How Does Information Technology Shape Supply-Chain Structure? Evidence on the Number of Suppliers

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Abstract: This research investigates the relationship between a manufacturer's use of information technology (IT) (particularly electronic procurement) and the number of suppliers in its supply chain. Will a manufacturer use more or fewer suppliers due to the increasing use of IT? Based on data from a sample of 150 U.S. manufacturers, we find no direct relationship between e-procurement and number of suppliers at the aggregate level. However, when we distinguish the type of goods purchased, we find that the use of electronic procurement is associated with buying from *more* suppliers for custom goods but from *fewer* suppliers for standard (or commodity) goods. It is possible that for commodity goods, an efficiently functioning transparent market ensures that a few suppliers are sufficient, whereas for custom goods the need for protection from opportunistic vendor holdup leads to the use of more suppliers. Further, the positive relationship between number of suppliers and electronic procurement for custom goods is *negatively* moderated by deeper buyer–supplier system integration. This implies that such integration can help buyers obtain better "fit" for their customized requirements, an alternative to increasing fit by employing more suppliers as proposed in the extant literature.

Key words and phrases: electronic procurement, information technology, interfirm coordination, number of suppliers, supply-chain structure, systems integration, transaction costs economics.

The use of information technology (IT) has led to new ways of coordinating supply-chain relationships [35]. Researchers seek to link IT to governance of buyer–supplier transactions, most commonly using transaction cost economics (TCE) [48, 49]. It has been argued that IT can reduce production and coordination costs both internally and externally, and that the net impact of these cost reductions will determine whether firms organize transactions internally or in market relationships [14, 24, 37]. IT also supports hybrid forms such as value-added partnerships, in which firms leverage IT to integrate closely with a limited number of partners in a supply chain [25]. It is then critical to understand how IT use shapes buyer–supplier relationships, because different relationships may carry different benefits and costs, which affect the effectiveness of sourcing in the supply chain [22, 53].

In particular, how firms decide on an optimal number of suppliers is of both theoretical and practical interest [12]. In the information systems (IS) literature, significant attention has been given to addressing the optimal number of suppliers that a firm should use, and how that is affected by the use of IT. Researchers have made conceptual arguments that IT utilization could lead firms to work with either more [37] or fewer

[14] suppliers. Other work has highlighted the role of IT in the creation of value-added partnerships ("virtual integration") with fewer suppliers [2]. However, more recent research expects Internet-based technologies such as Web services to enable firms to connect their IS with more suppliers at a relatively low marginal cost [9, 53].

Empirically, the evidence is also mixed. There has been evidence of a shift toward the use of fewer suppliers in the electronics industry [46]. For instance, Dell reduced its supplier base by 75 percent while implementing major IT systems to better coordinate production and supply-chain operations [34]. Yet Boeing has been using more suppliers in its global supply chain for the 787 Dreamliner. A recent survey found IT use associated more frequently with an *increased* supplier base [19]. Therefore, the relationship of IT use to the number of suppliers with which firms do business is an important yet open topic worthy of further research.

In this work, we specifically focus on *electronic procurement* (e-procurement), which refers to procurement processes that are conducted using common data standards and via IT-based platforms [41, 53]. This is the type of IT that is used directly to support transactions between buyers and suppliers and thus most likely to affect the choice of number of suppliers. We conducted a survey in the U.S. manufacturing industry and used the data to investigate how e-procurement relates to number of suppliers. Our work contributes to the literature on IT use in supply-chain contexts, both empirically and theoretically.

We examine empirically the relationship of IT with number of suppliers, while prior research has been mainly focused on conceptualization (e.g., [26, 33, 37]) or case research (e.g., [13]). We find no direct relationship between the volume of goods purchased via e-procurement and the number of suppliers at the aggregate level. Yet when we further address the nature of goods purchased, we find that number of suppliers is *positively* associated with e-procurement for *custom goods* and *negatively* associated with e-procurement for *standard goods*. To our knowledge, this is the first time such a distinction has been made. The different relationship is consistent with a TCE-based notion that custom goods procurement involves more asset-specific supplier relationships with greater potential for opportunism, and e-procurement enables buyers to use more suppliers and thus avoid vendor holdup. For commodity goods, in contrast, an efficiently functioning transparent market reduces the risk of opportunism, so e-procurement can be used to automate frequent transactions with fewer suppliers.

We also distinguish transaction-oriented e-procurement from deeper integration of buyers' and suppliers' IS. Our results show that the positive relationship between number of suppliers and e-procurement for custom goods is moderated by the extent to which firms integrate IS with their suppliers: deeper integration is associated with using fewer suppliers. This suggests that such tighter integration can help buyers obtain better "fit" for their customized requirements through close coordination in supply chains. It is an alternative to increasing fit by working with more suppliers as proposed in prior literature [2]. Our theoretical contribution, then, is to show that the relationship between IT use and number of suppliers is not straightforward, but depends on the types of goods exchanged and the nature of the IT in use.

Theory Development

Transaction Cost Economics and Number of Suppliers

TCE IS A USEFUL LENS TO UNDERSTAND THE RELATIONSHIP OF IT to number of suppliers [2, 14]. TCE states that firms face the risk of opportunism when they are in a situation bargaining with a small number of other firms, particularly when relationship-specific investments are required [48]. It is generally expected that having more suppliers reduces such risk of opportunism, as the buyer is less dependent on any particular supplier. In addition, having more suppliers can reduce the cost of having to settle for a poor *fit* (i.e., for a less than ideal combination of product features, quality, and reliability of supply) [2]. Nonetheless, using more suppliers raises coordination costs as the buyer must search, negotiate contracts, monitor and enforce compliance, and coordinate efforts with each supplier. Thus, the number of suppliers chosen by any firm involves finding an optimal balance among the following key transaction factors—fit, coordination costs, and risk of opportunism [14].

These key transaction factors are summarized in Table 1, along with their potential impact on the number of suppliers selected, and the primary and secondary effects of IT on those factors. On one hand, IT can reduce coordination costs as procurement processes are standardized and automated, thus reducing the cost of working with more suppliers [37]. Also, IT can reduce the costs of searching for new suppliers to achieve better fit [20]. Based on these factors, the expected impact of IT would be an increased number of suppliers, as the benefits of better fit can be achieved without greatly increasing search and coordination costs [2].

On the other hand, IT might favor reducing the number of suppliers. In this case, the most important factor is the potential of IT to reduce the risk of shirking or opportunism associated with a small numbers bargaining situation [14]. This is due in part to IT's potential to monitor supplier performance and detect opportunism, because IT use leads to greater information transparency along the supply chain [52]. It is also due to the fact that IT investments may be less relationship-specific than other investments, especially as ITs are becoming more open and standardized [14]. Indeed, firms are increasingly using industrywide IT (both technology platforms and data standards) in interfirm coordination [54]. As a result, IT enables a buyer to work more closely with fewer suppliers, reducing search and coordination costs without taking on additional transaction risks. This was conceptualized as the "move to the middle" hypothesis by Clemons et al. [14].

