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Research Note

Information Technology in Supply Chains: The Value of IT-Enabled Resources Under Competition

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In this study, we seek to better understand the value of information technology (IT) in supply chain contexts. Grounded in the resource-based theory in conjunction with transaction cost economics, we develop a conceptual model that links three IT-related resources (backend integration, managerial skills, and partner support) to firm performance improvement. The model differs from previous studies by proposing a moderating effect of competition on the resource-performance relationships. Using data of 743 manufacturing firms, our analysis indicates significant contribution of IT to supply chains, which is generated through development of the digitally enabled integration capability and manifested at the process level along the supply chain. The technological resource alone, however, does not hold the answer to IT value creation. In fact, managerial skills, which enable adaptations on supply chain processes and corporate strategy to accommodate the use of IT, are shown to play the strongest role in IT value creation. Furthermore, backend integration and managerial skills are found to be more valuable in more competitive environments. While commodity-like resources have diminishing value under competition, integrational and managerial resources become even stronger. Overall, our results shed light on the key drivers of IT-enabled supply chains, and provide insights into how competition shapes IT value.

Key words: IT business value; competition; supply chain; resource-based view; moderation effect; intangible resources; backend integration; managerial skills
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1. Introduction

Innovations enabled by information technology (IT) are creating new ways for firms to manage supply chain relationships (Sambamurthy et al. 2003). Firms such as Cisco, General Electric, Wal-Mart, and Dell are using IT to coordinate processes along their supply chains, including upstream procurement, internal production, and downstream sales and customer services, as well as overall information sharing along the supply chain (Lee 2002). The use of IT has received significant attention in the supply chain context, which "involves the flows of material, information, and finance in a network consisting of customers, suppliers, manufacturers, and distributors" (Lee 2000, p. 31). Accordingly, recent research has viewed *supply chain management* (SCM) as "a digitally enabled inter-firm process capability" (Rai et al. 2006, p. 226).

Here the term "digitally enabled" means an integration of inter-firm processes through IT on the Internet platform, with the integration spanning the entire scope of the supply chain that extends both upstream and downstream operations (Lee 2000). The digitally enabled SCM differs significantly from vertical integration in traditional organizations in that supply chain partners are integrated via *information flows* rather than ownership. It also differs from the traditional approach to supply chain coordination that directly relied on the linkage of physical processes such as shipment, inventory, and warehousing (Barua et al. 2004). Thus, a key feature of digitized SCM is the shift from connection of physical processes to information-based integration across upstream and downstream operations (Zhu 2004).

How does such a shift to digitally enabled integration affect the efficiency of a supply chain? This is a critical question for firms investing in IT to improve supply chains (Rai et al. 2006, Zhu et al. 2006). In our research context, we seek to better understand *performance improvement*—i.e., the degree to which a firm has gained improved business processes and enhanced competitive position—as indications of value creation through the digitally enabled SCM. More broadly, this is related to IT business value (Hitt and Brynjolfsson 1996, Zhu et al. 2004). By analyzing the relationship of IT-enabled resources to performance improvement in supply chain contexts, this work will contribute to the ongoing debate on "IT-value paradox" (Zhu and Kraemer 2005, Banker et al. 2006).

Furthermore, this research looks into the contingencies that environmental factors may affect IT value (as called for by Melville et al. 2004). In particular, competition tends to shape technology-performance relationships (Barney 1986, Porter 1991). Thus far, IT value under *competition* is still an open issue (as reviewed by Wade and Hulland 2004): While intense competition makes it more difficult to retain value from technologies *per se* (Porter 2001), firms such as Dell and Cisco leverage their digitally enabled networks to achieve real-time information flow along their supply chains, leading to superior firm performance, even in highly competitive environments (Lee 2004). As such, how competition shapes the technology-performance relationships deserves further attention.

The above considerations lead to the following key research questions: How will IT-enabled resources affect firm performance at the process level along the supply chain? Will improved process performance lead to increased competitive position? How will competition moderate these relationships?

To better understand these questions, we draw on insights from the resource-based view (RBV) and particularly leverage what has been established by Zhu and Kraemer (2005). They developed a framework to assess IT-enabled resources at both the front end and the back end. We enrich the discussion by incorporating insights from transaction costs economics. The purpose of the present study is to synergize the literature to achieve a deeper understanding of IT value under competition, particularly in the supply chain contexts, through a narrower but more focused study on supply chain integration in the manufacturing industry (relative to our earlier work). This study leads to an improved understanding of how certain constructs should be positioned in the nomological network of IT value in supply chain contexts, for example, by including new variables such as managerial skills and partner support. Another extension is the positioning of competitive intensity as a moderator in IT value creation. Along this line, the current paper contributes new evidence on how the technology-performance relationships may be moderated by competitive intensity, a result not found in previous studies.

2. Theory

2.1. The RBV on Supply Chain Integration

As we seek to study IT value in digitally enabled supply chains, we draw primarily on the RBV on how technology creates value (Zhu and Kraemer 2002, 2005). The RBV attributes improvement in firm performance to valuable resources or resource bundles (Barney 1991, Peteraf 1993). From the RBV, one lens through which to look at IT value creation is "an indirect role for IT in firm performance. The basic logic is that IT affects other resources or processes which, in turn, lead to competitive advantage.... Therefore, researchers may find it particularly beneficial to use intermediate-level dependent variables at the business process, department, or project level" (Wade and Hulland 2004, pp. 129–130). In light of this logic, we will pay particular attention to the relationship of IT-enabled supply chain integration to a firm's process performance.

