STRATEGIC INFORMATION UPDATING: A BAYESIAN ANALYSIS OF FIRM ENTRY TIMING INTO AN INDUSTRY STANDARD-SETTING ORGANIZATION

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ABSTRACT

Much is known about the drivers of firm-level technology standards adoption, as well as the consortia that are responsible for creating them. In this study, we explore some new but related issues: the *strategic information updating* decision-making process that firms use in determining their timing of entry into a *standard-setting organization* (SSO) that supports the formation and promulgation of business process standards. We evaluate alternative theories to characterize the micro-level decision-making processes that firms engage in, consistent with our observations of high-level co-opetition behavior in SSO entry timing. They include strategic information transmission and signaling, cheap talk and social learning, and information cascades and rational herd behavior theories. Our empirical analysis involves a 20-year panel data set from a leading industry SSO with over 101 global public firms. The results reveal that the entry timing of a firm changes as an industry SSO matures and strategic information updating occurs. We employ Bayesian econometric analysis to reveal how the hazard rates of firm entry adjusts over time. Our results show that there were temporal effects with respect to the period-wise likelihood of SSO entry. In the early years when the SSO was young and the process standard was still in its early stages of development, more changes were apparent that would have made information updating more valuable for firm SSO entry decision-making. With the passage of time though, the hazard rate for firm SSO entry stabilized, and the value of new information on the solidification of the proposed process standards diminished. Our evaluation of the alternate theoretical interpretations of observed entry behavior leads us to propose a set of five stages to characterize the evolution of a de facto process standard and to show how the theories map to the stages.

Keywords: Bayesian econometrics, cheap talk, herd behavior, process standards, rational expectations, standard-setting organizations, strategic information transmission, signaling, survival analysis.

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"There are innumerable social and economic situations in which we are influenced in our decision-making by what others around us are doing."

– Abhijit V. Banerjee (1992, p. 797)

"… testing a process theory should be based on the relative explanatory power of alternative theories that are available or that can be developed to explain the phenomenon."

– Andrew H. Van de Ven (2007, p. 205)

1. INTRODUCTION

Strategic information updating will influence managerial decision-making and lead industry firms to adjust their entry strategies. During the evolution of a standard, industry firms will establish their timing of entry into a *standard-setting organization* (SSO). Over the course of a standard's growth, the SSO and its participating members will announce information to prompt firms to join. The drivers for firm entry change in their strength and relevance over time, and the dynamics of an industry SSO can also have an impact on the strategies employed. Cooperation among competing firms is required to establish industry process standards. *Co-opetition* is a new business dynamic that combines competition and cooperation to generate a more profitable and favorable business environment (Brandenburger and Nalebuff 1996). Choosing the appropriate timing of entry can be a challenging task. Firms face tradeoffs in their decision about timing, since there is a cost associated with delaying choice, yet every action becomes immediately visible to others (Zhang 1997).

We will explore multiple theories to reveal how strategic information updating leads to different observed propensities for firms to enter an SSO at distinct times during the evolution of a process standard. The theories we explore include strategic information transmission and signaling, cheap talk and social learning, and information cascades and rational herd behavior. Multiple theoretical perspectives are appropriate because the dynamics of an industry SSO is complex, and firms adapt their entry strategies over time. It is unlikely that a single theoretical perspective is sufficient to explain how firms' timing of entry will evolve over the lifetime of an SSO. Other studies that use a multiple theoretical lens to evaluate a problem include Blinder et al.'s (1998) work on price stickiness.

In recent years, a key focus of firms has been to *standardize processes*. A driving force for industry process standards is the chance to reduce costs via process outsourcing (Davenport 2005). Additionally, process standards support software vendors in delivering a unified procurement strategy for enterprise software (Kauffman and Tsai 2009). Other factors that influence standards participation include: standards reduce the likelihood of vendor lock-in; collective actions from mid-size vendors enable them to compete with larger vendors; and larger vendors that pursue proprietary standards may try to cripple a standard's development. Since various firm objectives are present, an *industry-wide process standard* takes several years to form, and for it to be successful, the cooperation of various stakeholders within the industrial community is required (Markus 2006).

When it comes to industry SSO entry, each firm has control over when it joins to maximize firm value. Rational firms will join the SSO if and only if the expected benefits are higher than the costs of doing so (Zhao et al. 2007). A firm's timing of entry becomes critical because the emergence of new standards can potentially impact a firm's competitiveness in the marketplace. Teece's (2006) *profiting from innovation framework* suggests that success at innovation is strongly related to management's market entry timing decisions, and is also dependent on the *value appropriability regime* that is in place. Clemons and Knez (1988) offer reasons why firms adopt both offensive and defensive strategies for IS innovation in introducing key elements of timing and cooperation in strategic IS decision-making. Other theoretical perspectives help to explain why firms join early, late, or not at all. Among them are vendor influences on firm switching costs (Chen and Forman 2006), firm efficiency differences and R&D intensity (Gupta et al. 2008), and firm evaluation of incumbent vendors' staying power in the marketplace (Dedrick and West 2006).

To study the effects of strategic information updating on firm entry, we address these research questions. How does the relationship between firm characteristics and industry SSO entry timing change as a standard matures and strategic information updating occurs? What theoretical perspectives enable us to explain a firm's strategic timing of entry? What additional knowledge can be obtained by using a process-focused analysis method such as the Bayesian survival analysis to explore managerial decision-making and firm strategies for entry into an industry SSO?

Understanding how firms' entry timing strategies unfold during process standardization can empower firms to formulate better strategies for industry SSO entry. Furthermore, it can offer insights into how we can accelerate the growth of standards. The rate at which firms join an industry SSO influences how quickly industry standards evolve. Cindy Fuller, Executive Director of ASC X9, a consortium that supports standards for the financial services industry, notes that standards efforts can "move as fast as the industry wants to move …" (Vijayan 2009). She explains the challenges firms face when deciding on industry SSO entry: "Organizations everywhere have to determine whether they will choose to show industry leadership in standards activities and management or whether they will simply follow what is produced by others … Clearly, lack of management understanding misses the strategic nature and benefit of standards to the business" (Fuller 2008).

We adopt a process study approach to communicate the complexity of firm entry behavior that occurs during the evolution of a process standard (Van de Ven 2007). We use baseline survival analysis and Bayesian econometrics to study the extent to which strategic information updating alters firm entry timing into an industry SSO. Our empirical study captures 20 years of data from 1988 to 2007 for 101 public global member firms of the TeleManagement (TM) Forum, a communications industry SSO that defines process standard for its industries. The TM Forum founded the industry de facto standard, the Business Process Framework (eTOM), once known as the Enhanced Telecom Operations Map.

We provide background on relevant theory in Section 2. In Section 3, we present our theoretical perspectives on the different reasons for firms' timing of entry into an SSO as it evolves and develops a process standard. We discuss data collection and model variables in Section 4. The baseline survival analysis model and results are presented in Section 5, followed by the same for the Bayesian survival analysis model in Section 6. We provide a discussion in Section 7 in which we evaluate the efficiency of the different theoretical explanations related to our study context and attempt to draw some unifying conclusions about them. Section 8 concludes with managerial implications, contributions and limitations.

2. THEORY

Managerial decision-making is often driven by information updates that are related to internal organizational and strategy changes, and external technology, market and regulatory events (Bardhan et al. 2009). To be successful, it typically is necessary for firms to update and adjust their strategies based on what they learn about the environment in which they are competing. We will explore a variety of theories to evaluate organizational entry into settings that involve some form of decision-making under uncertainty, where information updating is possible relative to opportunities to compete with and cooperate with other firms. These include the adoption of technologies and the timing of the rollout of new products. Another instance occurs when firms make decisions to enter into industry organizations that require the sharing of intellectual property but also confer informational benefits on the participants related to the technologies, the processes, and the environment in which the organization operates. See Table 1 for an overview of the theories we will discuss.

2.1. Strategic Information Transmission and Signaling

A theoretical lens with which to view decision-making processes that are consistent with strategic information updating and co-opetition is to think of information sharing as being tactical. When a firm considers an opportunity to be involved in any sort of industry organization or coalition, it typically joins with the intention to promote the sharing of information, or to obtain some kind of relevant information that creates value. Crawford and Sobel (1982) describe *strategic information transmission* as the sharing of specific information by one party with another party. This is often done because the sender and the receiver will obtain some benefits from the shared information, or because the reception of the signal by the sender will have beneficial effects on the welfare of both the sender and the receiver. For example, the sender's goal may be to provide enough information in the signal to elicit a favorable response or action from the receiver. The amount and type of information that are made available may also have implications for the value that is exchanged and for the reactions to the different signals. It is common for industry organizations to release information to motivate outside firms to participate in its activities.