Given these competing perspectives, whether or not IT use is associated with an increase or decrease in the number of suppliers depends on the balance of its impact on these factors—coordination cost, fit, and risk. The net impact depends in part on the marginal cost of buyer–supplier IT linkages, and the relationship specificity of the associated IT investments. If additional suppliers can be added easily to existing interfirm IT systems such as those based on cheap technologies and open standards, then marginal coordination costs will be low and buyers are likely to work with more suppliers to achieve better fit. But if the marginal cost of making IT connections is

Table 1. Transaction Cost Perspectives on Number of Suppliers

Transaction factors	Impact on the number of suppliers	Impact of IT	Alternative or secondary effects
Coordination cost	Higher coordination costs favor using fewer suppliers	IT can reduce coordination cost by standardizing and automating information flows	If establishing IT connection is costly, coordination costs may be increased
Cost of poor fit	Favors using more suppliers to get better fit	IT reduces search cost, allowing firms to find suppliers with better fit	IT enables close coordination with suppliers to achieve better fit
Risk of opportunism	Favors using more suppliers to avoid small numbers bargaining	IT can reduce risk through better monitoring	If IT investments are less relationship-specific than other investments, risk can be reduced
Noncontractible investments*	Favors working with fewer suppliers to create incentives	IT can enable more complex products and processes that require noncontractible investments	IT-enabled business process integration is a form of noncontractible investment

high, as in the case of expensive technologies or relationship-specific integration [47], the economics will favor working with fewer suppliers in order to reduce up-front costs and to recoup those investments over a larger volume of transactions with each supplier [14].

As listed in Table 1, an additional factor is supplier incentive to make noncontractible investments (in quality, reliability, or other performance measures), which can be increased by reducing the supplier base [2]. Here a buyer firm may decide to accept a greater risk of opportunism to encourage its suppliers to make such investments in return for a greater share of the buyer's total business. The role of IT here is more indirect, for instance, in creating an environment in which noncontractible investments are more important, such as by speeding product cycles or enabling more complex business processes [33]. Also, deeper integration of IT systems between firms may by itself require noncontractible investments on the part of the seller; hence, sellers may need to be given incentives to make such investments as well [52].

Theory Enrichment: Nature of Product and Type of IT

We enrich and refine the above perspectives by addressing the nature of the product being supplied and the type of IT employed in the buyer–supplier relationships. Each of these two factors can affect the relative importance of coordination cost, the cost of poor fit, risk of opportunism, and the importance of noncontractible investments. Each also can affect the impact of IT on those variables.

The Nature of the Product

Manufactured goods can incorporate both standard and custom components [11]. For a standard commodity input (such as nuts, bolts, resistors, or memory chips), the potential cost of poor fit is lower, as inputs from different suppliers are interchangeable. For custom components (such as application-specific integrated circuits or molded plastic enclosures), the importance of fit is high, as a highly specific part is required and only a few suppliers may be able to provide this input. Also, the cost of coordinating with suppliers is likely to be higher for custom goods, as suppliers need more information to meet unique requirements for the buyer [16]. Finally, the risk of opportunism is likely to be lower for standard goods, as a buyer can more easily find a substitute supplier if a current supplier tries to act opportunistically. For custom goods, the risk of relying on a small number of suppliers is greater, as asset-specific investments are likely to be involved and supply uncertainty is greater [48, 49].

Therefore, the potential impact of IT on costs associated with poor fit, coordination, or opportunistic behavior will be affected by the nature of the goods. If the importance of fit is low, as in the case of standard goods, then the potential benefits of using IT to search for more suppliers will be limited. If fit is more important, as in the case of custom goods, then the benefits of using IT to find suppliers who offer a better fit with buyers' needs will be greater and may lead to the use of more suppliers. When the risk of opportunism is high, as in the case of custom goods with few suppliers, the use of IT to monitor suppliers and prevent shirking will be more valuable, and may help avoid the risks of a small numbers bargaining situation [14]. Because of these differences, we would expect different effects from IT use for procurement of standard commodities than for customized inputs.

The Type of IT Employed

The use of IT to automate routine purchasing processes, such as order processing and invoicing, can be accomplished by adoption of established protocols such as electronic data interchange (EDI) or extensible markup language (XML)-based standards [38, 53]. The marginal cost of adding another trading partner in this case is likely to be relatively low once the firm has put in the necessary infrastructure and adapted its own processes and systems to generate data in the required formats. Adoption of such standardized technologies enables buyers to use more suppliers in order to achieve better fit without a corresponding increase in coordination costs [2].

By contrast, deeper integration of processes between firms is likely to require more extensive IT integration, for instance, sharing data between enterprise systems or adoption of compatible applications such as computer-aided design or supply-chain management systems [53]. In such cases, the marginal cost associated with integrating additional suppliers may be high [2]. After these linkages are established, information to provide more complex products and processes can be exchanged and suppliers will be able to fine-tune their production to the needs of the buyer, thus providing better fit [5]. As such, we expect differential relationships between IT use and number of suppliers when such enhanced integration is created.

The Conceptual Model

Based on the theoretical discussion above, we propose a conceptual model as presented in Figure 1. As introduced earlier, our work is focused on the context of firms using IT to conduct transactions electronically, via electronic procurement. Our model is concerned with how the extent of *e-procurement use* (i.e., *volume of transaction via e-procurement*) may relate to firms' choice of the number of suppliers. By definition, our e-procurement variable represents the operational aspect of sourcing over IT-enabled electronic platforms. Also, gauging the extent of e-procurement by transaction volume is consistent with the literature [42, 45]. More broadly, prior work has used percentage of interfirm transaction conducted via electronic platforms to assess the degree of electronic integration based on interorganizational systems [51, 54]. Our work is built on these previous studies.

Furthermore, in line with the theoretical extension discussed in the previous subsection, we propose two additional factors in the model. First, we consider the nature of the product in e-procurement and differentiate *standard goods versus custom goods*. Second, we posit *buyer–supplier systems integration* to represent a key dimension of the type of IT deployed, referring to the degree to which a buyer firm's systems are integrated with systems and databases of its suppliers [41]. It is worth noting that

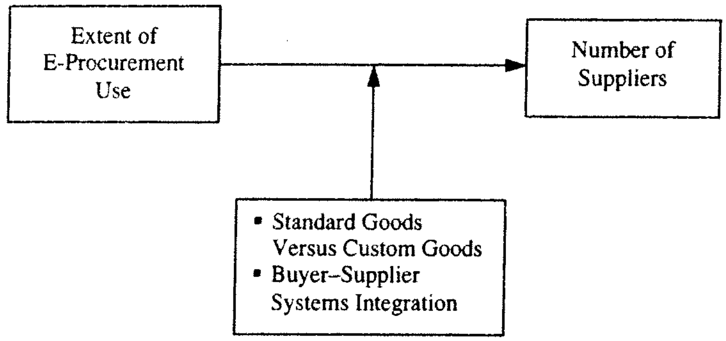

Figure 1. The Conceptual Model

while e-procurement use, as defined above, reflects the transactional nature of IT use in supply-chain contexts, systems integration provides the IT infrastructure for more "explicit coordination" between buyers and suppliers [14, 43].[1] As discussed earlier, the relationship of e-procurement to number of suppliers may be contingent on systems integration and the types of products being purchased. Their influence is formally hypothesized in the next section.

Hypothesis Development

Hypotheses

E-Procurement and Number of Suppliers

FOLLOWING THE ABOVE DISCUSSION, we propose that IT use may impact the transaction factors (as summarized in Table 1) that determine the number of suppliers, leading to either an increase or a decrease in the number of suppliers. Depending on how each of those factors is affected and also the relative strength of those effects, it is possible that the number of suppliers could be higher or lower. As a result, we present two alternative hypotheses, positing that IT use may be associated with either more or fewer suppliers.

