Do Firm R&D Investments Drive Decisions to Join? On the Value of Standard-Setting Organizations in the Consumer Electronics Industry

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Abstract

Academic research does not yet have a precise understanding of what drives firms' decisions to participate in standard-setting organizations (SSO). We explore the relationship among consortium participation decisions, firm-level R&D investment intensity and production efficiency. We develop theoretical arguments that capture the tradeoffs for joining. They include benefits from steering the future direction of standards, and R&D and knowledge spillovers from other members. Also present are costs from membership fees and risks of free-riding through information disclosures on intellectual property. We develop hypotheses for empirical analysis. We use a logic model to evaluate managerial decisions to join SSOs involving a large data set of publicly-traded consumer electronics firms. The data cover five SSOs in the consumer electronics industry that joined SSOs by 2006. Our results provide evidence that the likelihood of joining an SSO increases with a firm's R&D investment intensity. More efficient firms are more likely to join too.

Keywords: Economics, empirical research, IT investments, R&D, spillovers, standards, standard-setting organizations, theory development.

1. INTRODUCTION

Standard-setting organizations (SSOs) have become increasingly important institutions, especially in the information and communications technology (ICT) and electronics industries [6]. These organizations are industry groups that set common standards in a variety of significant areas [20]. We are particularly interested in the information and process sharing and cooperation aspects of SSOs. We will examine SSOs that are structured as cooperative alliances resulting from collective actions by companies seeking a common solution to some kind of technology, information or process standards. We put less focus on SSOs that promote a particular proprietary product or set of products via shared strategy or actions.

Academic researchers have not yet achieved a good understanding of what drives firms' decisions to join SSOs [22], or what strategic value [19] SSO membership brings to firms. Understanding strategy for SSO membership is an important challenge for researchers and professionals concerned with standard-setting governance, development of industry-wide standardization process and management of standards [29], [32]. Although the literature offers valuable insights on many issues related to standardization, such as startup problems and standards competition [30], studies on the value of standard-setting institutions are scarce.[1]

This paper represents our attempt to fill the gap in the literature and contribute to the broader efforts that are occurring within the IS discipline. Our theory captures the tradeoffs that a firm faces in its decision to join an SSO. We examine how firm-level characteristics, R&D investment efficiency and production efficiency affect its decision. The main benefit of joining an SSO is that a member firm gains the opportunity to learn about new technologies, business processes and other know-how developed by other members. Implicit in membership is the sharing of this kind of knowledge. Members usually pay a participation fee, which can substitute for some larger R&D expenditures. According to the World Wide Web Consortium [31], becoming a member of an SSO may also help a firm get a sense of the directions for future standards – and even help to steer them to some extent – and gain insight into market trends. Senior executives in technology, marketing, operations and R&D should not ignore SSOs: they are too important to the future health of their firms [4], especially when an industry is undergoing a lot of technology-driven changes. Joining an SSO is costly though. Member firms typically are required to disclose process or technical *intellectual property* (IP) related to standard setting and to license it on a reasonable basis – even to competitors [12].

A firm's incentive to join an SSO is influenced by the tradeoff between the benefits of R&D spillovers from other SSO members through a *network externality* [11] and the costs of membership fees and disclosing *intellectual property* (IP). We know from other field study work we have done that participation decisions also depend on firm-level characteristics. Indeed, we expect *firm heterogeneity* to play a role: not all firms can appropriate equal benefits from joining an SSO, since they have different competitive circumstances, and varied intensities of R&D

[1] Examples are the 2006 *MIS Quarterly* special issue guest-edited by John King and Kalle Lyytinen, and this five years-and-growing Standards and Standardization Mini-Track at the Hawaii International Conference on Systems Science.

investment and levels of production efficiency. In light of these tradeoffs, it is not clear how R&D investment intensity affects firms' decision to join an SSO. We will develop theoretical arguments that indicate that firms with relatively higher R&D investment intensities are more likely to join SSOs, despite competitive concerns about high-value IP disclosures. Our theoretical perspective also indicates that firms with relatively higher productivity and lower unit costs are more likely to join SSOs.

To examine the plausibility of our theoretical predictions, we studied consortium memberships listed at ConsortiumInfo.org (www.consortiuminfo.org). We merged the membership data with measures of firm characteristics taken from the Compustat Global Basic dataset. The data set covers 1,271 publicly-traded firms. To examine determinants of firms' participation decision, we analyze a cross-sectional logit model. This permits us to assess the extent to which R&D investment intensity, production efficiency, and relevant control variables explain the firms' decisions to join an SSO. In line with the theoretical predictions, we find that higher R&D investment intensity and higher productivity are associated with statistically significant increases in the likelihood of firm membership in the five different SSOs in the consumer electronics industry. A 1% increase in R&D investment intensity leads to a 2-3% increase in firm odds to join; also a 1% increase in productivity leads to about a 2% increase in SSO membership likelihood. These results lend support to our theory that firms with high R&D investment intensity and productivity tend to join SSOs.