Table 1. Strategic Information Updating Process Theories Consistent with Co-opetition

THEORY	MAIN IDEAS OF THE THEORY	RELATED BEHAVIOR OBSERVED
Strategic information transmission	Sender transmits a signal to receiver who then takes action that determines the welfare of both (Crawford and Sobel 1982).	Industry organizations release information to motivate outside firms to participate in its activities.
Signaling	Observable characteristics attached to the individual that are subject to manipulation (Spence 1973).	Firms send specific signals by strategically determining their timing of entry into an industry organization.
Cheap talk	Communication that does not directly affect payoffs (Farrell and Rabin 1996).	A firm discloses private information to its partner in order to create more value.
Social learning	Economic agents base their decisions on the experience of others (Ellison and Fudenberg 1993).	A firm may delay industry organization entry until it observes that similar firms have been able to benefit from their involvement.
Information cascades	Individuals choose to ignore their own private information to follow the actions of those ahead of them (Bikhchandani et al. 1992).	There are instances when a large number of firms all decide to join an industry organization during the same period.
Rational herd behavior	Individuals follow the behavior of others, and there is the underlined assumption that everyone else is rational (Banerjee 1992).	A cluster of firms joins an industry organization during a period when there is not yet a clear understanding in the market of the payoffs.

Spence (1973) introduced the idea that informational impacts of signaling might affect the observed market equilibrium in a given context, causing it to shift. For example, signals about pricing discounts lead to fierce price competition in a market. He noted that *signals* are observable and subject to manipulation by interested individuals, including firms. He also identified *indices*, which are also observable signals but cannot be altered by the sender. For example, sex and age are the unalterable indices of an individual customer. While firms are unable to alter their characteristics or indices in the short run when they engage in strategic behavior, they have full control over the timing of entry into a market or an industry organization and the signals they send related to these actions. In a market setting, it is typical that every signal a firm transmits becomes "market data" that are available to update the strategic decisions of other firms. Spence further indicates that it is common for individuals with the same preferences and opportunities to make similar decisions. The same is true for firms, with the result that the related economic theory predicts that firms with common characteristics are likely to enter industry organizations or markets close in time to one another. The presence of *signaling costs*, and limited time and human resources that make organizations heterogeneous in different ways may dissuade them from acting in unison.

2.2 Cheap Talk and Social Learning

Another theoretical lens for the strategic information updating process that is consistent with the co-opetition behavior that we are exploring is called *cheap talk*. It is a form of informal communication that has no direct or immediate effects on an organization's payoffs but leads to *social learning*. Farrell and Rabin (1996) identify multiple scenarios in which informal information sharing occurs. With cheap talk, the sender becomes important. If the sender and receiver have different preferences, then information shared between them may be disregarded as noise (e.g., price-sensitive consumers vs. luxury goods consumers). On the other hand, it is possible that *credible information* is transmitted by cheap talk. For example, firms involved in strategic alliances often swap private information with one another, and as may be the case with firms that are a part of an industry organization. Information shared in such cases is likely to bear more weight, since there is less incentive for a partner firm to lie. This kind of information sharing behavior is likely to be observed in settings that are characterized by co-opetitive behavior on the part of firms. In fact, they must share private information to create value through cooperation.

Ellison and Fudenberg's (1993) study shows that when the relative profitability of a technology is unknown, economic agents will base their decisions on social learning that they obtain through knowledge of the experience of others. Within a learning environment, agents will observe their neighbors' choices and note the payoffs that are generated. They also will periodically reevaluate their own decisions and make choices different from other agents under full information due to their heterogonous nature. At the level of the firm, this kind of behavior is evident in the formation of strategic alliances, intra-industry organizations, and cross-industry working groups. A firm may delay entry into such groups until it arrives at some acceptable level of assurance that it will benefit like other similar firms in its industry. On the other hand, entry by another organization that is truly heterogeneous – for example, one from an entirely different stakeholder category, such as a retailer or producer vs. an intermediary or a regulator – may have a limited to no bearing on its decision. Another possibility is that the increase in popularity of an industry organization can cause a firm to reconsider and update its original strategic choice. Often, we observe a tendency for firms in markets to gravitate towards the "popular choice," as demonstrated by technology adoption bandwagons (Ellison and Fudenberg 1993).

2.3 Information Cascades and Rational Herd Behavior

Another possible theoretical lens for us to consider as a candidate process theory to support the higher-level observation of co-opetitive behavior among firms involves behavioral anomalies with their information processing. *Information cascades* occur when individuals choose to ignore their private information to follow the actions of those who have acted ahead of them. This lens is often used to explain why small shocks can lead to dramatic shifts in mass behavior and how with little information, individuals may all converge on one action (Bikhchandani et al. 1992). We often witness such behavior expressed with nearly "viral" consumer purchases of popular electronics goods, such as the iPod and the Wii. This kind of behavior also occurs at the level of the firm, for example, with micro-level decisions on the part of firms that lead to rapid adoption shift with respect to various kinds of technology standards (e.g., IEEE 802.11a, b, and g, etc.). Consistent with this theory is the observation of firm-level behavior where there are periods in which there is very little activity, but then there are other instances when a large number of firms all decide to join an industry organization or movement during the same period.

Information cascades need not be negative, although in some cases they can be when individuals and firm-level decision-makers focus on the wrong kinds of information from the marketplace. This may cause them to make mistakes with how they update their strategic information to gauge the value of some action. With technology, for example, the faster that there is some agreement that a "critical mass" of adoption has been achieved, the more rapid the later diffusion process will be, up to the point of market saturation (Robertson and Gatignon 1986). Bikhchandani et al. (1998) explain that positive payoff externalities lead to conformity. There are, however, instances where a firm will rely on its private information to determine whether participation in an industry organization will generate sufficient value, as illustrated by Anderson and Holt's (1977) experiment on information cascades.

Rational herd behavior happens when individuals follow the behavior of others, and there is the underlying assumption on the part of individuals that what everyone else is doing is rational because they have information that the followers do not. In a variety of strategic information updating and decision-making under uncertainty contexts with respect to technology adoption or entry into industry organizations, there may be instances where other firms are observed to act, adopt or participate at some point in time. In spite of this, others in the market may not have a clear understanding of why any firm has elected such an action. For example, there are cases in which firms join industry associations with the objective of gaining an inside position but provide limited support for future success of the organization.

With situations such as this in mind, Banerjee (1992) introduced the idea of *herd externalities* and how an individual can inflict negative impacts on the rest of the population by ignoring his own information and doing the "wrong" thing in terms of broader social welfare. He states that unless the previous decision- maker gives the "right" signal, there will be some potential for others (i.e., "the herd") to make the incorrect choice. For this reason, herd behavior is often observed to occur during periods when there is not yet a clear understanding in the market of the payoffs associated with specific actions (e.g., adopting a certain technology, joining a particular strategic alliance and so on).

3. PROCESS THEORIES, INFORMATION UPDATING, AND SSO ENTRY

During process standardization, strategic information updating of firms occurs due to information released by different sources. Information can originate from the industry SSO that is responsible for the creation and growth of the standard. Industry firms that are pushing their own agendas will also disseminate information that is aligned with their standards strategy. A firm's timing of entry will depend on the updates it receives and its overall co-opetitive strategy.

3.1 Strategic Information Updating during Process Standardization

An industry SSO serves as a *coordination mechanism* where collective participation achieves optimal results. Bringing stakeholders together provides a pool of richer knowledge for members to draw from, adding value to the SSO. An industry SSO is the primary informant of standards-related news. We can think of the SSO as a source of strategic information transmission. An SSO's goal is to support the development and accelerate the adoption and diffusion of an industry standard; therefore, the organization will provide information to entice firms to join. An SSO updates the market with announcements about new and existing members and the various standards-related activities. As strategic information updating is happening, firms must determine how to react. Because a lot of information will be put out by the SSO, some portion of it is likely to be "noise" in the sense that it will have a limited impact on outside firms (e.g., due to lack of relevance, or other information has been released that leads to similar conclusions).

So, what are some of the major kinds of announcements transmitted by the SSO during process standardization? A key announcement from an industry SSO is the list of its founding members. Depending on who the founding members are, the list will have an impact on subsequent followers. Strategic partners of the founding members may follow immediately, thus reflecting information cascades. At this stage, it is impossible for the firms to make any predictions about the future of the standard. However, a firm may follow blindly with the underlying notion that the firm it is following has some private information about the utility of participation (Walden and Browne 2009). The list of founding members can also be used to explain why certain firms do not join. We do not expect the founding members to receive support from firms that are direct competitors when uncertainty is high. During the early stages where a concrete standard has not been defined, information cascades are fragile. A competing standard can easily emerge to replace the developing standard.

At some point, announcements will emerge to show that a standard has been defined, and something tangible exists. There is a published specification of the standard that can be shared with the masses, and it is evident that information asymmetry exists for firms that are not members of the SSO. While it is possible that knowledge can leak due to cheap talk, firms will need to join to gain full access to information on the standard. Given that a first signaling of the standard has occurred, is it enough to prompt firms to enter or will the standard need to reach a certain level of maturity? As the standard undergoes refinement, the industry will receive updates on its progress and it may eventually become a de facto standard.

During these various stages, firms must decide on the merits of the standard and determine whether they should join the SSO. Announcements of these key events can potentially trigger rational herd behavior. Walden and Browne (2009) explain that when it comes to observational learning, decision makers often follow one another but do so in the correct direction because the probability of being correct increases as more decisions are made. Another announcement that can lead to herd behavior is revealing that a key industry firm has joined. Dominant firms have the ability to drive bandwagon effects (Katz and Shapiro 1985). Strategic information updating of managerial decision-making is an ongoing activity. It begins as soon as a group of firms come together to establish a standard.

