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Zhang, Xuan; Van Donk, Dirk Pieter; van der Vaart, Taco

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The different impact of inter-organizational and intra-organizational ICT on supply chain performance

Supply chain
performance

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Xuan Zhang

*School of Business Administration,
Zhongnan University of Economics and Law, Wuhan, China, and
Dirk Pieter Van Donk and Taco van der Vaart
Faculty of Economics and Business,
University of Groningen, Groningen, The Netherlands*

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Abstract

Purpose – The purpose of this paper is to clarify the different roles of intra- and inter-organizational information and communication technology (ICT) in improving supply chain performance. It proposes different mechanisms to explain how intra- and inter-organizational ICT interact with supply chain integration, and contribute to supply chain performance. The main research question is: What are the distinctive roles of inter-organizational ICT and intra-organizational ICT in improving supply chain performance?

Design/methodology/approach – The paper builds on original survey data of 320 Chinese manufacturing firms gathered in China.

Findings – The paper shows that inter-organizational ICT has a positive direct relationship with supply chain performance and this relationship is mediated by supply chain integration. Intra-organizational ICT has no direct relationship with supply chain performance. However, intra-organizational ICT moderates the effect of the supply chain integration on supply chain performance.

Research limitations/implications – The paper argues that more research into the specific roles and interaction of ICT with business processes is needed in order to better understand its role in improving supply chain performance.

Practical implications – For managers the findings show that inter- and intra-organizational ICT play a different role in the improvement of supply chain performance: the first leading to more supply chain integration, which in turn improves performance, while the second needs additional investment in integrative practices to help improve supply chain performance.

Originality/value – This paper adds to the debate on the role of ICT in improving supply chain performance and shows that a detailed investigation into underlying mechanisms, and the interaction of ICT with other business processes is valuable.

Keywords Supply chain performance, Information sharing, Supply chain integration, Cooperative relationship, Inter-organizational ICT, Intra-organizational ICT

Paper type Research paper

Introduction

Companies that invest in information and communication technology (ICT) have a common question to answer. Do investments in ICT really improve supply chain performance? Numerous failures in practice have put doubt on this seemingly easy to answer question. It seems that ICT does have an impact on supply chain

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performance, but our understanding of how some companies do obtain positive results and others do not, is unclear. The main thrust of this paper is that inter- and intra-organizational ICT play a different role in the improvement of supply chain performance. The use of inter-organizational ICT (that connects organizations through electronic linkages) leads to more supply chain integration which in turn improves performance, whereas intra-organizational ICT (ICT within an organization such as ERP) improves the quality of information and as such acts as a condition for effective supply chain integration.

The interrelationships between ICT, supply chain integration and supply chain performance have received extensive attention within the literature. Although, overall the literature seems to suggest that ICT has a positive effect on performance, it is hard to say if and how individual technologies or types of ICT technologies affect specific performance measures. In a review of the literature, Zhang *et al.* (2011) conclude that the ambiguous role of ICT in supply chains originates from the diversity in ICT constructs and technologies that are incorporated in the different research models. This paper contributes by explicitly recognizing the distinctive roles of inter-organizational ICT and intra-organizational ICT in order to understand if and how ICT affects supply chain performance.