> *Hypothesis 1a: In the context of buyer–supplier transactions, the use of e-procurement is positively associated with the number of suppliers.*

> *Hypothesis 1b: In the context of buyer–supplier transactions, the use of e-procurement is negatively associated with the number of suppliers.*

H1a is motivated by the argument of Malone et al. [37] that IT use will lead to greater reliance on outside markets (outsourcing) rather than internal production (hierarchies). Shifting activities from inside the firm to outside sourcing may involve the use of new suppliers. In this regard, the number of suppliers may be an increasing function of IT use. Further, even when it is certain that an input can be purchased from an existing supplier, IT can enable buyers to search for and purchase from more suppliers and thus reduce the cost of poor fit, without a corresponding increase in coordination costs. The expected result will thus be the use of more suppliers [2].

H1b is motivated by the "move to the middle" hypothesis by Clemons et al. [14]. It is based on the assumption that the increased search and coordination costs associated with using more suppliers may outweigh the benefits of better fit or reduced opportunism. In this view, a high level of buyer–supplier coordination may act as an alternative means to achieve better fit, as long as the potential for opportunism can be mitigated by the use of IT to monitor supplier behavior. An important factor is the marginal cost of coordinating with additional suppliers; if it is high enough, then the benefits of having more suppliers might be outweighed by the cost of coordination [2, 14]. Finally, in the case where the use of IT makes noncontractible investments more important, for instance, by increasing the complexity of products or interdependence of processes, it may lead to reducing the number of suppliers [2, 33].

Standard Versus Custom Goods

When a buyer uses IT to purchase standard goods, the buyer is more concerned about reducing coordination costs than about costs of poor fit and risk of opportunism [11]. Standard goods have similar or identical characteristics from different sources of supply. Therefore, the benefits of improving fit, through transacting with a greater number of suppliers, are limited. A buyer of standard goods can use standard data formats to communicate product specifications, reducing marginal coordination costs with each supplier. This also makes it easier to switch to alternative suppliers and thereby decreases the risk of opportunism by existing suppliers. These effects are consistent with the argument made by Clemons et al. [14] that IT can lower coordination cost without increasing the inherent transaction risk with a small supplier base. In a transparent and efficient market, a few sellers might be sufficient to provide an adequate supply with minimal risk. Furthermore, while IT helps a buyer search among multiple suppliers for the lowest prices for standard goods, once a search is done and suppliers are chosen, the buyer often can get even better pricing by concentrating orders with fewer suppliers to obtain volume discounts [18]. This further motivates the buyer to reduce the number of suppliers.

> *Hypothesis 2: In the context of purchasing standard goods, the use of e-procurement is negatively associated with the number of suppliers.*

In contrast, when purchasing custom goods, controlling the risk of supplier opportunism and the costs of poor fit is likely to be more important [8, 11]. Because custom goods have more specific features tailored to a buyer's needs than standard goods, achieving a high degree of fit is more important. One way of improving fit is to find and evaluate more suppliers, which can be done at lower cost through using IT [2, 44]. As an example, Apple previously relied on Motorola and IBM as suppliers of microprocessors for its Macintosh PC line. Yet when it designed its first iPod, it turned to a small start-up called PortalPlayer for the key processor rather than work with its existing suppliers, as PortalPlayer already had a product that could easily be adapted to fit Apple's requirements [36]. In this case, Apple was able to achieve better fit in a custom input by adding a new supplier. As IT can lower search costs, the use of IT is likely to lead firms to work with a larger number of suppliers of custom inputs across their product lines.

Also, since higher levels of coordination are needed with suppliers of custom inputs to ensure availability and share technical information [16], it will take more time and money for a buyer to set up relationships with alternative suppliers. Consequently, the buyer is more likely to be locked in to existing suppliers for custom goods than standard goods, creating a greater risk of opportunism [40]. One mechanism for a buyer to reduce opportunism risk is to increase its pool of suppliers and thus reduce its reliance on any particular supplier [26, 48]. The use of IT, by lowering search and coordination costs, makes it economically feasible for a buyer to increase its supplier base. Thus, we expect the following hypothesis to be true when potential for opportunism is high:

> *Hypothesis 3: In the context of purchasing custom goods, the use of e-procurement is positively associated with the number of suppliers.*

Buyer–Supplier Systems Integration

The above relationship for custom goods (H3) may be moderated by buyer–supplier systems integration. Systems integration enhances information sharing and streamlines communications between buyers and suppliers [53], which can enable suppliers to meet the more complex product requirements of custom goods [5, 43]. For instance, an electronic linkage that maps suppliers' engineering data with the buyer's procurement database helps suppliers responsively adapt products and processes to the buyer's needs [41]. As such, systems integration lowers the need for the buyer to work with more suppliers of custom goods, and therefore can serve as an alternative means to achieve better "fit." As an example, PC makers such as Hewlett-Packard, Dell, and Gateway generally rely on a small number of contract manufacturers with whom they have set up tightly integrated interorganizational systems for product design, production planning, and order processing [17]. As such, in order to increase fit, buyer–supplier systems integration is viewed as a *substitute* for expanding the firm's supplier base.

In addition, establishing deep buyer–supplier systems integration is more expensive than using e-procurement to automate transactions. Automatic invoicing and payment systems are becoming commodity-like and access to these systems can be gained easily through the marketplace [52]. In contrast, developing deeper systems integration requires investments that are specific to the coordination procedure [47, 50]. Systems integration thus entails higher up-front investments, which in turn may lead to the use of fewer suppliers. Finally, buyer–supplier systems integration is a form of noncontractible investment. To motivate suppliers to make this type of noncontractible investment, the buyer may choose to work with fewer suppliers to give each a greater volume of business [2, 33].

In sum, buyer–supplier system integration moderates the relationship between e-procurement and number of suppliers as it offers the potential to improve fit without adding suppliers, allowing firms to use fewer suppliers. It also increases the marginal cost of doing business with each supplier. These effects suggest that, although we expect a positive relationship between the number of suppliers and e-procurement for custom goods (H3), the positive relationship would be negatively moderated by the degree of buyer–supplier systems integration.

> *Hypothesis 4: In the context of purchasing custom goods, the positive relationship between e-procurement and the number of suppliers is negatively moderated by buyer–supplier systems integration.*

Finally, we expect a *weaker* moderation effect of buyer–supplier systems integration in the context of purchasing *standard* goods. The reason is that the major benefit of systems integration for the buyer is improved "fit," which, as discussed above, may not be a critical consideration for buyers of standard goods. Also, the need for noncontractible investments is lower for standard goods. Therefore, these factors are less likely to come into play as they do with custom goods. This leads to our final hypothesis:

> *Hypothesis 5: In the context of purchasing standard goods, buyer–supplier systems integration has a weaker moderation effect than in the context of purchasing custom goods.*

Controls

In addition to e-procurement, firm- and industry-specific characteristics and the environment where e-procurement is used may also affect the number of suppliers. These factors are incorporated as control variables and are discussed in turn below.

Firm Characteristics

In our research context, we consider two major firm-level characteristics, scale and scope, that may influence the number of suppliers.

Scale. In general, the number of suppliers that a firm employs will increase with the firm's production scale. We use sales as a proxy to scale [10]. As sales increase, the firm would need more inputs for its production and thus likely seek new sources of supply. Thus, we expect the number of suppliers to be an increasing function of sales.

Scope. Scope refers to the extent to which a firm operates in multiple product lines and market segments. When the firm's operations expand into a new market segment, the expansion is generally associated with establishing relationships with new suppliers in the market [24]. Therefore, the number of suppliers used by a firm is expected to be an increasing function of its scope.

Furthermore, a firm's scale and scope have been shown to be related to IT use [27]. Accordingly, significant relationships between IT use and the number of suppliers, if found, could be attributed to effects of common influential factors, scale and scope.

