
The Impact of ERP Implementation on Business Process Outcomes: A Factor-Based Study

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ABSTRACT: Failures in large-scale information technology implementation are abundantly documented in the practitioner literature. In this study, we examine why some firms benefit more from enterprise resource planning (ERP) implementation than others. We look at ERP implementation from a technological diffusion perspective, and investigate under what contextual conditions the extent of ERP implementation has the greatest effect on business process outcomes. Using empirical data, we find that the extent of ERP implementation influences business process outcomes, and both ERP

radicalness and delivery system play moderating roles. For information systems (IS) practice, this study helps managers direct their attention to the most promising factors, provides insights into how to manage their complex interactions, and elaborates on their differential effects on business process outcomes. For IS research, it integrates innovation diffusion theory into our current knowledge of ERP implementation and provides theoretical explanations for ERP implementation failures.

KEY WORDS AND PHRASES: business process outcomes, enterprise systems, ERP effects, ERP implementation, ERP radicalness, information technology innovation, innovation diffusion theory.

DESPITE SIGNIFICANT INVESTMENTS IN INFORMATION TECHNOLOGY (IT), a considerable number of firms have not been able to derive full benefits from their IT investments, largely due to their inability to effectively deploy IT in their value-chain activities and business strategies [3, 10, 23]. IT implementation is important because it enables a firm's competitive strategies by lowering production costs, achieving operational flexibility, enhancing supplier or customer linkages, and enhancing or creating new products and services [70]. While some implementations of enterprise resource planning (ERP) systems have led to significant reduction in inventory and in administrative costs, and millions of dollars in logistics savings at firms such as Dow Corning, IBM, and Texas Instruments [47, 75, 82], others have led to failures at firms such as AMR Corporation, Dow Chemical, Hershey Foods, Fidelity Brokerage Services, and FoxMeyer [82]. Such conflicting results have prompted an empirical examination of the factors that lead to differential outcomes across firms.

Most factor-based studies explain the role of one or more organizational (e.g., delivery system), technological (e.g., divisibility, radicalness), user, task, or environmental factors that affect adoption, implementation, or outcomes of innovations [23, 37, 38, 43, 84]. Researchers have suggested that (1) organizational and technological factors are most important, difficult to manage and control, and more beneficial to the organization than the other factors [33, 54, 61, 84], and (2) depending on the specific technology in question, organizational factors vary and should be measured as a combined technology-organization factor [37]. Further, a recent review of the technology strategy literature in Fichman [37] identified four broad-based technology-organizational factors that can significantly explain not only the *increase in variance* or the *expected value of potential payoffs* but also the *option value* of an IT platform adoption. These factors are the (1) radicalness of technology, (2) divisibility of technology, (3) extent to which products or processes have the potential to be improved by innovation, and (4) extent to which a firm possesses innovative capabilities and endowments (i.e., delivery system). Because IT platform adoption begins with baseline IT implementation, the option value of the adoption increases with the increasing variance of potential payoffs or with the increasing expected value of potential outcomes; the increase in option value subsequently increases the propensity of firms to make positioning investments that support the initial adoption of IT platforms [37].

Most research on critical success factors for ERP implementation (e.g., [9, 96]) has followed the above dominant paradigm for IT innovation research without specifically considering the complex interactions among the factors. For the most part, researchers have been concerned with identifying a set of direct antecedents of innovation, with each antecedent assumed to have independent effects on the outcome variable. It is assumed that innovations are beneficial, and the organizations that have a greater quantity of “the right stuff” (such as management support, knowledge, and resources) are expected to exhibit both greater quantity (such as frequency and extent of implementation) and quality of IT innovation (such as efficiency, productivity improvement, or usage) [36]. There are, however, three generic assumptions of how innovation-related conditions lead to performance effects: (1) quantity of innovation directly causes performance; (2) traditional innovation antecedents have direct or moderating effects on performance; and (3) novel variables, which exist outside the bounds of the dominant paradigm, have moderating effects on performance [36]. Further, because the organizational innovation factors can interact in complex ways, they must be viewed holistically to find out (1) which combinations of factors are more important in explaining the outcomes and (2) under what contextual conditions the performance effects are greatest in order to draw valid conclusions [36]. Accordingly, Fichman [37] suggested that (1) divisibility, delivery system, and radicalness should have positive and multiplicative effects that should increase the variance or the expected value of outcomes; (2) the effects of radicalness on outcomes are unclear because such initiatives have a greater potential value and cost more; and (3) there is a need for further empirical studies to carefully consider their potential effects.

In this study, we examine ERP implementation from a technological diffusion perspective [23, 52] to find out when and under what contextual conditions the extent of ERP implementation has the greatest effect on business process outcomes. The research model, presented in Figure 1, suggests that the extent of ERP implementation can have the greatest effect on business process outcomes when there is a robust delivery system and when the radicalness of ERP implementation is high due to a firm’s increased business process complexity and information intensity.

Research Framework

ALTHOUGH ERP IMPLEMENTATION HAS BEEN STUDIED from a variety of perspectives, a recent review of the ERP implementation literature suggests that “implementation” does not mean the same thing to everyone [31]. Most frameworks for understanding IT implementation are ingrained in innovation diffusion theory [3, 23, 38, 39, 52, 61]. From a technological diffusion perspective, IT implementation is defined as an organizational effort to diffuse an appropriate IT innovation within a user community [23, p. 124]. For an IT innovation to be successfully assimilated (implemented, used, and diffused), it first needs to be implemented [34]. Researchers have argued that the extent of implementation is a better measure for quality of innovation (outcomes) than adoption, as not all innovations that are adopted actually get implemented, and implementation brings the benefits of adoption [36, 95].

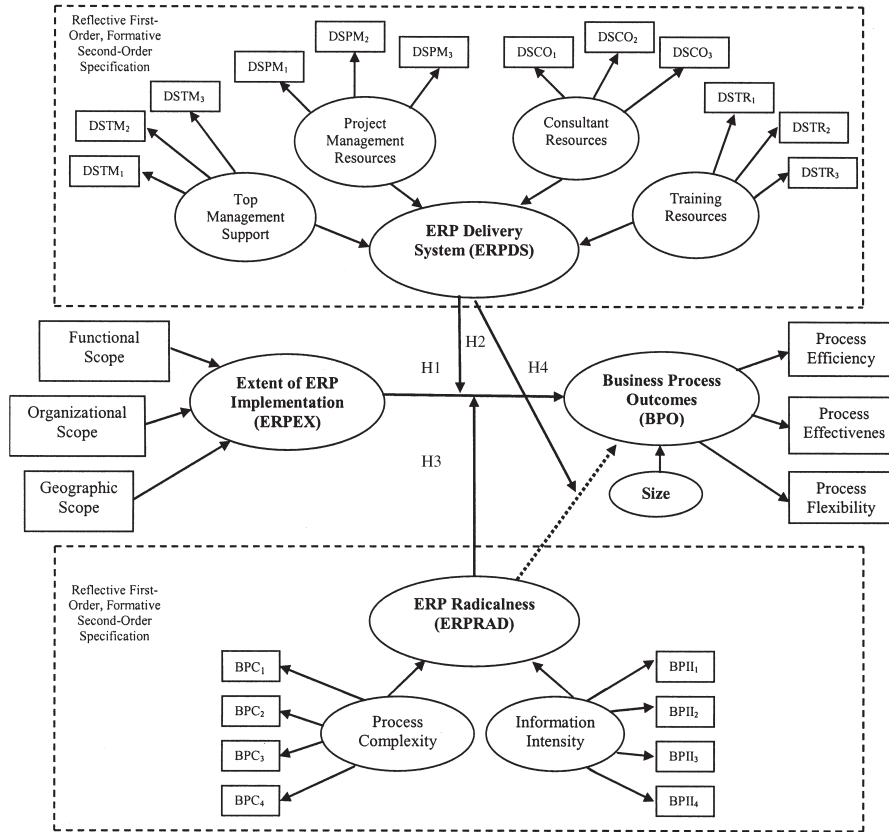


Figure 1. Research Model

Extent of ERP Implementation

The quantity of IT innovation has been conceptualized as the *extent* to which an organization adopts innovations often, adopts them early, and/or adopts them thoroughly [35]. ERP implementations is divisible to the extent that it can be divided up for sequential or incremental implementation by functions, departments, the entire company, multiple companies, locations, or regions. Because divisibility¹ of ERP systems allows for incremental implementation, it serves to enhance managerial flexibility and expected potential returns. Extent of ERP implementation defines the types of benefits that can be derived from an ERP system, and specifies the degree to which an ERP system will change process integration in the business units of the enterprise [57]. Concomitantly, it is also one of the major problems, challenges, and opportunities that ERP adopters face when implementing ERP systems [56, 58]. Recent research [72] has shown that ERP projects with greater functional, organizational, or geographic scope result in positive, higher shareholder returns; the highest increase (3.29 percent) in returns are found for ERP purchases with greater functional, organizational, and geographic scope, and negative returns are found for projects with lesser scope.

