research, we have been able to establish some of the non-technological factors as significant predictors of the probability of adoption, but we have not been able to meaningfully compare the technological factor with these non-technological ones. Like the legendary Sisyphus, they must continue to wage this debate without a satisfactory resolution.

This research had Arthur's hypothesis [1], that technological choice is the result of historical small events that are essentially random, as its null hypothesis. This study rejects that null hypothesis for the technological choice process in voluntary standards committees, a domain not explicitly covered by Arthur's work.

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