To rule out this alternative explanation, scale and scope should be incorporated as controls.

Industry Characteristics

Industry-level characteristics may influence the costs of coordination in markets [49], and thereby the number of suppliers.

Demand Uncertainty. Demand uncertainty has been widely recognized as a significant factor that will increase market coordination costs (e.g., [45]). To cope with demand fluctuations, a firm may need to frequently adjust the volume of procurement and even modify the design of its product. This entails additional coordination tasks to communicate with suppliers about the changes in order volume and the modified design of parts that constitute the product [8]. The need for closer coordination may lead the firm to use fewer suppliers. We thus expect a negative relationship between demand uncertainty and the number of suppliers.

Industry Concentration. Industry concentration is a key element of market structure [32]. An increasing concentration in the buyer firm's industry reduces the pool of potential buyers, which might imply a larger pool of potential suppliers for each individual buyer. Therefore, the number of suppliers that a buyer employs may become greater as the firm's industry becomes more concentrated. On the other hand, firms in less-concentrated industries have lower bargaining power, which would motivate them to increase their supplier pool in order to avoid the small numbers bargaining situation [26]. As such, industry concentration might impact number of suppliers, but a priori the direction of impact is not clear.

IT Environment

As we seek to analyze the role of IT in supply-chain structure, we need to control for the environment in which IT is deployed. This includes both the firm's IT systems and those of its suppliers. IT environment may influence the external coordination costs relative to the internal production costs and also the specificity of IT investments. These factors in turn may affect the number of suppliers, as discussed below.

Internal IT. In a manufacturing setting, a firm's internal IT consists of systems to manage internal material flow and digitize internal production processes, including material requirements planning (MRP), enterprise resources planning (ERP), shop floor management, and production planning and forecasting [4]. These systems help improve internal information flow, increasing both the efficiencies and the quality of the internal operations [53]. As a result, internal production may substitute for external sourcing [10]. Meanwhile, the improved internal information flow may also enhance information exchange with suppliers [53]. For example, ERP can help identify raw materials and components that need to be replenished and automatically trigger electronic ordering systems [7]. Furthermore, since the production processes are standardized and centralized via ERP, the possibility of releasing wrong orders (e.g., wrong part codes or obsolete parts) can also be reduced [5]. In this regard, internal IT also reduces external coordination costs, favoring the use of more suppliers. Given that these effects (lower internal production/coordination costs versus lower external coordination costs) will have opposite effects, we include internal IT as a control, but a priori its net effect is not clear.

Supplier Use of Compatible Technologies. In our research setting, this is defined as the number of suppliers that are using compatible IT systems for electronic transactions and information sharing. Greater use of compatible technologies by suppliers reduces the marginal coordination cost, as IT connections with suppliers can be made more easily, thus favoring working with more suppliers [37]. In contrast, when there are only limited suppliers with compatible systems, the firm must make more extensive efforts to link up each supplier, adding to investments and coordination costs and thus favoring working with fewer suppliers [48, 49].

Skill Requirement. Finally, using IT to coordinate with suppliers may require the firm to acquire or develop additional technical and managerial skills [1]. Such skill requirements lead to the development of specialized human capital to support electronic transactions, which is another dimension of transaction-specific assets [48]. As skill requirements increase, it is thus expected to increase coordination costs and decrease the number of suppliers.

Data and Variables

Data

To test the hypotheses proposed above, we conducted an empirical study. Our data were collected from two sources, a primary survey and the Compustat database. We conducted a firm-level survey to obtain information about e-procurement volume, number of suppliers, buyer–supplier systems integration, internal IT, and suppliers' use of compatible technologies. Data from Compustat were used to measure firm scale and scope and industry characteristics.

In the survey, e-procurement was defined as "purchasing materials and parts for production on the Internet or through EDI," the two major platforms for e-procurement in industry [41]. We focused on the manufacturing industry, because manufacturing firms deal with physical products and have widely used e-procurement [4, 42]. In addition, confining the survey within a single industry helps eliminate the influences of other industry-specific factors that otherwise could confound the results.

The survey questionnaire was designed based on a comprehensive literature review and interviews of managers. We tailored the survey questions to manufacturing firms and refined the questionnaire via several rounds of pretests and revisions. An expert panel reviewed each of the items on the questionnaire for its content, scope, and purpose to ensure content validity. We also performed pilot tests with eight firms. After revising the questionnaire based on the feedback from the expert panel and the pilot test, the survey was conducted during June–July 2005 using computer-aided telephone interviews. The sample framework was obtained from the Dun & Bradstreet Database, a list source representative of the entire U.S. manufacturing industry. For our research purpose, we added a screening question at the beginning of the survey to filter out firms that did not purchase through e-procurement. We chose director/vice president of procurement as targeted respondents, because they were best qualified to answer questions about the number of suppliers and the volume of e-procurement. We used random sampling to minimize potential biases. Our final data set includes 150 firms, with a response rate of 32 percent.

After we received the data set, we checked for consistency of the data and any potential bias on key variables such as size. We found that distribution of firm size reflected a balance of large and small firms. We compared responses from early and late interviews using analysis of variance (ANOVA) and Kolmogorov–Smirnov test. Overall, the results indicated no systematic differences between the two groups. They also did not differ in sales and the number of employees according to ANOVA. These results suggested no significant bias caused by the data collection process. Finally, we examined nonresponse bias and did not find statistically significant differences in terms of sales and the number of employees. Table 2 shows sample characteristics. All of our variables are defined below, and the summary statistics are shown in Table 3.

Dependent Variable

ln(*#SUP*)

ln(*#SUP*) is the number of suppliers that a firm was using (*#SUP*), which was log-transformed to reduce data variation.

Independent Variables

EPCUS

EPCUS is the percentage of custom parts and materials for production that were purchased via e-procurement. This variable, adapted from prior research [7, 42, 45], reflects the volume of transaction via e-procurement in relative to total online and offline procurement.

EPSTD

EPSTD is similarly the percentage of standard parts and materials for production that were purchased via e-procurement.

Table 2. Sample Characteristics ($N = 150$)

Characteristics	Category	Frequency	Percent
Industry	Industrial machinery and computer equipment (SIC = 35)	35	23.3
	Electronic equipment (SIC = 36)	32	21.3
	Instruments, medical and optical goods (SIC = 38)	22	14.7
	Transportation equipment (SIC = 37)	17	11.3
	Others (SIC = 22, 23, 25-28, 30, 31, 34, 39)	44	29.4
Annual sales (in million $US)	(mean = 1,435, median = 102, standard deviation = 5,415)		
	< 10	14	9.3
	10–49	27	18.0
	50–199	34	22.7
	200–999	26	17.3
	> 1,000	26	17.3
	Missing	23	15.3
Number of employees	(mean = 6,192, median = 533, standard deviation = 18,039)		
	< 100	22	14.7
	100–499	34	22.7
	500–2,999	35	23.3
	> 3000	34	22.7
	Missing	25	16.7
Number of suppliers	(mean = 612, median = 125, standard deviation = 1,384)		
	< 49	36	23.9
	50–149	34	22.7
	150–299	28	18.7
	300–999	20	13.3
	> 1,000	23	15.3
	Missing	9	6.0

%CUSGOODS

%CUSGOODS is the share of custom goods in all parts and materials for production. Then, we computed the following variable:

$$EPTOT = \%CUSGOODS \times EPCUS + (1 - \%CUSGOODS) \times EPSTD.$$

This represents the percentage of e-procurement for all purchases.