Typically, studies that incorporate both intra-organizational ICT and inter-organizational ICT to capture the effect of ICT on supply chain performance do not present consistent, significant findings (e.g. Li *et al.*, 2009; Jeffers *et al.*, 2008). In contrast, studies that only incorporate inter-organizational ICT seem to offer more consistent findings. A few studies found that inter-organizational ICT has a direct effect on supply chain performance (Da Silveira and Cagliano, 2006; Frohlich and Westbrook, 2002). Other studies show that inter-organizational ICT directly helps to improve integrative practices such as information sharing (e.g. Paulraj *et al.*, 2008) or coordination between partners (e.g. Vickery *et al.*, 2003; Prajogo and Olhager, 2012), and subsequently improves supply chain performance (Vickery *et al.*, 2003). For intra-organizational ICT, past studies show that intra-organizational ICT is significantly associated with superior performance of the focal firm and relates to measures as cost, product quality, return on invest, and innovation (Zhou *et al.*, 2009; Powell, 2013; Huang and Handfield, 2015). However, in the context of supply chain management (SCM), intra-organizational ICT has hardly been addressed and there seems no clear relationship with supply chain performance (Cagliano *et al.*, 2006). Recently, Clegg and Wan (2013) state that little is known about the fit between ERP systems and inter-organizational cooperation. Based on the literature the conclusion seems justified that intra-organizational ICT does not affect supply chain performance directly. However, the existing studies fail to explore other ways through which intra-organizational ICT might influence supply chain performance. Kotha and Swamidass (2000) indicate that intra-organizational ICT controls manufacturing processes and generates unambiguous and precise process-related information, which enables integrative practices to be more effective. Consequently, this paper argues and aims to investigate that intra-organizational ICT acts as a condition for effective supply chain performance. This idea is in line with the suggestion of Zhang *et al.* (2011) to investigate the difference between inter-organizational and intra-organizational ICT. In conclusion, the literature provides some support for the central theme of the present paper that inter- and intra-organizational ICT play a different role in the improvement of supply chain performance: the first as an enabler for supply chain integration, and the second as a condition for effective supply chain integration. However, this idea has

not been fully developed nor explored in the extant literature. Therefore the main research question of this paper is:

Supply chain
performance

RQ1. What are the distinctive roles of inter-organizational ICT and intra-organizational ICT in improving supply chain performance?

This study finds support in the resource-based-view (RBV). The RBV provides guidance on how to explore the relationship between ICT resources and performance, which provides a cogent framework to evaluate the strategic value of information systems resources (Wade and Hulland, 2004). Specifically, the RBV presents an organization as a bundle of resources, that generate competitive value from ICT only in combination with other organizational resources (Wade and Hulland, 2004) such as SC integration. This idea is used to develop the hypotheses for the assumed different mechanisms through which intra- and inter-organizational ICT improve supply chain performance.

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Theoretical background

Although it is generally believed that ICT plays a critical role in SCM activities, the measurable impact of ICT applications on supply chain performance remains debated. Zhang *et al.* (2011) reviewed the literature with respect to the direct and the indirect effects of ICT. First, ICT is captured as intra-organizational ICT (Cagliano *et al.*, 2006; Ward and Zhou, 2006), inter-organizational ICT (Da Silveira and Cagliano, 2006; Hsu *et al.*, 2008), and as a mixture of the two types of ICT (Bayraktar *et al.*, 2009; Jeffers *et al.*, 2008), which makes it hard to compare the results or to understand the ICT-supply chain performance relationship. Subramani (2004) suggests that types of ICT can be associated with differences in outcomes. Second, the literature has examined two different mechanisms for the indirect effects of ICT. The first suggests that ICT usage influences supply chain performance primarily through its impact on supply chain integration (Hsu *et al.*, 2008; Kim and Lee, 2010; Wang *et al.*, 2013). The second assumes a moderating effect of ICT: ICT works as a condition for strengthening the relationship between integration and performance (Kim and Narasimhan, 2002; Jeffers *et al.*, 2008). However, as argued the literature lacks a systematic study to examine and compare different types of ICT (inter- and intra-organizational) and mechanisms comprehensively.

Inter-organizational ICT and intra-organizational ICT

Usually two categories of ICT resource are distinguished: internal and external (Savitskie, 2007; Liang *et al.*, 2010). Bhakoo and Choi (2013, p. 432) define inter-organizational ICT as “the technology-based infrastructure that acts as a conduit for facilitating transactions, sharing information with trading partners, coordinating activities and establishing governance structures between firms.” Following Savitskie (2007, p. 456) intra-organizational ICT can be defined as “information technologies and/or practices used to share information within a firm. In general, this includes the databases and applications which facilitate integrating financial, accounting, and supply chain operations with a particular focus on logistics systems.” According to Liang *et al.* (2010, p. 1144) internal ICT resources (intra-organizational ICT) “help firms to enhance internal control capabilities, strengthen cooperation performance between the departments, and improve capacity of the system and development.” Such intra-organizational ICT is used to control and monitor internal processes by supporting computerization of the operational process. Traditional systems like ERP fall into this category. On the other hand, external resources (inter-organizational ICT)