Revenue generation and cost reduction are the two major dimensions of process performance improvements through supply chain integration (Mukhopadhyay and Kekre 2002). Such improvements, seen from the RBV, stem from *resource synergy* along the supply chain. Effective SCM aims to synchronize supply, production, and delivery (Lee et al. 2000). For this to happen, firms needs to leverage the connectivity of the Internet to create an inter-firm digital platform, enabling real-time information sharing, and improving coordination of allocated resources across the supply chain (Lee 2004). The *digital platform* helps establish connections among separate resources owned by supply chain partners, thus translating them into bundles of coexisting resources responsive to each other (Zhu and Kraemer 2002). This is consistent with the notion of creating resource synergy as advocated by the RBV (Conner 1991). The value, in our supply chain contexts, may be manifested in revenue generation and cost reduction.

A case in point is the practice by Cisco. Although the contract manufacturers and partners are not owned by Cisco, the digitally enabled integration enables Cisco to take advantage of their manufacturing equipments, distribution channels, and service networks. This allows it to concentrate on developing new products to cope with changing market demand, while outsourcing physical production. The outcome is an advantage of agile supply chain, leading to revenue growth and market expansion (Kraemer et al. 2006).

More broadly, integration across separate stages of a supply chain allows each supply chain partner to focus on the operation at its own stage. This may eliminate the burden of acquiring duplicate resources (which are required by operations at other stages), thus increasing resource utilization and decreasing operational costs. Cost reduction can be further achieved through resource synergy among horizontal partners (Lee 2002). For instance, because of the risks of supply disruption, firms often keep safety stocks for key components. Holding excess inventory, however, reduces asset productivity. Alternatively and more effectively, firms can share safety stocks with other firms that also need the component (Lee 2002). As illustrated by Cisco's e-hub through which Cisco's suppliers share safety inventories, not only are the risks of supply disruption shared through inventory pooling, but also the costs of maintaining the safety stocks are spread over partners. In order for this to happen, the supply chain must be digitally integrated.

2.2. Transaction Cost Economics in Supply Chain Context

While the RBV suggests value creation through resource synergy, performance improvement in a supply chain can also be achieved by *efficient coordination*. This can be understood through the lens of transaction cost economics (TCE). Explicitly recognizing the costs of coordination among economic entities in markets, TCE stresses that a firm's central task is to coordinate transactions efficiently (Williamson 1985). IT can lower coordination costs, and in supply chain contexts, digitally enabled integration capability can substantially improve transactional efficiencies through increased information sharing and communications capabilities, resulting in improved supply chain performance (Zhu and Kraemer 2005).

Furthermore, TCE sheds light on the role of the digitally enabled SCM in competitive environments. An important feature of a competitive environment is the extensive competitive actions in the markets,[1] such as competitive entry, price change, supplier alliances, and new product introduction (Ferrier 2001). To improve performance or even survive in competitive environments, a firm needs to adapt its businesses to respond to competitive actions (Sambamurthy et al. 2003). If a manufacturer's operation is frequently affected by competitors' actions, it may face greater needs to coordinate with supply chain partners. For example, a manufacturer that needs to modify the design of its product, because of market entry or new products launched by competitors, also needs to modify the design of upstream components that constitute the product; it may also need to rearrange downstream channels for new product distribution. These may induce considerable coordination tasks (Bensaou 1997). Accordingly, technologies that help reduce coordination costs are more valuable in intensely competitive markets.

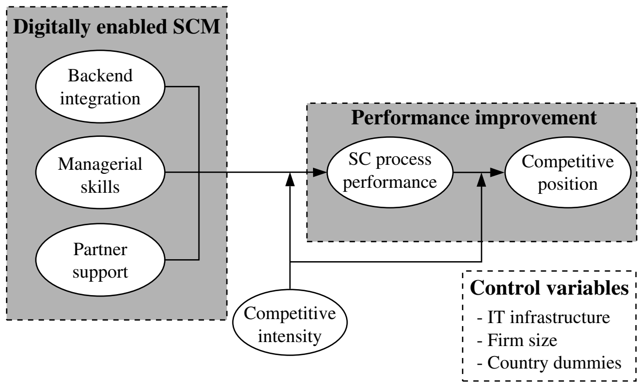
3. The Conceptual Model and Hypothesis Development

3.1. The Conceptual Model

Based on the above theoretical perspectives, we develop a conceptual model as shown in Figure 1. Consistent with our research purpose, we specify performance improvement as the dependent variables;

[1] This view of competition is rooted in the strategic management literature (Jacobson 1992, Ferrier 2001). Recent IT research has also considered how IT-enabled capabilities improve a firm's agility to respond to competitive actions (Sambamurthy et al. 2003).

Figure 1 The Conceptual Model



we identify key resources for the digitally enabled supply chain as the independent variables. The model relates these key resources to performance improvement. Then, as we seek to study how competition may shape performance improvement, we posit competitive intensity as an environmental moderator. Below, we discuss these variables in turn and explain why we have chosen them.

3.1.1. The Dependent Variables: Performance Improvement. Following the resource-based theory on IT value creation discussed above, the dependent variables include improvements in both *process-level performance* and *competitive position*, with the former being an intermediate dependent variable at the process level along the supply chain. While competitive position has been a classic dependent variable commonly used in the RBV literature (Wade and Hulland 2004, Bharadwaj 2000), several recent papers started to examine IT's relation to firm performance improvement at the business process level (Ray et al. 2004, Banker et al. 2006). The underlying rationale is that the value of resources is achieved through the use in specific processes, which, in turn, may lead to higher-level measures such as improved competitive position (Porter 1991).[2] As such, the model in Figure 1 proposes a sequential relationship, from resources to process performance then to competitive position.

