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Web Technology Adoption and Knowledge Barriers

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Much of the technology diffusion research has focused on the "intention to adopt" of an adopting unit to explain its adoption behavior; the opportunity for adoption and the underlying adoption propensity are often not differentiated. However, the opportunity to adopt need not be uniform among adopting units. From the perspective of organizational learning, we argue that the differential opportunity to adopt originates from knowledge barriers (KB) and varied degrees of involvement of supply-side institutions (SSI) that can lower these barriers. In this article, we investigate the effect of such KBs and SSIs on the timing of adoption of the World Wide Web technology. The results confirm the major hypothesis of this study: that KBs delay adoption time and indicate the significant explanatory power that the learning perspective can add to the traditional adoption model. The findings of this study (a) explain why certain firms delay their adoption of potentially profitable innovations, (b) imply suitable diffusion strategies for firms promoting innovations, and (c) provide information on the adoption of World Wide Web technology.

technology adoption, knowledge barrier, World Wide Web,
supply-side institution, organizational learning

1. INTRODUCTION

In the recent past, the Internet and the World Wide Web (Web) have emerged as technologies that can revolutionize communication and business processes in organizations. However, recent reports indicate that the adoption of Web technology is not the smooth sailing many organizations assumed it would be and that lack of relevant knowledge portends significant barriers that may delay or otherwise impact the adoption process [1–5]. What impact do knowledge barriers (KB) have on Web

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technology adoption? Existing adoption models provide limited insights into how the lack of relevant knowledge may impact technology adoption.

With the emergence of highly knowledge-intensive technologies (e.g., the Web, hyper-media, data warehouses), the traditional paradigms of technology diffusion are increasingly being questioned.[1] Much of the technology diffusion research has focused on the intention to adopt of an adopting unit to explain its adoption behavior; the opportunity for adoption and the underlying adoption propensity are often not differentiated. In this article, we differentiate between adoption opportunity and adoption propensity and suggest that the opportunity to adopt critically influences the timing of technology adoption. Thus, one of the key objectives of this study is to determine the additional explanatory power that the opportunity to adopt dimension can contribute to the traditional adoption model.

Technology diffusion is much more than a mere transfer of information from the source of the innovation to the adopting units; often, it involves the creation of new knowledge by adopting units. From the perspective of organizational learning, we argue that the differential opportunity to adopt originates from KBs faced by potential adopters [6]. Organizations may address such KBs by seeking the assistance of supply-side institutions (SSI; e.g., external consultants). This perspective of technology diffusion raises two interesting research questions:

1. To what extent does the KB faced by a firm, with respect to a technological innovation, affect the timing of adoption?
2. To what extent does the involvement of SSIs facilitate early adoption?

In this article, we address the previous questions in the context of Web technology adoption. More specifically, we examine the impact of KBs on the timing of Web technology adoption at two levels: (a) the corporate Web site and (b) the corporate intranet. The remainder of the article is organized as follows. In the next section, we differentiate between intention to adopt and opportunity to adopt and introduce the concept of the KB. Following that, we describe the research model. In Section 3, we explain the data and the research methodology. This is followed by a discussion of the results and their key implications.

2. THEORETICAL BACKGROUND AND HYPOTHESES

2.1 Intention to Adopt Versus Opportunity to Adopt

Traditional models of technology diffusion [7, 8] assume that all adopting units enjoy the same opportunity to adopt and that adoption behavior is merely a reflection of the varying intention to adopt (or innovativeness) of different adopting units. Intention to adopt is characterized in the literature by economic factors (e.g., cost, profitability, relative advantage) and behavioral–usage factors (e.g., complexity, ease of use, compatibility, observability) [8–10]. Such a demand-side focus of the

[1] The diffusion theoretic approach [8] and economic approach [7] are representative of the traditional models of technology diffusion.

technology diffusion research has been criticized [11], and the development of the organizational learning paradigm [12, 13] may serve to correct this imbalance in innovation studies.

According to the communications perspective of innovation diffusion, a potential adopter can acquire both *awareness knowledge* (which relates to factual information about the innovation) and *how-to-knowledge* (which refers to the knowledge required to productively utilize the innovation in a particular work context) associated with an innovation from external sources; that is, they could be transferred from one context to another [8, 14]. Although such an assumption might have been true for first-generation information technologies (ITs; e.g., spreadsheets, databases), it is particularly untenable, however, for the utilization of the more knowledge-intensive and complex technologies, where the how-to-knowledge "often has to be discovered *de novo* within the user organization" ([6], p. 6). In other words, far from being easily transferable to the user organization, the how-to-knowledge may face barriers and be relatively immobile [15, 16]. In the information systems (IS) literature also, studies have indicated the presence of such KBs [17, 18].