The extent of ERP implementation is defined here as ERP functional scope (system range), organizational scope (system reach), and geographic scope [11, 51]. *ERP functional scope* refers to the range of business functions (accounting, manufacturing, sales, etc.) that share ERP implementation. Greater ERP functional scope is achieved through the implementation of multiple or cross-functional ERP modules. It provides data and process integration across functions and more benefits than a single function implementation [12]. It can facilitate the exchange of data between applications for monitoring and managing business activities across the extended enterprise. Moreover, it enables end-to-end automation of business processes, thereby allowing firms to react more quickly to changes in business conditions. *ERP organizational scope* is defined as the organizational locations that the ERP implementation can reach (link), such as departments, divisions, entire company, multiple companies, and so on. It specifies the degree to which the system will change managerial autonomy, task coordination, and process integration in the business units of the enterprise, and is associated with project management difficulties. *ERP geographic scope* refers to the regional, national, and global reach of the ERP implementation. By integrating their ERP systems with those of their trading partners, firms primarily hope to reduce cost, and improve business processes, data integrity, and customer service.

ERP Delivery System

The outcome of innovation in an organization is not only a function of the organization's contextual factors but also depends on how the innovation is nurtured throughout its implementation. The means by which an innovation is supported, managed, and nurtured is called the innovation delivery system [53]. Because innovations' capabilities/endowments vary depending on the specific technology in question, they need be considered holistically and as a combined technology-organization factor [37]. Fichman's [36] literature review on identifying the characteristics of effective delivery systems pointed to organizational factors (e.g., top management support, technology champion, training, links to consulting services) and process model factors (i.e., the fit of the process model with the technology and organization) that used to guide innovation implementation. Therefore, the factors that are selected next are those organizational contextual factors that facilitate assimilation of IT innovations and are also among the critical success factors for ERP implementation.

Much research in IT innovations and ERP implementation has pointed to top management support, training, consultant, and project management resources (see Table 1). When top managers do not buy in to the goals and plans of the ERP project team, the chances of success are slim; although good project managers can contribute to buy-in, success requires a concerted effort at the top, training, and good project management skills [58, 76, 96]. A clear definition of objectives, a project plan, an achievable schedule, and careful tracking of project progress are also mentioned as requirements for successful ERP implementation [96]. ERP implementation success is dependent not only on the internal project leaders who have "earned their stripes" leading strategic projects but also on the availability of consultants who can fill the

Table 1. Delivery System

Delivery systems factors	Related work
Top management support	Armstrong and Sambamurthy [3]; Bingi et al. [9]; Boynton et al. [10]; Grover et al. [43]; Leonard-Barton [53]; Leonard-Barton and Deschamps [55]; Markus and Tanis [56]; Markus et al. [57]; Meyer and Goes [61]; Robbins and Duncan [73]; Umble et al. [96]
Project management resources	Al-Mashari et al. [2]; Dewar and Dutton [28]; Ryan [78]; Scott and Vessey [82]; Somers et al. [87]; Umble et al. [96]
Training resources	Al-Mashari et al. [2]; Bingi et al. [9]; Brown and Vessey [12]; Fichman [33]; Scheer and Habermann [80]; Umble et al. [96]; Wheatley [98]
Consultant resources	Bingi et al. [9]; Dewar and Dutton [28]; Eveland and Tornatzky [32]; Gable [41]; Gupta [45]; Robey et al. [74]; Ross [77]; Slater [85]; Umble et al. [96]

gaps in client–server architecture knowledge and ERP experience by function [12]. Consultants are most often used as implementation partners at two to ten times the cost of the ERP software for the initial implementation, and as much as 80 percent of the total cost can go to consulting services [80]. The need for consultant support increases exponentially with the extent of ERP implementation because of the difficulties associated with configuring a large number of modules, the scope of the system, and coordination of operations.

ERP Radicalness

Radicalness is defined from the perspective of process of innovation.² Radical innovations are fundamental and revolutionary changes in technology that are clear departures from existing practices; radicalness refers to the extent (low to high) to which an innovation represents technological changes and thus implies new behaviors for organizational subsystems or members [28]. IT innovations can be used to improve business processes by implementing systems that integrate business functions and by integrating data and processes along the various links in the value chain, either for internal operations or for the external marketplace [11]. They can be used for (1) process innovations within the information system (IS) function to enhance the efficiency or effectiveness of IS function (type I), (2) enhancing the administrative work processes from new IT products and services (type II), and (3) integrating IT in core value chain activities and business strategies that directly affect a firm's financial performance (type III) [89].

ERP software is a type III IT innovation because it facilitates organizational data and process integration, and results in fundamental improvements in business processes [43]. Most organizations decide to implement ERP systems to lower the cost of their

in-house development and maintenance of their legacy systems, and to derive benefits in their core business activities. ERP implementation enables firms to integrate their business processes by business process standardization, innovation, and improvements [26, 47, 71, 75, 77]. It can help firms integrate vast amounts of information and can reduce the need to navigate many different systems to acquire and disseminate information [71]. While a business process is essentially composed of discrete and detailed activities performed on, or in response to, incoming information, the complexity (i.e., nonroutineness, difficulty, uncertainty, and interdependence) and information intensity associated with those activities are the most important aspects of any business process. We discuss next why higher levels of business process complexity and information intensity result in radicalness of ERP implementation.

Business Process Complexity

Business processes are activities underlying value-generating activities for transforming inputs to outputs in the value chain [60]. Reducing business process complexity is a key business reason to adopt ERP systems in both small and large companies with simple or complex structures [56]. ERP systems can reduce business process complexity by (1) solving maintenance problems associated with aging legacy systems, (2) presenting “one face to the customer,” (3) facilitating better business intelligence on finished goods inventory or planned production capacity “available to promise” to the customer on a regional or global basis, and (4) reducing complexity of intricate transactions that involve multiple system platforms across a single business unit, multiple sites, and multiple business units. Therefore, the higher a firm’s business process complexity, the higher the radicalness of its ERP implementation as a result of its potential to enable fundamental and radical changes in the firm’s business processes and their outcomes.

Business Process Information Intensity

Information intensity is the amount of information processing required to effectively manage a firm’s products, services, and value-chain activities [70]. Porter and Millar [70] suggest that products or services with high information intensity are those that (1) mainly provide information, (2) involve substantial information processing, (3) require especially high costs for buyer training, (4) have many alternative uses, and (5) are sold to buyers with high information intensity in their own business. Higher information intensity results in data integration difficulties and creates greater strategic opportunities for innovative applications of IT. Firms have implemented ERP systems to eliminate poor productivity and performance problems associated with the fragmented information produced by legacy systems [26, 71]. Business process information intensity is a key technical reason for the adoption of ERP by firms to reduce their data integration problems [56]. ERP implementation can reduce data integration problems by (1) eliminating redundant data entry and concomitant errors; (2) reducing difficulty in data analysis; and (3) managing, integrating, and sharing data

associated with products, services, and value-chain activities across the firm [56, 71]. The higher a firm's business process information intensity, the greater the necessity to integrate a vast amount of information and reduce the data integration problems associated with legacy systems. This results in ERP radicalness because such implementation will not only enable radical improvements in the way that the vast amount of information is handled but it will also have a radical effect on the firm's business processes and their outcomes.

Business Process Outcomes

The process-oriented perspective is useful for identifying various ways IT can provide business value either via existing or planned IT systems [62]. Rather than looking at the level of a firm's output measures for determining business value, the process-oriented perspective favors process-oriented assessment of IT business value. From the perspective of resource-based theory, business processes provide a context within which one can examine IT business value [70]. This perspective is based on the argument that the first-order effects of IT investment occur at the *operational level* [6, 62]. IT can improve individual processes by enabling business process integration across physical and organizational boundaries [7]. In addition to operational benefits, IT benefits are classified at higher tactical and strategic levels, and at infrastructure and organizational levels [83, 97]. As discussed by Shang and Seddon [83], although these dimensions have been outlined separately, they nevertheless interact: operational benefits may come with increased managerial effectiveness; strategic benefits rely on process efficiency; infrastructure benefits result in business flexibility, reduced cost, and increased capability; and organizational benefits can be realized in parallel with managerial benefits.