The SCM literature suggests specific variables as proxy for process performance. For example, Mukhopadhyay and Kekre (2002) analyzed increased sales (strategic benefits) and decreased procurement costs (operational benefits). Subramani (2004) used a similar specification and examined the overall cost efficiency in the operational benefits category. Rai et al. (2006) further included improved customer services in the strategic benefits category. Collectively, the literature supports a three-dimensional framework proposed in Zhu and Kraemer (2005), which is adopted in this work: improvement in upstream operations (reduced procurement costs, lower inventory costs, and improved coordination with suppliers), improvement in internal operations (increased internal process efficiencies and staff productivity), and improvement in downstream operations (increased sales, wider segments, and improved customer services).[3] According to the literature, the three dimensions jointly represent performance improvements at the process level (Zhu and Kraemer 2005).

3.1.2. The Independent Variables: Key Resources Enabling Supply Chains. Using the RBV to study IT value, researchers have noted that improving firm performance through IT deployment depends on the combination of IT infrastructure, integration, relevant skills, and supportive relationships in IT management (Armstrong and Sambamurthy 1999). Based on a review of prior studies, a typology of IT-related resources has been proposed (Wade and Hulland 2004). It includes three types of resources that may contribute to performance improvement: (a) inside-out resources are deployed from inside the firm with a focus on technical platform, skills and development; (b) outside-in resources emphasize leveraging external resources and managing external relationships; and (c) spanning resources integrate the firm's inside and outside resources, such as the capability of IT-strategy integration.

[2] While RBV typically focuses on relative performance, it is also true that unless a business process has been improved relative to a firm's own prior performance, it cannot be improved relative to competitors. Hence, this can be seen as meeting necessary (though not sufficient) conditions for evidence of relative performance improvement. Note that the process performance measures are highly correlated with the Competitive Position variable (to be shown later). Meanwhile, we recognize that these are not the optimal measures for an RBV-framed study. We thank the associate editor for pointing this out.

[3] These three dimensions are adapted from Zhu and Kraemer (2005) with identical measures as originally used in that study to gauge the impact of IT on procurement, internal operation, and sales.

As a general framework, this typology must be situated within appropriate research contexts and with variables tailored to the specificity of the IT innovation. The RBV literature stresses that "firms compete on the basis of 'unique' corporate resources that are valuable, rare, difficult to imitate, and nonsubstitutable by other resources" (Bharadwaj 2000, pp. 170–171). While it is often challenging to find resources that precisely fit these requirements, we have tried to use them as guidelines and have found that three resources—*backend integration*, *managerial skills*, and *partner support*—seem particularly relevant in our research setting. They are identified for the following reasons:

(1) The digitally enabled SCM requires integrated systems at the back end that would enable information flow among various units of the firm and across the supply chain. We thus specify a variable to represent a firm's capability of *backend integration* which "links Web applications with back-office databases and facilitates information sharing along the value chain" (Zhu and Kraemer 2005, p. 67). By connecting separate systems on common data standards and communication platforms, it provides the "nerve system" for the supply chain to function. Unlike the commodity technologies, backend integration "is often tailored to a firm's strategic context and is woven into the organization's fabric, which is not transparent to competitors" (Zhu and Kraemer 2005, p. 71). Thus backend integration is a key resource for the digitally enabled supply chain.

(2) SCM requires not only resources inside a firm, but also external resources provided by partners along the supply chain (Bensaou 1997). As emphasized in prior research, the effectiveness of SCM depends on the support of a cluster of suppliers and partners (Lee et al. 2000). In contrast to traditional stand-alone IT innovations, digital supply chain integration is characterized by inter-firm linkages. Hence, we incorporate *partner support* into our model for SCM, which refers to the degree to which supply chain partners have compatible information systems to support inter-firm processes.

(3) Beyond technology resources, value creation in SCM requires *managerial skills* of aligning IT with business strategy and managing transformation in processes and structures (Armstrong and Sambamurthy 1999). Such managerial skills are important, because IT applications in SCM may induce changes in supply chain, for instance, multichannel coordination and mass customization at the downstream, and continuous replenishment program and vendor managed inventory at the upstream. Firms thus need managerial skills to orchestrate the adaptations in technology, strategy, and business processes. Therefore, we include managerial skills in the model.

In sum, the above three resources are identified within the framework proposed by Wade and Hulland (2004) and suited for the SCM context. Backend integration creates an integrated digital platform and requires internal technological skills (inside-out). Partner support reflects the extent to which external resources (suppliers' and business partners') support inter-firm coordination (outside-in). Managerial skills enable a firm to glue these inside and outside resources into the overall corporate strategy (spanning). In addition, note that it is not commodity resources that are being measured here. Obtaining these resources involves developing firm-specific capabilities (i.e., backend integration and managerial skills) and fostering supportive relationships in the supply chain (partner support). These are not easy to achieve and will be difficult to replicate by competitors. As such, their existence may be viewed as evidence of underlying capabilities that could meet the criteria of "uniqueness" of resources (Bharadwaj 2000).[4]

3.1.3. The Moderating Variable: Role of Competition. The RBV needs to be fitted for the specificity of the environment (Melville et al. 2004).[5] One of the important environmental factors is competition. Business value of resources is contingent on competition, and resources may play different roles in highly competitive environments as opposed to less competitive environments (Barney 2001). Our model thus incorporates competition, which may exert moderation effects in two ways.

First, the earlier TCE-based discussion suggests different performance improvements through the use

[4] We thank the associate editor for pointing this out.

[5] For instance, Miller and Shamsie (1996) showed that a firm's knowledge and skills are more valuable resources in changing environments than in stable environments.

of the same technology resource, that is, the digitally enabled capability of efficient coordination would be particularly valuable as competition intensifies. In addition, in competitive environments, firms need to cope with competitive actions (Ferrier 2001). They rely on managerial skills for agile actions in response to the changing conditions of the markets (Sambamurthy et al. 2003). This has been emphasized as the key to successful SCM in competitive environments (Lee 2004). Thus, managerial skills are particularly valuable for firms operating in highly competitive environments. A similar argument can be made about partner support. Hence, the links from the three resources to process performance may be moderated by competition.