BSSI

Buyer–supplier systems integration was measured by the degree to which the buyer firm's IS are integrated with those of suppliers. This operationalization follows previous research on buyer–supplier integration in the supply-chain context [41, 43].

Table 3. Summary Statistics and Correlation Matrix

		Mean	Median	Standard deviation	Correlation matrix (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1)	*ln(#SUP)*	5.09	5.01	1.94	1											
(2)	*EPCUS*	0.27	0.10	0.38	0.27***	1										
(3)	*EPSTD*	0.40	0.27	0.39	0.09	0.47***	1									
(4)	*%CUSGOODS*	0.57	0.60	0.29	0.02	0.06	0.01	1								
(5)	*BSSI*	2.53	2.00	1.35	−0.18**	0.16*	0.25***	−0.07	1							
(6)	*ln(SALES)*	5.01	4.85	2.32	0.60***	0.28***	0.08	0.09	−0.09	1						
(7)	*ENTROPY*	0.21	0.00	0.42	0.39***	0.19*	0.13	0.04	−0.15*	0.55***	1					
(8)	*UNCER_DIF*	0.14	0.14	0.09	−0.14*	−0.07	−0.04	−0.13	0.14*	−0.10	−0.09	1				
(9)	*HHI*	0.21	0.16	0.16	0.04	0.10	−0.03	0.04	−0.01	0.09	0.03	0.37***	1			
(10)	*INTERNALIT*	2.14	2.16	0.88	0.44***	0.20*	0.16*	−0.16*	−0.04	0.39***	0.18**	−0.07	−0.12	1		
(11)	*SUPTECH*	3.80	3.70	1.53	0.02	0.42***	0.44***	−0.13	0.40***	−0.02	0.10	0.08	0.02	0.09	1	
(12)	*SKILLREQ*	4.34	2.27	1.92	0.01	0.01	0.08	−0.05	0.28***	0.10	0.12	0.05	0.04	0.04	0.30***	1

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Control Variables

ln(*SALES*)

Annual sales was used as a proxy for firm scale and was log-transformed to reduce data variation [10].

ENTROPY

Firm scope was measured by the entropy measure [29]. Suppose a firm has N industry segments, indexed by i. Let α_i = (the firm's sales in industry i)/(the firm's total sales). Scope is measured as

$$ENTROPY = \sum_{i=1}^{N} \alpha_i \ln(1/\alpha_i).$$

We obtained information about firms' segment sales from Compustat.

UNCER_DIF

We measured demand uncertainty as follows [21]. Using data from Compustat, we computed the total sales in an industry (three-digit SIC sector) during the past 15 years (1990–2004, in 1990 constant dollars), denoted as S_t (t = 1990, 1991, ..., 2004). The standard deviation of the first difference of the time series $\ln(S_t)$ was used to proxy for demand uncertainty.

HHI

The Herfindahl–Hirschman index (*HHI*) was used for industry concentration, the sum of the squares of the market shares of all firms in the three-digit SIC industry [32].

INTERNALIT

A firm's internal IT was measured by four items: whether the firm had MRP, ERP, shop floor management, and production planning and forecasting in use. Factor scores (*INTERNALIT*), obtained based on the four items through principal component analysis, were used to gauge internal IT.

SUPTECH

Supplier use of compatible technologies was measured by two items: the degree to which existing suppliers process orders through the Internet and the degree to which existing suppliers process orders using EDI. Factor scores (*SUPTECH*) based on the two items were used to represent the degree to which compatible technologies had been installed by suppliers for e-procurement.

SKILLREQ

Skill requirement was measured by two items: difficulty of finding staff with skills of managing Internet-based procurement and difficulty of finding staff with skills of managing EDI. Factor scores (*SKILLREQ*) based on the two items were used to tap the difficulty of acquiring needed skills for conducting e-procurement.

Results

Results of Hypothesis Testing

WE CONDUCTED MULTIVARIATE REGRESSION ANALYSIS to investigate the relationship between the number of suppliers and the independent variables, controlling for firm- and industry-level characteristics. We estimated the following regression equations to test our hypotheses:

$$\begin{aligned}\ln(\#SUP) = \beta_0 + \beta_1 EPTOT + \beta_4 BSSI + \beta_5 BSSI \cdot EPTOT \\ + \beta_8 \ln(SALES) + \beta_9 ENTROPY + \beta_{10} UNCER\_DIF + \beta_{11} HHI \\ + \beta_{12} INTERNALIT + \beta_{13} SUPTECH + \beta_{14} SKILLREQ\end{aligned} \quad (1)$$

$$\begin{aligned}\ln(\#SUP) = \beta_0 + \beta_2 EPCUS + \beta_3 EPSTD + \beta_4 BSSI + \beta_6 BSSI \cdot EPCUS \\ + \beta_7 BSSI \cdot EPSTD + \beta_8 \ln(SALES) + \beta_9 ENTROPY + \beta_{10} UNCER\_DIF \\ + \beta_{11} HHI + \beta_{12} INTERNALIT + \beta_{13} SUPTECH + \beta_{14} SKILLREQ,\end{aligned} \quad (2)$$

where all variables are as defined in the previous section. We estimated regressions of ln(*#SUP*) against e-procurement and buyer–supplier systems integration (*BSSI*). Equation (1) treats e-procurement at aggregation (*EPTOT*), while Equation (2) distinguishes the procurement of standard goods versus custom goods (*EPCUS, EPSTD*) separately. To evaluate the moderation effects as proposed earlier, we included interaction terms between e-procurement and buyer–supplier systems integration as independent variables [3]. We also controlled for firm scale and scope, industry characteristics, and IT environment.

The results are shown in Table 4. As shown in column (1), the coefficient of *EPTOT* is nonsignificant, suggesting that e-procurement at aggregation has no significant relation to the number of suppliers. Column (2) breaks e-procurement in two categories, purchasing custom goods versus standard goods. The coefficient of *EPCUS* is *positive* and significant, whereas the coefficient of *EPSTD* is *negative* and significant. These results indicate that in the context of purchasing custom goods, e-procurement is *positively* related to the number of suppliers. In contrast, in the context of purchasing standard goods, e-procurement is *negatively* related to the number of suppliers. When the analysis aggregates data for standard and custom goods, there is no support for either of the two competing hypotheses proposed in H1. When the type of goods purchased is taken into consideration, the empirical evidence supports our theoretical expectation on how e-procurement may relate to the number of suppliers (H2 and

Table 4. Regression Results

Dependent variable = ln(#*SUP*)

	(1)	(2)	(3)	(4)	(5)	(6)
	β	β	β	β	β	β
E-procurement						
EPCUS		0.23*	0.23*	0.29***		0.24**
		(1.91)	(1.92)	(2.74)		(2.20)
EPSTD		−0.21**	−0.17*	−0.23**		−0.20**
		(−2.14)	(−1.66)	(−2.52)		(−2.39)
EPTOT	0.02				0.05	
	(0.23)				(0.36)	
Moderation by integration						
BSSI			−0.13	−0.08	−0.08	−0.11
			(−1.36)	(−0.62)	(−0.62)	(−1.37)
BSSI × *EPCUS*			−0.20*	−0.20**		−0.19**
			(−1.81)	(−1.96)		(−2.12)
BSSI × *EPSTD*			0.12	0.10		0.10
			(1.14)	(1.22)		(1.14)
BSSI × *EPTOT*					−0.08	
					(−0.89)	
Scale and scope						
ln(*SALES*)	0.50***	0.50***	0.53***	0.43***	0.35***	0.50***
	(5.47)	(4.99)	(5.31)	(3.19)	(2.88)	(5.94)
ENTROPY	0.16	0.13	0.11	0.11	0.18	
	(1.52)	(1.20)	(1.00)	(0.76)	(1.33)	

