
The Role of Information Systems Resources in ERP Capability Building and Business Process Outcomes

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ABSTRACT: Many enterprise resource planning (ERP) implementation projects fail despite huge investments. To explain such failures, we draw on the resource-based view (RBV) of the firm to define various dimensions of information systems (IS) resources. Using resource-picking and capability-building arguments, we examine the relationships between IS resources and ERP capabilities to find out whether they have

complementary effects on outcomes. Empirical results from a survey of manufacturing firms that recently implemented ERP systems support the hypothesized model. For IS research, this study further develops the complementary and capability-building roles of IS resources, integrates RBV into our current knowledge of ERP implementation, and provides theoretical explanations for when or under what conditions building ERP capabilities has the highest impact on business process outcomes. For IS practice, it emphasizes the importance of IS resources in building ERP capabilities, provides preliminary measures for IS resource dimensions, and demonstrates their impact on firms' ERP capabilities and consequent business process outcomes.

KEY WORDS AND PHRASES: business process outcomes, complementarity, ERP capabilities, IS resources, resource-based view, resource-picking and capability-building mechanisms.

FIRMS OFTEN SPEND MILLIONS OF DOLLARS implementing large-scale enterprise resource planning (ERP) systems in order to gain significant operational and strategic outcomes [66, 81]. New license revenue for the 2004 ERP market grew 9.4 percent or generated \$5.8 billion during 2004, and the worldwide market for ERP applications is forecast to grow with a compound annual growth rate of 7.7 percent from 2004 to 2009 [30]. However, many ERP implementations in technologically sophisticated and financially sound firms fail to realize their expected outcomes [79]. The size and complexity of ERP systems make them inherently difficult to implement [56]. The stark contrast between the expected benefits and actual outcomes calls for a theoretical and empirical investigation of the key drivers for business process outcomes [53].

Although substantial research has been published on ERP implementation (e.g., [32, 41, 76]), most published research, even the prescriptive ones, are unable to adequately explain the outcomes of such implementation [74]. We suggest those firms that possess and effectively deploy information systems (IS) resources critical for ERP implementation are likely to benefit more from their ERP initiatives than firms that do not. We draw on *resource picking* and *capability building* [49] and *complementarity* [55, 70] arguments to examine the relationships between IS resources and ERP capabilities to find out whether they have a complementary impact on outcomes. *Complementarity* arises when a resource produces greater returns in the presence of another resource than it produces by itself [55, 69, 77, 93]. While the resource-based view (RBV) of the firm recognizes the complementary role of resources, it is not well developed in the theory. Melville et al. [55] suggested that (1) the existence and magnitude of the complementarity between any two resources vary depending upon organizational and technological contexts, (2) it is not clear which resources are more important for each setting, and (3) the detailed mechanisms by which they combine are not clear either. In this study, we propose an ERP capability-building model and then empirically test the hypothesized model using a field survey of manufacturing firms that recently implemented ERP systems. Two research questions are addressed:

RQ1: Do IS resources have direct or combined effects on building ERP capabilities?

RQ2: When or under what conditions does building ERP capabilities have the highest impact on business process outcomes?

Theoretical Foundations

THE RBV OF THE FIRM IS AN EMERGING PERSPECTIVE in strategic management that explains firm performance in terms of internal resources and capabilities. Although there are increasing interests in the RBV of the firms in IS research [13, 93, 98], with the exception of a few studies mentioned, most have not systematically examined the relationships between IS resources and capabilities [69], or distinguished organizational capabilities based on their complexities [46], or examined the complementary role of IS resources in building information technology (IT) capabilities [70, 86]. As explained below, these build the theoretical foundations for this study.

Resources are generally rare, inimitable, and nonsubstitutable firm-specific assets that add value to firms' operations by enabling firms to implement strategies that improve efficiency and effectiveness [8]. In contrast, *capabilities* refer to firms' abilities to perform a coordinated set of tasks, utilizing internal resources, for achieving desired outcomes [37]. They are often developed in strategic, functional, and subfunctional areas by combining physical, human, and technological resources [4]. Although there is no predetermined functional relationship between a firm's resources and its capabilities [35], Makadok [49] made a useful distinction: a resource is an observable but not necessarily tangible asset that can be independently valued and traded, while a capability is unobservable and hence necessarily intangible, cannot be independently valued, and changes hands only as part of its entire unit. Makadok [49] further suggested that economic rents are created when firms are more effective than their rivals in selecting and deploying resources to *build* capabilities, and that *resource picking* and *capability building* are not necessarily independent but *complementary* activities. While resources by themselves can serve as the basic unit of analysis, firms build capabilities by assembling these resources into unique configurations, thereby transforming inputs into outputs of greater worth [4, 96]; capability building refers to the ability of firms to build unique competencies that can leverage their resources [88].

Organizational capabilities differ in their complexity. Not all capabilities are at a *strategic level*, which requires strategic resources that are valuable, rare, imperfectly imitable, and nonsubstitutable, to lead to sustained competitive advantage. Some may be *supplemental*, *enabling*, or at a *functional/operational level*, which may establish a minimum ground for competition without being by themselves sufficient to achieve advantage vis-à-vis competitors [47]. While most IT capability-building studies tend to focus on strategic level and on integrated IT from a strategic resource perspective (e.g., [78, 93]), functional-level capability-building studies have an operational or a process-oriented focus, and emphasize process improvements at the functional/business process levels [33, 46, 58, 69, 100]. To the contrary of implicit belief that IS functional

capabilities are nondifferentiating commodity services that could be outsourced with little consequence [39], recent research [69] suggests that targeted deployment of IS resources in building IS functional capabilities can have significant strategic value and rent yielding by enabling an organization to use IT to develop distinctive competencies. Both functional- and strategy-level capabilities can enhance a firm's dynamic capability creation [37, 46, 61, 93].

A firm's distinctive capabilities are embedded in business processes (routines) by enabling it to be more effective than its rivals in *selecting, combining, integrating,* and *deploying* those resources [49, 93]. Bharadwaj extended the traditional notion of organizational capabilities to a firm's IS function and defined a firm's *IT capability* as its ability to assemble, integrate, and deploy valued IT-based resources in combination or to copresent with other resources and capabilities [13]. IT capability refers to a firm's ability to identify systems meeting business needs, to deploy these systems in a cost-effective manner, and to provide long-term maintenance and support for these systems [77]. It is the manner in which a firm leverages its investments in resources and integrates these resources to build systems that can have an impact on the firm's overall efficiency, effectiveness, and flexibility [54, 75]. It is defined as an integrated set of reliable IT infrastructure services that support existing applications and new initiatives. It is composed of four resources: (1) IT components resources, which are the IT assets; (2) human IT infrastructure, which includes knowledge resources; (3) shared IT services, which are the user-specific IT capabilities; and (4) shared and standard applications [96]. Consistent with the notion of IT capability, recent research further defines IS capabilities as "the routines within the IS department that enable it to deliver IT services to the organization" [69, p. 244], such as IS planning sophistication, system development capability, IS support maturity, and IS operations capability.

As a type of IS/IT capability at the functional/operational level, ERP capabilities can result in creating shared and standard applications by enabling firms to retain data integrity and manage multiple business functions [75, 96]. These can enable new opportunities for firms by achieving competitive differentiation and offering products or services at a lower cost [92], by supporting tight links with its customers and suppliers [91], and by providing business flexibility with flexible IT architecture. An inflexible (nonintegrated) IT architecture, however, is characterized by system incompatibilities, which severely restrict a firm's IT capability and its delivery of new solutions [19, 28, 77]. IT architecture is, therefore, considered a core IT capability [31], because it can contribute to IT infrastructure and functional-level capabilities [69] and cannot be cast aside to ERP vendors. Keen [43] argues that a sophisticated IT capability enhances the business degrees of freedom by enhancing intra-organizational connectivity (across departmental units throughout the enterprise) and extra-organizational connectivity (with key external business partners).

Teece et al. further argued: "Capabilities cannot easily be bought; they must be built" [88, p. 529]. A mixture of people and practices continuously enact capabilities such as Wal-Mart's collaborative forecasting and planning system and Dell's logistics management system [38]. Similar to the case for building e-commerce capability [99], *ERP capability* is often tightly connected to the resource base embedded in a firm's

business processes, which may vary across firms depending on their unique resource endowments. Regardless of how commodity-like some IS resources may be, building ERP capability requires removing the barriers associated with legacy system incompatibilities to build a firm's IS/IT capability. Therefore, ERP capabilities are clearly not commodities because they must be built (implemented). In the research model illustrated in Figure 1, IS resources are key drivers for building ERP capabilities. Also, IS resources and ERP capabilities are shown to have complementary impact on business process outcomes.

IS Resources

A recent literature review indicated that, to a large extent, IT has been viewed as a stand-alone resource [89]. Ross et al. [77] identified technical, human, and relationship resources as three categories of IS resources that are critical to developing a firm's IS/IT capability. While Barney [8] proposed physical, human, and organizational capital, Bharadwaj [13] suggested tangible, human, and intangible resources, and Ravichandran and Lertwongsatien [69] mentioned IT infrastructure sophistication, human capital, and partnership quality. Based on six traditional resources, Wade and Hulland [93] recommend that for research that examines specific technologies, a set of more *narrowly defined* resources is appropriate. Therefore, we focus on three classes of IS resources that are critical to building a greater scope of ERP capabilities and to producing better outcomes. These are knowledge, relationship, and IT infrastructure resources. These resources are heterogeneously distributed across firms, and their presence or absence may explain the differential scope of ERP capabilities and outcomes.