Thus, the organizational learning perspective of technology diffusion [6] suggests that the adoption of technological innovations involves the creation of new knowledge by adopting units and firms that are unable to carry out this knowledge creation process may be prevented from adopting the innovation, even if they have the intention to adopt. In other words, the opportunity to adopt a given innovation may differ among adopting units based on their ability to address the innovation-based learning needs. Such a perspective is more accurate in the case of newer ITs. Until recently, the range of uses to which IT could be applied tended to be fairly well defined and limited; in other words, there were a handful of ways in which a technology could be utilized. However, with the emergence of more knowledge-intensive technologies such as the Web and data warehousing, opportunities for their exploitation are not so clearly defined and apparent and are often highly context and firm specific. Such technologies have been characterized in recent literature as advanced information technologies [19], malleable, and exhibiting greater levels of interpretive flexibility [20].

Given this, the importance of the opportunity to adopt dimension in studying technology adoption and diffusion is apparent. In this study, our focus was on the differential opportunity to adopt among firms arising from potential KBs and on the involvement of SSIs that can lower these barriers. Next, we briefly discuss the various levels of Web technology adoption and then present the research model.

2.2 Web Technology Adoption

Three broad levels of Web technology adoption can be identified: (a) information access, (b) work collaboration, and (c) core business transactions [21, 22]. At the lowest level, Web technology can be used as a tool for disseminating information about products–services, corporate mission, organizational policies, and so on and to channel feedback from internal–external entities (e.g., employees, customers, investors). At the next level, it can be used to facilitate real-time work collaboration

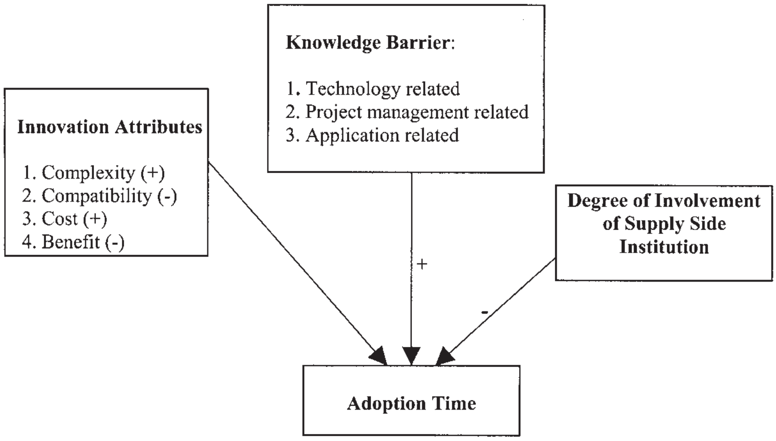

Figure 1. The research model.

and document flow between different entities within or without the organization. At the third and highest level, Web technology can be directly integrated with the core business processes and transactions.

Within each level, adoption may involve different degrees of complexity. For example, at the first level, information dissemination can occur via a passive mode (e.g., establishing the corporate Web site) or a more active manner (e.g., using "push" technologies). Similarly, work collaboration can involve mere sharing of documents (e.g., via an intranet) or more complex Internet-based collaborative decision making and conferencing. Finally, at the third level, core business transactions may involve providing simple facilities for online order placement or may involve highly integrated business transactions across the supply chain (e.g., extranet-based vendor replenishment system).

In this article, we examine Web technology adoption at two levels: information dissemination and work collaboration. For the purposes of this study, adoption of Web technology for information dissemination is defined as the establishment of the corporate Web site, and adoption for work collaboration is defined as the implementation of the corporate intranet.

2.3 Research Model

Figure 1 presents the research model. The objective was to find whether the opportunity to adopt dimension (characterized here by the KB and the degree of involvement of SSIs added any explanatory power to the traditional adoption model. Thus, to enable us to compare and determine the additional explanatory power, we incorporated the traditional adoption model [8] in our research model through the four important innovation attributes (complexity, compatibility, cost, and relative advantage) [9].

2.3.1 KB and Timing of Adoption. The KB associated with an innovation relates to the gap between the learning requirements posed by the innovation and the existing knowledge level of the adopting unit. The learning requirements vary based on the nature of the innovation and the extent of its deployment within the adopting unit. For example, a firm using Web technology to maintain an electronic catalog of its products–services on the Internet may require much less knowledge creation compared to if it were integrating the technology with its internal business processes. On the other hand, firms vary in their ability to address the learning requirements associated with an innovation [14].

With respect to Web technology, KBs can be examined along three dimensions:

1. *A technology-related KB:* relates to the lack of knowledge regarding the appropriate hardware and software infrastructure, technology features, security, standards, vis-à-vis the unique business context of the organization.
2. *A project-related KB:* refers to the lack of knowledge regarding resource requirements (financial, human) for Web-based application development, development methodology–process–duration, project leadership, functional participation, and so on.
3. *An application-related KB:* relates to the lack of knowledge regarding the business objectives that will be served by the Web-based application, the value of the various technology features for the adopting unit, the key business assumptions required to be made for deploying the technology, the potential for integrating the application with existing IT applications, and the impact of the Web application on the current organizational structure and systems [21–23].