Second, competition may also affect the degree to which process gains convert to improvements in relative competitive position (Barney 1991). Evidence shows that, possibly because of competitive imitation, significant productivity gains may not always translate into improved competitive position (Hitt and Brynjolfsson 1996). Hence, competitive intensity is proposed to moderate the relationship between process performance and competitive position (Figure 1).

Control Variables. Variations in firm performance can be better explained only when controls are appropriately applied. First, we need to control for firms' heterogeneity of *IT infrastructure*. Based on Zhu and Kraemer (2005), IT infrastructure comprises personal computers (PC), intranet, extranet, electronic data interchange (EDI), and electronic fund transfer (EFT). It provides a technological foundation in SCM, but the technology components, as included in the above definition, are commodity-like and do not seem to meet the RBV criteria (Bharadwaj 2000). Hence, we treat it as a control variable, rather than a theoretical variable.[6] Second, we need to control for *firm size*. Large size might be a positive factor for value creation given the associated financial resources available to large firms (Rogers 1995); yet it could also be a negative factor, as the digital transformation in SCM may be retarded by the complex organizational structure and hierarchical decision-making in large firms (Zhu and Kraemer 2005). Third, as our study includes firms from multiple countries, we need to control for *country-specific effects* because each country has its particular economic environment for IT applications (Kraemer et al. 2006). We use a series of country dummies to control for exogenous factors at the country level.

3.2. Hypothesis Development

3.2.1. Backend Integration. Backend integration may improve process performance by establishing collaborative connections among separate resources owned by supply chain partners. For instance, backend integration increases information transparency among partners that would pool inventory and share resources. With real-time data about inventory and material requirements, cost-effective transshipment of goods can be performed from one firm with excess inventory to the other with excess demand (Lee 2002). This benefits the former by reducing inventory-holding costs and the latter by fulfilling a growing demand. Backend integration also creates value by improving coordination efficiency. The supply chain literature suggests that efficient coordination plays a key role in reducing the "bullwhip effect," which often causes either excessive or inadequate inventory in the supply chain so that overall cost efficiency is compromised (Lee et al. 1997). By streamlining information flow and substituting information for inventory, backend integration may increase supply chain efficiency and reduce costs (Milgrom and Roberts 1988), with supportive evidence from the retail industry (Zhu and Kraemer 2005). Therefore, we propose:

Hypothesis 1A. *Backend integration is positively related to process performance improvement.*

[6] This modeling choice should not be interpreted as a blanket statement that IT infrastructure does not meet RBV criteria. IT infrastructure was viewed as a resource by some other studies, e.g., Bharadwaj (2000), which however emphasized the "synergistic benefits of integrated systems." That is, "the architecture that removes the barriers of system incompatibilities and makes it possible to build a corporate platform for launching business applications is clearly not a commodity" (Bharadwaj 2000, p. 172). IT infrastructure, as measured in our study, does not seem to meet RBV criteria because we measured only the "commodity-like components," and in no way captured the synergistic elements that might make these resources firm-specific.

Meanwhile, backend integration may show a more positive effect in highly competitive environments. Competitive actions tend to make the environment fast-changing and information-intensive (Sambamurthy et al. 2003). Such an environment raises the need to communicate market-related information and coordinate with supply chain partners so as to respond quickly to the changing markets. Thus, efficient communication and coordination through backend integration become more important in more competitive environments. This may be illustrated by the following cases. In the 1990s when rivals introduced new generations of PC using Intel's new microprocessors, Compaq took more time to modify its PC models because of less efficient coordination with suppliers/partners. Consequently, it lost market share throughout the decade. By contrast, backend integration enables Dell to achieve efficient coordination with suppliers. Dell can operate with work-in-progress inventory significantly below industry average. As a result, Dell incurs lower costs to adjust manufacturing lines in response to both new products in the markets and disruption in supply. An integrated supply chain is also vital to Dell's innovative business model—direct sales and build-to-order, which is critical for its performance in the competitive PC industry (Dedrick and Kraemer 2005). This discussion leads to the following hypothesis:

Hypothesis 1B. *Backend integration will have a stronger relationship with process performance improvement in more competitive environments.*

3.2.2. Managerial Skills. As defined earlier, *managerial skills* represent firms' ability to manage technology-strategy alignment, organizational changes, and process redesign to accommodate the use of IT to improve firm performance. Firms achieving technology-strategy alignment can attain more value from IT (Clark and Hammond 1997). The SCM literature also highlights the importance of adapting supply chain structures and processes in deriving business value. For instance, evidence shows that, in managing buyer-supplier relationships, supply chain restructuring is associated with greater improvements in logistics costs and order cycle time (Kopczak 1997). In a study of electric data interchange (EDI), Clark and Hammond (1997) find that SCM involving adoption of EDI and redesign of procurement processes yields performance improvements more than an order of magnitude greater than adopting EDI alone. Together these studies suggest the critical role of managerial skills in improving the effectiveness of a digital supply chain.