Knowledge Resources

A firm's knowledge resources are the unique skills, expertise, insights, experience, and intellectual capital that it uses for building IT capability. Knowledge exploitation requires sharing relevant knowledge among members of a firm to promote mutual understanding and comprehension. Knowledge resources of a firm can be categorized into tacit and explicit. While tacit knowledge resides in the minds of human resources, explicit knowledge is embedded in organizational processes, routine, rules, and product and process technologies [12, 13, 77]. Knowledge resources are less mobile and not easy to obtain, and, therefore, are able to generate long-term economic rent. The importance of these resources was first articulated by Attewell [6], who contended that successful implementation of complex systems in firms is constrained by their inability to overcome knowledge barriers associated with implementing such systems. These resources have been widely recognized to be critical drivers for a firm's performance [55] and for rent yielding [54, 77]. They are sourced from a vendor or are possessed by an in-house technical pool.

Two types of knowledge resources that are especially relevant for building ERP capabilities are business process and project management knowledge. *Business process knowledge* refers to knowledge associated with a given application domain targeted

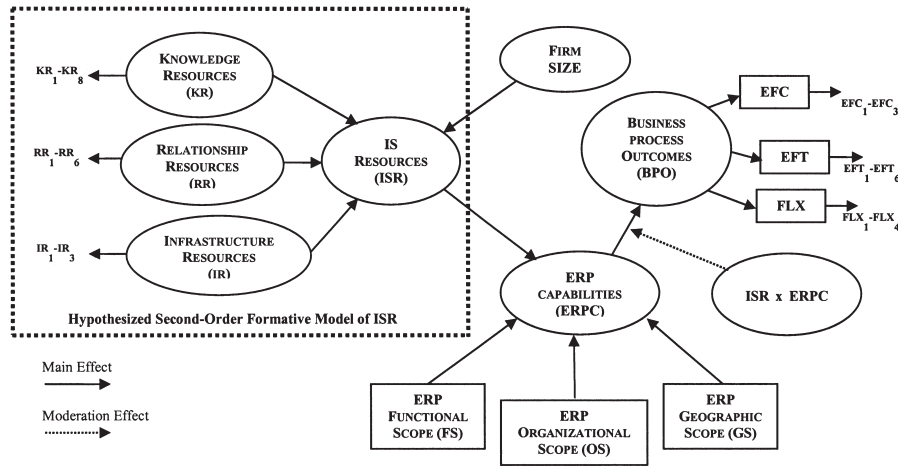


Figure 1. ERP Capability-Building Model

for ERP implementation [77]. Business process know-how is essential for accurate elicitation of system requirements, integrating data and process across value-chain activities, and providing the means for tracking system performance. Being mired in daily IS operational problems, IS personnel are often ill-equipped to acquire the business knowledge necessary for building ERP capabilities. ERP systems often require multiple kinds of specialized expertise and an internal team will not have such requisite knowledge. Therefore, firms typically contract IT consulting firms that have been designated as consulting partners for the specific ERP vendor [16]. The use of consultants has been identified as one of the critical success factors for ERP implementation [14, 82]. Despite a mix of performance ratings reports for some consultants, most have experiences in specific industries, comprehensive knowledge about certain modules, and are better able to determine which suite will work best for a given company.

Project management knowledge includes expertise, experience, skills, rules, and standards that are needed to develop applications, manage systems development activities, “bind” IT infrastructure components into reliable services [96], and manage a project implementation life cycle [93]. Although project management is an organizational resource, and not specifically an IS function resource, an effective project manager needs to have credibility among stakeholders and successful IS project management experiences [31]. Such business, technical, and project management knowledge evolves through learning-by-doing and accumulation of experiences. It is considered to be corporate-level knowledge assets [13], often the result of years of interaction between IS staff and business users, and usually institutionalized via team processes, collaborative learning, and sharing of work practices. Excellent project management is considered as one of the critical success factors for the various stages of ERP imple-

mentation [82, 90] and for managing ERP implementation risks [79]. Successful ERP implementation requires a clear definition of objectives and scope, a project plan, an achievable schedule, and careful tracking of project progress [90].

Relationship Resources

Relationship resources consist of sharing risk and responsibility of IT application development between IT and business unit management [77]. One major component of relationship resources is the trust that is developed between IT groups and business units through a history of interactions, which can influence their knowledge-sharing behavior [59]. Recent research has shown that for ERP customization, trust directly affects client assessment of the worthiness of business relationships even when the ERP qualities are brought into account [34]. Because the development of trust takes time, it can constitute a source of social capital and competitive advantage for the firm [8]. In past literature, the social capital theory (SCT) is concerned with the significance of *relationships as a resource* for individual action, and has been proposed as the source of “organizational advantage” [59]. Unlike other forms of capital, social capital is owned jointly by the parties in a relationship, and no one player has, or is capable of having, exclusive ownership rights [17]. Moreover, although it has value in use, social capital cannot be traded easily. Relationship resources, therefore, are difficult to imitate because they develop over many years of cooperation and trust building. Further, relationship resources tend to be socially complex, relatively immobile, nonsubstitutable, inimitable, and rare [95]. Rarity implies that these resources are not simultaneously available to a large number of firms [4]. Relationship resources facilitate the free flow of information allowing the firm to transform and exploit information. They are essential for getting business units to agree on common business processes, which are necessary for ERP implementation. Relationship building is a core IT capability that facilitates wider dialogue between the business and IS and involves developing user understanding of IT potential [31]. Unless the line management and IT groups can coordinate their responsibilities and accountabilities, the firm is unlikely to acquire, deploy, and leverage its IT resources effectively [71]. In the context of building ERP capabilities, knowledge sharing and trust building require building *relationship resources*, which can be accomplished by active business user and top management involvement in implementation [77, 94]. This involvement in ERP implementation will result in building trust by process-based mode [34], which is based on creating a good track record in the ongoing relationship and the investment that the trusted party makes in the relationship.

User involvement helps define system functional and design requirements, and thereby ensures that the delivered system will meet user needs and acceptability standards [83]. Markus [50] described how lack of user support at a global firm led to an underutilization of a technologically sound financial accounting system, which ultimately led to the system’s demise. Relationships with users are manifested by active user participation and involvement in the identification of system requirements,

process logic for new systems, and IS use [83]. Active involvement of business users can greatly enhance the chances for IS project success [11, 15]. User relationships are often ingrained in a firm's long-term organizational history, are firm specific, nontransferable, and therefore capable of generating long-term economic rents. Such resources build IT capabilities by establishing strong coordination, cooperation, and goal setting among business units and IS personnel [31, 93], a process that has been referred to as synergy and partnership [24, 77, 93].

Research on the impact of IS resources on firm performance has also pointed to *top management involvement* as one of the most important critical success factors for various stages of ERP implementation [82]. Top management, by virtue of sponsorship roles in large IS projects, provides visibility and credibility to new IS implementation projects, secures necessary funds and resources to staff and maintain these projects, and protects them from premature demise such as during organizational cost cutting [11]. Prior research suggests that (1) top management must understand the needs and scope of an implementation and facilitate integration of emerging technologies in order to exploit the business value of IT innovations, and (2) top management involvement is strongly associated with a firm's progressive use of IT and plays a key role in successful IT implementation by allowing implementation teams to cross functional barriers [37, 48].

IT Infrastructure Resources

Infrastructure resources refer to a firm's shared *IT assets* (e.g., hardware, software tools, networks, databases, and data centers). They are the foundations for a firm's IT architecture, which is the blueprint or design that supports multiple applications and user groups across the firm [75, 77]. From a strategic resource perspective for building strategic-level capabilities, the individual IT asset is commodity-like, widely available, imitable, and relatively easy to obtain, and is therefore incapable of generating long-term economic rents, and generally not found to be a source of sustained competitive advantage [54, 70]. Reliable IT infrastructure resources, however, can ensure the success of IT architecture, which tends to be highly firm specific and evolves over a long period of time during which gradual enhancements are made to reflect changing business needs [3, 80].

ERP Capabilities

Keen [43] has defined the business functionality of a firm's IT capability in terms of its range and reach. Similarly, ERP capabilities are defined in terms of ERP range, reach, and geographic scope capabilities [42]. *ERP functional scope* is the range of business processes that are shared by ERP implementation. Greater system range capability is achieved through the implementation of multiple cross-functional modules. It provides integration of data across functions and more benefits than a single-function implementation [16]. By using application integration brokers, firms are able to deploy real-time ERP range capabilities via ERP suites. Such ERP range capabilities

can facilitate the exchange of data between applications, and monitor and manage business activities across the extended enterprise. They can also enable end-to-end business process automations, thereby allowing firms to react more quickly to changes in business conditions. *ERP organizational scope* describes the locations that the ERP system can reach (link), such as departments, divisions, entire company, multiple companies, and so on. *ERP geographic scope* refers to the geographic reach of the ERP implementation, such as regional, national, and global. By integrating their ERP systems with those of their trading partners, firms hope to reduce costs and improve business processes, data integrity, and customer service. Prior research suggests that performance advantages provided by a system of complements are sustainable [63], and imitating such systems is difficult because of size, complexity, and implementation challenges [73].

Business Process Outcomes

From the RBV perspective, business process provides a context within which one can examine IT business value [51], and is a vehicle to build and materialize organizational capabilities [37, 93]. Process-oriented perspective is based on the argument that the first-order effects of IT investment occur at the functional/operational level by pointing to process efficiency, effectiveness, and flexibility as various formulations of outcomes (e.g., [9, 35, 58]). Improving operational efficiency, effectiveness, and flexibility have been shown to lead to improved profitability, earnings valuation, and competitiveness [55, 84].