At the operational level, IT creates business value by having three separate, but related, effects on business processes: (1) *automational effects*, which refer to the efficiency perspective of value derived from the role of IT as a capital asset being substituted for labor and from its role in cost reduction; (2) *informational effects*, which are the results of IT capacity to store, process, and disseminate information; and (3) *transformational effects*, which refer to IT's ability to facilitate and support process innovation and transformation [62]. From a business process manager's perspective, the effects of these business process outcomes will be reduced cost and cycle time, and improved productivity, quality, and customer service benefits [83]. Automational effects result in *process efficiency* by reducing inventory costs, increasing throughput, reducing labor costs, and increasing reliability [5]. Informational effects result in *process effectiveness* by increasing resource utilization, reducing waste, increasing responsiveness, and improving quality [70, 88]. Transformational effects result in *process flexibility* by enabling product and service innovation, reducing cycle times, and improving customer relationships [6, 50, 63]. Prior research has shown that improving process efficiency, process effectiveness, and process flexibility leads to improved profitability and earnings valuation [91].

Hypotheses Development

RESEARCH ON IT ASSIMILATION AND FIRM PERFORMANCE has suggested that IT must enable firms' value-chain activities and business strategies before they can exhibit any significant business value [8, 79]. Business process improvements have always been major motivations for ERP implementation [71, 75]. Prior research on benefits of ERP systems suggests that because these systems automate business processes and enable process changes, at the operational level, they have the potential to result in cost and cycle time reduction, as well as productivity, quality, and customer services improvements [71, 83]. ERP divisibility, however, affects decisions regarding the extent of ERP implementation and whether it should be a big bang deployment, a phased rollout, or incrementally implemented [58]. Fichman [37] suggested that increases in innovation divisibility extend the potential for incremental implementation, which in turn increases the expected value or variance of potential payoffs. These subsequently lead to increases in option value of positioning investment in IT platforms, and increase the propensity of firms to make positioning investments that support the initial adoption of IT platforms. Therefore, it is reasonable to assume that there is a positive relationship between extent of ERP implementation and a firm's business process outcomes, which leads to the following hypothesis:

Hypothesis 1: Extent of ERP implementation has a positive association with business process outcomes.

When organizations are structurally complex and geographically dispersed, implementing ERP systems can involve difficult, and possibly unique, technical and managerial choices and challenges [2, 58]. The manner in which these concerns are addressed can play a major role in the ultimate success of the ERP implementation [96]. For example, the differences in these factors to support SAP R/3 implementations were among the primary reasons for the success of the implementation at Dow Corning as compared to the failure of the implementation at FoxMeyer [82]. Firms that have better delivery systems are expected to innovate more economically with a greater probability of success. Because better delivery systems are expected to increase managerial flexibility and increase the ability to recognize and exploit follow-on projects, it concomitantly is expected to increase the option value of positioning investments in IT platforms and increase the expected value of returns [37]. Therefore, one would expect that the relationship between the extent of ERP implementation and business process outcomes may operate conditionally; it will depend on whether there is high or low delivery system support. Consequently, a greater extent of ERP implementation can lead to higher business process outcomes for those firms with high delivery system support than for those with low delivery system support. Therefore, the following hypothesis is proposed:

Hypothesis 2: Greater extent of ERP implementation in conjunction with greater delivery system support is positively associated with higher business process outcomes.

Radicalness of IT innovations is suggested to affect IT adoption, implementation, and implementation outcomes [37]. Incremental implementation of innovations is associated with better implementation of organizational innovations [54] and software packages [40]. However, rapid, big bang-style ERP implementations are especially prone to disaster because of the potential for intended and unintended consequences of ERP implementation on the structure of business [58, 96]. Although radical changes can still be enacted through a sequence of incremental implementations, radical innovations impose greater implementation challenges [28, 65]. Increases in radicalness are expected to increase the variance of potential returns and to increase the option value of positioning investments in IT platforms [37]. Therefore, we expect that ERP radicalness influences the association between the extent of ERP implementation and business process outcomes such that the higher the ERP radicalness, the higher will be its association. Hence, the following hypothesis is proposed:

Hypothesis 3: Greater extent of ERP implementation in conjunction with greater ERP radicalness is positively associated with higher business process outcomes.

Prior studies suggested that the effects of radicalness on the expected value of returns from innovation are unclear, because technologies that enable more radical improvements typically require more changes in organizational processes and have wide-ranging intended or unintended consequences that can increase the variance of potential returns [37]. Innovation-related capabilities/endowments become important for radical innovations because such innovations impose greater implementation challenges [28]. Fichman [37] suggests that the interaction between radicalness and innovation-related endowments seems likely. We expect that the “nature” of the relationship between ERP radicalness and business process outcomes varies as a function of the delivery system; the existence of an appropriate delivery system moderates the effect of ERP radicalness on business process outcomes such that the higher the firm’s delivery system support, the higher will be its effect. Thus, we propose:

Hypothesis 4: Greater ERP radicalness in conjunction with greater ERP delivery system support is positively associated with higher business process outcomes.

Research Methodology

Construct Measurement

THE FOUR CONSTRUCTS OF INTEREST TO THIS STUDY were extent of ERP implementation, ERP delivery system, ERP radicalness, and business process outcomes. For each construct, we identified its underlying domains and created corresponding items. We assessed all measures for content validity using expert opinions; for internal validity, we used a pilot study to assess the nature of the relationships among the constructs. We modified problematic items as necessary. This strategy helped ensure that the measurement scales possessed adequate content validity, while allowing us to test

for their psychometric properties (i.e., scale reliability and construct validity). Scale items are presented in the Appendix and described next.

Prior research on IT implementation and innovation suggested that measures used to operationalize the extent of implementation can vary depending on researchers' objectives and the nature of the focal innovations (see [35, 99] for discussions of the different approaches to measure extent of implementation). The extent of ERP implementation (ERPEX) was measured by the ERP functional, organizational, and geographic scope. *ERP functional scope* was measured as the range of the implementation project and by a summation of the number of business functions covered by the ERP implementation. *ERP organizational scope* was measured by the number of locations (departments, divisions, entire company, multiple companies, etc.) targeted for ERP implementation, and *ERP geographic scope* was measured by the geographic reach of the implementation (i.e., single site, multiple sites, national, or worldwide).

ERP delivery system (ERPDS) was assessed by first-order factors that measured the effective management and support of the implementation process: top management support, project management resources, consultant resources, and training resources. Consistent with its conceptualization, delivery system is proposed as a second-order factor formed by the four first-order constructs. *ERP radicalness* (ERPRAD) was measured by a second-order factor formed by the degree of a firm's business process complexity and information intensity. *Business process complexity* (BPC) was measured by the degree of nonroutineness, interdependence, complexity, and uncertainty in business processes. *Business process information intensity* (BPII) was measured by (1) the number of steps in production or service process, (2) the extent of information use, (3) the frequency of information updating, and (4) accuracy of information [13, 70].

Business process outcomes (BPO) was measured by the extent to which the ERP implementation led to process efficiency, effectiveness, and flexibility in the adopting firms. *Process efficiency* was measured by the extent to which the use of the ERP implementation reduced the operational costs and decreased the input/output conversion ratio. *Process effectiveness* was measured by the extent to which the ERP implementation provided better functionality, enhanced the quality of the users' work in terms of better access to corporate data, higher level of enterprisewide data integration, better sales forecasts, and improved quality of operations. *Process flexibility* was measured by the extent to which the ERP implementation had provided firms with more flexibility in response to changing business environments by providing new ways to customize their processes and become more agile. The constructs, with the exception of ERPEX, were measured using five-point Likert scales anchored with "strongly disagree" and "strongly agree." For the analysis, BPO was measured using a summative scale representing each of the three dimensions of efficiency, effectiveness, and flexibility.

In addition, prior research suggests that firm size can play an important role in implementing radical innovations [61, 94]. Larger firms, with their larger operating budgets, technology base, and resources, are generally able to implement more extensive ERP systems. On the other hand, large firms tend to be less flexible than smaller firms because they need more communication, coordination, and support to effect

radical innovations [64]. To help us provide a better explanation for the moderating effects of the ERPDS and ERPRAD on the relationship between ERPEX and BPO, we controlled for the confounding effects of firm size (as a proxy for firms' financial resources). This study controlled for firm size by computing the natural logarithmic transformation of the number of employees [27, 92].