The rest of the paper is organized as follows. §2 provides background and related literature on SSOs. §3 sketches our theory development. §4 present the main hypotheses. §5 follows with details on data, methods and results. §6 interprets our analysis and results in managerial and business policy terms. §7 concludes and provides thoughts on some of the limitations of this study.

2. LITERATURE

We next discuss SSOs, the role of network externalities, and their intellectual property (IP) policies. We assess the areas of literature on which our work builds, and also indicate how our work differs.

2.1. Standard-Setting and SSOs

Industry standards are vital to many aspects of the economy. Standards can be created in several different ways. One outcome is a *de facto standard*, which occurs when the commercial the success of a format or standard achieves a critical mass and comes to dominate an industry, as in the case of the success of the VHS format over the Beta format in video cassette players. Other times, a government body may adopt standards for public welfare reasons, such as electrical wiring codes for building. Traditional ways of creating anticipatory standards operate at a slower pace than technology evolves, so a new class of standards-setters typically appears in the standardization arena: the SSOs. [2] Major goals of SSOs include establishing technical standards to ensure compatibility and interoperability of a wide array of products, leading to a *de jure standard*. One example is the World Wide Web Consortium (W3C). Its standards for HTML, CSS, and XML are used universally to facilitate asynchronous and unmonitored communication among Internet users.

2.2. The Role of Network Externalities

In general, SSOs help in creating direct *network externalities* for participants by engaging in synergistic activities such as sharing intellectual property, joint development of complimentary products, and agreeing to specifications for components. In other words, standardization creates a direct network externality for SSOs members because one member's output from R&D investment benefit other members. Network externalities from standardization support compatibility among products from different producers and product values increase with standards-driven compatibility too [11].

This kind of externality implies coordination problems though, because of the discrepancy between private individual and collective network-wide gains [29]. A firm's decision relative to its R&D investments depends on the interaction between its private gain and the collective gain that comes from knowledge spillovers [21] created by network externalities.

2.3. Intellectual Property (IP) in Standard-Setting

Most SSOs involved with technology have proprietary information and IP policies [20]. These policies generally require that members disclose and license to one another (although not to the public) IP that may relate to standards. *Intellectual property* must be broadly defined to be meaningful in this study's context, so we include considerations like process knowledge and technical know-how, as well as the forms of IP that are typically recognized by the law (e.g., related pre-patent materials, details in procedural documents, etc.). These IP disclosures speed up knowledge diffusion through meetings and provide incentives for firms to join an SSO [13].

The value of joining an SSO becomes larger when more firms participate because members can free-ride on other firms' process and product knowledge, and other IP, to some extent [25]. The larger the number of members,

[2] *Anticipatory standards* must be created before widespread acceptance of the device or services. They emerge from the cooperation among existing competitors, or by new entrants that offer a precursor of the potential standard product or service. *Participatory standards* are developed, tested and used in an interactive environment. *Responsive standards* occur to codify a product or service that has been sold with some success.

the larger will be the total amount of IP that can potentially become available. IP-related policies can either free up or constrain the flow of positive network externalities for firms which invest heavily in R&D. They create asymmetric externality benefits for joining an SSO between firms with large and small R&D investments. They also enlarge the discrepancies between the private gains from a firm's own R&D investments and the collective gains from other members' R&D investments.

2.4. Literature on SSOs

Little research has addressed SSO impacts. Most IS standardization studies have focused on the content of new anticipatory IT standards, the standard-setting process [23] and standards competition [30]. Studies related to impacts of standards on organizational strategy are notably scarce [22]. King et al. [19] call for more research on the institutional aspect of standard-making.

Economists study *de facto* standard-setting, with no specific role for organizations involved in standard-setting (e.g., [11]). They view SSOs as settings where competitors can resolve conflicts [26]. Few studies have analyzed SSOs from an R&D investment perspective either.

3. THEORY

Before presenting the theoretical arguments, we first underline our conceptualization of an SSO and discuss the cost-benefit tradeoffs for joining. Then we discuss how firm characteristics – R&D investment efficiency and production efficiency – impact a firm's decisions to join.

3.1. SSOs: Key Concepts

We view an SSO as a forum for cooperation to develop and sponsor technical standards [1]. In the absence of a dominant firm or a single obvious technology in the market, explicit alliances among rivals or potential rivals, SSOs appear to develop standards [24]. An SSO is frequently considered to be a *limited-time venture* launched to achieve a single goal. Sometimes, it will have a broader mission, and will seek to set multiple standards necessary to enable the evolution of a new category of business services and products. The most common structure is a *joint venture*. Thus, an SSO is like an alliance with participants willing to cooperate to achieve similar goals.