To address the knowledge gap, organizations may decide to create the new knowledge internally or seek external assistance. In either case, it involves additional time and introduces potential delay in the adoption process. Internal knowledge creation involves considerable organizational learning. Organizations need to capture the required factual knowledge and convert it gradually into firm-specific and context-specific knowledge [24]. On the other hand, a more common response of organizations facing KBs is to seek external assistance [6]. This introduces delay as it involves searching for suitable external agencies that can provide the required services, establishing mutually beneficial contracts, developing the required trust and relationships, and so on [25]. In addition, deployment of knowledge-intensive technologies (e.g., Web technology) calls for a much deeper involvement of the external agency in the adoption process, thereby further enhancing the delay.

The higher the KB is for an adopting unit, the more likely that adoption will be delayed. Note that the KB is not linked to the adoption decision but only to the time of adoption. Furthermore, we differentiate between the three types of KBs and argue that, although all of them are likely to delay the adoption, they may impact the adoption time to different degrees. Hence we have the following hypotheses:

H1: The lower the KB of an adopting unit is, the earlier the adoption will occur.

H1a: The lower the technology-related KB of an adopting unit is, the earlier the adoption will occur.

H1b: The lower the project-related KB of an adopting unit is, the earlier the adoption will occur.

H1c: The lower the application-related KB of an adopting unit is, the earlier the adoption will occur.

2.3.2 SSIs and the Timing of Adoption. When an adopting unit faces a KB, it may employ the services of external agencies or SSIs [6]. SSIs come into play where knowledge is scarce and learning is burdensome and may play roles ranging from training the organization members to create the new knowledge themselves to being active participants in the knowledge creation process. Indeed, the SSI may be viewed as an intermediary in the process of creating the knowledge required for adopting an innovation, and the services provided by them complement the new product (or innovation). Two factors portend the important role of such knowledge intermediaries in Web technology adoption: (a) the rapid and continuous changes in the underlying technologies that create new KBs and (b) the lack of key Web-based development skills in the internal IS departments of the adopting units [1, 21].

The interaction of the SSI with the adopting unit may occur at multiple levels, including the technology level, project or system level, and business level. At the technology level, the focus of the interaction would be on providing factual knowledge on the technology and analyzing the suitability of various technologies vis-à-vis the unique infrastructural requirements of the firm. At the project or system level, the primary focus is on providing managerial and technical guidance in executing the design and implementation of Web application projects. At the business level, the interactions are at a much broader level and focus on integrating the business and the technology [22]. In the context of Web technology, it would include, for example, being actively involved in identifying the target community for the corporate Web site, in defining the criteria and policies for intranet content management, and in redesigning business processes to exploit Web technology. The changed role of the SSI (from a knowledge transfer agent to a knowledge creation partner) has important implications on its interactions with the adopting unit and consequently on the adoption process. The greater the intensity of interactions of the SSI with the adopting unit, the tighter its integration with the adoption process will be. This in turn enables the adopting unit to exploit the economies of learning that the SSI brings to the table and to derive critical time advantages in the adoption process [6, 18]. Hence, we argue that given the same level of KB, organizations that interact with their SSIs at all three levels (i.e., have a greater degree of involvement) adopt the technology earlier.

H2: The greater the degree of involvement of the SSI is, the earlier the adoption will occur.

2.3.3 Control Variables. We incorporate two control variables in our research model: (a) firm size and (b) competitive intensity. Researchers have found firm size to be an important variable in adoption [8, 26, 27]. Firm size has been used as a surrogate measure for slack resources as well as for risk-taking propensity. Here, we need to control for firm size as larger firms may have more extensive resources that may impact the timing of adoption. Similarly, competitive intensity has been identified as an important variable to influence adoption [28]. Firms may be forced to adopt certain innovations due to competitive pressure [29, 30]. Because the respondents in this study belonged to multiple industries with varying levels of competitive intensity, we decided to include competitive intensity as the second control variable.

3. RESEARCH METHOD

3.1 Method and Data

The data for validating the hypotheses were collected with the survey method in two phases. Study A, conducted in 1997, focused on the lowest level of Web technology adoption, that is, establishment of the corporate Web site. Study B, conducted in 1999, focused on Web technology adoption at the second level, that is, establishment of the corporate intranet.

A preliminary version of the survey questionnaire was developed based on a literature review and on interviews with IS managers in four large organizations that had recently adopted Web technology and with four Web technology service providers in the state of New York. The multi-item constructs method was used with each item measured based on a 7-point Likert scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*). Table 1 describes the research variables, and Table 2 describes the scales used for the two key constructs: KB and degree of involvement of the SSI. Three multi-item scales were developed to measure the three types of KBs. The items for technical knowledge (three items) were related to knowledge on Web technology features and the software and hardware infrastructural requirements. Items on project management (four items) were related to project activities, functional involvement, project duration, and personnel skills. Items on application knowledge (eight items) were related to the type–nature of applications, the business objectives that were served, and so on. The overall KB was operationalized as the simple mean of the three types of KBs.