(*continues*)

Table 4. Continued

	(1)	(2)	(3)	(4)	(5)	(6)
	β	β	β	β	β	β
Industry characteristics						
UNCER_DIF				−0.33***	−0.38***	−0.26**
				(−2.63)	(−3.12)	(−2.57)
HHI				−0.10	−0.02	
				(−0.82)	(−0.13)	
IT environment						
INTERNALIT				0.22**	0.25**	0.27***
				(2.36)	(2.61)	(3.31)
SUPTECH				0.02	0.02	
				(0.13)	(0.19)	
SKILLREQ				−0.09	−0.09	
				(−0.75)	(−0.81)	
N	110	111	106	83	82	96
R^2	0.39	0.43	0.46	0.55	0.51	0.55
Adj. R^2	0.38	0.41	0.42	0.48	0.45	0.51
F	22.9***	20.2***	11.8***	7.22***	7.53***	13.18***

Notes: t-statistics are shown in parentheses. Heteroskedasticity-robust variance estimator is used. All regressions contain a constant. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

H3). This underscores the importance of distinguishing the types of products under e-procurement.

Column (3) of Table 4 includes moderation effects of buyer–supplier systems integration. It shows a significant and negative interaction between *BSSI* and *EPCUS*, suggesting that buyer–supplier systems integration negatively moderates the relationship between the number of suppliers and e-procurement for purchasing custom goods. This is expressed mathematically as

$$\partial \ln(\#SUP)/\partial EPCUS = 0.23 - 0.20 \times BSSI, \qquad (3)$$

which indicates that, for purchasing custom goods, e-procurement is associated with an increase in the number of suppliers, but this increase is limited by stronger buyer–supplier systems integration. In contrast, the interaction term between *BSSI* and *EPSTD* is nonsignificant in the context of purchasing standard goods. These results support our hypotheses about the moderation effects of buyer–supplier systems integration (H4 and H5).

Column (4) of Table 4 presents our full model, including all controls. Compared to columns (2) and (3), the results are qualitatively robust. Column (5) estimates the interaction effect between *BSSI* and *EPTOT*, which turns out to be nonsignificant. A plausible explanation is that, since buyer–supplier systems integration plays a significant moderating role only for custom goods, there is no significant moderation effect on the overall e-procurement. It is possible that information is lost as measures are aggregated. Column (6) excludes the nonsignificant controls in column (4). The significance levels of all coefficients in column (6) are consistent with the results in column (4) and no significant coefficients change in sign. Thus, our empirical results seem robust.

Among the controls, ln(*SALES*) has a significant coefficient in all regressions. This is intuitive in that large firms in general have more suppliers. The coefficient of *ENTROPY* is positive but not statistically significant. This may be due to the positive correlation between scale and scope (0.55), which weakens the statistical significance of *ENTROPY* (given that scale has been controlled for).

Demand uncertainty (*UNCER_DIF*) has a significant and negative coefficient, which is consistent with our theoretical expectation that coordination costs increase and the number of suppliers decreases with demand uncertainty. As discussed earlier, industry concentration may have positive or negative influences. Here we find a nonsignificant coefficient of *HHI*.

Within an IT environment, *INTERNALIT* has a significant and positive coefficient. As theoretically predicted, internal IT can reduce both internal production costs and external coordination costs. Our results show that, on balance, internal IT is associated with using more suppliers. The other two controls for IT environment, *SUPTECH* and *SKILLREQ*, are nonsignificant. It might be the case that compatible technologies have been increasingly diffusing in industry and it is becoming less difficult to hire IT professionals to manage e-procurement systems. As a result, these two variables do not contribute significantly to the variance in the size of the supplier base.

Robustness Check

Regression Diagnostics

We assessed the regression assumption that error terms follow a normal distribution, in particular in finite samples [23]. According to the Jarque–Bera test [31], our sample does not violate the normality assumption. We evaluated the influence of multicollinearity by checking the Belsley–Kuh–Welsch (BKW) index [23]. In each of the regressions in Table 4, the BKW index is below 4, suggesting no harmful multicollinearity [23]. We also conducted post hoc statistical power analysis [6]. Following the procedure described by Cohen [15] and using 0.05 as the cutoff for type I error, we found that the statistical power in each of the regressions in Table 4 is above 0.8, the conventional cutoff recommended for IS research [6]. Finally, in all of our regressions, we used a heteroskedasticity-robust variance estimator.

Moderation Effects

We assessed the robustness of the moderating effects by using another method, group analysis [28]. Table 5 presents results of the robustness check for the full regression model (column (4) in Table 4). We classified firms in our sample into three groups based on the level of buyer–supplier systems integration: low level ($BSSI < 3$), medium level ($BSSI = 3$), and high level ($BSSI > 3$). The analysis in Table 4 assumes that the multiplicative interaction represents the nature of moderation; in contrast, group analysis can be used to detect any other type of moderation relationship [28].

Column (1) of Table 5 models base effects of e-procurement (represented by *EPCUS* and *EPSTD*) and differential effects of e-procurement for the high-level *BSSI* group. The differential effects indicate by how much the effects of e-procurement differ when *BSSI* is high compared to the base effects.[2] As shown in column (1), the base effects of *EPCUS* and *EPSTD* are positive (0.37, $p < 0.01$) and negative (–0.24, $p < 0.05$), respectively. When *BSSI* is high, there is a significant and negative differential effect of *EPCUS* (–0.58, $p < 0.05$). These estimates indicate that *EPCUS* is positively related to the number of suppliers, while the positive relationship decreases as *BSSI* increases to the high level. This is consistent with the finding in Table 4 that *BSSI* plays a negative moderating role for custom goods. The differential effect of *EPSTD* is nonsignificant when *BSSI* is high, also consistent with the result in Table 4.

Similarly, column (2) of Table 5 specifies differential effects of e-procurement in both the medium-level and the high-level *BSSI* groups. The results show a significant and negative differential effect of *EPCUS* when *BSSI* is high (–0.57, $p < 0.05$), while no other differential effects are significant. Again, these results are consistent with what we saw in Table 4.

Alternative Measures

Column (3) of Table 5 uses number of employees (log-transformed), ln(*EMP*), as an alternative proxy for scale. Column (4) uses another proxy for demand uncertainty,

Table 5. Robustness Check

Dependent variable = ln(#*SUP*)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	β	β	β	β	β	β	β
EPCUS	0.37***	0.32**	0.33***	0.32***	0.30***	0.26**	0.27**
	(3.23)	(2.60)	(3.05)	(2.72)	(2.72)	(2.22)	(2.16)
EPSTD	−0.24**	−0.24**	−0.26***	−0.26***	−0.23**	−0.22*	−0.23**
	(−2.48)	(−2.27)	(−2.92)	(−2.87)	(−2.52)	(−1.90)	(−2.45)
EPCUS (high *BSSI*)	−0.58**	−0.57**					
	(−2.38)	(−2.31)					
EPCUS (medium *BSSI*)		0.36					
		(1.01)					
EPSTD (high *BSSI*)	0.19	0.20					
	(0.88)	(0.87)					
EPSTD (medium *BSSI*)		−0.12					
		(−0.37)					
BSSI			−0.07	−0.08	−0.10	−0.07	−0.10
			(−0.63)	(−0.65)	(−0.79)	(−0.54)	(-0.73)
BSSI × *EPCUS*			−0.19*	−0.19*	−0.19*	−0.20**	−0.23**
			(−1.86)	(−1.85)	(−1.88)	(−2.01)	(−2.12)
BSSI × *EPSTD*			0.11	0.12	0.09	0.11	0.16
			(1.22)	(1.26)	(1.08)	(1.13)	(1.58)
ln(*SALES*)	0.43***	0.44***		0.43***	0.48***	0.40***	0.39***
	(3.29)	(3.39)		(3.19)	(3.83)	(3.03)	(2.71)
ln(*EMP*)			0.42***				
			(3.20)				