At the operational level, IT creates business value by having three separate, but complementary, effects on business processes: (1) *automational effects*, which refer to IT capability in deriving value from the efficiency perspective by substituting capital asset for labor and by reducing cost; (2) *information effects*, which refer to IT capability in storing, processing, and disseminating information; and (3) *transformational effects*, which refer to IT capability in facilitating and supporting process innovation and transformation [58]. Besides operational benefits, IT benefits are also classified at higher tactical and strategic levels, and at infrastructure and organizational levels [81, 95]. Although these dimensions have been outlined separately, they nevertheless interact: operational benefits may come with increased managerial effectiveness; strategic benefits rely on operational efficiency; infrastructure benefits result in business flexibility, reduced cost, and increased capability; and organizational benefits can be realized in parallel with managerial benefits [81].

From a business process manager's perspective, ERP implementation results in reducing cost and cycle time and improving productivity, quality, and customer service benefits [81]. ERP capability is expected to result in business process *efficiency* (by reducing cost and cycle time, increasing productivity of the production process, and improving quality and customer service), *effectiveness* (by improving decision making and planning, and resource management and delivery), and *flexibility* (by building flexibility into IT infrastructure to reduce IT cost, by differentiating products

and services, and by establishing and maintaining external linkages to customers and suppliers) [72].

Hypotheses Development

ERP SOFTWARE PACKAGES ARE EXTREMELY COMPLEX, often coming in the form of tens of thousands of “configuration tables” that must be customized to suit a firm’s business needs. Such complexity places substantial strain on a firm’s knowledge resources and absorptive capacity [75]. In addition, ERP implementation often requires substantive changes in organizational business processes, routines, and roles. Because of the complexity of the ERP systems, implementation success depends on the internal project leaders who have “earned their stripes” leading projects that have a major process impact on the entire enterprise, and on the availability of third-party implementation partners who can transfer their knowledge and fill the gaps in client–server architecture expertise, package knowledge, and ERP project experience by function [16]. Knowledge resources aid ERP implementation efforts by helping identify and deploy technologies appropriate for ERP projects, integrating ERP with existing applications, and providing ongoing support for implemented systems. Therefore, knowledge resources will have a positive association with building ERP capabilities. Hence, we propose:

Hypothesis 1: Knowledge resources have a positive association with ERP capabilities.

Prior research has identified user and top management involvements as critical success factors for reducing the risks of large and complex implementation projects [11, 83]. Creation of a user steering committee, user participation on the project team, and user responsibility for education and installation are among the “best practices” for managing large-scale integrated projects [21]. Given that ERP implementation often costs millions of dollars for large firms, strong top management involvement is also crucial for its success [14]. The quality of senior management leadership has been found to impact IT assimilation within firms [5]. Senior managers’ vision for IT can evolve from using IT as a means for achieving operational efficiency, for changing the firm’s fundamental business processes and value-chain activities, or for changing the firm’s relationships with its suppliers and customers [80, 101]. Building ERP capabilities demands significant managerial resources. Top management involvement gives credibility to the ERP implementation team and drives ERP benefits to the next level. It requires senior management to establish priorities for building a greater scope of ERP capabilities. Active engagement, strong sponsorship, and leadership from corporate management are critical for ERP implementation success because ERP systems implementation demands fundamental changes in cross-functional business processes, and often costs millions of dollars in large firms [16]. Further, IS human capital has been shown to have a positive relationship with IS functional capabilities [69]. Hence,

Hypothesis 2: Relationship resources have a positive association with ERP capabilities.

IT infrastructure resources have been linked to business managers' ability and willingness to develop innovative IT applications [78], IT assimilation [95], and range and reach of business opportunities available to firms in applying IT to shape their global business strategies [43]. IT infrastructure resources are critical in developing, building, and assimilating IT capabilities, and in enhancing IT's productive value by aiding implementation, simplifying system integration across diverse applications, and creating economies of scale and scope in system maintenance [5, 95, 98]. In contrast, lack of IT infrastructure resources severely restricts a firm's IT capabilities and increases the costs of building or supporting IT solutions [70, 96]. Zhu [98] also found that IT infrastructure resources have a positive and complementary impact on a firm's e-commerce capability. Adequate infrastructure resources (e.g., hardware, software, network, and server and database technologies) need to be planned, in place, and reliably available well in advance both for pre- and post-ERP implementation stages [68]. Recent research [69] has shown that there is a positive relationship between IT infrastructure flexibility and IS functional capabilities. Hence, we propose:

Hypothesis 3: IT infrastructure resources have a positive association with ERP capabilities.

Resources are essential raw materials for capability building, and their availability determines a firm's ability to build such capabilities, which are often critical drivers of firm performance. Resource synergies and the significance of integration, combination, and cospecialization of resources have been emphasized in past research [87]. Further, some capabilities may derive from a contribution of a single resource, and others may require highly complex interactions involving the cooperation of many different resources [35, 55, 70]. For example, research has found that IT infrastructure resources do not explain significant variance among firms. However, human, shared knowledge, and business resources complementary to IT infrastructure resources create embedded advantage, which explains significant performance variance among firms [65, 70]. Similarly, because of resource synergies, individual dimensions of IS resources should not be viewed in isolation. As a collective, mutually reinforcing, and higher-order factor structure, which accounts for the relationships among knowledge, relationship, and IT infrastructure resources, IS resources are expected to have a combined impact on building ERP capabilities. Hence, we propose:

Hypothesis 4: IS resources have a positive association with ERP capabilities.

At the operational level, building ERP capability is expected to result in cost and cycle time reduction, and productivity, quality, and customer services improvements by enabling (1) cost-effective IS operations (via efficient and effective deployment of new applications and solving maintenance headaches associated with aging legacy systems) and (2) market responsiveness (via flexible IT infrastructure) [66, 81]. Prior

studies have suggested that the scope of ERP capabilities is a critical factor in the extent and types of benefits that can be derived from an ERP system; implementation of only financial modules of an ERP package in one business unit has the potential for quite different benefits than implementation of all ERP modules in every unit [52]. Recent research [67] 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 is found for ERP purchases with greater functional, organizational, and geographic scope, and negative returns are found for projects with lesser scope. However, prior research has suggested that (1) the effects of implementation of radical innovations (such as ERP systems) 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, which can increase the variance of the potential returns [32], and (2) building greater scope of ERP capabilities can result in greater project scale and complexity and can increase the risk of implementation failure [52]. It is important to see whether building ERP capabilities has positive effects on business process outcomes. Therefore, we propose:

Hypothesis 5: ERP capabilities have a positive association with business process outcomes.

Capabilities are special types of resources (i.e., organizational, embedded, non-transferable, firm-specific resources) whose purposes are to improve the productivity of other resources [49]. Resource picking and capability building complement each other; not only do firms need to be effective in selecting resources but they also need to be more effective than their rivals in deploying those resources for capability building [49]. In addition, certain organizational resources are complementary to the IS resources in generating IT business value. Melville et al. [55] examined the nature of resource synergies and further suggested that human IT resources are complementary to IT infrastructure resources, and they both create economic value for a focal firm by conferring operational efficiencies that vary in magnitude and type depending upon organizational and technological context. The study further suggested that (1) there are complementary relationships between certain IS resources in generation of IT business value, and (2) the existence and magnitude of the complementarity between any two specific instantiations of these resources vary depending upon the organizational and technological contexts. IT infrastructure and e-commerce capability, for example, have been shown to have positive complementarity effects on some measures of firm performance [98, 99]. These studies suggest that IT infrastructure resources can provide the platform to launch innovative e-commerce applications faster or more effectively than the competition, and that the e-commerce capability alone may be insufficient to impact performance measures. We expect to see complementary relationships among IS resources and ERP capabilities and predict that weakness in IS resources may undermine the value derived from building ERP capabilities. Consequently,

Hypothesis 6: Greater IS resources in conjunction with greater ERP capabilities are positively associated with higher business process outcomes.

Firm size has been shown to have a negative effect on e-business value creation [98]. Larger firms, with their larger operating budgets, technology base, and resources, are generally able to develop ERP capabilities. On the other hand, large firms tend to be less flexible than smaller firms, and firm size can thus play an important role in building ERP capabilities. Large firms tend to have more resources at their disposal; hence, firm size should affect IS resources. To help us provide a better explanation for the differential impact of IS resources on building ERP capabilities, we minimized, by controlling for, the confounding effects of the firm size (as a proxy for firms' financial resources) on IS resources. Also, smaller firms tend to centralize IT management, whereas larger firms tend to decentralize it [78].

Research Methodology

Measurement of Research Variables

TO ASCERTAIN AND MEASURE THE RELEVANT DIMENSIONS of our model, this process proceeded in four stages: development of the survey instrument, development of measurement scales, pretesting to assess validities of the survey instrument using a sample of Fortune 1000 firms, and data collection from a sample of manufacturing firms to test the proposed model. Domain sampling technique was employed to create measurement scales with adequate content validity [60]. Given the lack of prevalidated instruments for this study, indigenous scales were created following a literature review. We built on the use of interviews with experts, six senior IS or business managers (in two manufacturing firms in generic drugs and disk drive industries) who were closely associated with ERP implementation projects in their firms. These individuals included a chief information officer (CIO), an ERP project leader, a senior ERP consultant, and three business group managers in charge of overseeing ERP implementation in procurement, marketing, and planning/budgeting areas. After their review, we pilot tested the instrument with a sample of Fortune 1000 firms to assess the face and content validity of the measures.