The degree of involvement of the SSI was operationalized with a nine-item scale that included items on interactions at the technology, project, and business levels. The innovation attributes of complexity, cost, compatibility, and relative advantage were measured with items that were adapted from existing validated scales [26, 31, 32]. Firm size was measured as the natural logarithm of the annual sales revenue. Competitive intensity was measured with a single-item measure [33]. The two studies shared the same survey instrument except for a minor difference. For the second study, the survey instrument was modified by the replacement of the words *Web site* with the word *intranet* in the various items to denote the change in focus on the level of adoption.

For the pilot test, the survey instrument was sent to 29 organizations belonging to multiple industries in the state of New York, and 25 completed responses were received. The respondents were encouraged to comment on the length, wording, and instructions of the instrument. On the basis of the feedback, a few items were reworded. The data were also used to assess the reliability of the key construct scales. All the key constructs displayed acceptable reliability levels (Table 3).

For Study A, the survey questionnaire was sent to approximately 650 organizations in New York state in 1997.[2] The head of the IS department or the manager responsible for Web-based development was asked to respond to the survey. Follow-up questionnaires were mailed 2 weeks later. One hundred forty-eight completed responses were obtained (a response rate of 22%). For Study B, the sur-

[2] These organizations were members of a general commerce association that sponsored this study. The organizations were from different industries.

Table 1
Definition of Variables

Variable	*Description of the Measure*
Adoption time	Elapsed time until adoption is the time from the start of the observation until the adoption (i.e. when the firm first established its corporate Web site or Intranet) or until the observation period ends, whichever is earlier.[a]
Knowledge barrier technology project management application	Perceived knowledge gap on Web technology features, project activities, potential applications, benefits, and so on (also see Table 2).
Degree of involvement of SSI	Intensity of interactions at technology, project–system, and business levels (9 items; also see Table 2).
Cost	Cost of establishing a corporate Web site or intranet (2 items) [26, 32].
Benefit	Benefits of establishing a corporate Web site or intranet (2 items) [26].
Complexity	Complexity of establishing a corporate Web site or intranet (2 items) [26, 32]).
Compatibility	Compatibility of Web technology with other IT in use in the organization (2 items) [31, 32].
Firm size	Annual sales revenue (1 item)
Competitive intensity	Perceived competitive intensity within the industry (1 item) [28].

Note. SSI = supply-side institution.
[a]The observation period for Study A was Jan. 1995 to Aug. 1997 and for Study B was Jan. 1996 to Jan. 1999. The beginning dates for the two observation periods (Jan. 1995 for Level 1 adoption and Jan. 1996 for Level 2 adoption) were decided based on commonly accepted notions regarding the commencement of Web technology adoption (corporate Web sites and intranets) in business organizations in the United States. [22, 46, 47].

vey questionnaire was sent to the same set of organizations in 1999. One hundred thirteen completed responses were obtained (a response rate of 17%).

KB was measured retrospectively (i.e., respondents were asked to rate the knowledge gap of the organization when it started initial investigations for the establishment of a corporate Web site–intranet). To ensure reliable responses to the questions, only those responses where the respondent's tenure in the organization was longer than the time of adoption was included in the analysis. Thus, for Study A, out of the 148 responses, only 137 were used. For Study B, out of the 113 responses, only 103 were used. No significant respondent bias was evident when the research variables were compared across firm size (in terms of revenue) or across time–date waves of respondents. Table 4 summarizes the characteristics of the respondents. The majority of the respondents held the title of Director–Head–Manager of IS. The responding organizations covered a cross-section of industries, and this diversity strengthens the external validity of the study results. Of the 137 respondents in Study A, 63 (46%) had established the corporate Web site at the time of the study. In Study B, of the 103 respondents, 38 (37%) had implemented the intranet at the time of the study.

The measurement instrument was tested for various validity and reliability properties. To ensure content validity (representativeness or sampling adequacy of the construct domain), a review of the relevant literature was combined with interviews of IS managers in eight organizations. In the pretest, the instrument was put to qualitative testing of construct validity. Personal interviews were conducted with five IS managers in three organizations to locate and correct weaknesses in the questionnaire. Principal components analysis was conducted with varimax rotation to verify the discriminant and convergent validity of the key multi-item constructs. The standard criteria of eigenvalues greater than 1.0, a factor loading greater than 0.3, and a well-explained factor structure were used in the analysis [34]. The results are shown in Table 5. The results indicate that all the key constructs exhibit adequate validity. Reliability of measurement was as-

Table 2
Description of Scales: Knowledge Barrier and Degree of Involvement of the SSI