3.2 Firm Strategy for Standards and Standardization

Firms employ different strategies when it comes to standards and standardization. Kauffman and Tsai (2010) introduce the various countervailing forces and effects that occur in a *process standardization ecosystem*. Firms may form *coalitions* to reflect common participant interests and strengthen their ability to develop, launch and promote a standard. As a result, it is possible that firms of the same coalition travel as a herd when it comes to industry activities such as SSO participation. For vendors and users, SSO participation is critical since advanced insight into the development of a standard is invaluable. A de facto standard can cause a firm to be at a competitive disadvantage if incompatibility with existing technologies should arise (Axelrod et al. 1995); hence, firms are motivated to join early to minimize potential negative impact. However, the competitive nature of firms will cause some to pursue later entry. Firms face the challenge that their every move gives off a signal to the market. Early entry may cause other industry firms to believe that the vendor or user firm, in this case, has a large stake in the developing standard. Consequently, firms are careful about their timing of entry and the signals they send.

Once a standard is in motion, firms that wish to accelerate its growth will strategically transmit information that encourages other firms to join. On the other hand, firms that wish to slow a standard's growth may communicate information that devalues the standard. In an empirical study of the network technology industry, Leiponen (2008) reports that firms discuss, negotiate, and align positions on technical features with their peers through standard-setting committees and industry consortia in order to influence the evolution of their industry. When an industry SSO is young and there is not yet a clearly defined standard, one would expect a very low rate of entry. Previous work has shown that it is to a firm's advantage to defer technology investment until there is evidence that the technology will win out in the marketplace (Kauffman and Li 2005). However, sometimes a firm will be able to gain insights that others in the industry do not have. This is consistent with our observation that strategic information transmission can lead to one-off entry decisions even during periods of high uncertainty.

Social learning plays a big role in technology adoption and firm strategy. Less experienced firms commonly wait for cues from more experienced firms. Younger firms that face resource constraints will not be able to make risky decisions. They are more likely to practice a "wait and see" strategy and let others contribute to the initial investment. Later adopters are able to benefit from information externality or the spillover of nonpublic information from others' adoption decisions (Li 2004). They need to know that tangible benefits are present before they will make the investment to join. In their analytical study of collaborative standard development, Zhao et al. (2007) find that the aggregate contribution from all members during the standard development stage determines the intrinsic value of the final output, which then influences the benefits that these firms and subsequent adopters can obtain at the later adoption stage. Therefore, firms that are driven by social learning will tend to be later participants.

A primary benefit of standards is the potential for network externalities, which drive firms, even those that are direct competitors, to cooperate on standards development (Katz 1986). A standard typically goes through multiple iterations before a stable version is established. Until it reaches that point, we may observe evidence of information cascades or firms mimicking other firms. For example, a technology vendor may join in reaction to another technology vendor joining, so copycat behaviors may exist among stakeholders in the same category. With information cascades, small shocks can result in dramatic shifts; however, the presence of positive network externalities will change the entry dynamics quickly. When a standard starts to solidify and its benefits become clearer, we can expect the entry rate for industry firms to take off. Positive network externalities in information cascades are known to generate herd behavior (Kauffman and Li 2003). Additionally, they make information cascades less fragile by reducing the possibility of cascade reversals (Li 2004).

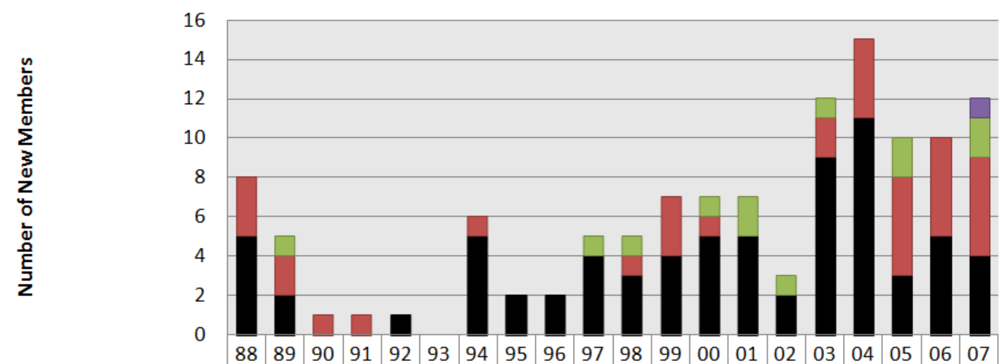
4. DATA AND VARIABLES

4.1 Data Collection

For the purposes of exploring strategic information updating behavior by firms that contemplate entering an industry SSO, in the context of the different theoretical perspectives that we have discussed, we sought to acquire a unique data set. The data that we collected consist of 119 global public firms for 20 years from 1988 to 2007. Due to missing data, we were left with a final list of 101 firms. These firms represent the members of the TeleManagement (TM) Forum (www.tmforum.org) for which we were able to acquire publicly available information. Over the last 21 years, the TM Forum has expanded globally. It currently has more than 700 member companies from 75 countries. The eight founding member firms are Amdahl Corp., AT&T, British Telecom, Hewlett-Packard, Northern Telecom, Telecom Canada, STC, and Unisys. For our sample, we focused on public firms due to accessibility of data, even though there are many private firms that are members. Represented in our data set are firms from Australia, Canada, China, France, Germany, India, Israel, Japan, Russia, the United Kingdom, and the United States.

The member firms in our data set are from one the following four *stakeholder groups*: analysts, technology users, system integrators, and technology vendors. *Analysts* are technology and market research companies that supply market intelligence, report on industry events, and offer advisory services on technologies and business strategies. *Technology users* consist of the following subcategories: service provider, network operator, mobile/wireless operator, cable/multiple system operator, consumer electronics and media/entertainment. They use the industry solutions provided by the technology vendors. Examples of industry solutions include business support systems (BSS) and operations support systems (OSS). *Systems integrators* are consulting firms or organizations that specialize in putting together technology components from different technology vendors and ensuring that they work together as a complete solution. Finally, *technology vendors* include network equipment suppliers and software suppliers. They supply industry hardware and software technologies. Figure 1 displays the number of new SSO participants for each year broken down by stakeholder category.

Figure 1. Annual Number of New Public Firm Participants for Each Stakeholder Category



	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07
Analyst	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
System Integrator	0	1	0	0	0	0	0	0	0	1	1	0	1	2	1	1	0	2	0	2
Technology User	3	2	1	1	0	0	1	0	0	0	1	3	1	0	0	2	4	5	5	5
Technology Vendor	5	2	0	0	1	0	5	2	2	4	3	4	5	5	2	9	11	3	5	4

4.2. Model Variables

Our model variables include firm characteristics of R&D intensity, employee efficiency, organization slack and management experience. *Firm characteristics* often provide insights into firm strategies with respect to technology and standards. Gupta et al. (2008) reveal how *production efficiency* and *R&D intensity* impact SSO entry. Smith et al. (1998) explore a firm's *financial characteristics*, such as *employee efficiency*, to explain its propensity to outsource IS. *Organizational slack* has an impact on firm sustainability and performance (Kettinger et al. 1994); it enables firms to experiment with new projects such as standards development. *Management experience* available in mature firms has a strong relationship with firm strategy formulation. Management experience with IT promotes its adoption and use (King and Teo 1996). More experienced firms often participate in multiple SSOs. We look to see if there is a relationship between firm characteristics and timing of entry into an industry SSO, and evaluate if the relationships change as an SSO matures and as information is gradually revealed.

The dependent variable is *AgeSSO*, the age of the TM Forum at the time of a firm's entry. The independent variables that we study are as follows. *lnFirmAge*, as a proxy for firm maturity and management's experience, is measured based on the natural logarithm of the firm's age at the time of its SSO entry. If a firm has annual R&D spending, then *R&DIntensity* is coded with a value of 1 to show that the firm has some level of R&D intensity or 0 to indicate no presence of R&D activities. *NetIncome* is a proxy for organizational slack. If the annual net income of a firm is positive, then the firm has slack and *NetIncome* is coded with a value of 1, and 0 otherwise. *lnEmpEfficiency* is the natural logarithm of employee efficiency, defined as revenue divided by the number of employees.[1]

We collected firm characteristic data from the COMPUSTAT North America and Global databases. Table 2 defines the model variables, Table 3 gives the descriptive statistics, and Table 4 presents the variable correlations.

Table 2. Definitions of Model Variables

VARIABLE	DEFINITION
Dependent variable	
AgeSSO	Age of TM Forum when a firm joined (in years)
Independent variables	
lnFirmAge	Natural logarithm of the age of the firm in years; proxy for management experience
R&DIntensity	1 if firm's annual R&D spending (in millions) is greater than zero, 0 otherwise
NetIncome	1 if net income (in millions) is positive, 0 otherwise; proxy for organizational slack
lnEmpEfficiency	Natural logarithm of revenue (in millions) / number of employees (in thousands)

Table 3. Descriptive Statistics of Model Variables (101 Firms)

VARIABLE	MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
RDIntensity	0.68	0.47	0	1
NetIncome	0.72	0.45	0	1
lnFirmAge	2.74	0.91	0.69	4.83
lnEmpEfficiency	5.32	0.65	3.65	7.36

Table 4. Correlation Matrix for the Study Variables (101 Firms)

	R&DIntensity	***NetIncome***	***lnFirmAge***	***lnEmpEfficiency***
R&DIntensity	1.000			
NetIncome	-0.062	1.000		
lnFirmAge	-0.098	0.192**	1.000	
lnEmpEfficiency	-0.171*	0.028	0.058	1.000
Note: Significance: *** $p < 0.01$, ** $p < 0.05$ and * $p < 0.1$. No pair-wise correlations are of concern.				