IS resources (ISR) were measured with three formative first-order constructs, by knowledge resources (KR), relationship resources (RR), and IT infrastructure resources (IR). Knowledge resources were measured by three items for measuring external consultants' business process knowledge (BPK) and five items for measuring project management knowledge (PMK). Relationship resources were measured by user and top management involvements. User involvement (UI) was measured by three items that tapped into the users' overall willingness to participate in defining data inputs/outputs, system needs, and ERP implementation requirements. Top management involvement (TMI) was measured using four items that tapped into senior management's enthusiasm, support, personal involvement, and overall leadership of the ERP implementation. IT infrastructure resources were measured using three items that assessed whether

hardware, software, network, and the necessary server and database technologies were in position prior to the ERP implementation. ERP capabilities were measured with three formative indicators: ERP functional scope (FS), organizational scope (OS), and geographic scope (GS). Business process outcomes (BPO), a first-order construct, were measured with 13 reflective items that assessed three related areas—business process operational efficiency (EFC), effectiveness (EFT), and flexibility (FLX).¹ In order to control for the possible variance of resources across industries, firm size (SZE) was entered as a control and was measured by the logarithm (base 10) of the total number of employees [86]. All measures are provided in Appendix A.

Data Collection

Empirical data for testing the proposed IS resources dimensions, ERP capabilities, and effect of building ERP capabilities on business process outcomes were examined using a mail-in field survey of U.S. manufacturing firms that have implemented ERP projects in the recent past. Data collected from a pilot test of Fortune 1000 firms were used for instrument validation and refinement only, while another survey of manufacturing firms was used for confirmatory analysis and hypotheses testing of the model shown in Figure 1. Data were collected spanning the period 2002 to 2003. In both cases, the survey questionnaire was mailed to the senior-most IS executive in each firm (e.g., CIO, vice president in charge of IS), along with a letter outlining the purpose of the research and soliciting their participation in the survey and a pre-addressed, stamped envelope for returning completed responses. No specific incentive was provided to participants for completing the survey, beyond promising them a copy of the aggregated results.

The pilot test survey was directed at firms listed in the Fortune 1000 database. A total of 123 responses were obtained after two rounds of follow-up requests (for non-respondents), for a response rate of 12.3 percent. As shown in Table 1, responses were obtained from a diverse group of firms. Typically, these firms had approximately 325 ERP business users. Seventy percent of the firms indicated that 100 percent of the ERP project was completed and that it took, on average, 16 months to complete. Sixteen percent indicated that their ERP project was 75 percent complete, and 12 percent completed at least 50 percent of the project. The mean number of full-time equivalent internal employees and external consultants devoted to the ERP implementation was 57 and 30, respectively.

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 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

Table 1. Descriptive Statistics for Pilot Test Data

Industry of Fortune 1000 organization	Number responding (percent)	Mean	Median	Standard deviation	Minimum	Maximum	Range
Manufacturing	44 (35.8)						
Banking	10 (8.1)						
Business services	6 (4.9)						
Consumer goods	0 (0.0)						
Retail	15 (12.2)						
Health care	6 (4.9)						
Financial services	3 (2.4)						
Petrochemicals	8 (6.5)						
Pharmaceuticals	2 (1.6)						
Transportation	4 (3.3)						
Utilities	8 (6.5)						
Other	17 (13.8)						
Total	123						
Number of months firm has used system since rollout		19.10	19.00	7.49	5	48	43
Number of full-time employees (internal) devoted to ERP implementation		57.56	45.00	42.51	10	250	240
Number of full-time consultants (external) hired for ERP implementation		30.37	20.00	37.07	5	300	295
Number of months to complete the project		16.00	15.00	7.15	6	60	54

Table 2. Descriptive Statistics for Manufacturing Firms Data

Employee count	Firms in database	Firms contacted	Surveys returned	Mean	Median	Standard deviation	Minimum	Maximum	Range
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						
Number of months firm has used system since rollout		18.60	18.00	18.60	18.00	6.59	6	36	30
Number of full-time employees (internal) devoted to ERP implementation		55.08	45.00	55.08	45.00	38.79	12	225	213
Number of full-time consultants (external) hired for ERP implementation		25.12	20.00	25.12	20.00	20.64	3	125	122
Number of months to complete the project		14.81	12.00	14.81	12.00	5.62	4	36	32

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. Response rate by firm strata and descriptive statistics are reported in Table 2. These firms reported an average of 350 ERP business users in the company. Sixty-six percent of the firms indicated that 100 percent of the ERP project was completed and that it took on average 15 months to complete. Nineteen percent indicated that their ERP project was 75 percent complete, and 11 percent completed at least 50 percent of the project. We checked to see if there was any difference in the scope of the ERP implementation based on these reported completion rates. Despite the differences in the completion rate, there was no difference in scope of the ERP implementation among the three groups based on an analysis of variance (ANOVA) test for differences in means among the three groups ($F_{FS} = 1.562$; $p = 0.201$, $F_{OS} = 2.205$; $p = 0.091$, and $F_{GS} = 0.458$; $p = 0.712$). Further, the mean number of full-time equivalent internal employees and external consultants devoted to the ERP implementation was 55 and 25, respectively. Based on chi-square tests, comparisons of firm revenues, resources, and employee counts between responding and nonresponding firms revealed no significant differences, suggesting no substantive nonrespondent bias.

To provide an additional check that our relationships were not a function of common method variance, we conducted a Harmon's one-factor test on the survey items [62]. If a substantial amount of common method variance exists, we would expect the unrotated factor solution to show one general factor accounting for the majority of covariance. In the analysis with the pilot data ($n = 123$), 72 percent of the variance was explained by 10 factors. The first factor explained 12 percent of the variance and the variance explained by the remaining factors ranged from 4.3 percent to 9 percent. The data from the manufacturing firms ($n = 148$) resulted in nine factors that explained 78 percent of the variance. The first factor explained 12 percent of the variance and the remaining variance explained by the other factors ranged from 5.5 percent to 11.2 percent. Although this does not conclusively rule out common source issues, we believe it indicates that common method was not a serious problem in our analyses.

Data Analysis and Results

Partial least squares, PLS-Graph version 3.0, Build 1060 [24], was used to test the research model. PLS supports the hierarchical component approach for modeling second-order factors in which the second-order factor is measured using the first-order factor scores (from the measurement model) as manifest indicators of the second-order construct [1, 10, 97, 98].² In PLS, such factors can either be formative or reflective. PLS was particularly well suited for analysis of our data given its flexibility to handle second-order constructs and constructs with both reflective and formative indicators [22, 23]. In the research model, all the first-order factors (KR, RR, and IR) are reflective. Formative indicators have several characteristics that cogently distinguish them from reflective indicators. First, formative indicators "form" the construct as a composite [23]. In contrast, reflective indicators are believed to "reflect" the unobserved,

underlying construct they posit to represent, with the construct giving rise to (or “causing”) the observed measures. Second, with formative indicators, omitting an item is omitting a part of the construct, whereas reflective indicators are interchangeable, and the removal of an item does not change the nature of the underlying construct. Third, formative indicators are not assumed to reflect the same underlying construct—that is, they can be independent of one another and measuring different factors. In fact, formative indicators of the same construct “can have positive, negative, or no correlation” with one another.

The PLS modeling approach involved two steps—validating the measurement model and then fitting the structural model. The former is accomplished primarily by reliability and validity tests of the measurement model, followed by a test of the explanatory power of the overall model by assessing its explained variance, and the testing of the individual hypotheses (structural model). A bootstrap resampling procedure was conducted and coefficients were estimated [25].

Estimation of Internal Consistency

The survey employed multi-item scales to measure the first-order factors. The measurement properties for the reflective constructs were examined by conducting confirmatory factor analyses using PLS. To assess the internal consistency of the reflective first-order factors of ISR and BPO, we examined coefficient alpha and composite reliability measures. For ERP capabilities (ERPC), the very nature of formative measurement renders irrelevant traditional assessments of convergent validity and item reliability [40, p. 201]. Accordingly, as seen in Table 3, coefficient alpha values ranged from 0.786 to 0.887. Likewise, the composite reliabilities for all measures were high, ranging from 0.886 to 0.933. Compared with coefficient alpha, which provides a lower bound estimate of internal consistency, the composite reliability is a more rigorous estimate of the reliability [23]. The recommended level for establishing a tolerable reliability is the 0.70 threshold. All coefficients were above 0.80 for strong reliability. Consequently, evidence for internal consistency and the scales reliability are provided by these results.

Dimensionality and Convergent and Discriminant Validity

Although we conceptualized ISR as a second-order construct, we also recognized plausible alternative specifications for the relationships between a high-level construct and its dimensions [45]. As shown in Appendix B, we specified alternative unidimensional and multidimensional first-order measurement models and assessed their relative fits. In the model 1 specification, ISR is treated as a unidimensional first-order factor that globally measures overall resources. It is assumed that this first-order factor can account for the variance among all 17 measurement items. It was expected that items belonging to the same scale would have factor loadings exceeding 0.70 on this common factor. As indicated by the results in Appendix B, although all the loadings were statistically significant based on *t*-statistics generated from running a bootstrap on the data, many

Table 3. Internal Consistency of Measures

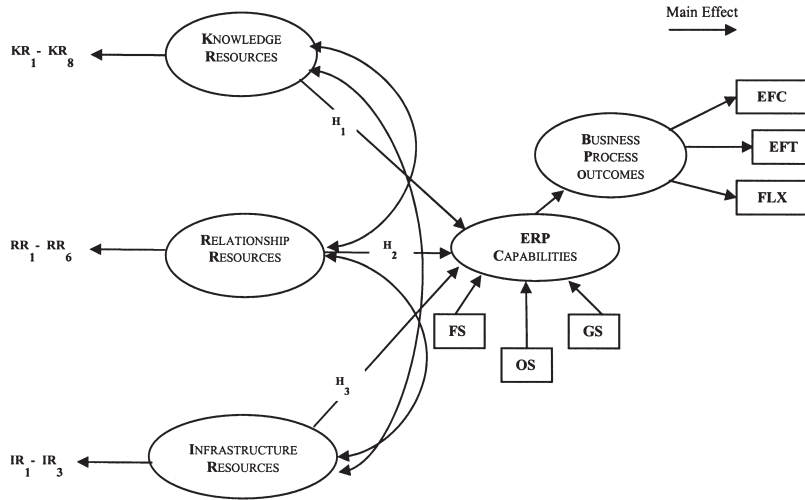
Measure	Number of items	Coefficient alpha	Composite reliability
IS resources (ISR)			
Knowledge resources (KR)	8	0.887	0.933
Relationship resources (RR)	7	0.839	0.886
Infrastructure resources (IR)	3	0.859	0.915
Business process outcomes (BPO)			
Operational efficiency (EFC)	3	0.786	0.935
Operational effectiveness (EFT)	6	0.844	0.887
Operational flexibility (FLX)	4	0.837	0.893

were below the acceptable threshold (0.60). Moreover, the average variance explained (AVE) was below 0.50 and considered unacceptable. Although the unidimensional conceptualization strategy can be effective and straightforward, it cannot discern the complex character of a firm's IS resources, which may be operationalized effectively in a formative way by a composite across different, unique sources of the construct. Hence, support for unidimensionality was not obtained. As a result, a more sophisticated structure is needed to understand and define how firms use ISR.