Construct
Knowledge barrier
My organization, when it started its investigation of the World Wide Web technology, had knowledge gap related to
Technology (3 items)
The features and capabilities of the Web technology
The type of software required to create and maintain a Web site
The type of computer hardware required to create and maintain a Web site
Project management (4 items)
The type of personnel skills required to create and maintain a Web site
The specific activities required to create and maintain a Web site
Persons/departments that should be involved in the Web site project
The likely duration of the Web site project
Application (8 items)
The nature of benefits that can be realized
The target community for the Web site
The nature of business activities that can be carried out through the Web site
The functions/departments that may benefit from the Web site
The nature of the costs associated with creating and maintaining the Web site
The nature of content most likely to be beneficial for the organization
The time that it would take for the benefits to be realized
The specific competitive advantage that the organization may derive
Degree of involvement of SSI
My organization, when it started its investigation of the World Wide Web technology, had knowledge gap related to
The SSI (9 items)
Demonstrated the features/use of the Web technology
Provided training on the Web technology
Helped formulate the plan for the Web site creation project
Assisted in implementing the required software and hardware infrastructure
Was responsible for creating the Web site
Helped identify the potential benefits for my organization
Was involved in defining the business objectives of the Web site
Was involved in defining content selection criteria and policies
Was involved in devising the overall strategy for the corporate Web site

Note. Based on a 7-point Likert scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*). For Study B, the words *Web site* were replaced with *intranet* to reflect the focus on the second level of Web technology adoption. SSI = supply-side institution.

sessed through Cronbach's alpha, which tests the stability of the scale. Table 6 shows the reliability of the constructs and their basic statistics. As the data indicate, the reliabilities of all multi-item scales were above the .6 level generally deemed sufficient for field work [35].

3.2 Adoption Probability

We assume that an adopting unit's probability of adoption is related to innovation and firm characteristics; cross-sectional differences in these characteristics drive the differences in adoption dates [36]. In other words, the time until adoption for a firm is conditional on the explanatory variables and follows some distribution, the exponential or Weibull distribution, for example. The study used adoption data indicat-

Table 3
Pilot Test: Reliability of Key Constructs

Construct	*Reliability*[a]
Technology-related knowledge barrier	.81
Project-management related knowledge barrier	.78
Application-related knowledge barrier	.73
Degree of involvement of supply-side institution	.72

Note. $N = 25$.
[a]Standardized Cronbach alpha.

Table 4
Characteristics of the Respondents

Characteristic	*Study A*[a]	*Study B*[b]
Respondent titles		
Director/head of IS	66	45
IS manager	26	39
Web master	5	9
Others	3	7
Respondent's tenure in organization		
Less than 2 years	2	4
2 to 4 years	36	33
5 to 10 years	49	55
More than 10 years	13	8
Industry		
Manufacturing	34	29
Wholesale/retail	26	22
Financial services	23	32
Health care	7	3
Others	10	14
Revenue		
Greater than 100 million	44	33
Between 10 and 100 million	51	63
Less than 10 million	5	4

Note. IS = information system.
[a]$n = 137$. [b]$n = 103$.

Table 5
Validity Analysis

Construct	*No. of Items*	*Eigenvalue*	*Variance Explained*
Technology-related KB	3	1.68	8.70
Project-management related KB	4	1.19	5.41
Application-related KB	8	3.02	12.3
Degree of involvement of SSI	9	4.38	28.2

Note. N = 137. An analysis done on Study B data also resulted in similar validity levels. KB = knowledge barrier; SSI = supply-side institution.

Table 6
Descriptive Statistics

	Study A[a]			*Study B*[b]		
Construct	*M*	*SD*	*Reliability*[c]	*M*	*SD*	*Reliability*[c]
Overall KB	3.3	1.12	—	3.1	1.09	—
Technology-related KB	4.2	1.23	0.84	3.8	1.13	0.83
Project-management related KB	3.2	1.65	0.82	3.3	1.25	0.79
Application-related KB	3.1	1.32	0.75	2.9	1.04	0.76
Degree of involvement of SSI	4.2	1.47	0.77	3.9	0.91	0.78
Cost	3.6	0.88	0.78	3.7	1.38	0.81
Benefit	4.1	1.35	0.82	3.6	1.15	0.81
Complexity	4.3	1.46	0.84	4.1	1.06	0.82
Compatibility	3.6	1.61	0.77	3.9	1.11	0.76

Note. KB = knowledge barrier; SSI = supply-side institution.
[a]n = 137. [b]n = 103. [c]Standardized Cronbach alpha.

ing how long it took for each firm to adopt Web technology (i.e., when the corporate Web site was first posted on the Internet and when the intranet was first implemented). Because our observations of adoption times are *right-censored* (i.e., some firms had not adopted Web technology at the time of the study), we employed an econometric technique called *hazard modeling*, which accommodates censoring [37–39]. Hazard models can explicitly incorporate covariates in the specification of time or probabilities to adopt so that the population is heterogeneous in the timing of adoption. Hazard models overcome limitations of previous work on technology adoption using cross-sectional models (e.g., regression) and are particularly important in studying the innovation diffusion process [40]. However, they have appeared in very few studies [36, 41].