Hypothesis 2A. *Managerial skills are positively related to process performance improvement.*

Managerial skills would also play a more significant role in more competitive environments. Facing competitive actions, firms need to modify processes and strategies. The supply chain literature documents several cases that illustrate the importance of strategic adaptation in competitive environments (Lee 2004). For instance, when Hewlett-Packard (HP) started making ink-jet printers in the 1980s, the printer-manufacturing technologies were still under development and the largest market was in North America. Therefore, HP set up both its R&D and manufacturing divisions in Vancouver, Washington. When demand grew worldwide and HP confronted more competitors, it needed to adapt its strategy, targeting the global market and achieving economies of scale to maintain low costs. With this strategic change, HP started developing its global supply chain, moving its largest production facility to Singapore. "By the mid-1990s, HP realized that printer-manufacturing technologies had matured and that it could outsource production to vendors completely. By doing so, HP was able to reduce costs and remain the leader in a highly competitive market" (Lee 2004, p. 108). In this case, information technologies enable HP to efficiently manage its supply chain on a global scale. More important, this case shows how managerial skills in supply chain adaptation lead to superior firm performance, especially when competition becomes more intensive. We put forth a formal hypothesis:

Hypothesis 2B. *Managerial skills will have a stronger relationship with process performance improvement in more competitive environments.*

3.2.3. Partner Support. For transactions to take place over the digital platform, it is necessary that supply chain partners adopt interoperable information systems and provide compatible services for each other. Conversely, information sharing and automated transactions will be hampered if compatible systems are not installed along the supply chain (Bensaou 1997). Therefore, partner support is proposed to be a supportive resource, positively associated with value creation in SCM. This is supported by previous research on interorganizational systems, especially EDI. For instance, the benefits of EDI adoption are found to be positively associated with the degree of support for using EDI from business partners (Ramamurthy et al. 1999). This rationale can be applied to our research setting, leading to the following hypothesis:

Hypothesis 3A. *Partner support is positively related to process performance improvement.*

Moreover, partner support would be more valuable in more competitive environments. As discussed above, the greater the partner support, the greater the degree of digitization along a firm's entire supply chain. This in turn may create more value in competitive environments, which follows our earlier argument that efficient coordination is more critical for firms operating under intense competition. A higher degree of digital integration with partners along the supply chain increases a firm's ability to obtain real-time information about demand changes, supply variations, inventory buildup, and competitive moves (Barua et al. 2004). The increased information transparency would help the firm adapt pricing and product design more promptly in response to market changes (Zhu 2004). Such agility increases in importance in competitive markets because intense competition tends to make the markets dynamic and firms must develop the ability to work with partners in the changing environments. Putting this as a formal hypothesis, we have:

Hypothesis 3B. *Partner support will have a stronger relationship with process performance improvement in more competitive environments.*

3.2.4. The Relationship Between Process Performance and Competitive Position. The resources discussed above may create value at the process level, which, in turn may (or may not) translate into enhanced competitive position. This proposition has been conceptually formulated in the RBV literature (Melville et al. 2004). It is also consistent with empirical evidence in the IT productivity literature (Barua et al. 1995, Zhu and Kraemer 2002): IT investment helps improve process-level performance, such as inventory turn and asset utilization; these process-level performance variables in turn help improve competitive position. Along this line, we propose the following hypothesis in supply chain contexts:

Hypothesis 4A. *Process performance improvement is positively related to improved competitive position.*

Furthermore, this relationship may be moderated by competition. The RBV contends that some gains in firms' relative competitive position may be competed away (Barney 1991). Consider, for example, that a manufacturer may reduce operational costs through efficient SCM, but it may experience price decline in the whole industry because competitors may also achieve efficiency gains and thus lower their prices, too. Consequently, the firm might see efficiency gains at the process level, but no improvement in its profitability relative to competitors (Hitt and Brynjolfsson 1996). As such, competition may reduce the firm's ability to appropriate the full value of IT. This leads to our final hypothesis:

Hypothesis 4B. *Process performance improvement will have a weaker relationship with improved competitive position in more competitive environments.*

4. The Empirical Study

4.1. Data and Measures

4.1.1. Data. To test the conceptual model and associated hypotheses proposed above, we used a data set generated from a large-scale survey designed to investigate Internet-based value chain activities.[7] The survey development and data collection were detailed in Kraemer et al. (2006) while tests of possible biases were reported in Zhu and Kraemer (2005).

[7] Sections of the database had been used in previous research, however, each paper used a different subset of the large database: Zhu et al. (2004) used data of the financial services industry to study IT payoffs in banks; Zhu and Kraemer (2005) used data of the retail/wholesale industry to study the use and value of the Internet for retailers; and the present research uses data of the manufacturing industry to study IT value in digitized supply chains. We have seen such uses of the same, especially large, databases for different purposes, much like the Computer Intelligence database was used in many of the IT productivity papers.

The manufacturing data set used in this study contains 743 firms. The sampling was random, stratified by firm size. The data in the final sample were checked for consistency and nonresponse bias was examined. No significant biases were found in terms of number of responses and respondents' titles. In addition, respondent positions (IS or non-IS managers) did not cause significant biases in the data.

In this study, we chose to focus on the manufacturing industry for the following reasons. First, focusing on one industry helps control industry-specific effects. Second, and more important, supply chains in the manufacturing sector comprise more stages than other industry sectors. Accordingly, SCM in manufacturing may involve more entities along the supply chain. Manufacturing firms need to manage transactions and coordination with material suppliers, contract manufacturers, logistic providers, and downstream partners (Zhu and Kraemer 2002, Subramani 2004). Anecdotal evidence suggests that manufacturing firms such as Dell and General Electric lead in using the Internet to digitize supply chain activities (Kraemer et al. 2006). The manufacturing industry is thus an appropriate testing field for our model.

4.1.2. Measures. We used survey items to measure model constructs (also listed in Table 1).[8] For the dependent variables, we measure improvements in *process performance* with the following items: improvement in upstream operations including reduced procurement costs (UO1), lower inventory costs (UO2), improved coordination with suppliers (UO3), improvement in internal operations including increased internal process efficiencies (IO1) and staff productivity (IO2), and improvement in downstream operations including increased sales (DO1), wider segments (DO2), and improved customer services (DO3). We measure *competitive position* by the extent to which the firm's relative position in competition has been improved through IT-enabled supply chain integration (CP).