The model 2 specification hypothesizes a multidimensional model where the 17 items form three uncorrelated, independent first-order factors. The model results revealed that for the reflective indicators at the first-order level, all loadings were above 0.70 on their respective factor and were statistically significant at the 0.001 level, which provides support for convergent validity. Composite reliability ranged between 0.88 and 0.93, thereby supporting the reliability of the measurement models. Supportive of discriminant validity among the constructs, the AVE was greater than 0.50. These results suggest that model 2, a multidimensional structure for ISR, is superior to a first-order factor model (model 1) in which ISR is unidimensionally conceptualized. Thus, support for multidimensionality of ISR is indicative of these results.

Next, we compared two nested models, model 2 (constrained model) and model 3 (unconstrained model). Model 3 has 17 items forming three freely correlated first-order factors. In support of convergent validity, all factor loadings are statistically significant ($p < 0.001$). In model 3, the pairs of correlations among the first-order factor are significantly different from zero, providing an advantage over model 2. The measurement items converge on their respective factors and are significantly related to their specified constructs. In addition, because none of the correlations between the pairs of resources are negative, a high value on one resource 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 [7], demonstrating that the content captured by KR, RR, IR are distinct from one another. All the criteria adequately demonstrate discriminant validity of model 3.

Model 3a Direct-Effects Model



Model 4 Second-Order Formative Moderator Model

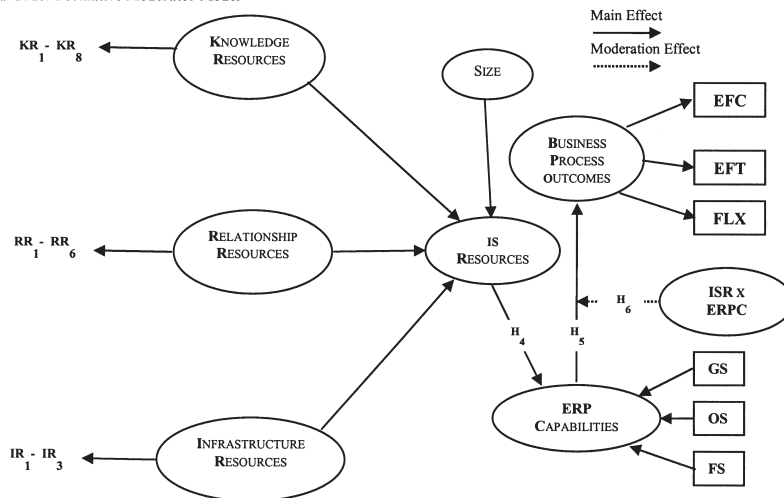


Figure 2. First-Order Direct Effects Model Versus Second-Order Formative Model of IS Resources

Second-Order Model

As shown in Figure 2, model 4 specification hypothesizes ISR as a second-order formative construct formed by three first-order factors made up of 17 items. Formative constructs are conceived to be “caused” by the underlying measurement items where each lower-order item represents a distinct contribution to the higher-order latent construct (see [27, 29] for a review). Although it was possible that the factors might be highly interrelated enough to be treated as reflective factors, this was not supported by the results. When we examined the correlations among the first-order constructs,

we did not find high correlations, which are indicative of the first-order constructs belonging to the same set, even if formative constructs need not be correlated [22]. We found the first-order factors for ISR correlated from 0.213 to 0.465, $p < 0.05$ (see Appendix B). These low to moderate levels of correlation are not indicative of our initial a priori expectation that a strong association among the dimensions would be found. In a formative model, KR, RR, and IR may be but need not be highly correlated, and these results suggest this is the case. A reflective model would have very high correlations among the first-order factors (greater than 0.70), thus a formative model seems more likely. Second, we examined the results modeling ISR with reflective first-order factors and found that although the path coefficients (0.59, 0.69, 0.78) were significant, not all were of high magnitude and greater than the 0.70 requirement [23]. Besides, because a change in KR, for example, does not necessarily imply an equal change in RR, a reflective model is less likely. Moreover, the effective use of the resources is likely to change over time and be affected in a different way by other factors [61]. As such, the subconstructs of ISR form a higher-order formative model that most accurately and parsimoniously captures the multidimensional nature of ISR.

Consequently, the dependent variable, ERPC, was included to facilitate the comparison between two final models: model 3a (extension of model 3 from previous stage) tests the direct effects of each of the first-order factors on ERPC, whereas model 4 suggests an explicit multidimensional structure whereby KR, RR, and IR combine to form an emergent force (ISR), which in turn can affect ERPC. Before testing to determine if the second-order formative model of ISR (model 4) is a better fit to the data than the first-order factor model (model 3a), we examined the models' statistics for reliability and convergent and discriminant validity. The results (see Appendix B) were similar and provided support for reliability and convergent and discriminant validity.

Hypothesis Testing

The adequacy of the psychometric properties in the measurement model enables us to further test our direct effect hypotheses (H1–H3) using the structural model (3a) depicted in Figure 2. Following Burton-Jones and Straub [18] to test the effects of modeling ISR as a higher-order construct, we tested two models—one included all three subconstructs (KR, RR, and IR) as independent components and the other model formed a higher-order construct using the factor scores of KR, RR, and IR as formative indicators. Model 3a includes only the first-order factors and models their pairwise covariance. It indicates that KR, RR, and IR can each have a positive association with building ERPC. The results for the direct effects model, presented in Table 4, indicated that only relationship resources were significant predictors of building ERPC (H2 supported). Although, the direct effects of KR and IR were marginally significant ($0.05 \leq p \leq 0.10$), these results failed to support H1 and H3. These findings rule out that two of the three resources can act as independent variables with significant association with ERPC, but more importantly, reinforces the notion that ERPC effects may be contingent on the combination of the three resources.

Table 4. Structural Model Results

Paths	Direct effects Model 3a	Second order Model 4
Structural model		
Hypothesized relationships		
KR → ERPC (H1)	0.258 (1.904)	N/A
RR → ERPC (H2)	0.470 (4.331)*	N/A
IR → ERPC (H3)	0.253 (1.891)	N/A
ISR → ERPC (H4)	N/A	0.502 (6.290)*
ERPC → BPO (H5)	0.501 (6.900)*	0.309 (2.976)**
ISR x ERPC → BPO (H6)	N/A	0.496 (6.125)*
Control variable		
SZE → ISR	N/A	0.150 (1.607) ^{ns}
Measurement model		
ISR ← KR	N/A	0.533 (2.666)**
ISR ← RR	N/A	0.493 (2.371)***
ISR ← IR	N/A	0.378 (2.185)***
ERPC ← FS	0.373 (2.640)***	0.450 (3.204)*
ERPC ← OS	0.261 (1.713)	0.400 (2.604)**
ERPC ← GS	0.504 (3.077)***	0.558 (3.660)*
BPO → EFC	0.769 (10.791)*	0.762 (10.047)*
BPO → EFT	0.701 (5.500)*	0.702 (8.387)*
BPO → FLX	0.739 (8.169)*	0.720 (10.040)*
Dependent variable (R^2)		
ERPC	0.551	0.322
BPO	0.230	0.439

Notes: Parameter estimates are standardized with t -values. Weights are shown for formative constructs. * $p < 0.001$; ** $p < 0.01$; *** $p < 0.05$.

As shown in Table 4, all first-order factors were significantly related with the second-order factor, ISR. While no minimum threshold value for weights has been established, the statistical significance of the weights can be used to determine the

relative importance of the indicators in forming the construct. As the interpretation of the weights is similar to the beta coefficients in a standard regression model, it is usual to have lower absolute weights as compared to loadings. We found that KR ($\beta = 0.533$; $t = 2.666$; $p < 0.01$) was a little more important than RR ($\beta = 0.493$; $t = 2.371$; $p < 0.05$) and both had a higher impact than IR ($\beta = 0.378$; $t = 2.118$; $p < 0.05$) on the higher-order construct. The second-order factor model is a more parsimonious model with fewer parameters to be estimated.

Next, we tested H4–H6 represented by the relationships shown in Figure 2. The structural link from ISR to ERPC (see Table 4) is positive and significant ($\beta = 0.502$; $t = 6.29$; $p < 0.001$). The results provide empirical support for H4 and validate our expectation that ISR as a set has a significant association with building ERPC. The predictive power of the model is shown by the R^2 values in Table 4. The model indicates that ISR explains 32 percent of the variance in ERPC and provides compelling evidence that the building of ERP capability is contingent on a collection of resources. The results further show that building ERP capability is significantly associated with BPO ($\beta = 0.309$; $t = 2.976$; $p < 0.01$), confirming support for H5. Although we controlled for the size of the organization, apparently it had no impact on ISR ($\beta = 0.150$; $t = 1.607$; $p > 0.05$).