help firms to adapt to the external environment and to improve the ability to work with external partners for cooperation and information sharing (Liang *et al.*, 2010); electronically linking different organizations in a supply chain beyond traditional enterprise boundaries such as network-based systems (Hong, 2002; Rajaguru and Matanda, 2013). Intra-organizational ICT and electronic linkages (representing inter-organizational ICT) are fundamentally different types of resources and following the above they might contribute to SC performance improvement in a different way (cf. Savitskie, 2007). We conceptualize inter-organizational ICT as electronic linkages, the essential and core element of it according to Barrett (1986-1987), that relate different organizations in a supply chain. Intra-organizational ICT is conceptualized as the information systems and technologies that plan, track, and order components and products throughout the manufacturing operation within the firm (Vickery *et al.*, 2003).

Supply chain integration

The RBV suggests that the impact of ICT depends on its interrelationships with other resources (Jeffers *et al.*, 2008; Beheregarai Finger *et al.*, 2014). For this reason, any effort to study the competitive implications of ICT should also include those resources which are influenced or enhanced by ICT resources. Supply chain integration is such an additional resource advanced by ICT (Subramani, 2004), which is confirmed by recent findings of Wong *et al.* (2015). Following the seminal paper of (Frohlich and Westbrook, 2002), supply chain integration can be defined as the extent of engagement with suppliers and customers. Two aspects of supply chain integration, also addressed as supply chain practices, are taken into account: information sharing and cooperative relationship. These are generally regarded as important aspects of supply chain integration (Van der Vaart and Van Donk, 2008; Handley and Benton, 2013). Cooperative relationship reflects the relational aspect of supply chain integration: “the extent to which [the buyer] perceives the relationship to be cooperative” (Handley and Benton, 2013, p. 120). A cooperative relationship implies a partnership relationship based on a joint problem-solving capability and flexibility in arrangements (Johnston *et al.*, 2004; Handley and Benton, 2013). Information sharing is mostly defined following Mentzer *et al.* (2001) as “the willingness to make strategic and tactical data available to other members of the supply chain” (p. 8), which relates among others to inventory levels, forecasts, and future plans. As such information sharing helps companies to improve the capability to respond to changing market requirement and communicated among trading partners across company borders (Howard and Squire, 2007; Du *et al.*, 2012).

Supply chain performance and supplier performance

Supply chain performance has been conceptualized in numerous ways (Van der Vaart and Van Donk, 2008; Zhang *et al.*, 2011), as aggregate financial and/or single operational performance measures, and referring to buyers and/or suppliers. Here, supplier performance is considered as the outcome variable of interest as we focus on the buyer-supplier relationship. Supplier performance has been extensively investigated, specifically in the context of supplier development programs. This body of literature shows how a supplier contributes to, and the importance of supplier performance for SC performance of the buyer (e.g. Krause *et al.*, 2000; Prahinski and Benton, 2004). Prahinski and Benton (2004) distinguish two streams for measuring supplier performance: competitive success factors (e.g. quality, delivery, price, service, and flexibility) and internal indicators, such as defects, schedule

realization, and cost. Given our focus on ICT, information sharing, and cooperation, we conceptualize supplier performance as how well a supplier is performing with respect to a number of operational delivery aspects as accuracy and speed, rather than defects and costs. Similarly, existing survey research on the ICT-performance relationship, acknowledged supplier performance as an operational measure of key competitive success factors (Jeffers *et al.*, 2008; Zhang and Dhaliwal, 2009).

The RBV perspective

This study uses the RBV as its theoretical lens to develop our hypotheses for the interrelations of ICT, SC integration and performance. The main argument of the RBV is that the firms' resources are the source of competitive advantage (Barney, 1991). Such resources can be both assets and capabilities (Wade and Hulland, 2004), which reflects on the one hand tangible technologies and other things to be used in offering products to markets, and on the other hand refers to repeatable patterns of actions in the use of assets (Sanchez, 1996). Following Jeffers *et al.* (2008) and Wade and Hulland (2004), this research regards ICT as such potential assets, which are complemented by supply chain integration as capability. Having resources is in itself not a source of advantage. However: the combination of assets and capabilities into what is labeled a bundle of resources might. The RBV helps to understand why some companies obtain better performance returns than others from similar ICT usage. Below the hypotheses specify the underlying mechanisms that explain how inter- and intra-organizational ICT, together with supply chain integration help to improve performance.