To jointly develop standards, a consortium provides a forum for cooperation among members of a group of firms that may otherwise be competitors [10]. They often invite members to join a *working group*, to actively participate in consortium activities and, most importantly, to contribute to the knowledge and understanding of developing standards. The Universal Home API (UHAPI), for example, requires its contributing members to submit property rights or copyrights that are essential to developing standards or specifications. It also requires its *associate members* to provide input to working groups. Most SSOs provide several types of membership with different obligations and rights, but all require some minimal level of knowledge sharing and contribution among members.

3.2. Benefits of Joining an SSO

Practitioners and academic researchers have identified several benefits for joining different types of SSOs. First, in some types of SSOs, proprietary vendors invest considerable time and effort in forming and participating in a consortium with the objective of injecting some proprietary element into the final standard, hoping it will be accepted in the marketplace [28]. Once accepted by consumers, they may achieve a larger network effect so that they are able to develop a *de facto* standard. It gives them a higher likelihood of adopters being locked into the current specifications and related future ones based on current specifications [8, 17, 27]. This benefit is more likely to materialize when an SSO is organized around development and sale of a proprietary technology

The second benefit for participants is the chance to engage in cost-sharing to avoid wasteful duplication in R&D expenses and knowledge acquisition [9]. SSO participants report this to be an important benefit. Firms also are encouraged to share their research output related to standards. Once a firm joins an SSO, it must agree to participate in a cooperative R&D project, wherein the consortium requires IP disclosure and technology patent licensing among members related to standards. The Home Audio Video Interoperability (HAVi) Consortium, for example, requires its members to contribute to increase knowledge and understanding of the HAVi specification. Katz [16] reports that allowing firms to share research output from R&D this way increases the efficiency of R&D efforts by eliminating wasteful duplication.

Different types of participants in a consortium achieve cost reduction in slightly different ways. There are two types of participants: standard creators and standard seekers [2]. *Standard creators* are normally the founding members of an SSO. They often require one another to disclose technology and IP essential to the developing standards. This policy increases the intensity of R&D spillovers, so that the research done by one firm can be used by another [16]. *Standard seekers*, in contrast, normally do not have developed technologies or patents in hand before they join. Yet they are required to attend working group meetings to share knowledge and insights about implementing and improving standards, processes and technical know-how. They create knowledge spillovers, so that investments in knowledge creation by one firm produce external benefits by facilitating innovation by other firms [14]. Such knowledge and information sharing has been found to further increase the productivity and profitability of R&D cooperation [15]. Joining an SSO, thus, helps all participants to reduce their R&D costs through R&D and knowledge spillovers.

3.3. Costs of Joining an SSO

Although firms receive the benefits described above, they also endure costs or losses related to consortium participation. The direct cost of joining a consortium is the annual membership fee, a non-refundable fixed cost. Most SSOs have several membership types, with fees ranging from $2,000 to $50,000 per year or more. Members also bear the risk of forfeiting valuable IP and may experience the *free-riding problem* associated with collaborative R&D, since technology, product and process knowledge tends to be a public good in SSOs. Some participants may conceal technological expertise while trying to absorb as much as possible from the others [3, 25].

When deciding whether to join an SSO, a firm faces a tradeoff between from cost-sharing gains and competitive advantage losses due to free-rider problems. A firm will wish to join an SSO if it can achieve positive net gains. Such gains and losses differ across firms though. Firm-level factors can help us to understand why some firms join while others do not. We are especially interested in how firm differences in R&D efficiency and production efficiency affect their decisions to participate in an SSO.

3.4. Efficiency and Participation

An SSO is formed based on an explicit agreement among some firms to jointly address a standardization issue. Such an alliance allows some members to reduce R&D costs by spreading them over multiple firms by combining the alliance members' specialties [9]. An SSO can change the average R&D efficiency based on R&D expenses per unit of output.

A firm with a relatively high *R&D efficiency* can only realize a small marginal increase in efficiency from joining an SSO. Such firms do not have a large reduction in R&D investments per unit of output. So firms with relatively high R&D efficiency in the industry may not find it beneficial to join an SSO. In contrast, a firm with relatively low R&D efficiency can gain from R&D and knowledge spillovers to increase its R&D efficiency and will have and incentive to join an SSO.

The second factor that affects the likelihood of a firm joining an SSO is its *production efficiency*. In markets for technology-based products, a firm with expertise in technology is likely to exhibit higher production efficiency. This efficiency is reflected in either high productivity or low unit costs. Firms with relatively high production efficiency can benefit from knowledge spillovers based on other members' expertise with greater ease. Compared with lower efficiency firms, efficient firms may not be as concerned with losses due to sharing IP due to their superior production capabilities. A firm with relatively lower production efficiency may lose competitive advantage due to lower production efficiency, since other free-riding firms with higher production efficiency may capture the associated benefits at a higher rate.