Our final set of hypotheses concerns the presence of an interaction between ISR and ERPC (H6). We hypothesize that ISR will moderate the relationships between ERPC and BPO. Chin et al. [25] point out that it may be more desirable to handle formative moderators differently from reflective constructs. Accordingly, the interaction term was formed by cross-multiplying all standardized items of each construct, following the procedure in Chin et al. [25]. The results suggest an assembly of knowledge, relationship, and infrastructure resources can significantly strengthen the influence building capabilities has on business process outcomes ($\beta = 0.496$; $t = 6.125$; $p < 0.001$) and support H6.

Comparative Analysis: Moderator Model Versus Baseline Model

As shown in Figure 2, to assess the interaction of ISR and ERPC on BPO, we estimated the model in two steps to judge the incremental variance explained by adding the moderating effect [25]. The test for the moderated relationship was conducted by using ΔR^2 to draw conclusions about the moderator effect size since “the use of the path coefficient of an interaction term will lead to spurious conclusions” [20, 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 [41]. We examined the change in R^2 by comparing the results of two models. The relationship between BPO and ERPC can be specified as follows:

Base model

$$\text{BPO} = f(\text{ERPC}, \varepsilon \dots), \quad (1)$$

and compared to the following model that includes the relationship of ERPC and the interaction of ERPC and ISR:

$$\text{BPO} = f(\text{ERPC}, \text{ERPC} \cdot \text{ISR}, \varepsilon \dots), \quad (2)$$

or more specifically by an equation³ of the form:

$$\text{BPO} = \beta_0 + \beta_1 \text{ERPC} + \beta_2 \text{ERPC} \cdot \text{ISR} + \varepsilon. \quad (3)$$

Consequently, ΔR^2 denotes the significance of the interaction term when added to the base model. Although the standardized path estimate from the product construct (ISR · ERPC) to BPO indicates how a change in ISR would change the influence of ERPC on the dependent construct (BPO), we need to compare the R^2 for the interaction model ($R^2 = 0.439$) with the R^2 for the main effects model ($R^2 = 0.230$). The true effect of the interaction term can be calculated through the effect size⁴ (f^2), where 0.02, 0.15, and 0.35 have been suggested as small, moderate, and large effects, respectively [26]. The f^2 statistic, which is based on the differences in R^2 between the two models, was determined and used to compute the pseudo- F -statistic⁵ [20, 25]. The interaction effect produces a significant effect size ($f^2 = 0.37$), thereby supporting the proposed moderating effects of ISR. An F -statistic that is significantly greater than 1.00 leads to rejection of H_0 : $\Delta R^2 = 0$. The analysis suggests that the additional variance explained by introducing the moderator, ISR, significantly adds to the variance explained in BPO. Consequently, we can conclude that ISR and ERPC demonstrate a mutually reinforcing complementarity relationship [98]. ISR and ERPC jointly improve BPO. Therefore, the impact of ERPC on BPO will be contingent on the level of IS resources; the impact will be stronger for firms with higher levels of IS resources in comparison to firms with lower levels.

Discussion and Conclusions

TWO RESEARCH QUESTIONS WERE EXAMINED in this study: Do IS resources have direct or combined effects on building ERP capabilities? and When or under what conditions do building ERP capabilities have the highest impact on business process outcomes? To answer the first question, we developed six research hypotheses by drawing from RBV of the firm [8] and the theory of complementarities [57]. Using survey data from a sample of U.S. manufacturing firms that have implemented ERP systems, we found significant evidence for the direct association of relationship resources (H2) and building ERP capabilities, but not for the direct association of knowledge or infrastructure resources. From a practical perspective, however, knowledge and infrastructure resources are important for both building ERP capabilities and outcomes. Our findings demonstrated that the direct effects models were not sufficient for explaining how firms build ERP capabilities. There is an additive effect of the set of resources on building ERP capabilities where the effect of each resource seemingly depends upon commingling with the others. Our study also found that the copresence of IS resources tends to supersede the direct effects of each IS resource alone. Integrated together, they result in a performance-enhancing resource bundle for building ERP capabilities. Therefore, individual IS resources should not be considered in isolation from each other, but should be treated in a collective and mutually reinforcing manner. This finding is similar to those reported in recent studies [2, 85, 86, 87, 98]. The copresence of

resources provides unique value to the firm. Moreover, the synergies arising from the copresence of resources are much more difficult to observe and imitate [87].

Regarding our second question, our results did provide compelling evidence that building ERP capabilities has positive association with business process outcomes (23 percent of the variance was explained). Also, we found that the association of building ERP capabilities with business process outcomes is contingent on the copresence of IS resources. The importance of the copresence of IS resources was demonstrated by their addition to the model. When they were included, it increased the explained variance in business process outcomes to 43 percent, and had a large effect size (f^2 of 0.37). This confirmed our hypothesis that IS resources can intervene to strengthen the relationship between building ERP capabilities and business outcomes. The notion of complementarities suggests that firms that possess a wide range of resources are better able to exploit the synergistic benefits of these resources than those that possess fewer resources or a lesser level of each resource [87]. This is important because competitors usually lack the strategic foresight to recognize complementarities [57]. Even if they recognize the complementarities, to imitate them successfully, they have to make simultaneous changes in IT infrastructure. Although we controlled for the impact of size (as a proxy for available slack resources) on IS resources, we did not find any impact. This may suggest that slack resources are not necessarily converted into IS resources in manufacturing firms.

Implications for Research

What are the implications of our findings for future IS research? First, we presented knowledge (project management knowledge, business process knowledge), relationships (top management support, user involvement), and infrastructure (hardware, software, network) resources, and validated their association and their relative precedence on building capabilities. We found that knowledge resources are the most critical resource for building ERP capabilities, followed closely by relationship resources, and both are more important than infrastructure resources. We also found that these IS resources have synergistic relationships. Second, we demonstrated the copresence effect arising from a synergy of multiple IS resources. While this effect was previously conceptualized and validated in the context of knowledge management [85, 86, 87], our study is possibly the first to demonstrate this effect within the context of ERP implementation. In doing so, we also demonstrated the generalizability of the notion of copresence among IS resources to new and additional contexts. Third, if ERP implementation is viewed as an instance of a large-scale IS implementation in organizations, the findings of our study, including our categorization of IS resources and their copresence effects, should be generalizable to other large-scale system implementation projects, such as customer relationship management systems and supply-chain management systems. We encourage future researchers to examine and extend our findings to other technological and organizational contexts to estimate the generalizability of our results. Future research should also examine the process by which individual IS resources are synthesized and integrated into higher-order

synergistic effects, which then drive building ERP capabilities. Such research can examine the structural elements that control or can enable this integration process, potential ways of leveraging a firm's existing relationship resources (e.g., interorganizational alliances) for building other necessary resources and capabilities, and empirical thresholds that may help define how interorganizational resources affect business process outcomes.

Implications for Practice

The three resource dimensions identified in this study and their respective contents provide a convenient checklist for IS managers to assess their firm's resources, to identify areas where their firms may be lacking, and to develop specific goals and action plans for improving each dimension. Such assessment is important for building ERP-related capabilities, and should precede any large-scale ERP implementation projects. Given that ERP projects are often of greater scale, scope, and complexity than most other IS projects and have a high risk of implementation failure [64], an assessment of IS resources may imply the difference between ERP success and failure in the implementing firms.

Creating and nurturing ERP capabilities are admittedly difficult managerial tasks, and require sustained investments in developing the firm's knowledge, relationship, and infrastructure resources, and careful planning and management of the same. The social capital theory, for example, suggests that relationship resources allow strategic networks to be built. These strategic networks facilitate knowledge sharing and eventual exploitation of knowledge [36]. Kumar et al. [44] have shown that face-to-face operations and closeness of business relationships have built enablers for knowledge sharing in business practices over the years. Building knowledge resources requires teaming up external consultants with domain experts from within the implementing firm, and opening up a two-way channel of communication between these two groups. This is, however, much more difficult to achieve in practice given the diverse backgrounds of external consultants and internal IT staff, divergent expectations and motivations regarding the ERP project, and a general disinterest to communicate in the interest of project expediency. Continual development of knowledge resources can greatly improve the identification, deployment, and management of infrastructure resources necessary for building ERP capabilities, whereas ad hoc development of these resources may hurt rather than help building ERP capabilities, eventually translating into lower outcomes.

Our complementarity hypothesis suggested that business process outcomes depend critically on a firm's ability to integrate and combine existing resources in order to build ERP capabilities. This further explains why many full-scale ERP implementations in large firms fail to realize their expected outcomes. This is because the effects of ERP capabilities on business process outcomes could be strengthened or weakened by the set of IS resources a firm has. Therefore, prior to building a higher scope of ERP capabilities, firms need to strengthen their level of knowledge, relationship, and infrastructure resources. Further, resource picking alone may not be sufficient for en-

suring outcomes of ERP projects, unless these resources can be combined effectively to achieve synergistic benefits. The precedence of IS resources for ERP capability building suggests that firms considering large-scale ERP implementation should first develop strong relationship resources and then recruit well-trained consultants and link them to core user groups in the organization for knowledge sharing and developing knowledge resources, prior to proceeding in investment in infrastructural resources. Further, ERP project managers need to ensure that (1) project objectives are clearly defined in terms of business process efficiency, effectiveness, and flexibility; (2) the sponsorship, involvement, and support of the top management and end users are secured; (3) standard project management processes are used for measuring or monitoring project size, scope, schedule, risks, and efforts; and (4) sufficient infrastructural resources are dedicated to get the job done in the time allowed. This sequence of resource picking and capability building may serve as an effective road map for firms contemplating ERP implementation.