5. A BASELINE MODEL FOR THE DRIVERS OF FIRM ENTRY INTO AN SSO

Our efforts to analyze the data are initially directed toward the development of a baseline explanatory model that reveals the extent to which the different variables impact the instantaneous likelihood of SSO entry by the firms that eventually choose to join. Although our dependent variable emphasizes the timing of entry, the overall thrust of the model is to identify the variables that matter and show their average impacts over time. For this purpose, we will use the *Cox proportional hazards model*, a semi-parametric method. The Cox model is used to study the occurrence of an event, which in our context corresponds to a firm's entry into the industry SSO. The Cox model makes a parametric assumption regarding the predic-

[1] We also explored the inclusion of a variable to represent firm size in terms of the number of employees, but ultimately found that the information it yielded about a firm's likelihood to enter at any given time was inconclusive. Thus, we have chosen not to discuss it further as either a main effect or a control variable, even though we initially thought it might be appropriate to do so.

tors' effects on the *hazard function*, but no assumption on the nature of the hazard function $h(t)$ itself (Harrell 2001). The model is $h_i(t) = h_0(t)\exp(\beta' x_{it})$, where $h_0(t)$ is the baseline hazard for firm i at age t, and x_{it} is the vector of time-varying explanatory variables for firm i at age t. Our predictors include firm R&D intensity, employee efficiency, net income, and age of the firm.

The *hazard rate* is the probability that a firm, which has not entered up to time t, decides to enter at time t. *Duration* refers to the amount of time that goes by before a new firm joins; it is measured by the age t of the SSO, with its birth in 1988 as the reference point. The model assumes a hazard rate at time t that is proportional to a baseline hazard function characterized by $h_0(t)$. The cumulative baseline hazard function is $h_0(t) = \int_0^t h_0(y)dy$. It represents the probability that a firm will not have entered by time t. *Censoring* normally occurs in hazard models where the event of interest occurred either prior to the study or never occurred during the period of the study. This is not a concern for our research since all of the firms that we studied are members of the TM Forum.

5.1. The Cox Proportional Hazard Baseline Model and Results

The Cox model assumes a *proportional hazard*, which means that the effect of the independent variables remains constant over time. Using the *Schoenfeld residuals test* (Therneaux and Grambsch 2000), we validated that the primary assumption is satisfied. Our model, expanded to include the four explanatory variables for the hazard rate of firm i at age t, is specified as:

$$h_i(t) = h_0(t)\exp[\beta_1\, R\&DIntensity_{it} + \beta_2\, NetIncome_{it} + \beta_3\, lnFirmAge_{it} + \beta_4\, lnEmpEfficiency_{it}]$$

We test the impacts of explanatory variables on firms' timing of entry into the SSO. The Cox model is appropriate since our interest is in the parameter estimates rather than the shape of the hazard function. The Cox model results for the four predictors *R&DIntensity*, *NetIncome*, *lnFirmAge* and *lnEmpEfficiency* are presented in Table 5. They include the estimated coefficient, β, for each explanatory variable x_i and the *hazard ratio*, $\exp(\beta)$. The *hazard ratio* reflects the marginal effect of a one-unit increase of an explanatory variable on the hazard rate (Harrell 2001). The model has a likelihood ratio statistic of 748.33 and χ^2 of 22.76 ($p < 0.01$).

The coefficient for *R&DIntensity* is positive, which shows that firms with R&D intensity had a greater likelihood of entry into the industry SSO throughout the period of study ($\beta_1 = 0.639$, $p < 0.01$). The hazard of entry for firms with R&D intensity is about 89.4% of the hazard for firms without it (hazard ratio = 1.894). The coefficient for *NetIncome* is positive, which implies that organizational slack contributed to a firm's propensity to enter the SSO ($\beta_2 = 0.398$, $p < 0.1$). The hazard of entry for firms with organizational slack is about 48.9% of the hazard for those without it (hazard ratio = 1.489). The coefficient for *lnFirmAge* is negative, which reveals that older firms were less likely to enter ($\beta_3 = -0.251$, $p < 0.1$). With a 2.72 years increase in the age of the firm, the hazard of entry goes down by an estimated 22.2% (hazard ratio = 0.778). Finally, the coefficient for *lnEmpEfficiency* is negative, which indicates that firms with higher employee efficiency were less likely, all else equal, to enter (β_4 = -0.426, $p < 0.01$). For a 2.72 unit increase in employee efficiency, the hazard of entry decreases by about 34.7% (hazard ratio = 0.653).

Table 5. Cox Proportional Hazards Model Results

VARIABLE	COEFFICIENT (STD. ERROR)	HAZARD RATIO
R&DIntensity (β_1)	0.639*** (0.224)	1.894
NetIncome (β_2)	0.398* (0.2283)	1.489
lnFirmAge (β_3)	-0.251* (0.148)	0.778
lnEmpEfficiency (β_4)	-0.426*** (0.0006)	0.653
Likelihood ratio statistic	751.41	
Model significance (χ^2)	19.68*** with 4 d.f.	

Note: The time period covered in the analysis is 20 years from 1988 to 2007. The standard errors are reported in the parentheses. Significance: *** $p < 0.01$, ** $p < 0.05$ and * $p < 0.10$.

5.2 Discussion

Our results reveal that R&D intensity, organizational slack, management experience, and employee efficiency are significant in the model and thus have an effect on firms' SSO entry timing: *R&DIntensity* and *lnEmpEfficiency* more strongly at the $p < .01$ level, and *NetIncome* and *lnFirmAge* more weakly at the $p < .10$ level. There is a positive relationship between R&D intensity and the hazard rate. Due to the potential impact of a new standard on existing technologies, firms that are invested in R&D are more likely to cooperate on standards development. We also observed a positive relationship between organizational slack and the hazard rate. Organizational slack offers a firm flexibility that allows it to experiment with new strategies, which also may include the possibility of cooperating with other firms on projects of joint strategic importance. There is a negative relationship between management experience and the hazard rate. Our interpretation is that from a competitive perspective, inexperienced firms have more to gain from cooperating with their competitors, which would justify why more experienced firms are less likely to enter, with all else equal. Finally, there is a negative relationship between employee efficiency and the hazard rate. Employee efficiency reflects the labor productivity of an organization. A possible explanation for the negative relationship is that firms with lower labor productivity have more to gain from cooperative efforts (e.g., lessons learned, experience, knowledge sharing, etc.), which might be helpful for them to improve their operational capabilities to achieve higher labor productivity.

We should stress that all of the results that we have reported in this initial analysis are intended to focus on "average" relationships. The results do not have the power to comment directly on the nature of strategic information updating, even though they are consistent with our overall research perspective on co-opetition. From the Cox proportional hazard model's estimation, we have been able to determine the extent to which the different variables "matter" in a general sense. What we cannot yet tell is how their influence may differ over time, as firms that contemplate participating in the SSO strategically update the information that they use to evaluate their timing of entry. We now turn to a more in-depth analysis of our data using a technique that will permit us to extract much more information about the effects of information updating on SSO entry.

6. STRATEGIC INFORMATION UPDATING: EMPIRICAL ANALYSIS OF SSO ENTRY

Since we asserted that strategic information updating will influence managerial decision-making, we will use a Bayesian survival analysis model to reveal the effects of new information on firm timing of SSO entry. Bayes theorem focuses on the revision of the probability of some outcome based on observations of the world over time. Bayesian models have often been used in studies of decision-making. Smith and von Winterfeldt (2004), for example, showed that probability theory and Bayesian statistics offer useful normative foundations in the domain of judgment and beliefs. Raiffa and Schlaifer (1959, 1961) did early work using Bayesian statistics in studies of decision analysis. Harsanyi (1967) also used a Bayesian perspective to explore player strategies in games with incomplete information. He revealed that expectations can be represented by subjective probability distributions. Players of the game update their probabilities based on the types of other players that join the game, as well as whatever information is revealed.

Bayesian analysis also has been applied in studies of income dynamics (Hirano 2002), marketing (Rossi and Allenby 2003), and survival data (Gamerman 1991). The methodology has not been widely explored in IS literature, however, it is beginning to emerge. For example, Banerjee et al. (2007) leveraged a Bayesian model to examine the impacts of industry, firm and e-commerce factors on Internet firm survival.

6.1. The Bayesian Information Updating Model

We extend the baseline survival model to create a *Bayesian survival analysis model*. A key weakness of the baseline survival model is that the model fails to leverage the explanatory power of senior management's processing of new information that a Bayesian survival analysis model offers. When we look at the lifetime of an industry SSO, in our case 20 years, we expect to see changes over time in the likelihood of firm entry timing.