4. HYPOTHESES

We now seek to test the ideas developed in §3. Our theory suggests that the likelihood of joining an SSO decreases with a firm's R&D efficiency. Although the firm has to disclose some IP to SSO members, it benefits from access to standards-related technology developed by other SSOs members. We use *R&D investment intensity*, a firm's R&D expenditure divided by its total output, to measure R&D efficiency. An R&D-efficient firm is more capable of controlling its R&D expense per unit of output, and thus will have a low R&D investment intensity. We will conduct a cross-sectional analysis to test the validity of this prediction based on:

- **Hypothesis 1 (The R&D Investment Intensity Hypothesis):** *The greater a firm's investment intensity in R&D, the more likely it will be to join an SSO.*

Our theoretical arguments also predict that a productively efficient firm has more incentives to join an SSO. An efficient member can gather benefits from standard-related technology faster than other members. This leads to our second hypothesis:

- **Hypothesis 2 (The Production Efficiency Hypothesis):** *The higher a firm's production efficiency is, the more likely it will be to join an SSO.*

Theoretically, production efficiency can be represented by either productivity or unit cost. But empirically, they are often measured differently. We examine how each affects firms' incentives to join an SSO. We also consider how they may jointly influence the overall impact of productive efficiency on SSO participation.

Productivity. This measures the inputs-output relationship in the production process. A firm with high productivity can produce more products for a given amount of input. Large market demand is required for this firm to profit from its high productivity though. This kind of firm will benefit more from joining an SSO, because it can redirect savings from R&D investment to its other core activities. Thus, we have:

- **Hypothesis 3 (The Higher Productivity Hypothesis):** *The higher a firm's productivity is, the more likely it will be to join an SSO.*

Unit Cost. Production efficiency is represented by unit costs. The *unit cost* is the total cost divided by the number of units produced. A lower unit cost indicates higher productive efficiency. We assert:

- **Hypothesis 4 (The Lower Unit Cost Hypothesis)**: *The lower the unit cost of a firm in production, the more likely it will be to join an SSO.*

Lower unit cost in production permits a firm to spend relatively less on producing products. A firm that is able to find a way to lower its unit cost will gain competitive advantage, and can confidently leverage R&D spillovers and knowledge sharing by joining an SSO.

5. DATA, METHODS AND RESULTS

We describe our data, the measurement of the dependent and independent variables in our model, and then formulate the model and present its estimation results.

5.1. Data

We collected data on membership for 1,271 firms in five SSOs in the consumer electronics industry, where product success depends on a firm's effective understanding of technology standards.[3] We used consortiumInfo.org (www.consortiuminfo.org) to identify our sample SSOs. This provides a comprehensive source of information on the Internet regarding standards, standard-setting, and open-source software. In Spring 2007, it listed seven SSOs under in "Consumer Electronics Industry" category. Two of those SSOs, the Coral Consortium and the International Forum on ANSI41 Standards Technology (IFAST), did not reveal information about their members at the time we collected data. We have no knowledge at this time to determine whether these are *missing completely at random* (MCAR) observations or otherwise, though it is likely to be the case. We believe that the missing observations are not tied to any observed or unobserved measurement. Thus we feel safe to assert that this is probably not a source of selection bias. This left just five SSOs in our sample.

We collected data on each SSO's members from their Web sites. This process identified 89 firms that joined at least one SSO, with some joining several. Our observations apply to just the month and year for which we collected data: November 2006. Then we used industry codes to identify consumer electronics firms that listed in the Compustat Global Basic Database – some 1,271 firms in all. This database only lists publicly-traded firms, so we were not able to identify private firms in the industry.

Our primary measures of firm performance for R&D investment intensity and efficiency are based data found in the Compustat Global Basic Database covering the years 1991 to 2005. Combining the firms' SSO membership information with other performance data yielded our final sample. The data consist of 46 SSO members and 1,225 other non-members in the consumer electronics industry. Each "observation" captures a firm's SSO membership status at the end of the year 2006. It also includes firm performance variables, which are averaged across 1991 to 2005, as a basis for creating a single cross-sectional data set anchored in 2006. The firms in our sample are from 17 different countries in Asia, Europe and North America. (See Table 1.)

Table 1. Sample Characteristics, $N = 1,271$

CATEGORY	% TOTAL	CATEGORY	% TOTAL
SSO Membership		*Annual Revenue ($ million)*	
Member	3.6	<1	2.7
Non-member	96.4	1-10	8.7
		10-50	19.5
		50-100	12.4
		100-500	30.4
		500-1000	8.2
		>1000	18.0
Country (or Region)		*Number of Employees*	
USA	82.5	<100	7.9
Canada	4.9	100-300	18.9
Germany	1.8	300-500	11.9
Israel	1.3	500-1,000	16.7
UK	1.5	1,000-3,000	19.7
Japan	1.0	3,000-5,000	6.4
Brazil	1.0	5,000-10,000	6.7
Others	7.7	>10,000	11.8

The composition of the data set is as follows. 82.5% of firms are U.S.-based, followed by Canada with 4.9%, Germany with 1.8%, and then the rest. The distribution of firms by size, based on annual revenues and number of employees, reflects the balance of large and small businesses in the consumer electronics industry. Thus, there is unlikely to be any firm size bias based on our selection of data. We also note the large portion of U.S. firms. These two things are an empirical fact of our data that accurately describes the real-world context, not selection bias.