Development of hypotheses

The direct effect of electronic linkages and intra-organizational ICT on supplier performance. Electronic linkages (representing inter-organizational ICT) enable information access to other organizations which in fact redefines and extends the organizational boundaries to the extent that a firm's value chain needs to be redesigned (Hong, 2002). Electronic linkages can help a company share data, information, and business applications with its trading partners; they provide the capabilities of electronic transactions including buying and selling goods and services; and facilitate communication and decision making for the purpose of increasing efficiency, effectiveness, competitiveness, and profitability for participating organizations (Wiengarten *et al.*, 2013). In contrast, intra-organizational ICT falls into the domain of office and factory automation systems that organize work more efficiently (Rysseel *et al.*, 2004). It is used for planning, tracking, and ordering components and products throughout the manufacturing operation within the firm (Vickery *et al.*, 2003). MRP and ERP are the well-known examples of such planning systems that support a variety of transaction-based functions, primarily within an organization. The different orientation of both types of ICT has consequences. Electronic linkages can be regarded as a medium to transfer information across organizational boundaries and therefore directly increase SC performance (Rosenzweig, 2009). In contrast, intra-organizational ICT needs to be embedded in the organization to be effective (Zhou *et al.*, 2009; Jeffers *et al.*, 2008). This is also reflected in Wade and Hulland (2004) who indicate a fundamental difference between the impact of internal and external ICT resources on performance. In particular, they propose that external ICT resources will have a stronger direct impact than internal ICT resources on performance, which seems to be confirmed by empirical studies, such as Da Silveira and Cagliano (2006) and Olson and

Boyer (2003). With regard to intra-organizational ICT, studies report significant effects in terms of higher product quality and lower product cost (e.g. Zhou *et al.*, 2009), but no significant direct effects on supplier performance (Ward and Zhou, 2006; Powell and Dent-Micallef, 1997). Therefore, the first hypotheses state that:

H1a. Electronic linkages have a positive and direct relationship with supplier performance.

H1b. Intra-organizational ICT has no direct relationship with supplier performance.

The effect of electronic linkages on supply chain integration and supplier performance. Following the idea of the RBV, the effect of electronic linkages on supplier performance can be increased when combined with supply chain integration practices. While using electronic linkages might be imitated, building relationship cannot and will thus improve performance. Li and Lin (2006) show that the usage of electronic linkages between organizations, increases the level of information sharing. Sanders (2007) shows that e-business technologies have a direct and positive impact on inter-organizational integration via information sharing. In addition, information sharing allows supply chain members to improve forecasts, flexibility, synchronize production and delivery, coordinate inventory-related decisions (Wang and Wei, 2007). Information sharing, enabled through electronic linkages improves performance and is considered as a hard to imitate capability as reflected in the following hypothesis:

H2a. Electronic linkages have a positive relationship with supplier performance via information sharing.

Electronic linkages aid supply chain partners in streamlining links, reaching joint decisions, synchronized communication, information recollection, and standardization (Saeed *et al.*, 2011). It is indicated that cooperation among firms is limited by the transaction costs of managing the interaction (Sanders, 2007). The use of electronic linkages reduces transaction costs and will move the relationship toward a partnership: correspondingly it develops a cooperative relationship among firms (Tan *et al.*, 2010). Through supporting electronic linkages, partners can reduce the chance of miscommunications when formulating strategic plans, and be more effective in joint planning and decision making (Kim and Lee, 2010). Cheng *et al.* (2001) indicate that an improved flow of information in terms of speed, quantity, and the level of confidentiality across the parties' boundaries ensures a cooperative relationship between parties. A higher level of cooperative relationship behaviors is found to be strongly linked to buyer satisfaction and the buyer's assessment of relationship's performance (Johnston *et al.*, 2004), which can be associated with supplier performance. The foregoing analyses all strongly suggest that electronic linkages contribute to better supplier performance via cooperative relationship, which together can be considered as a joint, inimitable resources. Therefore, the following hypothesis is:

H2b. Electronic linkages have a positive relationship with supplier performance via cooperative relationship.