For the independent variables, we measure *backend integration* using three items: the extent Web applications are electronically integrated with back-office information systems and databases (BI1), the extent company databases are electronically integrated with those owned by upstream suppliers and downstream partners (BI2), and the extent the firm has used the Internet to support information sharing along the supply chain (BI3). Specifically, BI3 is an aggregated index based on the following list: exchanging inventory data with suppliers, exchanging operational data with customers/business partners, formally integrating business processes with upstream partners and with downstream partners. The three items for *managerial skills* are: the firm's ability to adjust technology-strategy alignment to accommodate the use of IT and manage business process reengineering (MS1), the firm's ability to manage organizational change and supply chain restructuring induced by the Internet-based platform (MS2), the firm's ability to acquire expertise critical for managing Internet-based supply chain activities (MS3). We measure *partner support* using three items: the extent downstream customers have compatible systems in place to support Internet-based value chain activities such as online orders and information sharing (PS1), the extent upstream

Table 1 Constructs and Measurement Items

Constructs	Items	Weights
Backend integration	BI1	0.57
	BI2	0.61
	BI3	0.53
Managerial skills	MS1	0.43
	MS2	0.39
	MS3	0.37
Partner support	PS1	0.43
	PS2	0.49
	PS3	0.42
IT infrastructure	ITI1	0.50
	ITI2	0.52
Competitive intensity	CI1	0.48
	CI2	0.51
Performance improvement		
Upstream operations	UO1	0.38
	UO2	0.40
	UO3	0.39
Internal operations	IO1	0.31
	IO2	0.38
Downstream operations	DO1	0.36
	DO2	0.35
	DO3	0.31
Competitive position	CP	1.00

Note. All weights are significant at the $p < 0.01$ level.

[8] Many of these measures were designed based on previous studies (Zhu and Kraemer 2005).

suppliers have such compatible systems (PS2), and the extent Internet-based value chain activities are involved in government procurement (PS3).

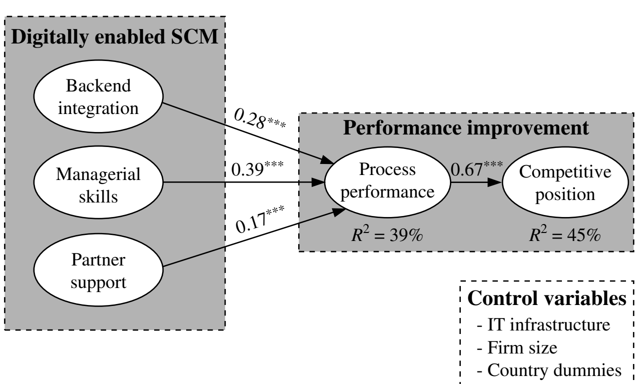
Drawing on the theoretical view of competition in terms of influence of competitive actions in the markets, we use two items to tap the moderating variable—*competitive intensity*, i.e., the degrees to which the firm is affected by competitors in the local market (CI1) and in the national market (CI2). For control variables, we measure *IT infrastructure* using two items: the number of PCs per employee (ITI1), and the number of related infrastructure technologies in place (ITI2, including EDI, electric funds transfer (EFT), intranet, extranet, local area networks, and wide area networks). We use the number of employees (log-transformed) as a proxy for *firm size*.

4.1.3. The Measurement Model. We used Partial Least Squares (PLS) to assess the measurement model. As shown in Table 1, all measurement items have significant weights ($p < 0.01$) with acceptable magnitude (Chin 1998). Thus, constructs measured by these items can be used to evaluate the model and associated hypotheses.

4.2. Analysis and Results

4.2.1. The Relationship of Resources to Performance Improvement. We estimated the structural model on the full manufacturing sample using PLS. The results are shown in Figure 2. The R^2s of process performance and competitive position are 39% and 45%, respectively, indicating significant data variation explained by the independent variables.

Figure 2 **Empirical Results on the Full Sample** ($N = 743$)



Note. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.

The three key resources for enabling the digital supply chain—backend integration, managerial skills, and partner support—have significant ($p < 0.01$) and positive paths to process performance. As indicated by the path magnitude, managerial skills show the strongest linkage to process performance ($\beta = 0.39$), followed by backend integration ($\beta = 0.28$), and partner support ($\beta = 0.17$). We also found a significant and positive linkage from process performance to competitive position ($\beta = 0.67$, $p < 0.01$). As suggested by these results, firms that have stronger backend integration, managerial skills, and partner support also attain greater process performance improvements, which, in turn, leads to enhanced competitive position.[9]

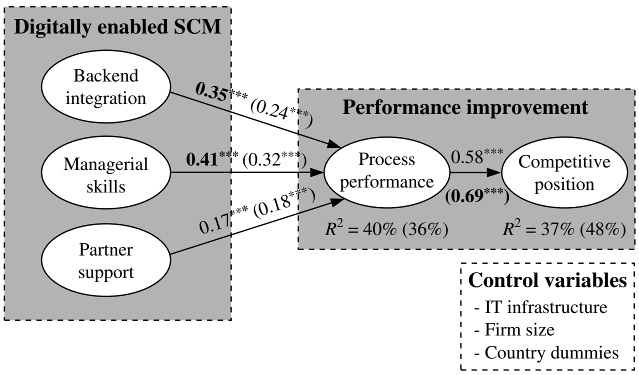
4.2.2. Moderating Effects of Competition. To examine the moderation of competitive intensity on the resource-performance relationship, we conducted a group analysis. By a hierarchical cluster analysis based on these variables, we split the full sample into two groups: firms in high-competition group ($N = 491$) versus low-competition group ($N = 218$).[10] We then estimated the structural model on the two groups, respectively. The results are reported in Figure 3. We tested the statistical differences between the two groups by comparing each path across the two subsamples. We used t-test to examine the statistical significance of the differences.