To test Hypotheses 1 and 2, we constructed and estimated a hazard model. The elapsed time to adopt or the failure time for a firm in the sample was the time from the start of observation until the adoption of Web technology occurred or the observation period ended, whichever was earlier. Here, the elapsed time to adopt, T, was a nonnegative random variable from a population of n independent firms and was conditional on explanatory variables. With a Weibull distribution[3] of T, the

[3]The Weibull distribution is a functional form that has been used in modeling technology diffusion and is considered more appropriate in the early stages of the diffusion process [36, 45].

conditional probability that firm *i* will adopt Web technology at time *t*, given that it has not done so by $t - 1$, is specified as

$$h_i(t) = \alpha t^{\alpha - 1} * e^{-\beta X_i} \,,$$

where X_i is a vector of explanatory variables for firm *i*, β is a column vector of unknown coefficients to be estimated,[4] and $\alpha t^{\alpha - 1}$ is used to allow the hazard rate itself to be a function of time. The conditional probability function, $h_i(t)$, is often referred to as the *hazard function* in the literature.[5]

4. RESULTS AND DISCUSSION

To determine whether a firm's opportunity to adopt added any explanatory power to the traditional adoption model, we constructed and compared three hazard models. Model 1 incorporated the traditional innovation attributes [8], namely, cost, benefit, complexity, and compatibility, whereas Model 2 included two additional constructs, overall KB and degree of involvement of SSI. Model 3 varied from Model 2 in that it incorporated the three individual components of KB.

For both Studies A and B, the results of the first estimation (Table 7) are largely supportive of the traditional innovation attributes: Benefit and compatibility had a negative impact on adoption time, whereas complexity had a positive impact.[6] The results of the second estimation (Table 8) show that KB did impact the timing of adoption. Firms with higher KB took more time to adopt. Similarly, the results also indicate that the degree of involvement of the SSI impacted adoption time. Thus, Hypotheses 1 and 2 were supported by both studies. The results of the estimation of Model 3 (Table 9) show all three types of KBs (technology-related, project-related, and application-related KBs) to be significant. Thus in both studies, Hypotheses 1a, 1b, and 1c were supported.

More important, we wanted to find out whether Model 2 and Model 3 were statistically different from Model 1 (proving that KB and degree of involvement of SSI provide statistically significant additional explanatory power to the traditional adoption model). Although hazard modeling does not provide an absolute measure of fit, it does enable comparison of two models to determine whether they are statistically different. A chi-square test of the difference in the log-likeli-

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[4]Estimated values of β can be used to measure the impact of an explanatory variable on $h_i(t)$, as the constant proportional effect on firm *i*'s conditional probability of adoption, by the application of logarithms on both sides of the equation.

[5]There are several ways to describe the distribution of *T:* (a) the cumulative probability distribution function, $Pr(T < t)$; (b) the corresponding probability density function, $f(t) = dF(t)/dt$; (c) the survivor function, $S(t) = 1 - F(t)$; and (d) the hazard function, $h(t) = f(t)/S(t)$. Each of the four functions can be used to derive the others. However, the hazard function is the most commonly used in the literature for convenience.

[6]Given our formulation of the Weibull model, a positive coefficient implies a negative impact on the hazard rate. In other words, a positive coefficient indicates that the larger the value for the associated explanatory variable is, the longer the mean time to adoption will be. Cost was found to be highly correlated with complexity in both studies; hence, to avoid multicollinearity problem, we dropped cost from the model. However, it had the same level of significance as complexity when included separately.

Table 7
Estimation Results: Hazard Model With Traditional Adoption Variables (Model 1)

	Study A[a]		*Study B*[b]	
Variable	*Coefficient*	*t Ratio*	*Coefficient*	*t Ratio*
Constant	4.14	6.97	5.25	5.83
Benefit	–0.23*	–2.45	–0.31**	–2.71
Complexity	0.16***	3.77	0.21***	3.40
Compatibility	–0.12*	–2.15	–0.19*	–2.27
Firm size	–0.03	–0.28	–0.01	–0.21
Competitive intensity	–0.09	–0.68	–0.07	–0.43

[a]n = 137; log-likelihood = –51.34. [b]n = 103; log-likelihood = –60.62.
*p < .05. **p < .01. ***p < .001.

Table 8
Estimation Results: Full Hazard Model (Model 2)

	Study A[a]		*Study B*[b]	
Variable	*Coefficient*	*t Ratio*	*Coefficient*	*t Ratio*
Constant	3.84	5.42	4.14	6.44
Knowledge barrier	0.28***	4.12	0.43***	4.38
Degree of involvement of supply-side institution	–0.13*	–2.02	–0.25**	–2.67
Benefit	–0.07*	–2.18	–0.10*	–2.11
Complexity	0.11*	2.28	0.14*	2.26
Compatibility	–0.09	–1.78	–0.07	–1.59
Firm size	–0.12	–0.34	–0.09	–0.24
Competitive intensity	–0.03	–0.32	–0.01	–0.29

[a]n = 137; log-likelihood = –26.47. [b]n = 103. ; log-likelihood = –24.31.
*p < .05.**p < .01 ***p < .001.