5.2. Measures

Dependent Variable. This is a binary variable, which indicates whether a firm has joined an SSO (1) or not (0). Among the 1,271 firms represented, 46 (or 3.6%) were members of an SSO in 2006. [4] If a firm or one of its subsidiaries – or even one of its individual employees -- joins more than one consortium, we treat this as one observation of an SSO member, not multiple observations for one firm. (See Table 2.)

R&D Investment Intensity. *R&D investment intensity* is a primary predictor in our empirical model, measured as a firm's R&D expenditure divided by its total output. We use the natural log of net sales as a proxy variable to represent this. Since our firm-level performance data are annual, we use average R&D investment intensity, dividing total R&D expenditure over the sample pe-

[3] The SSOs are the Consumer Electronic Linux Forum (CELF), the Home Audio Visual Organization (HAVi), the Home Gateway Initiative (HGI), the Serial ATA International Organization (SATA-IO) and the Universal Home API Forum (UHAPI).

[4] We assume that the selected firms' SSO memberships continued into 2005, matching our Compustat performance data.

riods by total net sales over the sample periods. We control for year and related macro-economic effects on firms' incentives to join SSOs this way.

Table 2. Description of Variables

VARIABLE	DESCRIPTION
SSO Membership	1 for a member, 0 otherwise
R&D Intensity	R&D expenditure / Net sales
Productivity	Net sales / Number of employees
Unit Cost	Operating expenses/Operating income
Firm Size	Number of employees
Firm Age	2006 less the 1st obs. year + 1 [(a)]
Prod1 ~ Prod4	Dummies for product areas

Notes: [(a)] *FirmAge* is calculated as (2006) - (the 1st year that Compustat tracked the firm's performance) + 1. So, if a firm that was first tracked by Compustat in 1991, its *Firm Age* will be 2006 – 1991 + 1 = 16. We admit that this is an imperfect proxy for a firm's true age, but it is acceptable to us for our exploratory research.

Production Efficiency. Recall that the production efficiency implies productivity and unit costs. A common proxy for productivity is *labor productivity*, based on output per worker. Although there are other proxies, such as output per hour/day/week or output per machine, output per labor is well-accepted. To test the Higher Productivity Hypothesis (H3), we used the *log of the firm's average labor productivity*, the average of total output divided by number of employees. To evaluate the Unit Cost Hypothesis (H4), we employed *average operating expense over operating income. Operating expense* is the expense of turning inventory into output. It is limited to costs that vary with output quantity, such as materials and purchased components.

Control Variables. Differences in SSO participation activities among different firms may result from other firm-level differences. Anecdotal evidence from industry sources suggests that *firm size* affects a firm's incentive to do R&D and innovation due to spillover effects and expectations [7]. The IP disclosure policy imposed increases the cost of joining an SSO more for a firm with large R&D efforts. We measure firm size as the log of number of employees for the empirical analysis.

It is possible that *older firms* will be more likely to have become a member of an SSO than newly-established firms. For various reasons, older firms in our data set may have joined SSOs before September 2006, when we collected data. So it is important for us to control for firm age. We used the difference between the year a firm was first observed in the Compustat Global Basic Database and the year we collected membership data as a proxy for firm age. Although this measure is a little rough, it reflects the relative age difference among observations well enough for our exploratory research purposes.

We also suspect that a firm's product portfolio may affect its incentive to join an SSO. For example, a firm producing cell phones will be more likely to join an SSO because cell phones are affected by ever-changing telecomm standards. Firms that operate in product areas that require more standardization may engage more in R&D activities. In contrast, a firm that makes hair blowers will not be so sensitive, since its standards rarely change. This makes joining an SSO less critical for this kind of firm. We used firm industry codes called DNUMs. They have a dual use in Compustat to identify the firm's *product areas*. Then we created dummies (*Prod1-Prod4*) to represent the firms' product portfolios. [5]

5.3. Model Formulation

To test our hypothesis, we used cross-sectional logit models with *SSO membership* as the *dependent variable*. Model 1 represents the effects of R&D investment intensity on firms' probability of joining SSOs, as a test of the R&D Investment Intensity Hypothesis (H1). Model 2 represents the effects of production efficiency on firm likelihood to join an SSO to test the Production Efficiency Hypothesis (H2). This model enables us to tests three hypotheses: the Production Efficiency Hypothesis (H2), the Higher Productivity Hypothesis (H3), and the Lower Unit Cost Hypothesis (H4), via variables for *productivity* and *unit costs*. In Model 3, we explore the joint effects of *R&D intensity* and *production efficiency* on firm probabilities for having joined an SSO by 2006. Our logit models are as follows:

- **Model 1 (The R&D Investment Intensity Model)**

$$Probability\ (SSO\ membership = 1) = \alpha_0 + \alpha_1(R\&DIntensity) + \alpha_2\ (FirmSize) + \alpha_3\ (FirmAge) + \alpha_4\ (Prod\ Dummies)$$

- **Model 2 (The Production Efficiency Model)**

$$Probability\ (SSO\ membership = 1) = \beta_0 + \beta_1(ProdEffic) + \beta_2(Firm\ Size) + \beta_3(FirmAge) + \beta_4(Prod\ Dummies)$$

- **Model 3 (The Joint Effects Model)**

$$Probability\ (SSO\ membership = 1) = \gamma_0 + \gamma_1(R\&D\ Intensity) + \gamma_2\ (ProdEffic) + \gamma_3\ (Firm\ Size) + \gamma_4(Firm\ Age) + \gamma_5\ (Prod\ Dummies)$$

We also establish Model 2A and Model 2B in which production efficiency is measured by *productivity* and *unit costs*, respectively. So the reader should expect to see

[5] Until recently, Compustat used its DNUM variable to indicate a company's main line of business. This code was generally based on the Standard Industrial Classification (SIC) code created by the U.S. Census Bureau. The Census Bureau has replacd SIC codes with North American Industry Classification System (NAICS) codes. Further, Standard & Poor's and Morgan Stanley have developed the Global Industry Classification System (GICS) codes. A company's industrial classification can change from time to time, but the DNUM code in Compustat data files generally reflects only the current classification, not the history of a company's industry affiliations. Thus, it may not pick up business strategy and business composition changes on the part of the firm over time.

these substitutions for *ProdEffic* in the full set of modeling results that we will present later.

5.4. Results

Table 3 presents the estimation results for all three models. All results are reported as *logit coefficients* and *odds ratios*. The latter ratios measure the impact of a *one unit change in an explanatory variable relative to the amount of change in the log of the odds between membership and non-membership in an SSO as of 2006*. The odds ratio is normally determined relative to the data by raising the exponential value, e, to the power of the estimated parameter, β, of the variable of interest, which gives e^{β}. We also account for firm-specific heterogeneity in size, age and product portfolio. Our empirical results, in general, are consistent with our predictions.

The estimates of the R&D Investment Intensity Model (Model 1) show an *R&D intensity effect* that is associated with a statistically significant increase in the probability of an electronics firm to join an SSO. Based on the odds ratio, a 1% increase in R&D investment intensity will increase the log odds of joining an SSO by 0.71%. We also would predict that the odds ratio of joining an SSO should increase by 2.0% for a 1% increase in R&D investment intensity.

In the Production Efficiency Model (Model 2), we first examined effects of efficiency as measured by productivity (Model 2A). The coefficient of productivity in Model 2A is significant and positive, which is also consistent with our prediction. A 1% increase in productivity again will increase an electronics industry firm's log odds of joining an SSO by 0.71%, with a similar associated prediction as for Model 1. Unit cost – a substitute for production efficiency in Model 2B – is not significant. So the relationship between unit cost and probability of observing that a firm joins an SSO cannot be specified based on our findings. We jointly tested the effects for productivity and unit costs (Model 2) and we obtained similar results to those we obtained from Models 2A and 2B.

We further tested for the overall effect of R&D intensity and production efficiency on the probability of becoming an SSO member. The effects of R&D intensity and productivity were still significant and consistent with the hypothesized signs (Model 3). The control variable for firm size using number of employees also is positive and significant. This implies that larger electronics industry firms, on average, are more likely to join SSOs.

Overall, our empirical results are consistent with our theoretical predictions. The results suggest that R&D investment intensity affects firms' incentives to join an SSO. Our results also suggest that the two facets of production efficiency – productivity and unit costs – somewhat differently affect a firm's decision to join an SSO. Productivity has a positive effect on the likelihood of participation, while the effects of unit cost are not clear. Finally, a firm's production efficiency appears to affect its decision to join an SSO. Overall, our empirical results and theory combine to suggest that a productive firm may be able to absorb the positive network externalities of technology developed by other members better than a less productive firm.

6. DISCUSSION

Understanding the relationship between R&D investment intensity, production efficiency and participation in SSOs is important for managers and policymakers. For producers in standards-based technology industries, such as electronics and telecommunications, understanding this relationship may inform decisions about SSO participation. By joining a standard-setting organization, a firm can increase its R&D efficiency and reduce R&D costs through R&D spillovers and knowledge spillovers. Even though a firm may cut back its own research efforts, it can obtain similar knowledge and technology from R&D spillovers. SSO members also must disclose relevant IP related to the standards. Firms like Sony or Hitachi focus more on sustaining continuous growth, via continuous brand equity, for example. They rely on highly-innovative technology to power their market-leading electronics products. Yet, they may simultaneously consider making investments in CRM to maintain strong customer relationships. They may not put all their "chips" down on new technology development. By joining an SSO, these firms can control their development costs and redirect the savings to their primary interests. This result provides a first step toward a better understanding of how a marginal change in R&D investment intensity influences a firm's ultimate decision to join an SSO.

