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Does Co-opetition Change the Game? A Bayesian Analysis of Participation Strategy in an Industry Standard-Setting Organization

Robert J. KAUFFMAN
Singapore Management University, rkauffman@smu.edu.sg

Benjamin B. M. SHAO
Arizona State University at the Tempe Campus

Juliana Y. TSAI
Arizona State University at the Tempe Campus

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DOES CO-OPETITION CHANGE THE GAME? A BAYESIAN ANALYSIS OF FIRM PARTICIPATION STRATEGY IN AN INDUSTRY STANDARD-SETTING ORGANIZATION

Robert J. Kauffman, Benjamin B. M. Shao, and Juliana Y. Tsai
W. P. Carey School of Business, Arizona State University, Tempe, AZ 85287
{rkauffman, benjamin.shao, juliana.tsai}@asu.edu

Abstract. Across different industries, we observe the emergence of industry *standard-setting organizations* (SSO) that focus on the creation of industry-specific process *standards*. Firms adopt a *strategy of co-opetition*, the combination of co-operation and competition, during standards development. We propose that a firm's co-opetition strategy is revealed to some extent by when it elects to participate in an industry SSO. *Bayesian information updating* offers an effective empirical modeling perspective for studying firms' participation strategies when managers' beliefs and uncertainties are factored into their decision-making. We analyze a panel data set of 73 U.S. public firms over a 20-year period. These firms are members of the TeleManagement Forum, an information, communications and entertainment industries SSO. We study organizational characteristics of member firms to understand how they relate to a firm's SSO participation strategy, thus capturing the co-opetitition dynamics of firms in the presence of process standardization. SSO participation strategies of firms do change as an industry SSO matures and as more information is gradually revealed. Additionally, there is a positive relationship between a firm's likelihood to participate and announcements of key process-related events. The participation dynamics show more change in the beginning, but eventually stabilize over time.

Keywords: Bayesian information updating, co-opetition, competitive strategy, processes, standard-setting organizations.

1. INTRODUCTION

In recent years, one of the key objectives of firms has been *standardized processes*. One of the driving forces for industry process standards is the chance to reduce costs via process outsourcing [10]. Process standards support software vendors in delivering a unified procurement strategy for enterprise software [28]. *R&D cooperation* also leads to cost reduction [27]. Standards reduce the chance of vendor lock-in. Also, collective action by mid-size vendors enables them to compete with larger vendors. Larger vendors, meanwhile, may pursue proprietary standards to cripple competing standards.

Because such a wide variety of firm objectives is present, an *industry-wide process standard* takes several years to develop and requires the cooperation of various stakeholders within the industrial community. New standards can impact a firm's competitiveness, its timing of participation in an industry *standard-setting organization* (SSO) becomes critical. [1] For example, small vendors recognize that standards can hinder and promote their chances to benefit from extreme differentiation. Teece's [41] *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.

A firm's SSO participation strategy during standards development reflects elements of co-opetition. Brandenburger and Nalebuff [4, pp. 4-5] define *co-opetition* as combining "the advantages of both competition and co-operation into a new dynamic which can be used to not only generate more profits but also to change the nature of the business environment in your favor." Co-opetition strategy is observed in various settings across multiple industries, and can be differently employed by heterogeneous firms. For example, rivals, Microsoft and Apple, have partnered where both firms can experience financial and competitive gains [5]. In the auto industry, Peugeot, Citroen and Toyota have partnered to design cars so they can be manufactured on a shared platform [15]. It is common for competing technology vendors to cooperate on standards when they can mutually benefit. IBM has been known to adopt SAP's standard, for example [26].

With co-opetition, firms send signals to other firms. SSO participation is one of the signals a firm can send, along with its level of participation (i.e., in a *passive role* as an observer, or in an *active role* as a board member), as is the formation of alliances. A firm that does not want its objectives revealed immediately or wishes to avoid the risks associated with early participation may delay entry. On the other hand, future payoffs for early participation may be higher than immediate payoffs since a firm is able to exert greater influence while a standard is still young. Thus, competing firms will be strategic when determining their timing for cooperation and entry into an industry SSO. Clemons and Knez [8] 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.

An SSO can also send signals by hosting annual events or publishing announcements in the form of press releases, product documents and customer case studies. As an SSO matures, more information becomes available. When managers acquire new knowledge, they often adjust their strategies. Each player adopts different *tactics* depending on its competitive position and overall goals. [2] Understanding how firm participation strategies

[1] A group that develops and publishes industry standards is also called a *standards development organization* (SDO).

[2] *Tactics* involve a procedure or a set of maneuvers that are used to achieve a particular goal.

unfold during process standardization can empower managers to improve their decision-making regarding future strategies for industry SSO participation.