Data Collection

Empirical data to test the hypothesized relationships were obtained by using a mail survey from U.S. manufacturing firms that have recently implemented ERP projects. Data collected from a pilot test was used for instrument validation and refinement and factorial validity, whereas data from the second survey was used for confirmatory analysis of measurement properties and hypothesis testing of the model shown in Figure 1. Usually, multiple surveys should not be aggregated unless all of the following conditions are met: the population surveyed, questionnaire, and sampling methodology are identical. Consequently, in our case, the two samples cannot be combined because they are not homogeneous—the pilot test involved large (Fortune 1000) corporations from a wide range of industries, whereas the second sample included firms of different sizes (via stratified samples) but belonging only to the manufacturing industry sector. In both cases, the survey questionnaire was mailed to the senior-most IS executive in each firm (e.g., chief information officer [CIO], vice president in charge of IS), along with a letter outlining the purpose of the research, soliciting their participation in the survey, and a postage-paid return envelope for mailing back completed responses. No specific incentive was provided to participants for completing the survey other than promising them a copy of the aggregated results.

The pilot test survey was directed to firms listed in the Fortune 1000 database. A total of 123 responses were obtained after two rounds of follow-up requests (of nonrespondents), for a response rate of 12.3 percent. The latter survey was directed at a stratified sample of U.S.-based manufacturing firms drawn from the Harris Nationwide Manufacturing database. We decided to focus our analysis on manufacturing firms for two reasons: (1) ERP implementation seemed to be particularly prevalent among these firms, and (2) we wanted to minimize potential confounding effects due to industry variations. To alleviate concerns about sample distribution, we stratified the total population of about 22,700 firms in the Harris database into four categories based on their employee counts: 3,000 and over, 1,000–2,999, 500–999, and 200–499. The survey was mailed to a random sample of firms in each of the four strata (fewer firms in the fourth stratum received the survey, because ERP implementation is less prevalent among smaller firms). A total of 550 firms were contacted, of which 104 firms declined participation. After two follow-up mailings, a total of 148 usable responses were obtained, for a respectable response rate of 27 percent.

Descriptive statistics and the response rate by firm strata are reported in Table 2. Over half (58 percent) of these firms had from 500 to 1,000 employees and 30 percent reported 3,000 or more. About 73 percent had between three and 26 full-time consultants, while 27 percent retained 27 or more full-time consultants. Almost half (48 percent) of

Table 2. Descriptive Statistics for Manufacturing Firms Data

Number of employees	Firms in database (firms contacted)	Surveys returned
3,000 and over	395 (200)	44
1,000–2,999	1,684 (100)	36
500–999	4,327 (200)	51
200–499	16,301 (50)	17
Total	22,707 (550)	148

Full-time consultants	Frequency	Percent
3–10	32	22
11–18	34	23
19–26	41	28
27–35	9	6
36–56	22	15
57–77	5	3
78–125	4	3
Total	147	100

Number of months system used since rollout	Frequency	Percent
6–11	6	6
12–17	36	35
18–23	18	18
24–29	30	30
30–35	7	7
36–41	4	4
Total	101	100

the firms have used their ERP system about 18 to 29 months since it was rolled out, 41 percent used their system between six and 17 months, and 11 percent reported using their system 30 months or longer. Statistical tests comparing firm revenues, resources, and the number of employees between responding and nonresponding firms revealed no significant differences, suggesting no substantive nonrespondent bias. The data were therefore suitable for testing our hypothesized research model.

Data Analysis and Results

To begin, we tested for common method bias using a post hoc procedure suggested by Podsakoff and Organ [69]. Using the principal components factor analysis, evidence for common method bias exists when a single factor emerges from the analysis, or one general factor accounts for the majority of the covariance in the interdependent and dependent variables. Because our analysis for our pilot data (first survey), as well as data from the second survey, resulted in multifactors, we can conclude that the data do

not indicate substantial common method bias. Data from the first survey were subjected to exploratory factor analysis (EFA) to gain insights as to the multidimensionality of the items. The results are presented in Table 3.

Data from the second survey of manufacturing firms (from the Harris database) were used for confirmatory factor analysis (CFA) on the measurement scales and to test the hypothesized model, because the construct validity was preliminarily verified with an EFA from the first survey. All reflective indicators were standardized consistent with recommendations for dealing with interactions [21, 24]. Because the study incorporated scales that were new to IS research, further retesting of these scales was deemed necessary to assess their robustness and generalizability to a different population of firms, and to derive confidence in subsequent model analysis.

PLS-Graph, version 3.00 [18], was used to test the hypothesized relationships among the study variables shown in Figure 1. The choice was motivated by several considerations. Partial least squares (PLS) can be used to estimate models that use both reflective and formative indicators, is more appropriate for analyzing moderating effects because traditional techniques cannot account for measurement error in exogenous constructs [59], allows for modeling latent constructs under conditions of nonnormality, and is appropriate for small to medium sample sizes [16, 17, 20].

Reflective Versus Formative Measures

PLS can represent both reflective and formative constructs, and the choice is guided by their assumptions. For reflective constructs, (1) indicators are manifestations of the construct, (2) changes in the indicator should not cause changes in the construct, (3) changes in the construct do cause changes in the indicators, (4) dropping an indicator should not alter the conceptual domain of the construct, (5) indicators are viewed as affected by the same underlying construct and are parallel measures that covary, and (6) indicators are required to have the same antecedents and consequences and to have a high internal consistency and reliability. Conversely, for formative constructs, (1) the indicators are defining characteristics of the construct, (2) changes in the indicators should cause changes in the construct, (3) changes in the construct do not cause changes in the indicator, (4) dropping an indicator may alter the conceptual domain of the construct, (5) it is not necessary for indicators to covary with each other, and (6) indicators are not required to have the same antecedents and consequences, nor have high internal consistency reliability [16, 17, 49].

Based on previous theoretical discussions, delivery system is defined as a means by which an innovation is supported, managed, and nurtured. A high level of delivery system support is caused by a high level of top management support, and by high levels of project management, consultant, and training resources. Although each resource may occur independently of the others, the changes in these resources will change the level of delivery system support rather than result from it. Similarly, BPC and BPII are formative (first-order) constructs that cause the level of radicalness rather than are influenced by it. Consequently, a molar approach [19] was adopted to test ERPDS and ERPRAD. As shown in Figure 1, both constructs were specified as

Table 3. Exploratory Factor Analysis of Pilot Test Data

Items	1	2	3	4	5	6	7	8	9	10
EFTO ₅	0.931	0.015	-0.131	-0.125	0.033	0.226	-0.091	-0.039	-0.014	-0.013
EFTO ₁	0.910	-0.002	0.002	-0.053	-0.015	0.034	0.007	0.033	0.064	0.002
EFTO ₃	0.735	0.090	0.051	0.150	-0.072	-0.170	0.066	-0.020	-0.017	0.043
EFTO ₄	0.721	-0.131	-0.019	-0.156	0.120	0.189	-0.074	0.009	-0.024	0.013
EFTO ₂	0.703	0.073	0.095	0.164	-0.106	-0.228	0.091	0.029	0.070	0.016
EFTO ₆	0.687	0.033	0.097	0.088	0.009	-0.218	0.036	0.004	-0.045	0.033
BPC ₃	0.030	0.982	-0.010	0.110	0.011	0.073	-0.077	0.038	0.007	0.014
BPC ₄	-0.005	0.722	0.001	-0.033	0.045	-0.035	-0.045	-0.130	0.120	0.082
BPC ₂	0.093	0.680	-0.038	0.089	0.046	0.163	0.063	0.021	-0.018	-0.124
BPC ₁	-0.039	0.599	-0.058	0.002	-0.042	-0.105	0.034	0.145	-0.170	-0.057
FLXO ₂	-0.052	0.020	0.825	-0.060	0.066	-0.026	0.017	0.073	-0.010	-0.039
FLXO ₁	0.016	-0.032	0.780	-0.088	0.067	0.159	-0.009	-0.047	-0.001	0.055
FLXO ₃	0.114	-0.052	0.660	0.116	-0.054	0.003	-0.002	-0.068	0.049	0.001
FLXO ₄	-0.007	-0.050	0.616	-0.020	-0.002	-0.026	-0.088	0.067	-0.145	-0.087
DSTR ₂	0.001	0.029	-0.063	0.823	0.018	0.161	-0.035	-0.006	-0.011	0.056
DSTR ₁	-0.018	-0.068	-0.015	0.751	0.099	0.082	0.011	-0.011	0.000	-0.042
DSTR ₃	0.026	-0.040	0.036	0.634	-0.037	0.304	-0.085	0.058	-0.021	-0.034
DSPM ₁	0.097	-0.029	-0.019	0.130	0.848	-0.184	-0.003	-0.058	0.004	-0.029
DSPM ₃	-0.024	0.024	0.012	-0.013	0.839	0.038	0.018	0.062	-0.016	0.070
DSPM ₅	-0.086	0.058	0.094	0.000	0.613	0.044	0.032	0.013	0.026	-0.030
DSTM ₄	-0.078	0.063	-0.021	0.177	-0.032	0.717	0.099	-0.019	-0.093	-0.043
DSTM ₃	-0.060	0.061	0.170	0.094	-0.093	0.652	-0.002	0.005	0.170	0.123
DSTM ₂	0.077	-0.065	-0.032	0.190	0.031	0.547	0.064	0.038	0.008	0.002