Our results also have implications for whether current IP disclosure policy is too strict to attract firms with high efficiency. Although an SSO would like to encourage high efficiency firms to join, its IP disclosure policies that are to balance public interests may discourage these firms. On this basis, we cautiously argue that even in spite of concerns that SSOs are somewhat crippled in their abilities to attract leading firms in the market, the current IP disclosure systems adopted in the consumer electronics industry appear to be reasonably effective. Our result further suggests that concerns regarding the appropriateness of IP policies may be misplaced. Thus, we conclude that good judgment regarding decisions to join an SSO can be based on R&D investment intensity and productivity.

Finally, our results on production efficiency effects provide clues to understand the participation behavior of competitors. Productive firms have abundant resources and knowledge, which permit them to absorb R&D spillovers faster than other firms. Platform leaders, such as Intel, Apple and Microsoft, are examples of such produc-

tive firms [5]. They are usually confident of their market leadership positions. They do not typically worry about the threat of losing market leadership because of disclosing essential IP. Instead, they would rather join an SSO to influence the future standards and establish a larger customer base by committing to such disclosure. The implication of our productive efficiency result is also important for firms that specialize in upstream technology (e.g., Rambus). Although they normally have high production efficiency, they do not have production, marketing or distribution capabilities to fall back on for capturing value. They view disclosing their IP as creating the potential for big losses – something which is highly undesirable to them. Joining an SSO helps them to gain recognition for their production methods, and the manner in which they achieve compatibility with standards. This will tend to increase market demand for their input technologies.

The decision of whether to join an SSO requires a careful analysis of the related tradeoffs. Our empirical results shed some light on this issue and suggest that a productive upstream technology producer is more likely to profit from joining an SSO, because its benefits from participation will be larger than their losses in sharing IP.[6] We further note that high productivity firms in our data set are not necessarily specialized upstream technology producers. They also include final product producers. We believe that our productivity results can be applied to both input technology producers and final product producers. In sum, a productively-efficient firm will be more likely to join an SSO. Our empirical results on this efficiency effect provide strong evidence to substantiate it.

7. CONCLUSIONS

We have sought to provide new insights regarding the impacts of R&D investment intensity on firm participation in SSOs. Our theory predicts that firms with higher R&D investment intensities are more likely to join SSOs, despite the membership fees and the risks from disclosing their typically superior IP and business practices to other member firms. We also predict that firms with higher levels of productivity (and thus lower levels of unit cost) are more likely to become members of SSOs.

We analyzed a data set on firm-level decision-making for joining five different SSOs in the consumer electronics industry in Asia, Europe and North America. Our empirical results are based on 1,271 observations on the SSO joining patterns of the firms we studied. They lend support to our theoretical finding that firms with high R&D investment intensity and high productivity are more likely to join SSOs. We have also made an effort to show that our theoretical predictions and empirical findings can be applied in practice to help managers in various IT and technology industries to gain advantage from joining SSOs to control R&D investment intensity.

7.1. Contributions

Our research provides direct evidence on a question of considerable importance to academics, managers and policymakers in standard-based industry: the relationship between R&D investment intensity, production efficiency and a firm's incentives to join an SSO. We showed that increases in the R&D investment intensity had an economically and statistically significant impact on the likelihood of participation in an SSO.[7] We advance prior research on standard-making in three ways. First, we show that firm-level characteristics, such as R&D efficiency and production efficiency, affect the decision to join an SSO. We used the impact of these characteristics on SSO membership to further examine strategies involved in standardization, building on the IS research directions set by Lyytinen and King [22].

Second, though prior research has focused on new IT standards and the standard-setting process (e.g., [23], our research is unique. It provides a new theoretical perspective for IS research. It also explores an empirical setting in which firm-level characteristics may work to change a firm's incentives to become an SSO member. Third, our research also provides new statistical evidence to show a basis for how firms' decisions to join an SSO may work.

An important outcome for IS research of our work is that we have found evidence to show that an SSO membership can substantially reduce R&D expenses by giving a firm access to other firms' know-how about standards and the related technologies. This opportunity drives an R&D-intensive firm to join an SSO; the value of participation overcomes the fear of potential losses from IP disclosures in SSO membership.

7.2. Limitations

Even though we have tried to empirically validate our theory and predictions, we have not captured all of the dynamics of standard-making that we are aware of from other field study research. First, our theory does not attempt to capture standard competition or the inner workings of how a firm chooses among competing standards

[6] Thanks for anonymous reviewers' suggestion to look at specialized upstream technology producers.