Intra-organizational ICT as a condition for effective supply chain integration. Intra-organizational ICT is supposed not to change external processes directly, but if it is combined with other resources it can be an important resource in the relationship between supply chain integration and supplier performance (Grover *et al.*, 1998).

Intra-organizational ICT improves the capability for data processing within an organization and provides high-quality information. Information quality includes aspects such as accuracy, timeliness, adequacy, and credibility of information (Monczka *et al.*, 1998). While information sharing and a cooperative relationship are important, the significance of their impact depends on information quality (Li and Lin, 2006). Jarrell (1998) notes that sharing information within the entire supply chain, can create flexibility, but that accurate and timely information is required. A cooperative relationship reflects how supply chain partners integrate decision making and are flexible in contractual arrangements in order to solve mutual problems (Johnston *et al.*, 2004; Handley and Benton, 2013). Accurate and timely information will provide a basis for such cooperative relationship behavior. The more accurate, timely and adequate operational information managers have, the better they know what happens within the firm, and the better they can cooperate with partners in joint decision making. It has been indicated that information notoriously suffers from delay and distortion as it moves up the supply chain (Li and Lin, 2006). To reduce information distortion and improve the quality of information in the supply chain, the available data have to be as accurate as possible. Li and Lin (2006) indicate that the higher the usage of intra-organizational ICT, the higher the level of information quality in SCM. The combination of two resources results in higher information quality and makes information sharing and the cooperative relationship between partners more effective and leads to improved supplier performance, which cannot be reached through investment in ICT alone. As a result, the next hypotheses are:

- H3a.* Intra-organizational ICT will moderate the relation between information sharing and supplier performance. More specifically, the relationship will be stronger under high usage of intra-organizational ICT than under low usage of intra-organizational ICT.
- H3b.* Intra-organizational ICT will moderate the relation between cooperative relationship and supplier performance. More specifically, the relationship will be stronger under high usage of intra-organizational ICT than under low usage of intra-organizational ICT.

Methodology

Development of questionnaire

The measures used were derived or adapted from the SCM and ICT literature. Earlier studies focus on EDI in measuring electronic linkages (e.g. Hill and Scudder, 2002; Hsu *et al.*, 2008), while recent studies relate electronic linkages to open-standard inter-organizational information systems or platforms (e.g. Markus and Loebbecke, 2013; Sodero *et al.*, 2013). Consequently, the items for electronic linkages were taken from Li and Lin (2006) and Saeed *et al.* (2005), which concentrate on contemporary ICT solutions based on internet and extranet. Internet was chosen as being open access, while extranet represents the extension of a private network onto the internet with special provisions for authentication, authorization, and accounting. It can be considered as a replacement or equivalent of EDI. The items used for measuring intra-organizational ICT were adapted from Ward and Zhou (2006). Information sharing by the buyer was measured using adapted items from De Toni and Nassimbeni (2000), Fröhlich and Westbrook (2002), and Giménez and Ventura (2003). The selected items relate to the extent to which the buyer communicates sales forecasts and (changes in)

production plans to the supplier. Cooperative relationship is based on items used by Johnston *et al.* (2004), reflecting how supply chain partners integrate decision making and solve problems together. Handley and Benton (2013) recently use similar items to measure cooperative relationship. As our target population is suppliers, we focus on how well the supplier satisfies the buyer's requirements. It was measured by adapting five items for buyer's satisfaction from Giménez and Ventura (2003) and Stank *et al.* (1999), asking to what extent improvements were made with respect to quantities ordered, special requirements, delivery lead times, delivery reliability, and advance notifications about late deliveries and stock-outs. The main reason for the focus on service and delivery aspects of performance is that ICT fosters capabilities for quick response and flexibility to deal with changes in market conditions (Goh *et al.*, 2007). In order to be able to control for possible effects of size, number of employees, and annual sales are incorporated. The exact wording of all items can be found in Table II.