(continues)

Table 3. Continued

Items	1	2	3	4	5	6	7	8	9	10
ESC ₂	0.029	-0.004	-0.004	-0.055	-0.032	0.099	0.980	-0.095	-0.002	-0.047
ESC ₁	0.056	-0.118	0.011	-0.073	-0.054	0.059	0.649	0.161	-0.090	0.029
ESC ₃	-0.089	0.070	-0.086	0.049	0.066	0.017	0.524	-0.027	0.099	0.028
DSCO ₃	-0.080	0.049	0.025	0.011	0.056	-0.068	0.026	0.866	0.097	0.077
DSCO ₂	0.055	0.081	0.052	-0.102	-0.032	0.110	0.054	0.650	-0.005	0.029
DSCO ₁	0.050	-0.057	-0.051	0.136	-0.010	-0.010	-0.083	0.588	0.007	-0.113
BPII ₃	-0.102	0.093	0.089	0.068	-0.034	-0.056	0.040	-0.043	0.739	0.017
BPII ₂	0.097	-0.087	-0.076	-0.121	0.024	0.022	0.029	0.031	0.672	-0.124
BPII ₄	0.013	-0.060	-0.031	0.007	0.006	0.077	-0.050	0.026	0.530	-0.036
BPII ₁	0.048	-0.096	-0.133	0.017	0.026	0.008	-0.017	0.165	0.433	0.026
EFCO ₁	-0.045	-0.030	-0.075	0.038	0.001	-0.025	0.028	0.010	-0.061	0.969
EFCO ₃	0.142	-0.024	0.025	-0.064	0.015	0.090	-0.037	0.002	-0.040	0.609
Eigenvalue	5.19	3.66	2.93	2.46	2.34	1.96	1.78	1.61	1.42	1.12
Percent of variance	13.88	9.45	7.23	5.92	5.63	4.59	4.14	3.42	2.97	2.12

Notes: Principal axis factoring; Promax with Kaiser normalization. EFTO = process effectiveness; BPC = business process complexity; FLXO = process flexibility; DSTTR = training resources; DSPM = project management resources; ESC = extent of ERP implementation; DSCO = consultant resources; BPII = business process information intensity; EFCO = process efficiency. Items removed from analysis: DSPM₂, DSPM₄, EFCO₂, DSTM₁. Boldface figures correspond to items that load highly on the factor.

Table 4. Intercorrelations Among Constructs

Latent construct	Interfactor correlations			
	I	II	III	IV
I. Extent of ERP implementation (ERPEX)	1.00			
II. ERP radicalness (ERPRAD)	0.321**	1.00		
III. ERP delivery system (ERPDS)	0.434*	0.365**	1.00	
IV. Business process outcomes (BPO)	0.509*	0.415*	0.713*	1.00

* $p < 0.001$; ** $p < 0.01$; *** $p < 0.05$.

reflective first-order, formative second-order constructs. The model also included and specified ERPEX, with formative indicators, and BPO, with reflective indicators, as first-order constructs.

Table 4 shows the correlation among constructs. The ERPEX and ERPDS are more strongly correlated to the BPO than ERPRAD. Although PLS is reasonably robust against multicollinearity and skewed responses [15], nonetheless, we performed the relevant assessment. We did not observe a high level of association between the exogenous constructs. Further, an examination of the variance inflation factors (VIF), eigenvalues, condition indices, and condition number did not provide evidence of multicollinearity [46]. Similarly, no evidence of heteroskedasticity was detected.

Measurement Model

We assessed the psychometric properties of the measurement model results, presented in Table 5, by examining individual item loadings, internal consistency, convergent validity, and discriminant validity. The loadings of the measurement items on their respective factors were above the threshold value of 0.70 and all are highly significant ($p < 0.001$). For the reflective measures, rather than using Cronbach's alpha, which represents a lower bound estimate of internal consistency due to its assumption of equal weightings of items, a better estimate can be gained by using the composite reliability measure [19]. As shown in Table 5, the internal consistency of all reflective constructs clearly exceeded the threshold of 0.70, suggesting acceptable reliability. Convergent validity is considered adequate when the average variance extracted (AVE) is 0.50 or more, and this condition was satisfied in all cases.

Although the internal and external validity of the scales are typically assessed, there is a significant difference in the interpretation of the measurement model for formative constructs. Measures of internal consistency and unidimensionality cannot be used to judge the quality of the measurement model involving emergent constructs [29]. Accordingly, the general practice is to examine item weights, which will usually have smaller absolute values than item loadings. As seen in Table 5, the weights for the formative construct, ERPEX, ranged from 0.48 to 0.58 and are statistically significant.

Table 5. Measurement Model Results Constructs

Constructs	Item mean	Item standard deviation	Loadings	<i>t</i> -statistic
Extent of ERP implementation (ERPEX) ¹				
Functional scope	3.18	1.182	0.585 ²	4.842*
Organizational scope	3.61	1.402	0.481 ²	4.076*
Geographic scope	3.03	1.311	0.508 ²	3.797*
ERP radicalness (ERPRAD) ³				
Business process complexity ⁴				
BPC ₁	4.263	1.058	0.788	9.451*
BPC ₃	3.398	1.159	0.722	6.721*
BPC ₄	3.400	1.160	0.734	6.987*
CR = 0.793; AVE = 0.561				
Business process information intensity ⁴				
BPII ₁	3.391	1.060	0.877	36.235*
BPII ₂	3.277	1.233	0.840	16.806*
BPII ₄	2.986	1.350	0.770	18.996*
CR = 0.869; AVE = 0.690				
ERP delivery system (ERPDS) ³				
Top management support ⁴				
DSTM ₂	3.202	1.130	0.912	81.024*
DSTM ₃	3.324	1.179	0.809	21.906*
CR = 0.853; AVE = 0.744				
Project management resources ⁴				
DSPM ₁	3.344	1.086	0.788	19.029*
DSPM ₂	3.432	1.082	0.836	29.579*
CR = 0.795; AVE = 0.660				
Consultant resources ⁴				
DSCO ₁	2.939	1.190	0.885	17.579*
DSCO ₃	3.391	1.079	0.737	7.412*
CR = 0.797; AVE = 0.664				
Training resources ⁴				
DSTR ₂	2.837	1.223	0.867	33.257*
DSTR ₃	3.081	1.163	0.769	13.736*
CR = 0.803; AVE = 0.672				
Business process outcomes (BPO) ⁴				
EFCO	3.45	1.010	0.758	14.898*
EFTO	3.55	0.750	0.806	19.798*
FLEXO	3.46	0.710	0.713	11.318*
CR = 0.804; AVE = 0.579				

Notes: ¹ First-order construct with formative indicators. ² Weights for formative indicators. ³ Formative second-order construct. ⁴ First-order construct with reflective indicators. CR = composite reliability; AVE = average variance explained. Items eliminated: BPC₂, BPII₃, DSTM₁, DSPM₃, DSCO₂, and DSTR₁. * $p < 0.001$.