We know from our multi-year field study that motivations of firms vary for industry SSO participation. Salman Mahmood, CEO of Averox Inc., joined the TM forum because "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" [2]. For Willy Ross, managing director of DataSynapse, the TM Forum provided a chance to "shape virtualization standards in the industry" [9]. A number of theoretical perspectives have been offered to explain why firms participate early, late, or not at all, including vendor influences on firm switching costs [7], firm efficiency differences and R&D intensity [22], and firm evaluation of incumbents' staying power in the marketplace [11], among others.

The presence of co-opetition strategy is stronger within an industry SSO because there is one body that supports the process standard for its entire industry, which is unlike a consortium that spans multiple industries. Since competing firms heterogeneously determine their optimal timing for standards cooperation, a firm's timing for entry can reflect its co-opetition strategy to some extent. Our goal is to understand the link between firm strategy for SSO participation and certain organizational characteristics. We achieve this using a *Bayesian information updating analysis model*.

We ask: How does the relationship between firm characteristics and industry SSO participation strategies change as an SSO matures and as information is gradually revealed? We also explore: How does co-opetition explain a firm's timing for SSO participation? How can a Bayesian information updating analysis model support the study of co-opetition in our context?

We use Bayesian analysis, also known as *Bayesian dynamic models* [1, 17], to capture the changing dynamics of interest. When studying environments of uncertainty where managers' beliefs are factored into their decision-making, Bayesian models offer an effective approach. Harsanyi [24] uses *Bayes theorem* to study *games with incomplete information*, where firms, as players, lack full information about other players or their own payoff function. In our study, the firms face a similar challenge; they cannot fully determine *a priori* what the outcomes will be should they participate early, mid, or late. Using Bayesian analysis, we can obtain a posterior distribution of the probability that a firm will participate at a particular time, so we can model the changing SSO participation strategies of firms as an SSO matures. Managers' intuition and previous experience represent the initial state of information. As more information becomes available, managers will factor new knowledge into their decision-making.

Our empirical study uses membership data from the TeleManagement (TM) Forum, an information, communications and entertainment industries standards organization. The TM Forum founded the Business Process Framework (the Telecom Operations Map, TOM, and later the enhanced version, eTOM), a de facto industry standard for business processes. We study 73 U.S. public firms over a 20-year period, from the time of the organization's birth in 1988 to 2007. In §2, we explore the co-opetition theory to shed light on tactics firms use in the game of business and apply these ideas to our context. We also explore the importance of firm characteristics in explaining participation strategies. Further, we survey the literature to understand how the Bayesian approach has been used in studies of managerial decision-making to illustrate its relevance in our context. We present our methodologies in §3 and discuss our data and empirical model in §4. We provide our results and discussion in §5. §6 concludes with contributions and limitations.

2. THEORY AND LITERATURE REVIEW

Managers form decisions in the presence of uncertainty and incomplete information. Their strategies are not fixed; on the contrary, they often will change as managers acquire new knowledge. This behavior is observed in firms' participation strategies in industry SSOs.

2.1. Co-opetition Theory and the Tactics Element

Brandenburger and Nalebuff [4] describe *co-opetition* in game-theoretic terms as a strategy that a firm can use to change the competitive terms in its business environment through five elements. One of the elements is *tactics*. In competition, it is difficult for a firm to anticipate what other players' next move will be. Each time a player makes a move, it alters the actions of other players. Players use tactics or actions to lift, preserve, or stir up a new "fog." An SSO's role is to lift it. The objective is to grow the organization and promote the development of standards by putting information out to the public. The perception of an SSO is that it is a *value creator*. For technology vendors, early participation can project perceptions of leadership when it comes to standards development. Technology vendors frequently employ different standards strategies [7]. As Brandenburger and Nalebuff indicate, what a firm chooses to do or not do sends signals to other players. At the same time, the *free-rider problem* can occur when risk-averse firms are reluctant to invest. Weiss and Cargill [45] note that for a firm to benefit from a standard, direct contribution is not required. Thus, we expect to see higher firm participation as a standard matures.

For some firms, concealing information represents another key strategy. Brandenburger and Nalebuff [4] suggest that firms try to "preserve a fog" by hiding information. Hence, a firm that wishes to keep its standards strategy hidden may prefer later participation. This, however, does not suggest that firms are fully exposed once they join an SSO. Firm participation does not necessarily equate to standards adoption. Part of the value in joining an industry SSO is the knowledge that one gains as a member. Having visibility of the activities that are occurring within a firm's industry can lead to potential competitive advantage. Firms can also use complexity to "stir up a fog" [4], since firms are often not transparent in their strategies; unpredictability is the key to effectiveness. Firms often react to the tactics of other firms, especially if another firm is a direct competitor. When a primary competitor has joined an SSO, would a firm follow suit immediately, or sit back and observe a while longer?

Under the situations described, it is easy to see how one firm's SSO participation strategy can easily influence the strategies of other firms. Numerous players are involved in the development of an industry standard, with the industry SSO itself as one of the key players. An SSO serves as the primary source for announcements and possesses the power to shape the perceptions of firms within its industry. For example, firms are likely to react when an SSO announces that a dominant player in the industry has joined the organization. Additionally, if a large technology user firm joins, technology vendors may be motivated to participate. After all, early participants play a major role in shaping a standard. We have yet to see much literature on how co-opetition strategies unfold in the presence of process standardization. As a result, it would be interesting and valuable for managers and researchers to understand how participation patterns of firms change as an industry SSO matures.