Limitations of the Study

It is important to interpret the study's results in light of its limitations. First, we used the key respondent approach to our survey study and directed our questionnaire at IS executives because they were best positioned to answer questions related to ERP implementation process and outcomes. However, it is possible that these responses might have been different if they were directed at business managers instead. In retrospect, cross-validating at least a part of our response with a sample of business managers would have greatly increased confidence in our results. We urge future researchers to consider such validation when conducting firm-level surveys using the key respondent approach. Second, we did not control for differences in the ERP systems across firms. Different ERP systems have different strengths. Further, some firms may choose to implement ERP within a narrow scope rather than enterprisewide. Hence, the motivation for ERP system selection and its impact on outcomes could differ across ERP systems. We suggest that future research control for differences in ERP systems and their scope. Third, we defined IS resources as being heterogeneous and immobile, but did not explicitly test for the heterogeneity or immobility of IS resources. Although our personal experiences with ERP implementation projects suggest that these variables are indeed heterogeneous and immobile (e.g., they require specialized infrastructure, consultants, etc.), failure to meet this criterion would not materially change our reported findings, but would only limit the sustainability of the effects of ERP capabilities on business process outcomes. Fourth, we measured business process knowledge with the use of experienced consultants in ERP project teams to highlight the fact that often external business process domain knowledge is necessary to build ERP capabilities. As shown in Table 2, the manufacturing firms had an average of 25 consultants. We did not measure the business process knowledge of the internal IT staffs. They sometimes have greater internal business process knowledge than external consultants. Hiring additional consultants may not be necessary as more and more experienced IT staffs are employed with strong internal and external

business process knowledge. Finally, our data is cross-sectional; we can report associations but are not able to determine causality, because we implemented a passive observation design (i.e., survey).

Conclusions

This study demonstrated that IS resources are key determinants for building ERP capabilities in firms, which in turn are required for delivering positive business process outcomes. We identified knowledge, relationship, and infrastructure resources as critical IS resources relevant to ERP implementation. Using empirical data, we demonstrated that mutually enhancing synergies exist between IS resources, building ERP capabilities, and business process outcomes. Therefore, rather than being concerned about the amount of investment in IT infrastructure resources, managers should be more concerned with the synergies among IS resources and ERP capabilities, and the business value of IT at the process level, because these are where the real benefits can be found. We expect that our study will generate renewed interest in the RBV of the firm and particularly in the notion of complementarity among IS resources and capabilities in the context of a large-scale IS implementation. Given that the impact of IS resources on business outcomes has been hard to demonstrate in prior research, we hope that our research has provided some directions for future research in this area by taking into account the issue of resource synergies.

NOTES

1. As recommended, for EFC, EFT, and FLX, we take a weighted average of the measurement items based on their contributions to the construct, instead of using a single-item measure through a simple average of the measurement items [25].

2. Specifically, factor scores are derived by multiplying each indicator by its estimated weight, summing all weighted indicators, and using the weighted sum to form factor scores. This approach is more rigorous than simply adding up the factors, because it takes into account the appropriate weight of each factor [98].

3. The sensitivity of results to the inclusion of an interaction term is often taken as a sign of multicollinearity. If there is high multicollinearity, it can lead to large standard errors on the model parameters. However, and more importantly, we are not directly interested in the significance or insignificance of the model parameters per se anyway. Instead, we are interested in the marginal effect of X on Y . In the case of Equation (3), this is $\partial Y/\partial \text{ERPC} = \beta_1 + \beta_2 \text{ERPC} \cdot \text{ISR}$.

4. Effect size $f^2 = [R^2(\text{included}) - R^2(\text{excluded})]/[(1 - R^2(\text{included})]$ [23].

5. The pseudo- F -statistic is computed using the formula $f^2 * (n - k - 1)$, with 1, $(n - k)$ degrees of freedom, where n is the sample size and k is the number of constructs in the model [25].

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Appendix A: Research Instrument

IS Resources

Knowledge Resources (KR₁–KR₈)

Business Process Knowledge (BPK)

BPK₁: Experienced consultants guided us throughout the course of the project.

BPK₂: External consultants brought in considerable expertise and experience into our project.

BPK₃: External consultants were experienced in our business processes.

Project Management Knowledge (PMK)

PMK₁: Formal project management tools and techniques were employed for this project.

PMK₂: The project's scope, size, and effort were estimated adequately.

PMK₃: The implementation risks were adequately evaluated, classified, and prioritized.

PMK₄: The implementation schedule was realistic.

PMK₅: Project managers in charge of the project were highly capable and experienced.

Relationship Resources (RR₁–RR₆)

User Involvement (UI)

UI₁: The user community was involved throughout the ERP implementation project.

UI₂: Business users participated in determining systems needs and capabilities.

UI₃: Business users participated in identifying input/output needs.

Top Management Involvement (TMC)

- TMC₁*: Senior executive provided legitimacy and visibility to the ERP project.
- TMC₂: Senior executive demonstrated a lot of enthusiasm and interest throughout the project.
- TMC₃: Upper-level managers were personally involved in the project.
- TMC₄: The overall level of management support in this project was quite high.

IT Infrastructure Resources (IR₁–IR₃)

- IR₁: Appropriate hardware, software, and network infrastructures were in place prior to ERP implementation.
- IR₂: Necessary server and database technologies were implemented before implementing the ERP system.
- IR₃: Necessary hardware and software were installed before the start of this project.

ERP Capabilities (ERPC)

- FS: 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):

- OS: Scope of implementation of your selected ERP: Department | Division | Entire company | Multiple companies | Other: _____
- GS: Geographical scope of implementation: Single site | Multiple sites | National | Worldwide

Business Process Outcomes (BPO)

Operational Efficiency (EFC)

- EFC₁: ERP implementation has improved our efficiency of operations.
- EFC₂: ERP implementation has lowered our costs of operation.
- EFC₃: ERP implementation has reduced the amount of rework needed for data entry errors.

Operational Effectiveness (EFT)

- EFT₁: Data provided by ERP add value to our operations.
- EFT₂: ERP implementation has improved timely access to corporate data.
- EFT₃: The ERP system provides a high level of enterprisewide data integration.
- EFT₄: ERP implementation helps us make better sales forecasts than before.
- EFT₅: The functionalities of ERP adequately meet the requirements of our jobs.
- EFT₆: ERP implementation has improved our quality of operations.

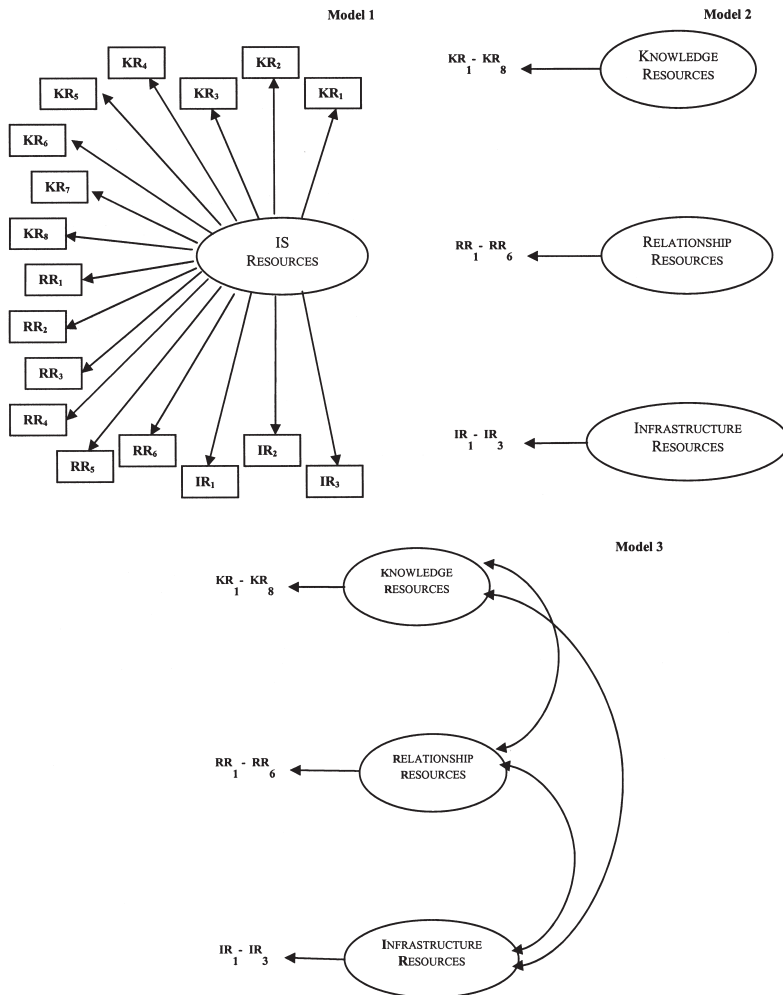
Operational Flexibility (FLX)

- FLX₁: ERP implementation has given us more ways to customize our processes.
- FLX₂: ERP implementation has made our company more agile.
- FLX₃: ERP implementation has made us more adaptive to changing business environment.
- FLX₄: ERP implementation has improved the flexibility of our operations.

Note: Each item was worded as a statement, to which respondents expressed extent of their agreement or disagreement by using a five-point scale. * The initial results of the measurement model indicated it was necessary to drop one nonsignificant indicator (TMC₁).