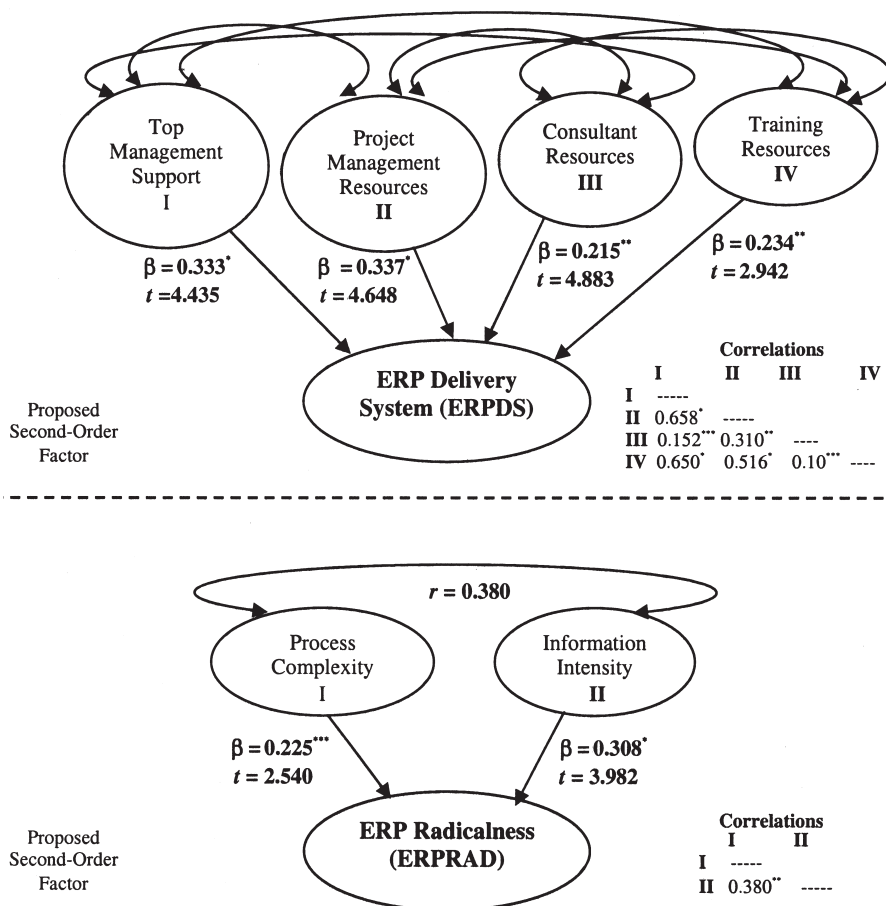


Figure 2. Second-Order Construct Results
 * $p < 0.001$; ** $p < 0.01$; *** $p < 0.05$.

Analysis of Second-Order Constructs

To estimate the hypothesized second-order model of ERPDS and ERPRAD, we modeled the coefficients (γ_i) of each first-order factor to the second-order factor using a principal components factor analysis, following the procedure in Diamantopoulos and Winklhofer [29, p. 271] rather than measuring the higher-order constructs with the measurement items of the first-order factors [21, 29, 30, 67]. The assessment of ERPDS and ERPRAD as second-order factors involved examining the correlations among the first-order factors. Tanaka and Huba [90] argue for the possible validity of a second-order factor if the first-order factors are highly correlated. Figure 2 shows that pairs of the first-order factors are correlated and significantly different from zero, suggesting a second-order factor structure and validating their expected relationships. Because none of the correlations between the pairs are negative, a high value on one does not preclude a high value on another. Moreover, the correlations among the

first-order constructs are below the suggested cutoff value of 0.90 [4], demonstrating that the content captured by the first-order factors are distinct from one another and indicative of discriminant validity.

The coefficients (γ_i) of the first-order enabling factors to the second-order factors are statistically significant, providing justification for the existence of the hypothesized formative second-order models [21, 29, 30, 67].

$$\begin{aligned} \text{ERPDS} &= \gamma_1(\text{DSTM}) + \gamma_2(\text{DSPM}) + \gamma_3(\text{DSCO}) + \gamma_4(\text{DSTR}) \\ \text{ERPDS} &= 0.333(\text{DSTM}) + 0.337(\text{DSPM}) + 0.215(\text{DSCO}) + 0.234(\text{DSTR}) \end{aligned} \quad (1)$$

$$\begin{aligned} \text{ERPRAD} &= \gamma_1(\text{BPII}) + \gamma_2(\text{BPC}) \\ \text{ERPRAD} &= 0.308(\text{BPII}) + 0.225(\text{BPC}). \end{aligned} \quad (2)$$

To assess content validity, we examined whether an indicator variable (aggregate measure weighted by first-order coefficients) was highly correlated with the direct measurement items. Even though the indicators serve as proxies of the second-order constructs, they can indicate content validity if the aggregate variables describe what they are intended to measure [92, 93]. The correlations ($r = 0.38, p < 0.001$ and $r = 0.40, p < 0.001$) for both constructs indicates acceptable content validity. Following the mediation tests using PLS, we tested whether the second-order factors (ERPDS and ERPRAD) fully mediated the effect of their respective first-order facets on the dependent variable (BPO). This test is done to confirm that the second-order construct is a more parsimonious representation of the first-order constructs that can capture their predictive power on the dependent variable (BPO) [92, 93]. The ERPDS was significant when all four first-order factors were controlled, suggesting it fully mediated the link between first-order constructs and BPO. Similarly, ERPRAD mediates the effect of the two first-order factors and BPO. These results support the conceptualization of ERPDS and ERPRAD as second-order constructs (see more details about the procedure in [66]).³

Testing the Structural Model

Overall, our hypothesized research model (see Figure 1) was supported. First, as seen by the structural model results presented in Table 6, the coefficients are in the appropriate direction, all are statistically significant, and provide support for the four hypotheses. Second, all but one of the standardized path coefficients exceed the suggested minimum standard of significance at 0.20 [17]. Third, the predictive power of the model is good. Overall, the model explains a considerable portion of the variance in BPO ($R^2 = 0.49$), and we confirmed that the variance explained due to the moderated effects was significant beyond the main effect [14, 21, 67, 68].

A bootstrapping resampling procedure was performed to obtain estimates of standard errors for testing the statistical significance of path coefficients using t -tests [16, 17]. The results are listed in Table 6. Consistent with H1, the main effect, ERPEX, had a positive and significant effect on BPO ($\beta_{\text{ERPEX}} = 0.313; t = 3.765; p < 0.01$). We used

Table 6. Structural Model Results

Hypothesized paths	Path coefficient (critical ratio)	Hypothesis supported
Main effects		
Extent of ERP implementation (ERPEX) → business process outcomes (BPO)	0.313 (3.765)**	Yes
Interactions:		
Extent of ERP implementation (ERPEX) × delivery system (ERPDS)	0.247 (3.914)*	Yes
Extent of ERP implementation (ERPEX) × ERP radicalness (ERPRAD)	0.251 (3.681)**	Yes
ERP radicalness (ERPRAD) × delivery system (ERPDS)	0.147 (2.330)***	Yes
Control variable:		
Size → business process outcomes (BPO)	0.268 (3.581)**	Yes

* $p < 0.001$; ** $p < 0.01$; *** $p < 0.05$.

firm size to control for organizational size effects. The results show that firm size was significantly related to BPO ($\beta_{\text{SIZE}} = 0.268$; $t = 3.581$; $p < 0.01$).

The Moderating Role of ERPDS and ERPRAD

We next examined moderating effects, which may serve to establish contingency conditions, and recognized that formative moderators need to be treated differently from reflective constructs [21].⁴ Typically, the interaction effect is tested before the direct effects when using a parametric technique (e.g., LISREL) [81]. That is, if the interaction effects are not statistically significant, then the two direct effects (ERPDS → BPO and ERPRAD → BPO) would be tested and interpreted. However, PLS, a non-parametric technique, is not constrained by these requirements. As shown in Table 6, ERPDS had a significant moderating effect ($\beta = 0.247$; $t = 3.914$; $p < 0.001$) on the relationship between ERPEX and BPO (H2 supported). Also, a significant moderating effect of ERPRAD for its influence on the relationship between ERPEX and BPO was found ($\beta = 0.251$; $t = 3.681$; $p < 0.01$), showing support for H3. As well, ERPDS significantly moderated the relationship between ERPRAD and BPO ($\beta = 0.147$; $t = 2.330$; $p < 0.05$), supporting H4. The standardized path estimate from each interaction term construct to BPO indicates how a change in the level of the moderator construct (ERPDS and ERPRAD) would change the influence of ERPEX (and ERPRAD) on the dependent construct (BPO). For example, ERPDS can potentially strengthen or weaken the effect of ERPEX on BPO and on the relationship between ERPRAD and BPO. Likewise, the effect of ERPEX on BPO can be strengthened (or weakened) by ERPRAD.