2.2. Firm Characteristics vs. Firm Strategies

Firm characteristics provide insights into firm strategies. For our study, we selected characteristics that can explain both a firm's cooperative and competitive strategy. The characteristics include R&D intensity, employee efficiency, firm size, organizational slack (with net income as a proxy), and senior management's experience (via firm age) to understand firms' strategies for SSO participation.

Gupta et al. [22], in a cross-sectional study, reveal how *production efficiency* and *R&D intensity* impact SSO participation. We have the opportunity to examine the same variables with panel data. Others have looked at production efficiency in different contexts of corporate strategies. Smith et al. [39] show that a firm's *financial characteristics*, such as *employee efficiency*, are able to explain its propensity to outsource IS. How does employee efficiency affect firms' SSO participation strategies? *Firm size*, which offers a firm certain advantages and limitations, can influence the strategies it employs. Thong [44] reports that firm size has a direct effect on IS adoption. Small firms face constraints of resource poverty, while resource availability allows large firms to foster innovation adoption [12]. These limitations and advantages associated with firm size either impede or promote SSO participation.

Another characteristic that we explore is *organizational slack*, commonly measured by a firm's net income. Organizational slack has an impact on firm sustainability and performance [29]. Firms with slack resources are able to extend beyond core business objectives to be involved in cooperative activities [38]. Finally, we look at *management experience*, which we measure by the age of the firm. Management experience has a strong relationship to firm strategies. Inexperienced firms find cooperative behavior attractive because they can gain efficiency through partnership [37]. A management's prior experience with IT can influence IT adoption and use [30]. More experienced firms participate in multiple SSOs and generally have the financial resources to be able to join earlier. They are better equipped with the knowledge to drive standards development and handle the uncertainties that are present during early stages of development. Table 1 summarizes these studies.

Table 1. Studies on Organizational Characteristics

CONSTRUCT	STUDY
R&D Intensity	R&D intensity provides insight into firms' likelihood of SSO participation [22]
Employee Efficiency	Efficiency reveals a firm's propensity to outsource IS [39]
Firm Size	Firm size has a direct effect on IS adoption [44]
Organizational Slack	Firms leverage organizational slack to achieve sustainability and performance [29]
Management Experience	Experience with IT influences IT adoption and use [30]

2.3. The Bayesian Perspective in the Strategy Context

We have chosen to explore SSO participation from a Bayesian information updating perspective. Bayes theorem focuses on the revision of the probability of some outcome based on observations of the world over time. People tend to revise their decisions based on newly-acquired information. There are multiple perspectives when it comes to studies of decision-making. Smith and von Winterfeldt [40] indicate that probability theory and Bayesian statistics provide the normative foundation in the domain of judgment and beliefs. Raiffa and Schlaifer [35] have provided some of the earliest works using Bayesian statistics in studies of decision analysis. Harsanyi [24] used a Bayesian perspective to explore player strategies in games with incomplete information. He reveals that expectations can be represented by subjective probability distributions.

So how does all of this relate to our study? Some level of uncertainty is always present in the execution of business strategy. During standards development, firms do not know *a priori* how long it will take a standard to gain industry-wide acceptance. At the start of the game, they do not know which firms, beyond the founding members, have an interest in the standard. Consider a firm that has decided the optimal time for entry into an

SSO is after a de facto standard has come into existence. However, as the firm is waiting for the standard to reach that status, it may learn that its major competitors have taken an interest in the developing standard and have decided to join the SSO. At that point, senior management may reevaluate its original strategy and decide that it is in the firm's best interest to join now because any further delay in participation may create competitive disadvantage. As a result, the original probability of when the firm would join has changed. Note the firm may not have the same reaction if the joining firms are from a different stakeholder category. Players will update their probabilities based on the types of players that join the game, as well as whatever information is revealed during the course of the game [24].

3. METHODOLOGY

We use Bayesian semi-parametric survival analysis, a Bayesian version of the Cox proportional hazards model, in our study. While survival analysis is often used in epidemiological studies, we are seeing its recent uses in studies of technology adoption and diffusion. By taking a Bayesian approach, we are able to estimate time-varying coefficients and show the impact of each independent variable on firm participation as an SSO matures.

3.1. Cox Proportional Hazards Model

The *Cox proportional hazards model*, a semi-parametric survival analysis model, is the most popular model for survival data. The Cox model is used to study the occurrence of an event. In our context, the *event* is a firm's entry into an industry SSO. The Cox model makes a parametric assumption regarding the predictors' effects on the *hazard function*, but no assumption on the nature of the hazard function $h(t)$ itself [23]. Firm characteristics, including R&D intensity, employee efficiency, firm size, net income and age of the firm, serve as indicators of its likelihood for survival. *Duration* refers to the amount of time that goes by before a new firm joins; it is measured by the age of the SSO, with its birth in 1988 as the reference point. The age of the SSO also represents the maturity of the standards organization. As an SSO matures, information is revealed, and managers will adjust their participation strategies based on it.