The questionnaire was translated into Chinese and translated back by three OM academics. Subsequently, an OM expert compared the questionnaires to make sure that in the translation process the content was not altered. In the pre-pilot study, the questionnaire was reviewed by five academics and evaluated through structured interviews with six executives.

Sample and data gathering

Recently, several studies co-authored by Chinese researchers (e.g. Flynn *et al.*, 2010; Li *et al.*, 2009; Huo *et al.*, 2014) have investigated supply chains in Chinese companies, showing the growing interest in and significance of China as "the manufacturer of the world." Following this established research, it seems that data gathering in China does not provide limitations for generalizability. Another reason for gathering data in China was convenience, as one of the authors is based in China. This guaranteed good access to organizations and helped to ensure a high response. To further assure a high response, two institutions were chosen to get access to companies: the China IT promotion institution and the Zhejiang Province Enterprise Association. The first aims to promote ICT application in industry. Its membership includes nation-wide manufacturing firms. Zhejiang Province Enterprise Association is based in one of the largest industrial areas in China. As this study is aimed at industrial suppliers, we checked whether the contacted companies were indeed suppliers. That resulted in 278 companies from the first institution and 386 companies from the second.

In data gathering we emphasized to select the most knowledgeable representative of the organization to answer the questions and to search for advice of colleagues if needed. They were asked to answer with regard to their most important buyer. We distributed the hardcopy version at the annual conference of the China IT promotion institution. We checked whether the person attending the conference was suitable. If not, the questionnaire was posted. For the Zhejiang Province Enterprise Association, the printed version was posted to the target companies directly. The above two steps were executed at the same time. Non-respondents were sent a reminder together with the electronic version of the survey. During the conference, we distributed 152 questionnaires and got 124 responses (response rate of 81.6 percent). Additionally, 43 companies responded to the survey posted to the 126 remaining target companies (response rate of 34.1 percent). The response from the Zhejiang Province Enterprise Association was 44.5 percent (172 returns from the 386 sent). Our final sample contains 320 respondents, due to incomplete answers. Therefore the overall response rate was 48.2 percent (320 out of 664). Our respondents were mainly

supply chain manager or chief information officer (both 30 percent), directors (21 percent), and (vice-)presidents (17 percent), which reflects that mainly high ranked representatives responded, being a good sign for the reliability of the answers (Phillips, 1981). The distribution of the SIC codes is provided in Table I. The data were examined for non-response bias by exploring differences between early and late respondents (Armstrong and Overton, 1977). We also checked for possible differences between the two samples. First, an ANOVA test did not show significant differences for the category means for annual sales revenues, number of employees, or the unit selling price of the primary product ($p \leq 0.05$). Further, a dummy variable was included to check for a possible effect of the two subsamples in all regression models. The results show that the intercept and slopes of the factors have no significant differences across the two subsamples, except for the interaction of intra-organizational ICT and cooperative relationship that has a significant difference between the two groups. By checking the slopes of the interaction, it is clear that the directions of the slopes are the same in both groups, though not significant in the Zhejiang Province group. The above results confirm that we can treat the data from the two sources as one homogeneous sample.

Data reduction and analysis

Common method variance is not an issue as Harmans single factor test (Podsakoff *et al.*, 2003) shows neither a single factor nor one general factor accounting for the majority of the variance (the first factor account for 31.68 percent). The Kaiser-Meyer-Olkin value (0.85) indicates satisfactory adequacy for a factor analysis. Then, a principal component analysis with a varimax rotation is conducted with all the items. In order to test our hypotheses, hierarchical regression analysis is performed using SPSS. Baron and Kenny's (1986) three-step hierarchical regression analysis procedure was adopted to test the mediating effect. With regard to the hypothesized moderating effects, the main effects were centered prior to the analyses, to avoid multicollinearity problems (Cohen *et al.*, 2003).