Appendix B

Alternative Measurement Model



Alternative Model Results

Model 1. Unidimensional first-order factor for ISR

	Outer model loadings			
	Sample estimate	Mean of subsamples	Standard error	<i>t</i> -statistic
Information systems resources (ISR): (composite reliability = 0.916, AVE = 0.400)				
BPK ₁	0.7296	0.7371	0.0402	18.1407
BPK ₂	0.7535	0.7629	0.0393	19.1584
BPK ₃	0.7396	0.7475	0.0397	18.6233
PMK ₂	0.7122	0.7075	0.0511	13.9505
PMK ₃	0.7339	0.7347	0.0434	16.9286
PMK ₄	0.7643	0.7611	0.0479	15.9527
PMK ₅	0.7557	0.7537	0.0546	13.8293
PMK ₁	0.7626	0.7600	0.0368	20.7292
TMC ₂	0.5911	0.5885	0.0739	7.9944
TMC ₄	0.5499	0.5431	0.0831	6.6160
UI ₁	0.4676	0.4587	0.0881	5.3104
UI ₂	0.5607	0.5563	0.0725	7.7338
UI ₃	0.5250	0.5238	0.0833	6.3051
TMC ₃	0.5321	0.5255	0.0868	6.1314
IR ₁	0.5571	0.5556	0.0798	6.9788
IR ₂	0.4079	0.4096	0.0910	4.4824
IR ₃	0.3969	0.3777	0.1046	3.7963

Model 2. Multidimensional factor for ISR with three *correlated* first-order factors (KR, RR, and IR)

Knowledge resources: (composite reliability = 0.933, AVE = 0.636)

BPK ₁	0.7983	0.7957	0.0357	22.3332
BPK ₂	0.8145	0.8118	0.0354	23.0281
BPK ₃	0.8050	0.8006	0.0370	21.7617
PMK ₂	0.7761	0.7747	0.0430	18.0649
PMK ₃	0.7997	0.7950	0.0423	18.8937
PMK ₄	0.7944	0.7905	0.0424	18.7383
PMK ₅	0.7935	0.7898	0.0426	18.6370
PMK ₁	0.7984	0.7914	0.0383	20.8430

Relationship resources: (composite reliability = 0.886, AVE = 0.565)

TMC ₂	0.7556	0.7574	0.0388	19.4499
TMC ₃	0.7763	0.7831	0.0338	22.9361
TMC ₄	0.7852	0.7872	0.0374	21.0099
UI ₁	0.7301	0.7237	0.0427	17.1139
UI ₂	0.7231	0.7132	0.0533	13.5612
UI ₃	0.7368	0.7269	0.0503	14.6388

Outer model loadings

	Sample estimate	Mean of subsamples	Standard error	t-statistic
Infrastructure resources (IR): (composite reliability = 0.915, AVE = 0.781)				
IR ₁	0.8741	0.8732	0.0229	38.0874
IR ₂	0.9055	0.9031	0.0185	49.0685
IR ₃	0.8718	0.8573	0.0336	25.9308

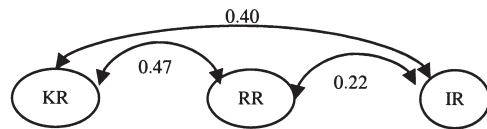
Model 3. Multidimensional factor for ISR with three *uncorrelated* first-order factors (KR, RR, and IR)

Knowledge resources (KR): (composite reliability = 0.933, AVE = 0.636)				
BPK ₁	0.7829	0.7752	0.0437	17.8997
BPK ₂	0.7990	0.7940	0.0426	18.7508
BPK ₃	0.7896	0.7828	0.0449	17.6030
PMK ₂	0.7845	0.7887	0.0417	18.8202
PMK ₃	0.8002	0.7975	0.0347	23.0583
PMK ₄	0.8095	0.8105	0.0355	22.8164
PMK ₅	0.8077	0.8099	0.0375	21.5401
PMK ₁	0.8039	0.8008	0.0339	23.7423

Relationship resources (RR): (composite reliability = 0.886, AVE = 0.564)				
TMC ₂	0.7490	0.7341	0.0880	8.5078
TMC ₄	0.7708	0.7548	0.0855	9.0179
TMC ₃	0.7617	0.7552	0.0895	8.5063
UI ₁	0.7292	0.7184	0.0796	9.1622
UI ₂	0.7451	0.7392	0.0746	9.9855
UI ₃	0.7498	0.7408	0.0785	9.5463

Infrastructure resources (IR): (composite reliability = 0.912, AVE = 0.775)				
IR ₁	0.9174	0.9206	0.0144	63.5014
IR ₂	0.8859	0.8865	0.0311	28.4913
IR ₃	0.8356	0.8112	0.0694	12.0435

Correlations among pairs of factors are significantly different from zero.



(continues)

Model 3a. Direct effects model

Outer model loadings					
	Sample estimate	Mean of subsamples	Standard error	<i>t</i> -statistic	
Knowledge resources (KR): (composite reliability = 0.933, AVE = 0.636)					
BPK ₁	0.7920	0.7834	0.0526	15.0630	
BPK ₂	0.8082	0.8020	0.0524	15.4309	
BPK ₃	0.7985	0.7906	0.0528	15.1221	
PMK ₂	0.7741	0.7688	0.0505	15.3408	
PMK ₃	0.7960	0.7897	0.0458	17.3778	
PMK ₄	0.8065	0.8037	0.0400	20.1813	
PMK ₅	0.7997	0.7940	0.0496	16.1124	
PMK ₁	0.8032	0.8002	0.0370	21.7114	
Relationship resources (RR): (composite reliability = 0.884, AVE = 0.561)					
TMC ₂	0.6999	0.6941	0.0858	8.1579	
TMC ₄	0.7296	0.7215	0.0900	8.1102	
TMC ₃	0.7177	0.7167	0.0902	7.9526	
UI ₁	0.7632	0.7502	0.0744	10.2615	
UI ₂	0.7880	0.7787	0.0633	12.4541	
UI ₃	0.7923	0.7821	0.0630	12.5775	
Infrastructure resources (IR): (composite reliability = 0.913, AVE = 0.777)					
IR ₁	0.9084	0.9120	0.0185	49.1668	
IR ₂	0.8853	0.8819	0.0386	22.9184	
IR ₃	0.8505	0.8282	0.0538	15.8217	
ERP capabilities (ERPC): (formative construct—CR and AVE not applicable)					
FS	0.3737	0.3601	0.1423	2.6263	
OS	0.2606	0.2603	0.1619	1.6100	
GS	0.5041	0.5112	0.1815	2.7774	
Business process outcomes (BPO): (composite reliability = 0.773, AVE = 0.533)					
EFC	0.7697	0.7600	0.0866	8.8891	
EFT	0.6769	0.6698	0.1144	5.9154	
FLX	0.7399	0.7316	0.0981	7.5453	
Correlations of latent variables					
	KR	RR	IR	ERPC	BPO
KR	1.000				
RR	0.464	1.000			
IR	0.398	0.231	1.000		
ERPC	0.570	0.632	0.462	1.000	
BPO	0.457	0.447	0.624	0.478	1.000
Multiple <i>R</i> ²					
ERPC	0.5508				
BPO	0.2300				

Model 4. Second-order model for ISR formed by three first-order factors (KR, RR, and IR)

Outer model loadings				
	Sample estimate	Mean of subsamples	Standard error	<i>t</i> -statistic
Knowledge resources (KR): (composite reliability = 0.933, AVE = 0.636)				
BPK ₁	0.7965	0.7943	0.0359	22.1923
BPK ₂	0.8122	0.8137	0.0346	23.4597
BPK ₃	0.8032	0.8038	0.0367	21.8905
PMK ₂	0.7766	0.7740	0.0443	17.5434
PMK ₃	0.7955	0.7917	0.0419	18.9658
PMK ₄	0.7954	0.7935	0.0395	20.1286
PMK ₅	0.7964	0.7907	0.0465	17.1204
PMK ₁	0.8037	0.8015	0.0318	25.2597
Relationship resources (RR): (composite reliability = 0.886, AVE = 0.564)				
TMC ₂	0.7454	0.7427	0.0436	17.0839
TMC ₄	0.7720	0.7689	0.0460	16.7972
TMC ₃	0.7624	0.7608	0.0458	16.6360
UI ₁	0.7346	0.7251	0.0528	13.9081
UI ₂	0.7409	0.7311	0.0418	17.7039
UI ₃	0.7519	0.7427	0.0456	16.4880
Infrastructure resources (IR): (composite reliability = 0.914, AVE = 0.780)				
IR ₁	0.8957	0.9010	0.0171	52.2944
IR ₂	0.8962	0.8970	0.0248	36.1121
IR ₃	0.8569	0.8272	0.0528	16.2160
ERP capabilities (ERPC): (formative construct—CR and AVE not applicable)				
FS	0.4095	0.4106	0.1513	2.6074
OS	0.4486	0.4209	0.1400	3.2047
GS	0.5585	0.5606	0.1526	3.6608
Business process outcomes (BPO): (composite reliability = 0.771, AVE = 0.528)				
EFC	0.7624	0.7642	0.0759	10.0408
EFT	0.7020	0.6786	0.0837	8.3871
FLX	0.7151	0.7242	0.0712	10.0478

(continues)

Correlations of latent variables

	KR	RR	IR	ERPC	ISR	BPO
KR	1.000					
RR	0.465	1.000				
IR	0.390	0.213	1.000			
ERPC	0.568	0.619	0.454	1.000		
ISR	0.782	0.677	0.585	0.643	1.000	
BPO	0.456	0.453	0.615	0.478	0.619	1.000
Multiple R^2						
ERPC	0.3220					
BPO	0.4390					

Note: Boldface values highlight the correlations between IS resources.

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