All of the firms eventually became members of the TM Forum. Therefore, *censoring*, which refers to cases where the event occurred prior to the study or never occurred during the period of the study, is not of concern. The probability that a firm, which has not participated up to time t, chooses to participate at time t is called the *hazard rate*. The hazard rate helps us to establish evidence for co-opetition strategy. The *survival function* is the probability a firm will participate at time t or later. A firm's hazard rate is $h_i(t, x_{it}, \beta) = h_0(t) \exp(\beta x_{it})$ 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. The parameters to estimate are β. Using the hazard rate, we can obtain a partial likelihood function for the data and parameter estimates using the maximum likelihood estimator [31].

3.2. Bayesian Information Updating Model

We extend the Cox model to create a *semi-parametric Bayesian model*. The Cox model assumes a *proportional hazard*, which means that the effect of the independent variables remains constant over time. Our use of the Schoenfeld residuals test [43] confirms that its primary assumption is met. The Cox model reveals an aggregate effect over time, which is a key limitation when studying the lifetime of an industry SSO. It fails to leverage the explanatory power of senior management's processing of new information that a semi-parametric Bayesian model offers. This kind of analysis has been applied in studies of income dynamics [25], marketing [36], and survival data [17]. The methodology has not been widely explored in IS literature; however, it is beginning to emerge. Banerjee et al. [1] leveraged a Bayesian model to examine the impacts of industry, firm and e-commerce factors on Internet firm survival.

With a *Bayesian information updating model*, we can reveal time-varying coefficients and observe relationships between explanatory variables and changes in firm participation over time. It allows us to model unknown distributions without resorting to strong parametric assumptions. The Bayes theorem focuses on obtaining the posterior distribution $p(\theta| y)$ [19]. 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 $p(\theta|y)$. Bayes theorem enables us to update existing knowledge with new information, as represented by these expressions.

SAS supports Bayesian analysis of the Cox model via WinBugs (for Bayesian inference using Gibbs sampling) [32]. The PHREG procedure in SAS uses the Gibbs sampler to generate a chain of posterior distribution samples 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 not the *joint distribution* [18]. 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. As part of the process, we run thousands of iterations and obtain a new set of values for all the parameters after each of the iterations. Extending the Cox model so that the β coefficients vary across time t, our hazard function is $h_i(t, x_{it}, \beta) = h_0(t) \exp(\beta x_{it})$.

4. DATA AND EMPIRICAL MODEL

We next discuss our data and empirical model.

4.1. Data Collection

Our data consist of 73 U.S. public firms from 1988 to 2007. They are members of the TeleManagement (TM) Forum (www.tmforum.org). Over the last 21 years, the TM Forum expanded globally, and it currently has over 700 member companies in 75 countries. Our sample includes *stakeholder* groups: *analysts*, *technology users*, *system integrators*, and *technology vendors*. Vendors include network equipment suppliers and software suppliers. Technology users consist of the following subcategories: service provider, network operator, mobile/wireless operator, cable/multiple system operator, consumer electronics and media/entertainment. Table 2 shows the number of annual new participants for each stakeholder category. We collected firm characteristics data from the COMPUSTAT North America database.

Table 2. Annual Number of New Participants

	YEAR									
	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97
Analyst										
User	1	1					1			
System Integrator		1								1
Vendor	2	1			1		4	2	2	4
Total	**3**	**3**	**0**	**0**	**1**	**0**	**5**	**2**	**2**	**5**
	YEAR									
	'98	'99	'00	'01	'02	'03	'04	'05	'06	'07
Analyst										1
User	1	2	1			2	2	1	5	3
System Integrator	1		1	1				1		
Vendor	2	3	4	3	1	4	10	2	1	4
Total	**4**	**5**	**6**	**4**	**1**	**6**	**12**	**4**	**6**	**8**

Note: We excluded four firms due to differences in their currencies.

4.2. Variables

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. *FirmAge*, as a proxy for firm maturity and management's experience, is measured based on the firm's age at the time of its SSO entry. *FirmSize* is the annual number of employees. *R&DIntensity* is calculated by taking the firm's annual R&D spending divided by its annual revenue. *NetIncome* is a proxy for organizational slack. *EmpEfficiency* is employee efficiency, as revenue / number of employees. Table 3 summarizes the dependent and independent variables. Tables 4 and 5 provide descriptive statistics.