As shown in Figure 3, *backend integration* has a significantly stronger effect in the high-competition group than the low-competition group (0.35 vs. 0.24; $t = 8.54$); *managerial skills* also have a significantly stronger effect in the high-competition group (0.41 vs. 0.32, $t = 6.78$), while *partner support* is not statistically different across the two groups (0.17 versus 0.18,

[9] Among the control variables, firm size is negatively related to process performance and competitive position ($p < 0.10$), indicating that larger firms are less likely to see performance improvements. This might be because of the structural inertia associated with large firms. That is, "while it has been commonly believed that large firms have more slack resources for committing required investments . . . , large firms are also burdened by structural inertia, possibly due to fragmented legacy systems and entrenched organizational structures" (Zhu and Kraemer 2005, p. 77).

[10] These numbers do not add to the full sample size as 34 firms have missing values on competitive intensity.

Figure 3 Empirical Results on Split Samples: High-Competition Group vs. Low-Competition Group



Notes. Estimates on the low-competition group are shown in parentheses. Numbers in bold are statistically greater than their counterparts.
$^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.

$t = -0.32$). Furthermore, the link from process performance to competitive position is weaker in the high-competition group (0.58 vs. 0.69, $t = -4.83$). These results suggest that the IT-enabled resources do generate value at the process level, but the value is partly competed away when gauged relative to competition. Overall, the results on split samples (Figure 3) support our theoretical expectation that competition moderates resource-performance relationships.

4.2.3. Robustness Checks. We checked for the robustness of these results to model specifications by estimating partial models. We first estimated a partial model by dropping backend integration; we obtained highly consistent estimates for managerial skills and partner support. Dropping managerial skills (or partner support) also yields qualitatively similar results compared to the full model.

Then, we analyzed how firms' engagement in business-to-consumer (B2C) selling may affect our results. In our sample, 13.3% of the manufacturing firms ($N = 99$) claimed that they conducted B2C selling on the Internet. We excluded these 99 firms and used the remaining sample to reestimate the model. The path estimates for backend integration, managerial skills, and partner support are 0.30 ($p < 0.01$), 0.37 ($p < 0.01$), and 0.17 ($p < 0.01$), respectively, consistent with the estimates in Figure 2. We also reestimated the model on the high- and low-competition groups, with the 99 firms excluded. We obtained consistent results again. These tests demonstrate the robustness of the results to sample selection.[11]

Finally, the influence of common method variance was believed to be an important issue for this kind of data, and it was assessed with multiple methods. First, we conducted Harman's one-factor test and found no significant common method bias (Podsakoff et al. 2003).[12] Second, to the extent feasible, we compared our survey data with information from other sources. We found that, for the US firms in our sample, the correlations between survey items for competitive intensity (CI1 and CI2 in Table 1) and the Herfindahl-Hirschman Index (an "objective" measure, conversely related to industry competition) to be -0.45 ($p < 0.01$) and -0.38 ($p < 0.01$), respectively. The significant correlations indicate these measures to be consistent. Third, it is noted that common method bias is less of a concern for research, like ours, with a moderation effect (Levin and Cross 2004). The logic is that, if common method variance is substantial, it should be present regardless of the level of the moderator. Then, it is difficult to explain why the independent and dependent variables are more or less strongly related depending on the level of the moderator. Hence, "[a moderation effect] indicates that respondents did not unthinkingly rate all items as

[11] We also tested whether our sample includes "extreme" cases that severely affect the results. We dropped firms below the 5th percentile and above the 95th percentile in terms of process performance. After deleting those "outliers," the results were still consistent with the full sample results. To determine whether the significant results were driven by sample size, we randomly split the full sample into two half subsamples, and once again obtained consistent results. In the interest of space, these results are not included here, but are available from the authors on request.

[12] Additional tests were conducted. (1) We ran Lindell and Whitney's (2001) test, using a "marker variable" to partial out common method variance from correlations among the model constructs. After correcting for common method variance, we found no material change in the correlations, indicating that they cannot be merely explained by common method variance. (2) We formed a proxy for common method variance by conducting a factor analysis involving all of the measurement items. The first factor emerging from the analysis "is assumed to contain the best approximation of common method variance" (Podsakoff et al. 2003, p. 893). We added the proxy (i.e., the first factor) into our model as an independent variable, and found that the significant resource-performance relationships remained unchanged, and that including the proxy only explained an additional 1% of the variance in process performance.

either high or low" (Levin and Cross 2004, p. 1482). To sum up, these tests suggested that our results were not driven by the common method variance.

5. Discussion

5.1. Major Findings from This Study

First, IT can create value in supply chain contexts. The value is generated through developing digitally enabled integration capability, and manifested at the process level.

As shown in the empirical results in Figure 2, backend integration is significantly associated with process-level performance along the supply chain. This finding highlights that IT can create value. In particular, the value is generated through effective use of the technology to improve upstream, downstream, and internal operations. This supports the RBV theory that common technologies can be converted into valuable resources through deployment in specific processes. As an implication for the IT value literature, our results suggest the usefulness to gauge intermediate firm performance and probe into the specific ways that IT is used to improve business processes.

Also, the significance of backend integration suggests that, in supply chain contexts, IT value creation stems more from the *integration* of various systems—both internally among business units and externally with suppliers and business partners—than from individual IT components. This speaks to the nature of the digitally enabled supply chain, that is, integrated supply chains glued by information flows. The theoretical literature has long emphasized the importance of efficient information flows in supply chains (Lee et al. 1997, 2000); our work provides empirical evidence about how information flows enabled by backend integration can improve supply chain performance in the manufacturing industry, which, in general, involves more supply chain entities than other industry sectors.

Second, managerial skills and partner support are significant value drivers in supply chains, suggesting that IT value comes more from "fitting the pieces together."