(continues)

Table 5. Continued

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	β	β	β	β	β	β	β
ENTROPY	0.13 (0.98)	0.13 (0.97)	0.11 (0.74)	0.09 (0.64)		0.12 (0.84)	0.15 (1.00)
HERF					0.04 (0.24)		
UNCER_DIF	−0.37*** (−3.12)	−0.39*** (−3.08)	−0.34*** (−2.70)		−0.33** (−2.52)	−0.41*** (−3.69)	−0.34** (−2.28)
UNCER_OLS				−0.24** (−1.98)			
HHI	−0.08 (−0.69)	−0.06 (−0.57)	−0.12 (−1.02)	−0.12 (−1.01)	−0.10 (−0.83)		−0.11 (−0.91)
CR4						−0.08 (−0.60)	
INTERNALIT	0.24** (2.43)	0.26** (2.38)	0.21** (2.11)	0.23** (2.37)	0.20** (2.20)	0.25*** (2.67)	0.20** (2.32)
SUPTECH	−0.02 (−0.22)	−0.02 (−0.15)	−0.04 (−0.31)	0.01 (0.05)	0.04 (0.36)	0.02 (0.15)	0.03 (0.22)
SKILLREQ	−0.10 (−0.98)	−0.10 (−0.93)	−0.07 (−0.61)	−0.07 (−0.56)	−0.07 (−0.57)	−0.11 (−0.93)	−0.03 (−0.28)
Industry dummies							Included
N	83	83	83	83	83	83	83
R^2	0.56	0.56	0.55	0.53	0.55	0.55	0.57
Adj. R^2	0.49	0.48	0.47	0.45	0.47	0.48	0.47
F	8.21***	6.85***	7.10***	6.66***	7.07***	7.18***	5.72***

Notes: t-statistics are shown in parentheses. Heteroskedasticity-robust variance estimator is used. All regressions contain a constant. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

UNCER_OLS, constructed as follows [21]: the time series $\ln(S_i)$, defined earlier when describing *UNCER_DIF*, was regressed on a constant and linear trend:

$$\ln(S_i) = constant + b \cdot t, \tag{4}$$

where $t = 1990, 1991, \ldots, 2004$. The standard error of this regression (*UNCER_OLS*) was used to gauge demand uncertainty. Column (5) measures firm scope using the Herfindahl index:

$$HERF = 1 - \Sigma_{i=1}^{N} \alpha_i^2, \tag{5}$$

where α_i is as defined earlier when describing *ENTROPY*. Column (6) measures industry concentration using the four-firm concentration ratio *CR4*, defined as the percentage of the total industry sales accounted for by the four largest firms in the industry [32].

It is clear in Table 5 that using these proxy variables yields consistent coefficient estimates. Thus, our results are robust to alternative measures.

Model Specification and Endogeneity

We estimated another model specification to further account for the "breadth" of e-procurement [39]. Our data set includes items indicating the numbers of suppliers with whom a buyer uses e-procurement to coordinate exchanging product information (*SUPINFO*), processing orders (*SUPORDER*), and managing order fulfillment (*SUPTRACK*), respectively. These items control for the breadth of e-procurement [39]. We relate them to the number of suppliers, and find a positive and significant regression coefficient on *SUPINFO* and nonsignificant coefficients on the other two variables. The estimated coefficients on the remaining explanatory variables are qualitatively unchanged.

We also tried to assess endogeneity to the extent possible within the limits of the data. One may be concerned that e-procurement may be endogenous in our model as *EPCUS* and *EPSTD* may be driven by some common factors at the firm level (such as a firm's capability of managing IT in general). IT use (e.g., *BSSI*) may increase *EPCUS* and *EPSTD*. As such, *EPCUS* may be endogenous; that is, a function of other independent variables such as *EPSTD* and *BSSI*. We performed the extended regression version of the Hausman specification test through a two-stage least squares (2SLS) regression analysis. The results suggest that endogeneity does not seem to affect the primary inferences drawn from Table 4.[3]

Finally, column (7) of Table 5 includes industry dummies as an additional test of robustness, which does not change the sign or significance of any relationship in the model.

Discussion

Major Findings

OUR OBJECTIVE IN THIS RESEARCH IS TO EMPIRICALLY TEST, in the context of e-procurement, the relationship of IT use to the number of suppliers engaged by manufacturers, and to incorporate two new factors: the nature of the product and the type of IT used. In doing so, this study adds new empirical evidence to the literature on IT use and firms' choice on number of suppliers.

Our initial models (see columns (1) and (5) of Table 4) analyze the association of e-procurement with the number of suppliers for all of a buyer's purchases. We do not find support for the argument that IT use will lead buyers to work with either fewer or more suppliers as posited in our alternative hypotheses H1a and H1b. The lack of significant results may be due to the difficulty of capturing dynamic relationships with cross-sectional data. It also could be due to the fact that the relationship of IT to the number of suppliers varies across different firms:[4] in an informed efficient market for standard goods, there is little need for a buyer to set up competitive bidding; in a custom goods market, a buyer may follow the "move to the middle" approach to reduce opportunistic risks, or the use of IT allows the buyer to coordinate with more suppliers. As such, the relationship between IT and number of suppliers may not show up at the aggregate level.

The latter interpretation is supported when we look at custom goods and standard goods separately (column (2) of Table 4). For custom goods, e-procurement use is associated with buying from a *larger* number of suppliers. This is consistent with the argument that the ability to use IT to achieve better fit without a corresponding increase in coordination costs is of greater importance for custom goods. In practice, firms might use technologies to increase the number of vendors who compete to supply custom goods; as a result, the number of suppliers goes up with increased IT usage. It also is consistent with the argument that the risk of supplier opportunism is greater for custom goods [8, 11], and firms may use IT to reduce that risk by increasing their supplier base [26].

For standard goods, we find that greater use of e-procurement is associated with using *fewer* suppliers. This can be explained by the fact that fit is not as important for standard goods, and the risk of opportunism is not as serious as buyers can more easily find alternative suppliers; hence, the benefits of using more suppliers are limited. Rather than using IT to do business with more suppliers, buyers may search for low-cost suppliers of standard goods and then concentrate their purchases with a few selected suppliers to obtain volume discounts, which is becoming a popular practice in supply-chain management [18]. These effects push in opposite directions for custom and standard goods, which may explain why the results are nonsignificant when the two are aggregated into one measure.

We also find that the relationship of IT to number of suppliers depends on the type of IS in use in the case of custom goods (columns (3) and (4) of Table 4). While e-procurement is associated with using more suppliers, systems integration between buyers and suppliers moderates that relationship, leading to buying from *fewer* suppliers. This can be seen as evidence that *buyers may use IT integration to achieve better fit (and tighter collaboration) with a smaller number of suppliers by sharing richer information about product and process requirements.*

This result confirms the observation that the manufacturing industry is moving toward value-added networks with supply-chain partners, especially in the case of custom inputs, where firms look to develop stronger partnerships with suppliers (as Dell and Cisco Systems are doing). Such explicit coordination may lower transaction risks of using a small number of suppliers by enabling better monitoring, while also increasing the marginal cost of coordination with additional suppliers, as more extensive IT integration is required [14]. Buyer–supplier systems integration also likely requires noncontractible investments to develop and maintain system compatibility as each partner's systems are upgraded and evolve. Such investments can be encouraged if suppliers are given a large enough share of the buyer's business to provide an adequate incentive.