4.3. Empirical Model

Our hazard rate $h_i(t)$ model for firm i at age t is:

$$h_i(t) = h_0(t)\ \exp[\beta_{1t}\ R\&DIntensity_{it} + \beta_{2t}\ NetIncome_{it} + \beta_{3t}\ FirmSize_{it} + \beta_{4t}\ FirmAge_{it} + \beta_{5t}\ EmpEfficiency_{it}]$$

where β_{kt} , $k = \{1,\ldots,5\}$ are the time-varying coefficients. Using an autoregressive model, AR1, the β values are updated. The model is $\beta_{kt} = \varphi\beta_{kt-1} + \varepsilon_{kt}$, $k = \{1,\ldots,5\}$, where φ are the parameters and ε_{kt} is a white noise process with zero mean and variance σ^2 [21].

Table 3. Definitions of Model Variables

VARIABLE	DEFINITION
Dependent variable	
AgeSSO	Age of TM Forum when firm joined
Independent variables	
FirmAge	Maturity of firm based on age (in years)
FirmSize	Number of employees (in thousands)
R&DIntensity	R&D spending (in millions) / revenue (in millions)
NetIncome	Net income (in millions), proxy for org. slack
EmpEfficiency	Revenue / number of employees (as above)

Table 4. Descriptive Statistics of Variables, 73 Firms

VARIABLE	MEAN	STD DEV	MIN	MAX
R&DIntensity	0.128	0.192	0	2.55
NetIncome	871.81	3,698	-38,468	14,065
FirmSize	52.43	78.14	0.023	386.56
FirmAge	24.44	25.92	-6	129
EmpEfficiency	291.78	155.09	36.45	1573

Note: The age of a firm can be a negative value if the founders of the firm joined the TM Forum before establishing their company.

Table 5. Correlation Matrix, 73 Firms

	R&D Intensity	*Net Income*	*Firm Size*	*Age Firm*	*Emp Efficiency*
R&DIntensity	1.0	-0.078	-0.260*	-0.157*	-0.154*
NetIncome	-0.078	1.0	0.442*	0.173*	0.172*
FirmSize	-0.260*	0.442*	1.0	0.576*	-0.018
FirmAge	-0.157*	0.173*	0.576*	1.0	0.100*
EmpEfficiency	-0.154*	0.172*	-0.018	0.100*	1.0

Note: Signif. * = $p < 0.05$. No pair-wise correlations are of concern.

5. RESULTS AND DISCUSSION

To obtain posterior distributions for the parameters, we used the Gibbs sampler. It generates random variables from a distribution [6] and uses *Markov chain Monte Carlo methods*, a class of simulation algorithms. We ran chains with 5,000 burn-in and 10,000 after burn-in iterations to check convergence. *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 estimation model convergence to establish the parameter estimates [20]. We checked for high sample autocorrelations, since they can result in biased Monte Carlo standard errors [14].

5.1. Bayesian Information Updating Model Results

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.

Our study of firm characteristics and industry SSO participation strategies reveals that all of the variables except employee efficiency exhibit a distinct pattern. As time progresses and the industry SSO matures, the coefficients begin to stabilize. Most of the changes in SSO participation strategies occur in the early years when the process standard is still in development mode. We next explore the SSO participation patterns for each firm characteristic as a means of getting a reading on the extent of the evidence of co-opetition strategies.

Coefficients for the Bayesian analysis model are reported in Table 6.[3] 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 no firms joined in 1990, 1991 and 1993 (Years 3, 4 and 6 in our data set), no results are reported. Coefficients can only be estimated for years in which at least one new firm joined the SSO. For 1988, 1989 and 1992 (Years 1, 2 and 5), the results did not converge to yield parameter estimates and the coefficients are not reported. This leaves us with coefficient estimates for 1994 to 2007 (Years 7 to 20) for the five variables we studied. We previously showed in Table 1 the number of new SSO participants for each year. We use box plots to display the posterior distribution results in Figure 1.

The relationship between *R&DIntensity* and the hazard rate experienced the most change from 1994 to 1999 (Years 7 to 12). It was positive in 1994 and 1995 (Year 7 and 8), became negative in 1996 and 1997 (Year 9 and 10), and increased in 1998 (Year 11) to a positive value in 1999 (Year 12). Beginning in 1999, it remained steady and was mostly positive all the way through to 2007 (Year 20). A positive coefficient shows that firms with higher R&D intensity are more likely to participate.

In the years that the TM Forum experienced an increase in the hazard rate of adoption, there were major developments in the process standard. The likelihood of SSO participation increased in 1998 and 1999 (Years 11 and 12). In 1998, the TM Forum announced the first official version of the business process framework TOM. In the following year, the TM Forum announced TOM Version 2, the version that eventually became the industry de facto standard. Starting in 1999 (Year 12), the relationship between *R&DIntensity* and the hazard rate began to stabilize.

The relationship between *NetIncome* and the hazard rate was positive for all the years except 2002 (Year 15). The positive coefficients reveal that for the majority of the years, firms with higher net income or more organizational slack were more likely to participate. The estimated coefficient increased in 1996 (Year 9) and again in 1998 (Year 11). Similar to *R&DIntensity*, the estimate began to stabilize in 1999 (Year 12). With the first increase in 1996, there was no corresponding process-related announcement, but the increase in 1998 coincided with the first official release of TOM.