Beyond technological resources, we have found managerial skills and partner support to be significantly associated with performance improvement, suggesting that managerial and relational resources are also critical for value creation in supply chains. Thus, successful SCM requires a firm to possess not only technological capability, but also managerial skills and external resources. This complements previous research that shows the importance of the digitally enabled technological capability (Zhu and Kraemer 2005).

In particular, our data show that managerial skills play the strongest role among the three key resources (Figure 2). As stated in hypothesis development, the importance of *managerial skills* can be attributed to the need to manage the coevolutionary changes in technology, process, and strategy in digitized SCM (Lee 2004). Broadly speaking, managerial skills fall into a category of intangible resources called "organizational capital," whose value has been shown in increasing firms' market value (Brynjolfsson et al. 2002). We find its significant value in driving another dimension of IT value—performance gains through supply chain integration, suggesting that organizational capital is an interesting topic warranting further study. Overall, our findings are consistent with the theoretical conjectures made earlier on the grounds of the resource-based theory. That is, technology alone may not hold the answer to IT value creation, but rather it works together with other intra- and interorganizational resources to create value in SCM.

Third, competition shapes IT value creation. In the supply chain context, backend integration and managerial skills become more valuable in highly competitive environments.

As shown in Figure 3, resources have differential effects in different environments. According to the RBV, resources that can be easily imitated by competitors are less likely to render performance advantage (Barney 1991), but the theory is less clear about what specific resources may lead to superior firm performance under competition. In the context of SCM, we find that backend integration and managerial skills have stronger effects in more competitive environments. The theoretical explanation is that the digitally enabled efficient coordination with supply chain partners and the agile adaptations on processes and strategies are critical organizational capabilities as competition intensifies. While the value of commodity-like resources diminishes under competition, integrational and managerial resources become even stronger. Our empirical evidence also adds to the burgeoning literature that examines IT value creation in competitive environments (Zhu and Kraemer 2005).

5.2. Limitations and Future Research

The key limitations of this study are discussed below along with avenues for future research. First, the survey used a single respondent in each firm, which might result in biases because of common method variance. While we have carefully assessed such possible biases by multiple methods, it would have been desirable to obtain data from multiple sources. For example, future research may collect accounting data to measure supply chain performance (e.g., inventory turn and procurement costs).

Second, our process performance measures reflect changes in firms' "absolute" performance, while RBV-based research should pay more attention to firms' *relative* performance. This should be extended in future research. Also, the use of a single-item measure for competitive position is a limitation. It will be useful to use accounting data, such as return on assets and return on investment, but we are unable to do so in this analysis. Another measurement item that needs refinement in future research is BI2, which was designed to evaluate electronic connections with downstream and upstream partners by the same respondent. We have learned that this is not the ideal way to measure them. More refined measures should tap the upstream or downstream of the supply chain separately.

5.3. Managerial Implications

This study offers several implications for managers. First, our model identifies technological, managerial, and external resources that are critical for the success of the digitally enabled SCM. It is essential that managers take these resources into consideration when transforming their physical supply chains into those based on digital connections and information flow. In particular, firms need to strengthen their *backend integration* so as to achieve seamless information flow among various information systems and databases both internally and externally across the production, supply, and distribution networks. This will become even more important as competition intensifies.

Second, managerial innovations are complementary to technological innovations. It is crucial for firms to achieve a strategic fit between management strategy and digitally enabled business activities. Firms facing intensive competition should proactively develop *managerial skills* to increase supply chain agility so as to respond quickly to market conditions and rival moves.

Third, managers should bear in mind that establishing information-linked strategic alliances with *business partners* is critical. The Internet has made the business environment more interconnected on a global scale. Firms are no longer working alone; they have to learn to leverage the external resources provided by suppliers, customers, and other supply chain partners. As illustrated by Dell and Cisco, firms that do this well will harvest great benefits from the streamlined connectivity of the supply chain.

6. Conclusions

Business value of IT continues to stimulate interest and debate among both academics and practitioners. In this paper we assess IT value in the context of digitally enabled supply chains, which has emerged as one of the major areas for companies to leverage IT to improve firm performance in global operations. This study attempts to present a theoretical viewpoint, supported by empirical evidence, on understanding IT value creation through digitally enabled supply chain integration. In doing so, this work makes an incremental but significant extension to a prior study by Zhu and Kraemer (2005). The two papers are related, but are clearly differentiated by the present work's different focus on digitall enabled SCM, use of a different sample (manufacturing), inclusion of new variables in the RBV-based model (managerial skills and partner support), and especially, the findings on the moderation effects of competition.

More broadly, this paper contributes to the literature on the digitally enabled SCM by developing a resource-based model of what resources are important to create value in supply chain contexts. The role of tangible IT has been extensively studied and the literature has called for research on value drivers of SCM that go beyond the technology (Rai et al. 2006). This paper identifies *intangible* resources, especially managerial skills and partner support, as key value drivers that work together with backend integration to improve firm performance, highlighting that integrational, managerial, and relational resources are critical in the global supply chain contexts.

Furthermore, this paper contributes to the IT value literature by addressing the role of competition in IT value creation, which to date remains an open issue. We find differential relationships of IT-enabled resources to performance improvements, contingent on competition. Under competitive regimes, the resource-performance relationships can be better understood in light of efficient coordination and organizational adaptations—theoretically anchored in the RBV and TCE. Accordingly, backend integration and managerial skills play a more significant role in value creation when competition is more intense. These results help to achieve knowledge accumulation and synergy about IT value, thus making an important contribution to a key research theme in the field.

These findings also add to the resource-based literature by linking resources to environments. This work highlights the fact that the role of resources needs to be situated within environmental contexts, such as competition. Therefore, RBV-based studies, when evaluating the value of resources, should condition the value on specific environmental factors. Our analysis provides some preliminary evidence for this general theoretical proposition. We hope this will serve as a base for future advances.

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