Table 9
Estimation Results: Full Hazard Model (Model 3)

	Study A[a]		*Study B*[b]	
Variable	*Coefficient*	*t Ratio*	*Coefficient*	*t Ratio*
Constant	4.11	5.29	4.97	6.82
Technology-related KB	0.19**	2.82	0.33*	2.21
Project-management-related KB	0.13**	3.20	0.19**	2.73
Application-related KB	0.21***	4.21	0.25***	3.93
Degree of involvement of SSI	–0.09*	–2.11	–0.11*	–2.09
Benefit	–0.04*	–2.02	–0.05*	–2.11
Complexity	0.08*	2.13	0.10	1.74
Compatibility	–0.01	–1.61	–0.03	–1.72
Firm size	–0.01	–0.16	–0.02	–0.17
Competitive intensity	–0.07	–0.19	–0.09	–0.24

Note. KB = knowledge barrier; SSI = supply-side institution.
[a]n = 137; log-likelihood = –25.31. [b]n = 103; log-likelihood = –23.39.
*p < .05. **p < .01. ***p < .001.

Table 10
Respondent Comments on the Major Hurdles to Web Technology Adoption

Technology-Project Related
Selecting appropriate Web technologies and standards; adapting to the rapid changes in the underlying Web technologies and introducing sufficient flexibility in the firm's technical infrastructure to accommodate future integration plans
Identifying project resource requirements, defining the outsourcing strategy, and selecting appropriate development methodology
Resolving project leadership issues ("in our organization both IS and marketing are currently leading parallel Web-based efforts")
Addressing the hidden costs of Web projects ("identifying secondary impacts of Web applications, change management costs")
Bench-marking Web projects and defining criteria for evaluating the success of Web sites–applications ("Is our corporate Web site catering to the needs of our customers?")
Security concerns not properly addressed by technology vendors
Application–business related
Establishing the link between the Web application and the business objectives
Lack of consensus within the organization on the type of information most appropriate for the corporate Web site–intranet; devising corporate data ownership policy and appropriate information-sharing and content-regulation policies
Evaluating the impact of Web applications on existing organizational structure and systems; redefining intraorganizational relationships
Evaluating security requirements of each Web application, identifying and establishing new security procedures to complement technical security features
Sharing the costs and benefits of interorganizational Web projects

Note. IS = information systems.

hood of Models 1 and 2 showed that they were statistically different for both studies ($p < .01$). Similarly, chi-square test of the difference in the log-likelihood of Model 1 and Model 3 also indicated the two models were statistically different in the two cases ($p < .01$). In short, the organizational learning perspective does contribute significant additional explanatory power to the traditional adoption model.

Table 10 shows a sample of respondent comments on the major hurdles in the adoption of Web technology at the two levels studied here. At the first level of adoption, the most important KBs were twofold: (a) How the corporate Web site should be used to serve the firm's business objectives, and (b) how the company could ensure that the Web site is responding to the needs of the varied stakeholders (customers, investors, employees). Indeed, as a recent report indicated, few firms have any clear idea as to what a corporate Web site can and should do.

> [Often] corporate Web sites do not serve the audience they are designed for, nor do they reflect the business strategies of the companies that create them … there is a huge gap between the potential offered by this [technology] and the ability of companies to exploit it. ([42], p. 67)

At the second level of adoption, the key KBs included formulating and implementing appropriate policies for intranet content management and tying specific intranet initiatives with the firm's business objectives and strategies.

The results also indicate that the degree of involvement of the SSI impacts adoption time. Specifically, for similar levels of KB, firms that involved their SSI to a greater degree adopted the technology earlier. Web technology adoption calls for a deeper level of knowledge of the business on the part of the SSI and, hence, their greater involvement in the adoption process. For example, identifying the target community, the most basic (but often overlooked) task for building an effective corporate Web site, requires the SSI to develop a thorough understanding of the business and important stakeholders of the adopting unit. The fly-by-night Web site developers who abound in this industry are more focused on utilizing the latest Web technology than on developing a Web site that serves some business objectives. Hence, it is the responsibility of the adopting unit to ensure that the SSI is integrated well with the adoption process.

Mediating institutions or SSIs share their "rare event learning" with potential adopting units [18]. Such learning provides crucial time advantages to adopting units in integrating the technology with the internal context. For example, one of the IS managers noted that, in her organization, a unique problem came up with respect to how the content common to two geographically and structurally separated divisions should be managed. The involvement of the SSI, who had addressed a similar problem in another firm, was instrumental in finding a fast and effective solution. Thus, the results of this study further underscore the important role SSIs can play in Web technology adoption.

Finally, the two control variables were not found to be significant in both the studies. The lack of significance of firm size as a control variable may indicate that, for the two levels of Web technology adoption studied here, resource requirements were not high enough to significantly influence the adoption behavior. Similarly, the lack of significance of competitive intensity may be explained by the limited competitive advantage or benefits that can be gained from merely establishing a corporate Web site or an intranet. Presumably, at higher and more complex levels of adoption (e.g., electronic commerce), where resource requirements as well as potential benefits are greater, both these variables may assume higher significance.