The relationship between *FirmSize* and the hazard rate showed the most change from 1994 to 1997 (Years 7 to 10). For all the years from 1994 to 2000 with the minor exception of 1996 (Year 9), the estimate was positive. Thus, larger firms were more likely to join the industry SSO. The estimated coefficient experienced a sharp decrease in 1996 (Year 9 in our data set) and became negative. Thereafter, it became positive again in 1997 (Year 10).[4] 1997 was when TOM was introduced as part of the SMART TMN initiative. In 2003 (Year 16), when eTOM became the de facto standard, the hazard rate dropped.

The relationship between *FirmAge* and the hazard rate changed the most from 1994 to 1996 (Years 7 to 9). It increased up to 1996 (Year 9) and stabilized. For all of the years minus 2006 and 2007 (Years 19 and 20), the hazard rate was negative. This suggests that less experienced firms were more likely to join the SSO than more experienced firms. The final variable we explored is *Emp Efficiency*. The relationship between *EmpEfficiency* and the hazard rate changed between positive and negative values during the study period. It increased in 1995, 1997 and 1999 (Years 8, 10 and 12). These years had key process-related events. In 1995, the TM Forum announced the Service Management Business Process Model, the first authoritative work on *telecom business process re-engineering,* and the TOM was introduced in 1997. In 1999, the SSO announced TOM Version 2, so the estimates make sense.

5.2. Discussion

It was difficult to conclude if firms with higher R&D intensity were more likely to participate in an industry SSO. The TM Forum has a mixture of stakeholders. Technology vendors have R&D spending; others (users and systems integrators) do not. So technology vendors are generally the dominant stakeholder in an SSO, which is why the hazard rate was mostly positive for the 14 years we analyzed. Firms undertaking R&D efforts are more likely to engage in cooperative arrangements for innovation [16]. Cooperation is advantageous in that it minimizes the risks associated with innovation.

[3] They reflect the use of data up to the year to which the coefficient estimate applied, as is common in Bayesian information updating analysis. This shows the *aggregate behavior* that results from individual firms' senior managers updating their reading on the appropriateness of SSO participation.

[4] We are continuing our data analysis for this and the other variables to ensure that there are no anomalies that are damaging the smoothness of the trajectory of the estimated Bayesian coefficient values.

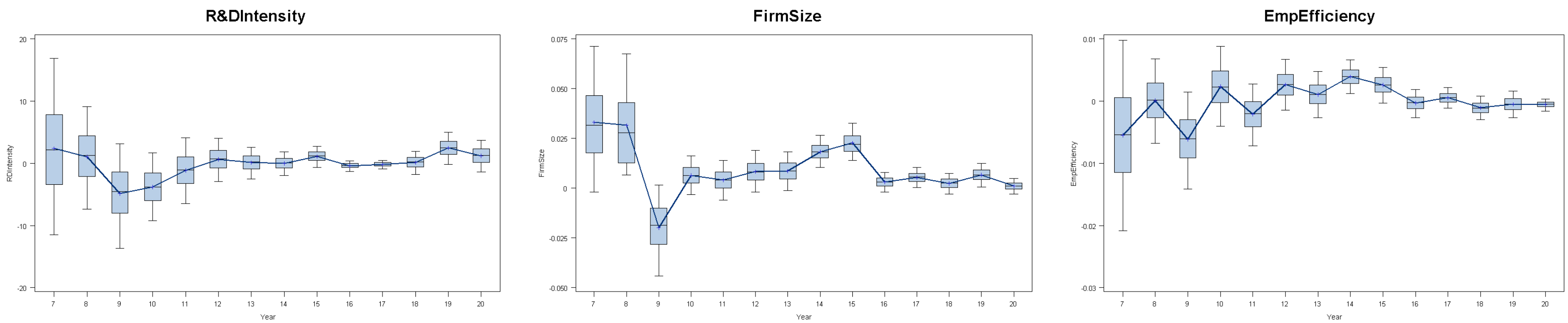
Table 6. Bayesian Information Updating Analysis Model Results