[7] We caution the reader that this preliminary conclusion is really a "trial balloon." The current design of this empirical study offers no intertemporal basis on which to base its claims. Instead, we are using fifteen years of data from 1991 to 2005 to characterize R&D and production efficiency and other firm descriptors as averages that drive SSO membership adoption in the sixteenth year, 2006. Our interpretation should be viewed by the reader as we truly intend to assert it: as an *exploratory result* on the basis of a *preliminary model* that applies a data set of *limited scope* and does not attempt (yet) to tease out all of the *underlying complexities*. Indeed, the reader should think of our results as *empirical regularities*, to which we attempt to bring one theoretical interpretation. As we gather better data, we will be able to work with panel data that permit us to study the instantaneous likelihood of SSO adoption, based on lagged firm performance data from one, two or more years prior.

[30]. For some ICTs, for example, there are several standards and technology generations competing at the same time. We see this with the current competition in wireless technology, including Wi-Fi and WiMax. Other examples in consumer electronics come with red-ray, blue-ray and HDTV-ready video disc players. Anticipation for market control may be another reason why a firm joins a specific SSO. [8] As firms use more external means of production and selling, their interest in market control gains increases. Our current theory focuses more on efficiency gains so that our results may not be directly applied to the firms that care more about market control.

Second, a firm's decision to join an SSO will be affected, as the value of doing this is likely to change over time [18]. Thus we see the possibility for heterogeneity in both strategic responses to market and standards changes, as well as drifting rational expectations. We hope to examine the optimal timing for firms to join an SSO and how R&D efficiency may affect time-to-join, in the cumulative research tradition of IS and economics pertaining to IT adoption under uncertainty. Third, a firm may join an SSO simply because of its intention to influence the standardization process. Though we did not consider this in our theory, we nevertheless note that doing it would help us to capture the real-world dynamics of SSO adoption more closely. We still believe that our R&D investment effect and our efficiency effect will stand up to additional scrutiny though.

As with any work involving empirical analysis, our data have limitations. We are only able to identify firms that had SSOs membership as of the year 2006, when we started to collect membership data. We are not able to identify members' time-to-join, or estimate panel data to explore how firm heterogeneity might lead to different degrees of interest to join an SSO. Also, we have data on only the consumer electronics industry. Thus we caution the reader not to generalize too far beyond this industry on the basis of the empirical results. It would be ideal if we could collect data across multiple industries, however, standard-setting efforts in other industries seem to take quite a bit longer. We also were not able to collect more firm performance data for private firms outside the U.S. Though our empirical estimates may be biased toward U.S. public firms, this does not influence our primary findings: increases in R&D investment intensity and efficiency provide firms' with incentives to join SSOs.

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Table 3. Empirical Results

VARIABLES	EFFECT	MODEL 1		MODEL 2 (PRODUCTION EFFICIENCY)		MODEL 2A (PRODUCTIVITY)		MODEL 2B (UNIT COST)		MODEL 3	
		COEFF	O/R	COEFF	O/R	COEFF	O/R	COEFF	O/R	COEFF	O/R
R&D Intensity	+	**0.71*****	**2.04*****	**0.68*****	**1.97*****					**1.11*****	**3.04*****
Productivity	+			0.24	1.27	**0.71*****	**2.03*****			**0.62****	**1.86****
Unit Cost	-			0.98***	2.65***			0.05	1.05	0.50*	1.65*
Firm Size	Control	0.87***	2.38***	-0.08	0.92	0.84***	2.31***	0.82***	2.26***	1.05***	2.85***
Firm Age	Control	-0.08	0.92	0.34	1.42	-0.07	0.93	-0.06	0.94	-0.08	0.93
Prod2	Control	-0.02	0.97	-0.84	0.43	-0.07	0.93	-0.002	0.998	0.65	1.91
Prod3	Control	0.93	2.53	0.16	1.16	-1.60	0.20	-0.92	0.40	0.31	1.36
Prod4	Control	-1.46**	0.23**	0.35		-1.3**	0.27	-0.79	0.45	0.33	0.72
Pseudo-R^2	Control	34%		35%		27%		0.35		43%	
Likelihood Ratio		114.59***		125.39***		74.61***		76.57***		86.12***	

Notes. Estimation method: Logit with maximum likelihood estimation. Model 1: The R&D investment intensity model. Model 2: The production efficiency model where efficiency is measured by both productivity and unit costs. Model 2A: The production efficiency model in which efficiency is measured by productivity. Model 2B: The production efficiency model in which efficiency is measured by unit costs. Model 3: The joint effects model. Dep. var. = SSO membership. Signif.: ***= $p < 0.01$, ** = $p < 0.05$, * = $p < 0.10$. O/R = logit odds ratio, which provides a basis for evaluating the log marginal effects of the coefficient estimates. Bold entries in the cells indicate coefficient estimates for variables that were significant at the standard level of $p < .05$ or better (** and ***).