With a *Bayesian information updating model*, we can obtain time-varying coefficients and observe relationships between explanatory variables and changes in firm entry behaviors. We can model the behavior without resorting to strong parametric assumptions. Bayes theorem focuses on the posterior distribution $p(\theta|y)$ (Gelman et al. 2004). The probability distribution for θ is based on the prior distribution $\pi(\theta)$ and is updated by combining information from the prior distribution and the data through the calculation of the posterior distribution $p(\theta|y)$: $p(\theta, y) = p(y|\theta)\pi(\theta) / \int p(y|\theta)\pi(\theta)d\theta$. The likelihood function for θ is any function proportional to $p(\theta|y)$. With Bayes theorem, we can show how managerial decision-making changes with updates of new information – a perfect fit for the SSO entry and strategic information updating decision-making context we consider.

The proportional hazards model allows the vector of coefficients β to vary across time t, and the general hazard function is $h_i(t, x_{it}, \beta) = h_0(t) \exp(\beta' x_{it})$. Our hazard rate $h_i(t)$ model for firm i at age t is:

$h_i(t) = h_0(t) \exp[\beta_{1t}\ R\&DIntensity_{it} + \beta_{2t}\ NetIncome_{it}\ + \beta_{3t}\ lnFirmAge_{it}\ + \beta_{4t}\ lnEmpEfficiency_{it}]$,

where β_{kt} , $k = \{1,\ldots, 4\}$ are the time-varying coefficients. Using an AR1 autoregressive model, the β values are updated as $\beta_{kt} = \varphi\beta_{kt\text{-}1} + \varepsilon_{kt}$, $k = \{1,\ldots,4\}$, where φ are the parameters and ε_{kt} is a stochastic process with zero mean and variance σ^2 (Greene 2008).

The statistical package, SAS, supports Bayesian analysis of the proportion hazard model via WinBugs (Windows-based Bayesian Inference Using Gibbs Sampling) (Lunn et al. 2000). The PHREG procedure in SAS uses the *Gibbs sampler* to generate posterior distributions to sample each parameter value from its *full conditional distribution*. The Gibbs sampler is used when the conditional distribution for each variable is known, but the *joint distribution* is unknown (Gelfand and Smith 1990). The Gibbs sampling algorithm generates an instance from the distribution of each variable, conditional on the current values of the other variables, so that each parameter is updated by treating all other parameters as fixed. The Gibbs sampler generates random variables from a distribution (Casella and George 2007) and incorporates *Markov chain Monte Carlo methods*, a class of simulation algorithms. As part of the process, it is typical to run thousands of iterations and to obtain a new set of values for all the parameters after each of the iterations. We ran chains with 10,000 burn-in and 20,000 after burn-in iterations to check for convergence.[2]

It is important for us to establish our approach to the interpretation of the Bayesian analysis results, since the methodology produces many coefficient estimates, as opposed to just one, and for which it might be possible to ascribe a number of different significance levels. The key insight is that the results need to be understood for the *estimated impact patterns* they suggest, as opposed to the specific values of any single coefficient estimate. This is different from the usual genre of statistical analysis in IS research, where the analyst is interested in establishing the conformity of the data filtered by an empirical model to the requirements for establishing whether there is evidence for a specific hypothesis to be true. With multiple theoretical perspectives, we place less interest as the analysts of record in this research on any single hypothesis. Instead, our innovation in this work is to find some ways to establish the consistency of multiple theories with observed patterns of SSO entry in the presence of strategic information updating by the firms that eventually ended up joining the organization.

6.2. Bayesian Information Updating Model Results

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[2] *Burn-in* refers to the practice of discarding an initial portion of a Markov chain sample so that the effect of initial values on the posterior inference is minimized. Inferences based on non-converged Markov chains can be inaccurate and misleading. We used the *Geweke test* to validate that estimation model convergence to establish the parameter estimates (Geweke 1992). Additionally, we checked for high sample autocorrelations, since they can result in biased Monte Carlo standard errors (Fan et al. 2002).

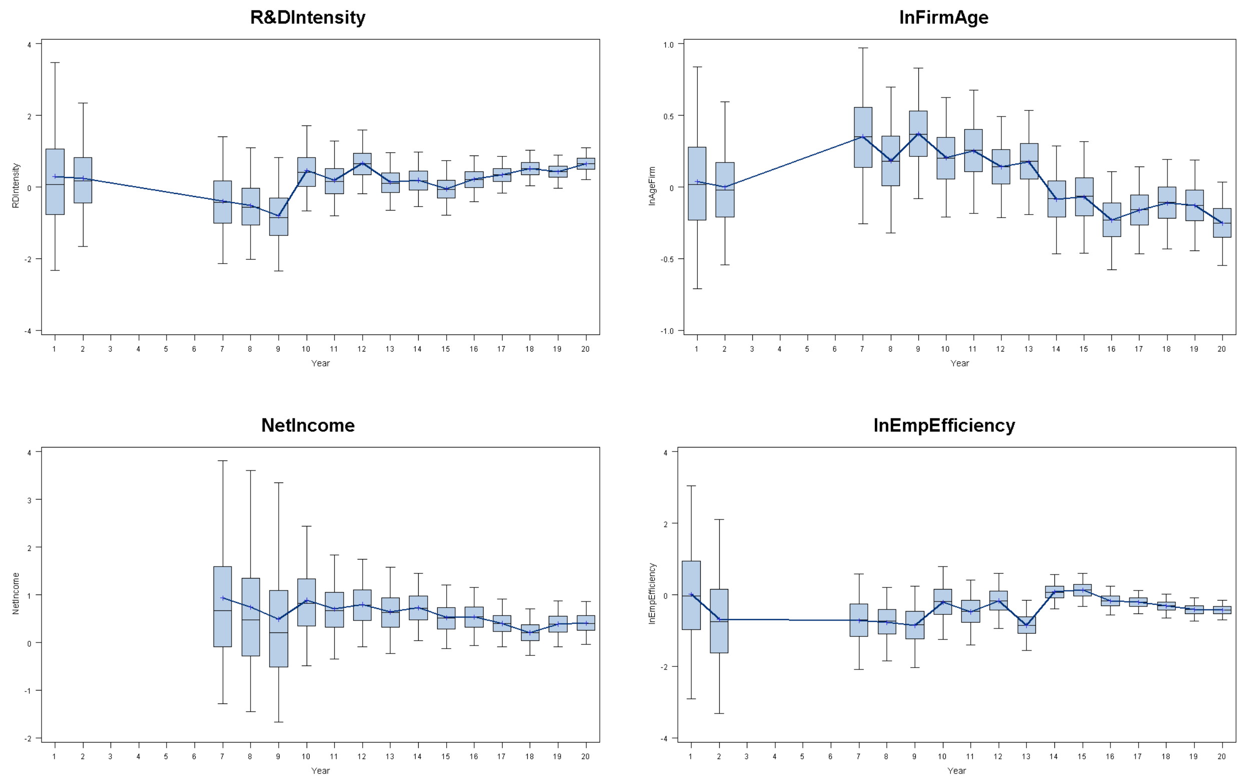
We now apply this perspective. Our study of firm characteristics and industry SSO entry reveals that all of the variables except firm age exhibit a distinct pattern. As time passes and the industry SSO matures, our evidence shows that the estimated values of the coefficients begin to stabilize. This makes sense on two levels. First, with the passage of time, there are more observers in the data set upon which to establish coefficient estimates. Second, it also is likely that the marketplace and the firms that exist within it will progressively come to understand what the value prospects are for the SSO, and they will have increasingly "true" reactions to the value it offers based on their heterogeneous understanding of how they can appropriate it for themselves through entry and adoption. We next explore the SSO entry patterns for each firm characteristic as a means of getting a reading on the extent of the evidence about the strategic information updating decision-making process and its consistency with the different theoretical explanations that we explored earlier.

The coefficient estimates for the Bayesian survival analysis model are reported in Table 6. Our results reflect the use of data up to the year to which the coefficient estimate applied, as is common in Bayesian information updating analysis. This captures the *aggregate behavior* that results from individual firms' senior managers updating their reading on the appropriateness of SSO entry. This style of results presentation is consistent with exploratory data analysis for patterns and aids us in making the incremental year-by-year information revelation and managerial responses plain. For each coefficient, its 2.5, 5, 50, 95 and 97.5 posterior distribution percentiles are displayed. Since there were missing data for the firms that joined in 1990, 1991, and 1992 and no firms joined in 1993 (Years 3, 4, 5 and 6 in our data set), no results are reported. Coefficient estimates can only be obtained for years in which at least one new firm joined the SSO. For 1988 and 1989, parameter estimates cannot be generated and is not reported for *NetIncome*, since all of the firms that joined in the first two years have positive net income so all of the values are 1. We previously showed in Figure 1 the number of new SSO participants for each year. We use box plots to display the posterior distribution results in Figure 2.