Two-digit SIC	Number	Percent
20. Food and kindred products	21	6.6
22. Textile mill products	47	14.7
23. Apparel and other product made from fabrics and similar	32	10
25. Furniture and fixtures	8	2.5
26. Papers and allied products	13	4.1
27. Printing, publishing, and allied industries	7	2.2
28. Chemicals and allied products	29	9.1
29. Petroleum refining and related products	21	6.6
30. Rubber and miscellaneous plastics products	24	7.5
32. Stone, clay, glass, and concrete products	3	0.9
33. Primary metal industries	9	2.8
34. Fabricated metal products except machinery and transportation equipment	17	5.3
35. Industrial, commercial machinery, and computer equipment	23	7.2
36. Electronic, other electrical equipment and components, except computer equipment	31	9.7
37. Transport equipment	15	4.7
38. Measuring, analyzing, and controlling instruments; photographic, medical, and optical goods, etc.	11	3.4
39. Miscellaneous manufacturing industries	9	2.8
Total	320	100

Table I.
Industry
classification

Results

In this section, the results of the factor analysis and subsequently the tests of our hypotheses are presented.

Factor analysis

To validate that electronic linkages and intra-organizational ICT are two distinct constructs, and to accurately categorize scales from ICT as part of either construct, a series of tests were conducted, starting with an exploratory factor analysis (EFA). In the EFA, individual items for each sub-scale loaded separately as proposed. Tests showed that dropping individual scale items did not yield significant improvement in measurement model fit of individual scales, suggesting that the individual scales are relevant to respective constructs. The average variance extracted (AVE) values further indicate discriminant validity. To assess whether alternate specifications of electronic linkages and intra-organizational ICT provide a better fit, it was tested whether the proposed measurement model ($\chi^2/\text{df}=3.06$, CFI=0.89, IFI=0.89, RMSEA=0.08) provides a better fit than all subscales loading on a single construct of ICT ($\chi^2/\text{df}=4.28$, CFI=0.82, IFI=0.82, RMSEA=0.10). The proposed measurement model showed a better fit. Finally, using the constrained-unconstrained approach, the change in χ^2 was 14.846 ($\Delta\text{df}=114.7$, $p<0.001$) suggests discriminant validity between electronic linkages and intra-organizational ICT.

Following the procedures in Paulraj *et al.* (2008), construct validity and unidimensionality were established using EFA and confirmatory factor analysis (CFA). The results are provided in Table II. Five factors with eigenvalues greater than 1 account for 66.07 percent of the variance. The items with loadings greater than or equal to 0.4 were regarded as significant and retained following the convention advocated by Nunnally (1988). Only one item "The parties are jointly responsible for making sure that tasks are completed" has a cross loading larger than 0.40 (0.43) on another component (information sharing). It seems logical that companies along a supply chain need to exchange information to make sure that the tasks for which they have a joint responsibility are completed. Therefore this item was retained. CFA measurement model was used to further establish unidimensionality and construct validity. The model fit indices ($\chi^2/\text{df}=2.7$, GFI=0.88, CFI=0.90, IFI=0.90, RMSEA=0.07) show that the model fits the data well and hence establish unidimensionality. All *t*-values for the individual paths show that indicators are significantly related to their underlying theoretical constructs and, hence, exhibit convergent validity.

Discriminant validity was evaluated by examining the factor correlation matrix. Usually correlations greater than 0.70 between factors are considered as problematic, which is not the case as Table III shows. Additionally, the squared correlation between two latent constructs were compared to their AVE estimates (Fornell and Larcker, 1981). Comparing the correlation coefficients given in Table III with the AVE values given in Table II, confirms that none of the squared correlations is higher than the AVE for each individual construct. Therefore, discriminant validity can be guaranteed.

Most constructs have Cronbach's α values around 0.80. Only the value of supplier performance (0.67) is lower, but close to the widely accepted cutoff value of 0.70 while greater than the minimum recommended value of 0.60 (Nunnally, 1988). Therefore, it seems save to conclude that measures are reliable. Additionally, following Bagozzi and Yi (1988), composite reliability (CR) scores were computed to assess construct reliability. Table II shows that all factors have CRs greater than 0.70, implying that the variance captured by the factor is significantly more than the