To further assess the association of ERPEX and the moderators' influence on BPO, in Table 7 we provide a summary of alternative model results. Model 1 contains only

Table 7. Alternative Model Results

Model	Standardized coefficient	<i>t</i> -statistic	<i>R</i> ²
(1) $BPO = f(\beta_{ERPEX}, \beta_{SIZE})$			
ERPEX	0.423	5.29*	0.320
SIZE	0.258	2.74***	
(2) $BPO = f(\beta_{ERPEX}, \beta_{ERPEX \cdot ERPDS}, \beta_{SIZE})$			
ERPEX	0.382	4.82*	0.417
ERPEX x ERPDS	0.326	5.77*	
SIZE	0.261	3.40**	
(3) $BPO = f(\beta_{ERPEX}, \beta_{ERPEX \cdot ERPDS}, \beta_{ERPDS \cdot ERPRAD}, \beta_{SIZE})$			
ERPEX	0.355	5.05*	0.435
ERPEX x ERPDS	0.306	4.87*	
ERPDS x ERPRAD	0.146	2.26***	
SIZE	0.236	2.85***	
(4) $BPO = f(\beta_{ERPEX}, \beta_{ERPEX \cdot ERPDS}, \beta_{ERPDS \cdot ERPRAD}, \beta_{ERPEX \cdot ERPRAD}, \beta_{SIZE})$			
ERPEX	0.313	3.76**	0.490
ERPEX x ERPDS	0.247	3.91*	
ERPDS x ERPRAD	0.147	2.33***	
ERPEX x ERPRAD	0.251	3.68**	
SIZE	0.268	3.58**	

* $p < 0.001$; ** $p < 0.01$; *** $p < 0.05$.

the main effect of ERPEX and the control variable (size), which were significant and explained 32 percent of the variance in BPO. Building on this, Model 2 added the interaction effect of ERPEX by ERPDS. Again, all constructs are significant and together they increase the explained variance in BPO to about 42 percent. Model 3 shows the relationship of the main effect (ERPEX) and two of the interaction effects (ERPEX \times ERPDS, ERPDS \times ERPRAD) to BPO. The constructs are significant and explain about 43 percent of the variance in BPO. The final Model 4 (our research model) indicates that ERPEX is significantly associated with BPO and the three moderators significantly delineate how the association between ERPEX and BPO changes according to the different levels of delivery system and radicalness. The test for the moderated relationship was conducted by using ΔR^2 to draw conclusions about the moderator effect size because “the use of the path coefficient of an interaction term will lead to spurious conclusions” [14, p. 484]. This approach prevents an incorrect interpretation of the significance of the interaction term when it is correlated with its constituent parts—that is, its main effect. By comparing the R^2 for the interaction model with the R^2 for the main effect model (excludes the interaction constructs), we can assess the strength of the moderating effects. The difference in R^2 can be used to estimate the effect size. The effect size⁵ (f^2) can be calculated as a gauge to determine whether the three interaction effects had a small (0.02), medium (0.15), or large effect (0.35) on BPO [22]. The model containing only the main effect ERPEX and control (Model 1) was compared to the research model (Model 4) containing ERPEX, the control, and the three interactions. As seen in Table 7, the inclusion of the interaction

effects increases the R^2 value from 0.32 to 0.49. The interactions had a large effect size ($f^2 = 0.490 - 0.320/1 - 0.320 = 0.25$). Thus, the relationship between ERPEX and BPO is moderated by ERP delivery system and radicalness. Although, as shown in Table 4, we observed high correlations between ERPDS and BPO ($r = 0.713$) and between ERPRAD and BPO ($r = 0.415$), we resisted the interpretation of the main effects of ERPDS and ERPRAD to avoid errors.⁶ Further, as was mentioned earlier, in the context of the ERP implementation, there are theoretical reasons for suggesting that both innovation antecedents (e.g., delivery systems) and novel variables (e.g., ERP radicalness) have moderating effects on outcomes. It is true that the existence of good project management, good training, good consulting, and top management commitment can ultimately result in better outcomes at the project level; at the business process level, however, it is hard to justify their direct effects in isolation without simultaneously considering the main effect of the ERP implementation on outcomes. After all, business process outcomes result as a consequence of the ERP implementation; and without proper integration of the resources to build capabilities (via ERP implementation), unused resources by themselves cannot result in outcomes at the business process level. Also, the direct effects of radicalness on outcomes are unclear because radical innovations can have wide-ranging intended or unintended consequences that can lead to increases in the variance of potential returns or increase in the expected value of potential payoffs.

Discussion

ALTHOUGH MOST CRITICAL SUCCESS FACTOR STUDIES ON IT implementation [42, 44, 86] typically include top management support, project management, end-user training, external consultants, and system and project characteristics, it is not clear how these factors interrelate, especially because it seems unlikely that they all work in isolation without affecting each other [1]. To the contrary, this study investigated the complex interactions among organizational and technological factors to find out whether these factors can affect each other in a reinforcing manner. The goals of our study were to determine under what conditions and by what mechanisms the extent of ERP implementation has the greatest effect on business process outcomes. We theoretically derived scales for extent of ERP implementation, radicalness, delivery systems, and business process outcomes. Our scales offered items for each of the constructs, which were subsequently linked together in a structural equation model. We draw on unique data sets collected from two surveys, which provided evidence of the scales' robustness and generalizability across two populations. The scales in this study exhibited good validity and should provide a useful tool for further inquiry into factors that can lead to differential business process outcomes as the result of an ERP implementation. We assessed the association of extent of ERP implementation, delivery systems, and radicalness with business process outcomes. The results validated our expectations.

These findings suggest that although the extent of ERP implementation is directly and significantly associated with business process outcomes, ERP delivery system and radicalness can have significant moderating effects. This suggests that the association is

stronger *when* firms have better delivery system support. Similarly, this association is moderated by ERP radicalness. That is, the higher the extent of ERP implementation, the higher will be the association between ERP radicalness and business process outcomes. This explains *by what mechanism* ERP radicalness is associated with business process outcomes. Further, the interaction of ERP delivery system and radicalness significantly moderates the association of the extent of ERP implementation with business process outcomes. This confirms prior research on the importance of an appropriate delivery system for radical innovations. It suggests that radical innovations may result in better business process outcomes when they are extensively implemented. Therefore, the results confirm previous findings that radical innovations can have wide-ranging intended or unintended consequences that can lead to increases in the variance of potential returns or increase in the expected value of potential payoffs.

Implications and Future Research

THIS STUDY MAKES SEVERAL CONTRIBUTIONS to IS research and practice. It builds upon innovation diffusion theory as it relates to ERP implementation literature. Although this theory has proved helpful in understanding the organizational and technological attributes that facilitate innovation diffusion over time in a variety of settings, this is the first empirical study that has applied this theory to an ERP implementation context and has examined its ability to predict business process outcomes to the best of our knowledge. The research model helps to identify why there will be a particularly high variance in potential outcomes and further validates when or under what conditions positioning investments in multiphase ERP implementation projects create real options on subsequent implementation and use of the ERP platform. Because ERP radicalness and delivery systems lead to increasing variance in potential outcomes, these factors should also be predictive of early ERP adoption; evaluation of these factors can also help managers direct their attention to most promising factors and provide insights into how to manage their complex interactions. This study explains why some firms adopting ERP systems will have higher expected returns from ERP implementation than others. Ultimately, the results can help managers in their decision to terminate or redirect troubled ERP implementation projects.

The second-order factor structure for ERP delivery system and radicalness categorize several critical success factors in ERP implementation and IT innovation literature. They provide parsimonious descriptions for complex interactions among factors that go beyond their independent effects and suggest that a combination of these factors may be necessary to affect business process outcomes. The set of first-order factors and their underlying dimensions provide holistic combinations of factors that can explain and provide sufficient conditions to have positive effects on the outcomes of complex ERP implementations. They suggest that the association between the extent of ERP implementation and business process outcomes is influenced by a better delivery system, and better delivery system can increase managerial flexibility by incremental implementation, and can serve to increase business process outcomes. They also suggest that ERP radicalness reinforces the association between the extent

of ERP implementation and business process outcomes; and, because of the ERP radicalness, full implementation is more likely given first-phase implementation. These results, therefore, suggest that the combination of organizational, technological, and implementation factors significantly enhances outcomes. Future research could use the extent of ERP implementation, radicalness, and delivery system to examine their combined or differential effects on (1) strategic importance of a firm's affected products or processes, (2) learning-related endowments surrounding ERP adoption, (3) ability to expand knowledge and skills to better assimilate and utilize ERP systems, and (4) ability to structure and interpret various implementation configurations.

ERP implementation has been one of the most significant challenges for IS practitioners in the past decade. For practice, we underscored the need for firms to secure a proper delivery system prior to ERP implementation because it represents a set of complementary managerial resources. Investing in individual elements is unlikely to achieve the desired outcomes. Firms that have better ERP delivery systems are expected to achieve better business process outcomes from their implementation efforts. Further, increases in expected outcome also increase the chance that the full ERP implementation option will actually be exercised [37]. This is especially important considering that higher extents of ERP implementation present major problems, challenges, and opportunities when implementing ERP systems. We have constructed a reliable instrument to help firms evaluate their level of delivery system along each dimension and identify areas where they may be lacking. Results suggest that managers should be more concerned with synergy among the technological, organizational, and implementation factors because that is where the real benefits can be found.