Table 6. Bayesian Survival Analysis Model Results

VARIABLE	POSTERIOR DISTRIBUTION PERCENTILE	DURATION (*AGE OF SSO* IN YEARS)									
R&D-Intensity		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	2.5	-2.34	-1.66					-2.14	-2.02	-2.34	-0.67
	5.0	-1.95	-1.35					-1.85	-1.79	-2.11	-0.53
	50.0	0.07	0.17	N/A				-0.43	-0.57	-0.85	0.41
	95.0	2.82	1.92					1.09	0.82	0.51	1.47
	97.5	3.47	2.34					1.40	1.10	0.82	1.71
		11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	2.5	-0.80	-0.19	-0.66	-0.54	-0.79	-0.41	-0.17	0.03	-0.03	0.21
	5.0	-0.65	-0.07	-0.54	-0.43	-0.67	-0.31	-0.08	0.11	0.04	0.28
	50.0	0.15	0.64	0.11	0.18	-0.07	0.20	0.34	0.51	0.43	0.64
	95.0	1.10	1.45	0.82	0.84	0.60	0.77	0.77	0.93	0.82	1.02
	97.5	1.29	1.60	0.97	0.98	0.74	0.87	0.86	1.02	0.89	1.10
NetIncome		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	2.5							-1.29	-1.45	-1.67	-0.49
	5.0							-1.04	-1.16	-1.41	-0.29
	50.0	N/A						0.67	0.47	0.20	0.81
	95.0							3.22	3.01	2.79	2.15
	97.5							3.81	3.61	3.35	2.44
		11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	2.5	-0.34	-0.09	-0.24	0.03	-0.12	-0.07	-0.10	-0.28	-0.09	-0.04
	5.0	-0.19	0.03	-0.10	0.14	-0.01	0.03	-0.02	-0.20	-0.02	0.03
	50.0	0.67	0.78	0.62	0.72	0.51	0.53	0.39	0.20	0.38	0.40
	95.0	1.63	1.59	1.41	1.33	1.09	1.06	0.83	0.62	0.80	0.78
	97.5	1.84	1.74	1.58	1.45	1.20	1.16	0.91	0.71	0.87	0.86
lnFirmAge		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	2.5	-0.71	-0.54					-0.26	-0.32	-0.08	-0.21
	5.0	-0.59	-0.47					-0.17	-0.24	0	-0.14
	50.0	0.02	-0.02	N/A				0.35	0.18	0.37	0.20
	95.0	0.69	0.48					0.87	0.61	0.75	0.56
	97.5	0.84	0.59					0.97	0.70	0.83	0.62
		11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	2.5	-0.18	-0.21	-0.19	-0.47	-0.46	-0.58	-0.47	-0.43	-0.44	-0.54
	5.0	-0.11	-0.16	-0.13	-0.40	-0.39	-0.52	-0.42	-0.38	-0.40	-0.49
	50.0	0.26	0.14	0.18	-0.08	-0.07	-0.23	-0.16	-0.11	-0.13	-0.25
	95.0	0.61	0.43	0.48	0.23	0.26	0.06	0.09	0.15	0.13	-0.01
	97.5	0.67	0.49	0.53	0.29	0.32	0.11	0.14	0.19	0.19	0.04
lnEmp-Efficiency		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	2.5	-2.90	-3.33					-2.09	-1.84	-2.03	-1.25
	5.0	-2.42	-2.87					-1.85	-1.67	-1.82	-1.06
	50.0	-0.04	-0.76	N/A				-0.70	-0.74	-0.84	-0.19
	95.0	2.52	1.61					0.39	0.06	0.07	0.61
	97.5	3.05	2.10					0.59	0.20	0.24	0.78
		11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	2.5	-1.40	-0.93	-1.55	-0.39	-0.32	-0.57	-0.53	-0.64	-0.73	-0.71
	5.0	-1.23	-0.81	-1.43	-0.32	-0.25	-0.51	-0.48	-0.60	-0.68	-0.66
	50.0	-0.46	-0.17	-0.85	0.07	0.13	-0.17	-0.20	-0.31	-0.41	-0.43
	95.0	0.26	0.48	-0.27	0.49	0.53	0.17	0.07	-0.03	-0.13	-0.19
	97.5	0.40	0.60	-0.15	0.57	0.61	0.24	0.13	0.02	-0.08	-0.15

Figure 2. Box Plots of the Posterior Distributions of the Model



Note: The box plots show the posterior distributions for the model based on each independent variable. The horizontal axes display the age of the SSO, in years, until the time of an event. Each box plot covers the central 95% of the distribution, so the ends of the arms for each box plot represent the 2.5 and 97.5 percentiles for the posterior distribution. The line connects the mean value of each year. Since there were missing data for the firms that joined in 1990, 1991, and 1992 and no firms joined in 1993 (Years 3, 4, 5 and 6 in our data set), no results are reported. For 1988 and 1989, parameter estimates cannot be generated and is not reported for *NetIncome*, since all of the firms that joined in the first two years have positive net income so all of the values are 1.

In the first two years of 1988 and 1989 (Years 1 and 2), the relationship between *R&DIntensity* and the hazard rate was positive. Then from 1994 to 1996 (Years 7 to 9), the coefficient became negative and decreased during those three years. It increased back to positive in 1997 (Year 10). There was a spike in 1997 and 1999 (Years 10 and 12). From 1997 on, it was positive all the way to 2007 (Year 20) with an exception in 2002 (Year 15). A positive coefficient shows that firms with R&D intensity were more likely to enter. During certain periods, the sign of the coefficient changes to negative to show that firms with R&D intensity were less likely to enter.

In the years that the TM Forum experienced an increase in the hazard rate of entry by industry firm, the SSO made announcements regarding key developments in the process standard. The likelihood of SSO entry increased in 1989 (Year 2), the year after the TM Forum was established and released news on the founding members. From 1994 to 1996 (Years 7 to 9), right around when the Service Management Business Process Model – the first authoritative work on telecom business process re-engineering – was introduced, there was a shift. Firms with R&D intensity were less likely to enter. The next two increases in entry were observed in 1997 and 1999 (Years 10 and 12). In 1997, TOM was introduced as part of a major new initiative called "SMART TMN." Then in 1999, the TM Forum announced TOM Version 2, the version that eventually became the industry de facto standard.

The relationship between *NetIncome* and the hazard rate was positive for all 20 years. The positive coefficients reveal that firms with positive net income or organizational slack were more likely to enter. The estimated coefficient increased in 1997 (Year 10). The increase in 1997 coincided with the announcement that TOM was introduced as part of the SMART TMN initiative.

The relationship between *lnFirmAge* and the hazard rate was mostly positive for the early years, all the way up to 2000 (Year 13). Starting in 2001 (Year 14), the estimated coefficient became negative and stayed negative for the remaining years to 2007 (Year 20). These results indicate that more experienced firms were more likely to enter the SSO during the early years; however, as the standard matured, more experienced firms were less likely to enter. The estimated coefficient increased in 1994 and 1996 (Years 7 and 9). It appears there was a spike the year prior to and after the announcement of the introduction of TOM as part of the SMART TMN initiative.

The final variable we explored is *lnEmpEfficiency*. The relationship between *EmpEfficiency* and the hazard rate was negative for most of the 20 years, with exceptions in 2001 and 2002 (Years 14 and 15). This indicates that, overall, firms with higher employee efficiency or labor productivity were less likely to enter into the industry SSO. The estimated coefficient showed a sharp increase in 1997 and 2001 (Years 10 and 14). It turns out that in 1997 TOM was introduced as part of the SMART TMN initiative.

6.3. Discussion

The Bayesian survival analysis allows us to see the changing dynamics of firm timing of entry into an industry SSO as strategic information updating occurs. Firms with R&D intensity were more likely to enter into the industry SSO. The TM Forum has a mixture of stakeholders. Technology vendors have R&D spending, but other stakeholders including users and systems integrators generally do not. Vendors are commonly the dominant stakeholders in an SSO, which explains why the hazard rate was more often positive for the 20 years we analyzed. Cooperative innovation is attractive to firms undertaking R&D efforts since it minimizes risk (Fritsch and Lukas 2001). Firms with organizational slack were more likely to enter into the TM Forum. Less slack indicates resource constraints. Firms with little slack have difficulty going beyond a primary objective (Dollinger 1990).

More experienced firms tended to be earlier entrants. The advantage that experienced managers have is that they know which skills to acquire through their alliances and how to benefit from those skills (Hamel 1991). More experienced firms can be adaptable in their entry timing, since they generally possess greater knowledge on standards development and have greater influence in the various industry consortia. On the other hand, less experienced firms tend to be followers and feed off the knowledge of more experienced firms. We find that firms with higher employee efficiency were less likely to enter. Within an SSO, a firm can easily connect with industry experts from a variety of stakeholder categories to enhance productivity and become more competitive. Kogut (1988) explains that the pursuit of market power and efficiency gains such as economies of scope and scale motivates firms to join in R&D ventures.

7. INTERPRETATION: EVALUATING THE DIFFERENT THEORETICAL EXPLANATIONS

In this section, we explore what the empirical regularities reveal to us about the effects of strategic information updating on firms' SSO entry timing strategies and evaluate different theoretical explanations. This leads us to build an integrated theoretical perspective on strategic information updating and its influence on managerial decision-making related to industry SSO entry.

7.1. Assessing Alternative Theories about Entry Decision-Making in the Industry SSO Context

The SSO and its member firms are more likely to use strategic information transmission during the early stages of process standardization to motivate firms to participate. Since a standard does not yet exist, uncertainty and risk are high. Although firms are less likely to join, one-off entry decisions do occur. Strategic information transmission can explain why the sign of a coefficient changes when strategic information updating occurs. The SSO recruits firms with contrasting characteristics to round out the organization and gain support from a range of industry firms, which are necessary to establish the momentum that is needed to grow the standard. For example, in the first couple of years, R&D-intensive firms had a higher likelihood of SSO entry, but this changed abruptly when the Service Management Business Process Model was announced. All of the sudden, R&D intensive firms had a lower likelihood of entry.