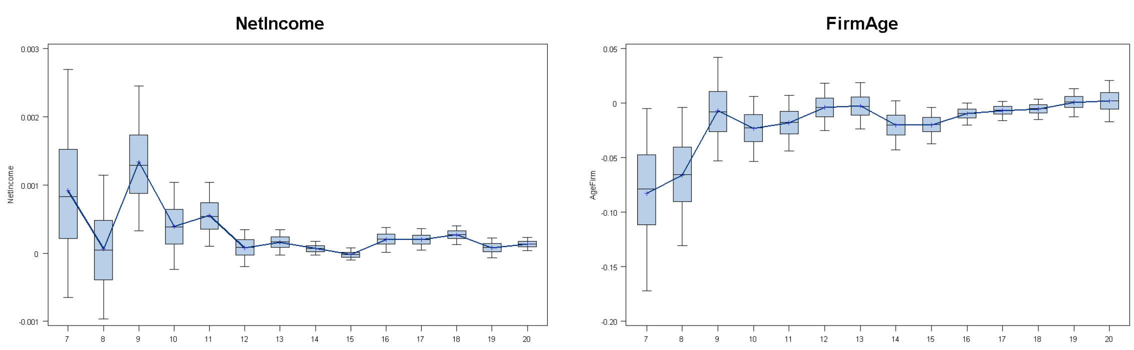
Variable	Posterior Distribution Percentile	Duration (*Age of SSO* in Years)									
R&DIntensity		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	2.5	N/A						-14.20	-9.13	-15.58	-10.39
	5.0							-11.46	-7.37	-13.63	-9.24
	50.0							2.13	1.29	-4.53	-3.83
	95.0							16.88	9.11	3.11	1.69
	97.5							20.36	10.62	4.50	2.84
		11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	2.5	-7.65	-3.57	-3.06	-2.35	-0.99	-1.48	-1.09	-2.16	-0.68	-1.89
	5.0	-6.50	-2.90	-2.53	-1.93	-0.63	-1.27	-0.92	-1.77	-0.17	-1.41
	50.0	-1.03	0.67	0.20	0.07	1.16	-0.34	-0.15	0.20	2.48	1.27
	95.0	4.12	4.04	2.57	1.86	2.73	0.40	0.43	1.89	5.03	3.73
	97.5	5.14	4.74	3.00	2.22	3.03	0.53	0.53	2.18	5.55	4.20
NetIncome		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	2.5	N/A						-0.00096	-0.00115	0.00016	-0.00036
	5.0							-0.00065	-0.00096	0.00033	-0.00024
	50.0							0.00083	0.00004	0.00129	0.00039
	95.0							0.00269	0.00114	0.00245	0.00104
	97.5							0.00311	0.00137	0.00269	0.00119
		11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	2.5	0.00002	-0.00026	-0.00007	-0.00005	-0.00012	-0.00002	0.00002	0.00010	-0.00010	0.00002
	5.0	0.00010	-0.00020	-0.00003	-0.00003	-0.00010	0.00001	0.00004	0.00013	-0.00007	0.00003
	50.0	0.00054	0.00009	0.00016	0.00007	-0.00002	0.00021	0.00020	0.00027	0.00008	0.00014
	95.0	0.00104	0.00034	0.00035	0.00018	0.00008	0.00037	0.00036	0.00040	0.00022	0.00024
	97.5	0.00114	0.00039	0.00038	0.00020	0.00010	0.00040	0.00039	0.00043	0.00025	0.00025
FirmSize		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	2.5	N/A						-0.0083	-0.0130	-0.0501	-0.0054
	5.0							-0.0018	-0.0066	-0.0442	-0.0032
	50.0							0.0315	0.0278	-0.0185	0.0064
	95.0							0.0713	0.0674	0.0015	0.0162
	97.5							0.0796	0.0758	0.0046	0.0184
		11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	2.5	-0.0082	-0.0039	-0.0033	0.0092	0.0124	-0.0031	-0.0008	-0.0042	-0.0006	-0.0036
	5.0	-0.0061	-0.0020	-0.0013	0.0105	0.0139	-0.0020	0.0003	-0.0030	0.0006	-0.0029
	50.0	0.0042	0.0081	0.0088	0.0182	0.0221	0.0032	0.0055	0.0025	0.0068	0.0011
	95.0	0.0139	0.0191	0.0182	0.0265	0.0326	0.0080	0.0104	0.0074	0.0125	0.0049
	97.5	0.0159	0.0215	0.0202	0.0283	0.0349	0.0088	0.0113	0.0084	0.0136	0.0056
FirmAge		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	2.5	N/A						-0.195	-0.145	-0.063	-0.059
	5.0							-0.172	-0.131	-0.053	-0.054
	50.0							-0.079	-0.065	-0.008	-0.023
	95.0							-0.005	-0.004	0.042	0.006
	97.5							0.009	0.009	0.054	0.012
		11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	2.5	-0.049	-0.030	-0.028	-0.047	-0.041	-0.022	-0.018	-0.018	-0.015	-0.021
	5.0	-0.044	-0.025	-0.023	-0.043	-0.037	-0.020	-0.016	-0.015	-0.012	-0.017