Limitations

IT IS IMPORTANT TO REMEMBER ANY RESEARCH STUDY is not without limitations and we recognize specific issues that warrant caution in interpreting our results. First, all the measures were self-report surveys. Consequently, the observed relationships may have been artificially inflated as a result of respondents' tendencies to respond in a consistent manner. However, more recent meta-analytic research indicates that although this problem continues to be commonly cited, the magnitude of inflation may be overestimated [25]. Second, this study relied on a sample of senior IS executives in U.S.-based manufacturing firms. The executives' perceptions of implementation practices and outcomes are, taken as a whole, grounded in industry-specific assumptions, which brings into question some boundaries on the study's generalizability. Consequently, in the assessment of the study's external validity, one needs to consider that the study involved senior IS executives within a manufacturing setting. This limits generalizations to other industries. However, because of their training, one might argue that IS executives would likely be more attuned to and concerned about issues of implementation than others within the organization. Moreover, they are likely to have a higher level of experience with technologies and well-formed beliefs and compelling perceptions about the system. In addition, there are a number of factors that suggest the results may generalize to other industries. For example, regardless of industry,

an ERP system promises to revitalize IT infrastructures and enable business process integration. Ultimately, however, generalizability is best addressed through replication in different contexts to identify the boundary conditions for the theoretical model. The knowledge garnered from a manufacturing environment will be invaluable in helping us extend this line of research further. Finally, the self-report measures for all constructs were obtained at the same point in time from the senior executives, which may increase the potential for common method bias. Moreover, the cross-sectional nature of the study does not permit causality to be inferred from the results. Finally, given the wide range of potential antecedents that can lead to higher efficiency, effectiveness, and flexibility, coupled with the fact that none of the studies conducted to date have provided theoretical and empirical examination of the factors that lead to differential outcomes of ERP implementation across firms, this is an important issue for future research to consider.

Conclusions

THIS STUDY COMMENCED WITH THE PREMISE that the extent of ERP implementation is a key determinant of business process outcomes. We examined ERP implementation from organizational innovation and technology assimilation perspectives to explain the role of one or more factors in determining business process outcomes. Empirical data collected from two field surveys were used to validate the study's measurement scales and data from manufacturing firms were used to test the hypothesized research model. We found broad-based support for our research model.

This study advances our understanding of the combined role of characteristics of technology (radicalness and divisibility) and organizational factors (delivery systems) on business process outcomes by focusing on ERP implementations. It suggests that a combination of these factors produces higher outcomes. It has provided empirical evidence for their multiplicative and differential effects on business process outcomes. Lessons learned from this study are useful for other organizations in their efforts to successfully implement ERP systems. The results of this study point to critical factors in ERP implementation that require more attention to ensure implementation success. They will benefit (1) organizations seeking to achieve higher business benefits from ERP implementations, (2) consultants seeking to work on these projects, and (3) researchers seeking to understand some of the barriers to successful ERP implementation and subsequent exploitation of such systems.

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NOTES

1. Divisibility is defined as the extent to which a technology can be divided for sequential and incremental implementation in such a way that each incremental segment positions the firm for positive payoffs, even if no further implementation segments are pursued [30].

2. Economists, however, focus on outcomes of innovation and define an innovation as radical when it reduces the cost of production so far that it makes the methods employed by incumbent firms obsolete [48]; radicalness is, therefore, defined in terms of the outcome of innovation and the extent of potential improvements in organizational products or processes enabled by the technology platform [37, 48].

3. Diamantopoulos and Winklhofer [29] identify four critical issues for successfully constructing indexes with formative indicators—content specification, indicator specification, indicator collinearity, and external validity. The following four steps can confirm a second-order model:

1. For content specification, identify subfactors that will capture the major facets for the second-order construct. Model the coefficients (relative weights) (γ_i) of the first-order enabling factor to the latent second-order factor using a principal components factor analysis, following the procedures in Diamantopoulos and Winklhofer [29, p. 270])

$$\eta = \gamma_1 x_1 + \gamma_2 x_2 + \dots + \gamma_n x_n.$$

Examine to determine if γ_1 first-order factors on η are significant.

2. Critical for the design of indexes with formative indicators is the choice of items, because the indicators must capture the scope of the construct. Identify items that capture the major subprocesses. For formative measurement models, the formative indicators define the index of the latent variable and collinearity among indicators would affect the stability of indicator coefficients. Determine whether the indicators of the subfactors reveal serious multicollinearity problems. Examine correlations among the first-order factors—very high correlations suggest first- and second-order factors may be reflective.
3. Test to determine if the aggregate second-order construct is highly correlated with the direct measurement items. This indicates if the aggregate variables describe what they are intended to measure (content validity).
4. Test for mediation of second-order factor to determine if it mediates the link from the first-order factors to the endogenous variable. This determines if the second-order construct is a more parsimonious representation of the first-order factors.

4. Because formative indicators are not assumed to reflect the same underlying construct (i.e., can be independent of one another and measuring different factors), the product indicators between two sets of formative indicators will not necessarily tap into the same underlying interaction effect. Consequently, the approach for formative indicators would entail using the formative indicators in conjunction with PLS to create underlying construct scores for the predictor and moderator variables, then taking those single composite construct scores to create a single interaction term. See online supplement at www.informs.org/Pubs/Supplements/ISR/1526-5536-2003-02-SupplA.pdf.

5. Effect size $f^2 = [R^2(\text{interaction model}) - R^2(\text{main effects model})]/[1 - R^2(\text{main effects model})]$ [66].

6. Carte and Russell [14] cautioned that when ratio scales are not used (as in our case), the main and interaction effects should not simultaneously be examined and suggested that investigators must avoid and resist temptations to interpret the direct effects in presence of the moderating effects. Consequently, we avoided this error by only hypothesizing the moderating effects of ERPDS and ERPRAD on BPO, and did not interpret their main effects because their moderating effects were found to be significant.

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Appendix. Measurement Scales

ERP Radicalness (ERPRAD)

Business Process Information Intensity

BPII₁: Our production/service operations require a significant amount of information processing.

BPII₂: There are many steps in our value chain that require frequent use of information.

BPII₃: Information used in our production/services operations needs frequent updating.

BPII₄: Information constitutes a large component of our product/service to customers.

Business Process Complexity

BPC₁: The business processes we deal with often cut across multiple functional areas.

BPC₂: We frequently deal with ad hoc, nonroutine business processes.

BPC₃: We generally have a high degree of uncertainty in our business processes.

BPC₄: A majority of our business processes are quite complex.

Extent of ERP Implementation (ERPEX)

ESC₁: Functional scope of implementation of your selected ERP (select all that apply):

Accounting/Finance | Manufacturing | Planning/Scheduling | Human Resources
| Sales/Distribution | Logistics/Inventory Control | Other (please specify):

ESC₂: Scope of implementation of your selected ERP: Department | Division | Entire company | Multiple companies | Other: _____

ESC₃: Geographical extent of implementation: Single site | Multiple sites | National | Worldwide

ERP Delivery System (ERPDS)

Top Management Support

DSTM₁: Senior executive demonstrated a lot of enthusiasm and interest throughout the project.

DSTM₂: The overall level of management support in this project was quite high.

DSTM₃: Upper-level managers were personally involved in the project.

Project Management Resources

DSPM₁: Formal project management tools and techniques were employed for this project.

DSPM₂: Project managers in charge of the project were highly capable and experienced.

DSPM₃: The implementation schedule was realistic.

Training Resources

DSTR₁: Significant time and resources were invested in training employees on using the new system.

DSTR₂: Adequate on-the-job training was provided to internal user groups to use the new system.

DSTR₃: Both technology and process training were provided to employees using the system.

Consultant Resources

DSCO₁: Experienced consultants guided us throughout the course of the project.

DSCO₂: External consultants were experienced in our business processes.

DSCO₃: External consultants brought considerable expertise and experience to our project.

Business Process Outcomes (BPO)

Process Efficiency

EFCO₁: ERP implementation has improved our efficiency of operations.

EFCO₂: ERP implementation has lowered our cost of operations.

EFCO₃: ERP implementation has reduced the amount of rework needed for data entry errors.

Process Effectiveness

EFTO₁: Data provided by ERP add value to our operations.

EFTO₂: ERP implementation has improved timely access to corporate data.

EFTO₃: The ERP system provides a high level of enterprisewide data integration.

EFTO₄: ERP implementation helps us make better sales forecasts than before.

EFTO₅: The functionalities of ERP adequately meet the requirements of our jobs.

EFTO₆: ERP implementation has improved our quality of operations.

Process Flexibility

FLXO₁: ERP implementation has given us more ways to customize our processes.

FLXO₂: ERP implementation has made our company more agile.

FLXO₃: ERP implementation has made us more adaptive to changing business environment.

FLXO₄: ERP implementation has improved the flexibility of our operations.

CFA indicated removal of the following items from analysis: BPC₂, BPII₃, DSTM₁, DSPM₃, DSCO₂, and DSTR₁.

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