This study has two key limitations. The first limitation relates to the scope of the study. Our primary objective was not to develop a comprehensive technology adoption model but to examine the value of the opportunity to adopt perspective. There might be other factors not considered here that influence the timing of technology adoption. Furthermore, following Attewell [6], we characterized the opportunity to adopt dimension in terms of the KB; future studies may focus on other characterizations to derive additional insights on technology adoption. Second, in the absence of validated scales, we had to develop and validate a suitable scale for measuring the KB construct. Although the reliability and validity of the scale have been verified, any new scale has potential for refinement.

5. IMPLICATIONS AND CONCLUSIONS

In this section, we summarize the key issues discussed in this article and explain their implications for research and practice related to technology adoption.

5.1 KBs and Web Technology

The central theme of this article relates to the importance of KBs in technology adoption. It is true that all technologies present KBs to adopting units. However, the nature of KBs presented by newer information technologies is significantly different and demands more innovative response from adopting units. The inherent flexibility and the rich capabilities of these technologies (in the case of Web technology, characteristics like modular–open architecture, ease of reconfiguring the user interface, transparent data-access methods, ability to integrate across varied platforms) require firms to imaginatively recombine different elements of these technologies into applications that serve unique business needs.

In this study, we show that KBs have significant impact on adoption timing and as such, provide a rigorous empirical validation of the organizational learning perspective of technology diffusion. Researchers and practitioners need to incorporate such a perspective when dealing with technology adoption. Many firms emphasize their intention (or desire) to adopt and focus on promoting the innovation within the organization; however, they fail to consider whether there are KBs that can potentially delay the adoption. More important, they should acknowledge that resolving such KBs involves significant organizational learning rather than transfer of knowledge from foreign contexts. This has important implications on resource and time allocation for technology adoption projects, defining business-technology linkages, the nature of partnerships with external consultants, and so on.

Although we identified several KBs at the two levels of adoption of focus here, it should be realized that they are bound to change over time as Web technology evolves. Furthermore, the intensity of some of the KBs will increase with the level of adoption. For example, security concerns, although relevant even at the lowest level of adoption, become more critical at higher levels as the nature of information shared and the associated risks change [43]. An important implication is that adopting units need to identify potential KBs beforehand and devise proactive measures to address them. As one of the respondents noted in the following:

> When we started our intranet project, the first thing we all acknowledged was the need to make explicit the organization-wide information sharing policy … and before we even started the project, we set up a team to do just that … in retrospect, that may well be the single factor that determined the success of our project.

This study also has important implications for technology vendors for devising appropriate product diffusion strategies and for playing a more proactive role in facilitating technology adoption. In the past, most of the innovations that posed KBs to adopting units involved large complex products and huge investments (e.g., manufacturing resources planning solutions) that justified the technology vendor working hand-in-hand with the adopting unit to overcome such barriers. However, Internet technology is an example of an innovation that need not involve significant investments by the adopter (and, hence, may not justify direct vendor involvement) but still may pose significant KBs. In such situations, the success of the product is dependent on how quickly the technology vendor can establish or train external consultants capable of providing a range of services to lower the KBs of adopting units. For example, the huge success of Novel's local area network (LAN) operating system in the late 1980s is partially attributable to the large number of Novel-certified, third-party agencies who guided the LAN technology adoption process of many organizations. Another approach would be for technology vendors who suspect there are KBs related to their new products to forge alliances with large consulting agencies (sharing with them product information even before the launch) who can match the vendors' product introduction with complementary services that lower potential KBs [44]. In short, the Internet industry needs to ensure that, along with the advancement of Web technology, a robust set of SSIs is also developed that can play a crucial role in lowering the KBs of potential adopters.

5.2 Adoption Study Methodology

This study has a methodological contribution to make to the adoption–diffusion literature. Prior studies examining the determinants of technology adoption have employed either regression analysis or logit modeling technique. Probit or logit models involve discrete dependent variables and are not sensitive to time. On the other hand, regression analysis is not able to deal with right censoring of the dependent variable (i.e., an organization may not have adopted an innovation at the time of the study) and may result in biased estimations. The hazard modeling approach accommodates both left and right censoring and, hence, as shown in this study, is an appropriate technique for studying adoption duration time.

5.3 Future Directions

Two promising directions can be identified for future research. The first relates to a more extensive investigation of the supply-side perspective of technology adoption. Although here we focused on the degree of interaction of the SSI with the adopting unit, future studies may examine other related factors. For example, the timing of entry of the SSI in the adoption process is as important as the nature of interactions. Similarly, organizations may deploy specific mechanisms to facilitate SSI–adopting unit interactions during the adoption process. By conducting analysis at a fine-grained level, we may derive additional insights on how the SSI should be effectively integrated with the adoption process to overcome potential KBs. The second research avenue relates to the nature of KBs. As noted earlier, given the rapid rate of development of Web technology, the nature of the KBs are bound to change significantly. Future studies may focus on providing a richer description of the KBs at various levels of Web technology adoption and examine their interrelations. The relations between the various types of KBs may be insightful in devising cost-effective adoption–diffusion strategies.

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