Signaling, on the other hand, offers a possible explanation for why firms with common characteristics joined shortly after each other. Like firms tend to make similar choices. Furthermore, signaling costs can discourage heterogeneous organizations from acting together. In 1988, the TM Forum announced that TOM Version 1 was available, and that Version 2 was going to be available in 1989. For both years, the strategic information updating activities of the firms did not affect the signs of the coefficients of the four model variables. Nevertheless, there was an increase in the likelihood of entry with the news of TOM Version 2, based on the impacts of strategic information updating by firms with similar characteristics.

While cheap talk can occur at all times, it is likely to result in more information being shared during the early stages of process standardization when a standard does not yet exist. Once the value of a standard is evident, it becomes more difficult for cheap talk to influence entry behavior. Cheap talk is useful because it allows us another way to explain one-off firm entry into an industry SSO.

Social learning and information cascades offer ways to explain why more firms join after a standard has been established and has had time to mature. Once the member firms start to grow, other firms can observe the positive or negative outcomes of their entry. Therefore, they will either base their decisions to join by learning from other firms' experiences or by following the actions of other firms. The expansion in member firms can lead other firms to believe that entering the SSO is the right choice. Moderate to large increases in the hazard rate of entry provide evidence of social learning and information cascades.

Instances where the value of the standard is not yet clear and there are large increases, we can attribute those behavior to information cascades and rational herd behavior. In 1997, TOM was introduced as part of the SMART TMN initiative. At this point, the standard was still very new, yet the hazard of entry experienced quite an increase. Several of the variables' coefficients increased by at least 0.5, with 0.56 for R&D intensity, 0.61 for organizational slack, and 0.65 for employee efficiency. Table 7 shows the changing effects of strategic information updating on firm entry timing. For each of the firm characteristics, we can observe how the likelihood of entry differs from the previous period, assuming that information updates are occurring in the marketplace. In addition, we can also see the effect on the hazard of SSO entry, both in terms of whether it increased or decreased and by how much.

Table 7. The Changing Effects of Strategic Information Updating on Firm Entry Timing

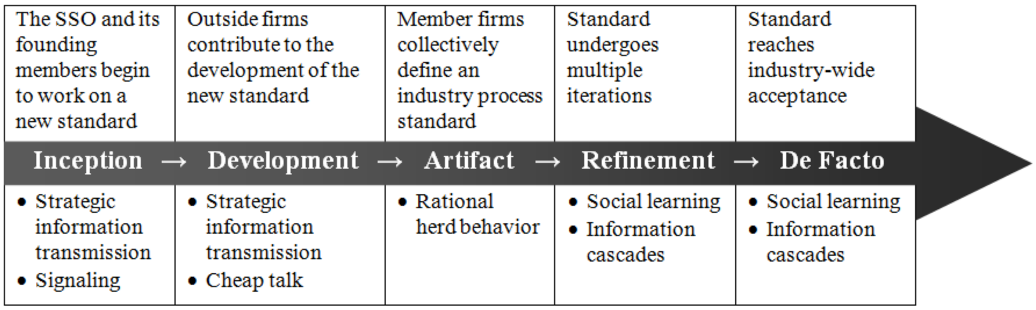
Information Updates	R&D Intensive Firms		Firms with Organizational Slack		More Experienced Firms		Firms with Higher Employee Efficiency	
	Likelihood to Join	Effect on Hazard	Likelihood to Join	Effect on Hazard	Likelihood to Join	Effect on Hazard	Likelihood to Join	Effect on Hazard
SSO created	Higher	--	Higher	--	Higher	--	Lower	--
Year after SSO established	Higher	Increase (+.10)	Higher	--	Lower	Decrease (-0.04)	Lower	Decrease (-0.72)
Service Mgmt. Business Model	Lower	Decrease (-0.14)	Higher	Decrease (-0.20)	Higher	Decrease (-0.17)	Lower	Decrease (-0.04)
TOM introduced as SMART TMN	Higher	Increase (+0.56)	Higher	Increase (+0.61)	Higher	Decrease (-0.17)	Lower	Increase (+0.65)
TOM Version 1	Higher	Decrease (-0.26)	Higher	Decrease (-0.14)	Higher	Increase (+0.06)	Lower	Decrease (-0.27)
TOM Version 2	Higher	Increase (+0.49)	Higher	Increase (+0.11)	Higher	Decrease (-0.12)	Lower	Increase (+0.29)
De facto standard developed	Higher	Increase (+0.27)	Higher	Increase (+0.02)	Lower	Decrease (-0.16)	Lower	Decrease (-0.30)

7.2. Strategic Information Updating and the Five Stages of Process Standardization

The Five Stages. Our evaluation of the multiple theories and empirical results leads us to propose that there are five stages to process standardization, from the time of its inception to when the standard becomes de facto. The different theories that we have discussed seem to offer process explanations for the behavior that we observed in the context of each of the different stages. The *inception stage* describes the period in which the SSO and its founding firms begin to work on the standard. Once work starts on the new process standard, outside firms can join to contribute to it in the *development stage*. At a certain point, the member firms will collectively define an industry process standard and reach the *artifact stage*. A new standard will go through multiple iterations in a process standard *refinement stage* before it is stable. Once a standard is mature, it may reach industry-wide acceptance, bringing it to the *de facto stage*.

During these stages, the industry SSO and its participating members will disclose information that reveals the progress of the standard. Subsequently, we observe changes in entry timing as the standard evolves. We illustrate in Figure 3 how process standardization maps to the five stages, and the theories that seem to be most applicable for analyzing the outcomes of strategic information updating at each stage.

Figure 3. The Five Stages of Process Standardization and Corresponding Theories



Additional Interpretation. A year after TM Forum's initial launch, a group of firms entered. At this early stage, information asymmetry among the firms was high, and it would have been difficult for them to assess the future value of the standard – a classic instance of entry decision-making under uncertainty. A possible theoretical explanation for why firms entered at this point is signaling. From the characteristics of the founding members, it is apparent that industry leaders played a central role in getting the TM Forum up and running. For example, at the time AT&T and British Telecom were among the top firms in the telecommunications services industry, and Hewlett-Packard and Nortel Networks (then Northern Telecom) were leaders in the technology hardware and equipment industry. What we know with signaling is that it is common for firms with similar characteristics to be aligned in their choices. Verizon (previously Bell Atlantic) also was highly ranked in the telecommunications services industry of the 1980s, and it followed suit in 1989. Another participant was IBM, then the #1 firm in the software and services industry. An alternative explanation for why a group of firms entered the TM Forum soon after it was established is strategic information transmission. The founding participants of an industry SSO typically recognize that for the organization and the developing standard to gain momentum, industry-leading firms must support it. Therefore, the founding firms engage in strategic information transmission to the industry leaders to encourage them to join.

During the SSO development stage leading up to 1994, very few firms joined. There are a couple of likely theoretical explanations for the one-off entry decisions that we observe during this stage. The first one once again is strategic information transmission. Firms that are outside the membership group often join because they receive private information from a member firm that it otherwise would not have obtained, and this information made reduce its uncertainty and increase its likelihood to enter. In this situation, the firm releasing the information may be trying to elicit some response from the non-member firm so that both firms will mutually benefit. Another explanation is cheap talk, the idea that decision-relevant information may be disclosed during informal communication, potentially affecting the degree of uncertainty that decision-maker perceived. An example is when an SSO member firm decides to shares its knowledge of the developing standard with another firm – possibly a strategic alliance or business partner – causing the firm to join as a result.

The next stage is the artifact stage, which means that the firms within the SSO have cooperated to the extent that a concrete specification of the standard exists, even if it may not have been fully promulgated or mandated for use in an industry. An example of this occurred in 1995, when the TM Forum announced publication of the "Service Management Business Process Model." This was the first authoritative work on telecom business process reengineering and a precursor to the "Telecom Operations Map" (TOM). Just prior to this time in 1994, there was a spike in firm entry into the TM Forum. A theoretical explanation for the observed pattern of firm entry that occurred is rational herd behavior. Even though the standard was not widely accepted and the payoffs were unclear at this stage, a group of firms appear to have joined because there was increasing awareness that the entering firms were rational and had insights on the viability of the developing process standard that were unknown to others but still of interest to them. It is interesting to note that the majority of the firms that joined in 1994 were technology vendors of the subcategory software suppliers. The entry of the largest software suppliers, Microsoft and Oracle, may have triggered the herd behavior among other software suppliers.

Once a standard has been announced, it will go through a period of refinement. There were multiple versions of the Business Process Framework, including TOM Versions 1 and 2. Version 2 went through several years of refinement before eTOM was announced as the de facto standard in 2003. During these years, the TM Forum experienced some growth in participation. The growth may be attributable to social learning; new entrants are able to see how other similar firms are benefiting from the standard. This leads them to base their decisions on the experience of others. Another alternative explanation is that newly-entering firms are mimicking the behavior of other industry firms, reflecting information cascades. Although the entering firms may not have perceived value in the standard that was developing, it is possible that the entry of other firms in the TM Forum caused them to ignore their own assessments and to join with other firms so as not to be left behind.