VARIABLE	POSTERIOR DISTRIBUTION PERCENTILE	DURATION (*AGE OF SSO* IN YEARS)									
	50.0	-0.018	-0.004	-0.003	-0.020	-0.020	-0.009	-0.007	-0.005	0.001	0.002
	95.0	0.007	0.018	0.019	0.002	-0.004	0.000	0.002	0.004	0.013	0.021
	97.5	0.012	0.023	0.023	0.006	-0.001	0.002	0.003	0.005	0.015	0.024
EmpEfficiency		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	2.5	N/A						-0.0243	-0.0081	-0.0157	-0.0052
	5.0							-0.0208	-0.0068	-0.0141	-0.0040
	50.0							-0.0054	0.0001	-0.0061	0.0023
	95.0							0.0097	0.0068	0.0015	0.0088
	97.5							0.0131	0.0080	0.0029	0.0103
		11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	2.5	-0.0082	-0.0022	-0.0033	0.0007	-0.0010	-0.0032	-0.0015	-0.0033	-0.0032	-0.0018
	5.0	-0.0072	-0.0014	-0.0026	0.0012	-0.0004	-0.0027	-0.0012	-0.0030	-0.0027	-0.0016
	50.0	-0.0021	0.0027	0.0011	0.0040	0.0026	-0.0002	0.0005	-0.0011	-0.0005	-0.0005
	95.0	0.0028	0.0067	0.0047	0.0066	0.0054	0.0018	0.0022	0.0008	0.0016	0.0004
	97.5	0.0037	0.0075	0.0055	0.0071	0.0060	0.0022	0.0025	0.0011	0.0021	0.0005

Note: For each parameter estimate, we show the 95% credible interval, a posterior probability interval, using the 2.5 and 97.5 percentiles and the 90% credible interval using the 5 and 95 percentiles.

Figure 1. Boxplots 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. A positive coefficient indicates that there is a positive relationship between a particular firm characteristic and the hazard rate. It reveals a firm's instantaneous likelihood to participate at a particular point in time.

We find that firms with more slack were more likely to participate. Less slack indicates resource constraints. Firms with no slack have a difficult time in extending beyond a primary corporate objective [13]. Slack enables a firm to take on more risk, such as introducing new products and entering new markets [33]. It fosters a culture for experimentation and creative behavior since slack protects firms from uncertainty in new projects [3].

Porter [34] states that firm size is a strong indicator of the scope of the firm's operations and its power to influence industry structure. We expect very small and very large firms to have different SSO participation strategies. Large firms have much intellectual property, so they do not want to be put into sharing regimes unless they know they can control the outcome. For innovations that are new to market, large firms have a higher propensity for cooperation [42]. Our data reveal that larger firms had a higher likelihood of SSO participation. Large firms' ability to achieve economies of scale makes it difficult for smaller firms to compete against them. As a result, we expect large firms to leverage the same advantage during standards development.

The SSO participation strategies of more experienced firms were harder to predict. Their strategies may be more complex or less transparent. As co-opetition theory reveals, complexity "stirs up a fog." On the other hand, less experienced firms had higher likelihood of participation all around. Employee efficiency did not reveal a trend; we are still trying to sort out why.

6. CONCLUSION

We used Bayesian information updating analysis to analyze the changing relationship between firm characteristics and industry SSO participation strategies over a 20-year period in order to understand firms' co-opetition strategies in the presence of process standardization.

6.1. Contributions

Co-opetition, a business strategy that combines elements of cooperation and competition, is present during standards development. We posit that a firm's co-opetition strategy is revealed to some extent by when it elects to join an industry SSO. We studied organizational characteristics to discover what they reveal about firm SSO participation strategies. Using Bayesian information updating analysis, we showed how firms' SSO participation strategies change when managers' beliefs and uncertainties are factored into decision-making. Firms are heterogeneous over time. The Bayesian analysis model allows us to estimate time-varying coefficients and examine how the relationship between the explanatory variables and the firms' participation strategies evolves.

Our results reveal that SSO participation strategies of firms do change as an industry SSO matures and information is gradually revealed. The hazard rate exhibits more change in the early years when an SSO is young and a process standard is still in its early stages of development. An interesting finding from our study is that the hazard rate stabilizes years before a standard becomes a de facto industry standard. We discovered that the hazard rate began to stabilize in 1999 (Year 12 of the timeline of our data observations) with the release of TOM Version 2. This was five years before eTOM became a de facto standard. Possible explanations include firms' rational expectations of the viability of a standard drives them to join, or an averaging effect of the beginning and ending behaviors of the firms. Another key finding is that R&D intensity fails to offer any strong insight into firm SSO participation strategy. This is surprising since a firm's R&D goals are heavily tied to its standards goals. Additionally, we find that there is a positive relationship between firm likelihood to participate and key process-related announcements. This confirms that when an SSO releases information regarding critical developments of a standard, it will affect firm SSO participation strategy.

6.2. Limitations

Our research has the following limitations. The first limitation is that our study is based on one industry SSO. Consequently, the findings may not be representative of all industry SSOs, which makes it difficult for us to generalize the results. Second, the sample consisted only of public firms since it was easier to obtain secondary data on publicly-traded firms, which means the results may not illustrate the behaviors of private firms. Additionally, we focused on firms in the United States only. The TM Forum is a global organization, and many of its members are from Europe and Asia. Because some regions may be more susceptible to contagion effects, participation strategies can vary across the different regions.

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