Limitations and Future Research

The above findings have important implications for both management and research. But before discussing the implications, it is appropriate to point out the limitations of this work. First, our sample framework only covered manufacturing firms, which limited the generalizability of our results. Another major industry sector that also uses IT in buyer–supplier relationships is retail/wholesale distribution [53]. Future research may cross-validate our model in the distribution sector.

Second, our analysis draws primarily upon the transaction costs perspective. We chose this theoretical angle because previous conceptual studies suggest its usefulness for understanding the relationship between IT and number of suppliers [14, 37]. Nonetheless, the agency theory challenges the key assumption of the transaction costs theory that managerial decisions, such as the choice of suppliers, are made to economize on transaction costs [30]. According to the agency theory, purchasing managers normally possess asymmetric information about the supply chain that top management may not know. Consequently, purchasing managers may act out of self-interest at the expense of the firm's value, and as a result, the number of suppliers used by a firm might deviate from the optimal number which minimizes transaction costs. This calls for research on IT's ability to reduce information asymmetry and IT's monitoring function within a firm [24]. This leads to another line of future inquiry.

Third, due to the cross-sectional nature of the data set, we can only show associations between e-procurement and number of suppliers. The lack of significant findings at the aggregate level does not necessarily imply an absence of the effect at that level, but might simply indicate the limitations of cross-sectional data. Our methodology also does not allow us to explore the causal effects of IT or to completely rule out endogeneity in the relationships identified. To more clearly disentangle causal relationships, future research should develop measures to explicitly evaluate changes in number of suppliers due to IT use, and more or less use of IT due to number of suppliers.[5] Another direction for future research is to conduct a longitudinal study, which can reflect the temporal changes in IT use and the number of suppliers and also investigate the causal relationships between them. It would be highly relevant to know how the number of suppliers changes as IT is being increasingly used in supply-chain management. In the extant literature, one example of investigating causal effects of IT is the time-series model in Brynjolfsson et al. [10], which examines the causal linkages between IT and firm size. However, to our best knowledge, information about number of suppliers is not available in any publicly available databases, and collecting data across multiple periods for the same sample of firms will be a challenging task. But longitudinal research should be useful to shed light on how firms, with the use of IT, adapt the way they govern economic activities in supply chains that are becoming increasingly global.

Managerial Implications

The findings in this study are important for managers in the areas of supply-chain management, procurement, and IS. These managers make decisions about the number of suppliers to work with and the types of IT linkages to set up with those suppliers [12]. Our findings show that there is no simple correlation between IT use and number of suppliers, but that managers' decisions must take into account the types of goods being purchased and the nature of intra- and interorganizational IS employed. According to our results, for standard goods, managers should consider e-procurement that enables them to identify low-cost suppliers and then concentrate purchases with a smaller number of suppliers to get the best price and efficiency.

For custom goods, at least two options are viable. One is to use simple e-procurement links with a larger number of suppliers to achieve better fit and reduce the risk of opportunism. Another is to invest in more extensive IT integration with fewer suppliers to achieve better fit through richer information exchange and closer coordination. This approach also creates incentives for suppliers to make noncontractible investments that will enable them to better meet the buyer's needs.

Which of these alternatives to choose may depend on several factors. For instance, if most suppliers have strong IT capabilities, then adding suppliers through e-procurement could improve fit at a relatively low marginal cost. But if supplier IT capabilities are weak, it makes sense to work with fewer suppliers and invest in IT integration to achieve better fit. Other factors also come into play in determining the number of suppliers. There may be a limited number of suppliers with the capabilities of providing the required custom goods; so the use of IT will not increase the pool of potential suppliers. Or a firm might need to add a supplier to offer different features or price points to its own product line, as Dell did when it added AMD as a supplier of microprocessors, ending its exclusive relationship with Intel.

A general insight for managers from this study would be to consider carefully the relationship of IT use and the optimal number of suppliers in terms of the costs and other factors that are most important to their businesses. Broad recommendations such as "develop partnerships with a small number of suppliers, supported by rich IT links" or "use the Internet to find new suppliers to better meet your needs" may make sense for some companies or some situations, and not others. Buyers must consider the value of improved fit and lower coordination cost and the potential risk of supplier opportunism, and how each of those might be changed by the use of e-procurement or the depth of buyer–supplier systems integration.

Conclusion

To conclude, this study makes both theoretical and empirical contributions in understanding the relationship of IT use to organization of economic activities along the supply chain, specifically the number of suppliers that buyers use. Prior research has made conceptual arguments that IT would lead to the use of either more or fewer suppliers [2, 14, 37]. By testing these arguments quantitatively, we find that it is necessary to distinguish between the types of goods being purchased and the nature of IT use. These results shed new light as highlighted below.

First, the fact that we get opposite results for standard and custom goods is consistent with the perspective that custom goods procurement involves more asset-specific supplier relationships than standard goods, hence increasing the risk of opportunism in a small numbers bargaining situation. This distinction has not previously been made explicit, or tested empirically, in research on IT's relation to number of suppliers. Our results operationalize and test the distinction of custom and standard goods empirically and thus provide an important insight into the role of this dimension of asset specificity in organizing supply-chain activities.

The interaction between e-procurement and buyer–supplier systems integration shows that IT cannot be looked at as an undifferentiated input with uniform effects, but that it is necessary to distinguish different types of interorganizational systems in modeling the effects of IT. Specifically, our analysis here shows that further differentiation is needed to distinguish between transaction-oriented e-procurement systems and deeper integration of buyer–supplier IS. In particular, deeper integration of buyer-supplier IS can help buyers obtain better "fit" for their custom input requirements. This is an alternative to the approach to increasing fit through employing more suppliers as proposed in the extant literature. At a higher level, these issues are important as companies continue to seek the most efficient ways to reorganize their supply chains in global operations, using IT to support different types of supplier relationships that match the type of goods procured.

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Notes

1. This variable is in line with the concept of "EDI depth" put forth by Massetti and Zmud [39]. At the most sophisticated level of EDI depth, "trading partners can directly access data maintained within the computer-based systems of the other trading partner" [39, pp. 340–341]. The variable buyer–supplier systems integration in our research taps the degree to which trading partners' IS are integrated together. High levels of such integration allow data exchange between computer-based IS.

2. The differential effects can be estimated by creating a dummy variable with value 1 for firms in the high-level *BSSI* group and value 0 otherwise, multiplying *EPCUS* and *EPSTD* by the dummy, and then including the two products as additional regressors.

3. At the first stage of the 2SLS, *EPCUS* is explained by all the other independent variables in Equation (2) and several additional variables (firm's IT capability, percentage of products that are built to order, and a dummy for the durable goods manufacturing sector). At the second stage, we include the estimated residual of the first-stage regression as an additional regressor in our regression equation. The regression coefficient on the estimated residual is nonsignificant, indicating that our model does not suffer from an endogeneity bias. To be conservative, we still perform a second-stage regression where *EPCUS* is replaced by the forecast value for *EPCUS* obtained from the first-stage regression. The estimated coefficients remain qualitatively unchanged.

4. The authors thank an anonymous reviewer for this suggestion.

5. The authors thank an anonymous reviewer for this insight.

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