By the time eTOM became the de facto standard, the hazard rate for firm entry had stabilized. During the early part of the de facto stage, we expect to observe continuing information cascades, as the market begins to lock in a sense of how much value is associated with the coming de facto process standard. More firms will join, but there will be fewer firms left to enter from the sidelines of the SSO's activities as time passes. Firms that took a social learning "wait and see" entry strategy will no longer delay their entry. This is illustrated for the TM Forum by the steady stream of new participants beginning 2003.

During the growth and evolution of an industry SSO, multiple theories are appropriate to explain the patterns of firm entry observed in the real world. The complexity of an industry SSO and the co-opetition dynamics that are present among its stakeholders make it difficult – and actually inappropriate – to interpret the related phenomena using a single theory. Strategic information transmission and signaling provide insights into entry timing during the inception stage. Strategic information transmission and cheap talk seem more relevant during the development stage. Then, rational herd behavior seems to offer a more meaningful way to view entry behavior during the artifact stage. Finally, social learning and information cascades appear to offer a more suitable basis for theoretical explanation during the process standard refinement stage and the de facto stage. By mapping the different theories to the five stages, we have been able to develop a more meaningful synthesis of the different theoretical perspectives that we proposed to learn from on the effects of strategic information updating on managerial strategies for industry SSO entry. We expect the views that we have developed here to be broadly applicable across other industry contexts.

8. CONCLUSION

Strategic information updating behavior, as we have argued in this research, characterizes the managerial decision-making process that determines a firm's timing of entry into an industry SSO. During process standardization, the industry SSO and its member firms release and react to new information that permits managers at firms that have not yet decided to join to update their knowledge. We have evaluated the capabilities of multiple theoretical lenses to provide a basis for interpreting different kinds of observed firm actions with the support of empirical findings produced by Bayesian survival analysis.

8.1. Managerial Implications

When it comes to timing of entry into an industry SSO, firms will position themselves to maximize the benefits of participating. We know from our multi-year field study that firms possess contrasting motivations for industry SSO entry; hence, their entry strategies will vary, especially as different information comes to the marketplace to which they can react. Firms such as Deutsche Telekom joined shortly after news came out that the SSO was established, and so there was little necessity for strategic information updating. The organization elected to join during a period of high uncertainty when an industry standard did not yet exist. For this organization, its main strategy was to drive influence, and today the firm continues to operate as a board member. Andreas Kindt, CIO of Deutsche Telekom and a recent TM Forum board member characterizes this motivation for entry, by stating that his firm was "pleased to join the TM Forum Board to help shape the direction in this time of massive change in our industry. Deutsche Telekom is undertaking some major transformations and a close relationship with the TM Forum is strategically important to us" (TM Forum 2008).

Not all firms adopt an early entry strategy though, and for them, the process of strategic updating of the information they use to gauge the value of participation and to get the entry timing right is more critical. For some firms, a mature SSO and its accompanying standard deliver more value. Several firms joined after eTOM became the de facto standard. They would have benefited from information that was released over time that pointed to the solidification of the market's expectations that such a standard would ultimately emerge. Salman Mahmood, CEO of Averox Inc., revealed his firm's reasons for joining the TM Forum in 2007, indicating that its activities "offer our company exceptional opportunities and events to gather up-to-date information on emerging needs in our industry and to meet with many of our industry's key policy and decision-makers" (BNET Staff Writers 2007). This is the sort of argumentation that will continue to be relevant with the passage of time, the recomposition of the TM Forum's membership and other changes and developments that are impacting the industries that are involved.

Both the industry SSO and its member firms are key players when it comes to strategic information transmission. The information released by them can accelerate or decelerate the rate of entry of industry firms, which can be observed to change over time in data sets like ours analyzed in the manner that we have. Our results reveal that during process standardization, there were periods with limited new entry activities, and then spikes in entry occurred which appeared to correspond to key process standardization events. Thus, information that became available leading up to those events would have increased the instantaneous likelihood for any firm to enter, but especially those firms whose characteristics heterogeneously predisposed them to be more likely to react. This leads us to believe that it is imperative for a consortium along with its member firms to demonstrate progress in standards development to entice outside firms to enter, drive SSO growth, and accelerate the adoption and diffusion of its standards. Furthermore, to promote participation, an SSO should do what it can to reduce technology uncertainties that firms face related to the standard that is under development (Zhao et al. 2007).

As firms plan their strategies for future industry SSO participation, there are several key points to consider. R&D intensive firms were more likely to join; therefore, firms that invest in R&D should consider early entry due to a standard's potential impact. Additionally, firms with no organizational slack should be cautious in their entry timing strategies. Our results reveal that firms with organizational slack were more likely to join an industry SSO. Since cooperation is a key element to growing an SSO and developing a standard, member firms may be expected to supply resources. We observed that more experienced firms were less likely to enter. Therefore, it appears that an industry SSO provides an environment for less experienced firms to gain new insights and absorb the expertise of more experienced firms. One of the key drivers for industry SSO entry is the benefits that can be obtained through cooperative R&D. We found that firms with a higher level of labor efficiency were less likely to join. Thus we see that a firm can potentially leverage industry SSO entry to increase its labor productivity.

For firms that wish to make a strong impact during the evolution of a new standard, our results seem to imply that there is a "window of opportunity" when most of the firm dynamics occur. A firm that believes it can influence a standard up to the period that a de facto standard emerges needs to take note of the fact that most of the activities will stabilize in the years leading up to it. Again, this is something that we expect firms will consider as they update the information they use to drive their strategic actions.

8.2. Main Findings and Contributions

Our research has yielded several main findings. We considered a number of different theories for the process that occurs when firms strategically update the information they have to guide decision-making about whether to enter an industry SSO. We evaluated the extent to which the observed empirical outcomes of entry timing are most closely associated with the following theories: strategic information transmission and signaling, cheap talk and social learning, and information cascades and rational herd behavior. All of these views of the micro-level decision-making processes that firms engage in are consistent with our observations of high-level co-opetition behavior in SSO entry; however, they differ somewhat in their concordance with the patterns of firm behavior that are observed in our empirical analysis. We were able to establish the relevance of a set of drivers that influence the timing of firm entry into an industry SSO.

Firm characteristics that affect entry timing include R&D intensity, organizational slack, management experience, and employee efficiency. The limitation of baseline survival analysis that we pointed out is that it fails to capture the changing SSO entry dynamics of firms as an SSO matures, but this limitation can be overcome through the use of Bayesian survival analysis. This permits us to account for temporal changes in the propensity of a firm to enter the SSO we have studied. This is especially interesting, since we have tried to understand managerial decision-making under uncertainty over a twenty-year period. After all, firms are heterogeneous, and their strategic interests are likely to evolve over time. Our results reveal that the entry timing of a firm is likely to change as an industry SSO matures and strategic information updating occurs. The hazard rates that we estimated in the Bayesian analysis exhibited more changes in the early years when the SSO was young and the process standard was still in its early stages of development. The hazard rate eventually stabilized as less new information emerged related to the promulgation of the SSO's process standard.

More importantly in this research, we were able to use the Bayesian analysis results to establish a basis for evaluating the relevance of a number of different explanatory theories for observed entry at a specific time. We have argued since the outset of this article that the observed behavior is consistent at a high level with co-opetition: the will of the firms that entered the SSO we studied to contribute cooperatively to the standard's development while competing with other members either directly or indirectly in other market settings. The evidence that we have provided offers a first step toward a fuller specification of a process theory for SSO development and evolution in light of how entering firms deal with strategic information updates that reflect an SSO value proposition that changes over time. With the idea of trying to develop a synthesis of our thoughts about the relevant theories, we have proposed a set of five stages to characterize the evolution of a de facto process standard.

8.3. Limitations and Future Research

There are areas unexplored in this study that leave opportunities for further examination in future research. Our study includes only public firms due to the limited access we had to the data of privately-held firms. This prohibited us from confirming whether strategic information updating behavior has the same effect on the SSO entry timing of private firms as it does on public firms. We are in the process of formulating additional research related to this group of firms. Another limitation that we faced is our inability to generalize the results for other contexts, since our findings are based on data from just one industry SSO. The results may not be representative for other industry consortia, and how strategic information updating for decision-making under uncertainty works for other kinds of SSOs. Nevertheless, we believe that we have accomplished some important first steps in that direction. We will expand our study by developing empirical cross-comparisons for the SSOs that operate in different industries. Additionally, our focus for this research has been on an industry SSO that supports a process standard. Will strategic information updating have different impacts on firms' entry timing strategies in a technology-focused SSO? Will it trigger migration behaviors that are different from what we observed (Nickerson and zur Muehlen 2006)?

Our data set did not allow for the stratification of results on intertemporal propensity to enter the SSO by stakeholder categories. Since we studied only 101 firms, stratification would have led to too small samples for each of the stakeholder categories. Consequently, we were unable to observe whether strategic information updating was statistically associated with different patterns of observed SSO entry behavior for the various stakeholders. It is possible that the observed timing of SSO entry, reflecting somewhat different strategies for entry are in play across the stakeholder groups, since they have contrasting objectives for SSO participation. Will strategic information transmission from the SSO resonate the same way for all stakeholders, especially since the resulting outcomes of a process standard on a technology vendor will be different from those of a technology user and systems integrator? Our analysis does not yet take into account the complexity of stakeholder interests within an industry SSO, though we are examining different approaches that may make this possible.

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