Items	1	2	Factor		
	3	4	5		
<i>F1: intra-organizational ICT: $\alpha = 0.77$, $CR = 0.77$, $AVE = 0.55$ (please indicate to what extent these technologies used in your company)^a</i>					
MRP/MRP II			0.78		
Advanced planning and scheduling (APS)			0.81		
Computerized integrated manufacturing (CIM)			0.70		
Manufacture execution system for production management			0.70		
<i>F2: electronic linkages: $\alpha = 0.75$, $CR = 0.76$, $AVE = 0.52$ (please indicate to what extent these technologies used in your company)^a</i>					
Use electronic mail with the key buyer					0.86
Have an internet connection with the key buyer					0.74
Have an extranet connection with the key buyer					0.64
<i>F3: information sharing: $\alpha = 0.89$, $CR = 0.89$, $AVE = 0.66$ (please indicate the degree to which you agree with each statement)^b</i>					
Receive information about changes in the production plans of our key buyer at once			0.82		
Receive information about the sales forecasts from our key buyer			0.78		
Receive information about the production plans of our key buyer			0.72		
Receive information about stock levels from our key buyer			0.69		
<i>F4: cooperative relationship: $\alpha = 0.90$, $CR = 0.90$, $AVE = 0.70$ (please indicate the degree to which you agree with each statement)^b</i>					
The parties would rather work out a new deal than to hold each other to the original terms		0.87			
The parties will be open to modifying their agreement if unexpected events occur		0.82			
The parties are jointly responsible for making sure that tasks are completed		0.76	0.43		
Problems that arise in the course of this relationship are treated as joint rather than individual responsibilities		0.82			
<i>F5: supplier performance: $\alpha = 0.67$, $CR = 0.79$, $AVE = 0.54$ (provide an indication of the improvement of your organization's performance relative to three years ago. In case the relationship with your key buyer is shorter than three years, please refer to the improvement of your performance since the start of the relationship)^c</i>					
Responds to the special requirements of the key buyer					0.66
Notifies the key buyer in advance about late deliveries or stock-outs					0.66
Delivers on the agreed date					0.64
Provides the quantities ordered by the key buyer					0.63
Has a short delivery lead time					0.61
Eigenvalue	6.38	2.14	1.95	1.80	1.04
Percentage of variance explained (%)	31.89	42.61	52.35	61.34	66.51
Notes: KMO = 0.86. ^a Scale = no use-significant use (1-5); ^b scale = totally disagreed-totally agreed (1-5); ^c scale = far worse-far better (1-5)					

Table II.
Results of principal
components analysis,
including all
measurement items

variance indicated by the error components. Taken together, the results from the instrument development process show that the theoretical constructs exhibit good psychometric properties.

Testing hypotheses

Table III displays the means, standard deviations, and correlations of the variables. The individual variables and the variates were checked for linearity, homoscedasticity,

Table III.
Univariate statistics
and Pearson
correlations among
the variables

and normality (Hair *et al.*, 2009). The analyses did not reveal any significant problem with respect to the assumptions to use regression analysis. Regression diagnostics revealed no multicollinearity among the variables. Specifically, the variance inflation factors associated with each regression coefficient ranged from 1.097 to 2.743, showing no relevant multicollinearity.

Tables IV and V present the results of the analyses. The number of employees and annual sales are included as control variables. *H1a* and *H1b* refer to the direct effect of electronic linkages and intra-organizational ICT. As can be seen in Table IV(a), electronic linkages has a significant impact on supplier performance ($\beta = 0.18, p < 0.01$) while there is no significant direct effect for intra-organizational ICT ($\beta = 0.1, ns$). Thus, *H1a* and *H1b* can be accepted.

Variable	Mean	SD	1	2	3	4	5	6	7
1. No. of employees	3.17	0.89	–						
2. Annual sales	3.12	1.11	0.79**	–					
3. Electronic linkages	3.05	0.87	0.24**	0.30**	–				
4. Intra-organizational ICT	2.37	0.76	0.51**	0.53**	0.35**	–			
5. Information sharing	2.49	0.96	0.31**	0.29**	0.56**	0.28**	–		
6. Cooperative relationship	3.00	0.91	0.27**	0.23**	0.34**	0.31**	0.58**	–	
7. Supply chain performance	4.02	0.39	0.20**	0.14**	0.21**	0.16**	0.28**	0.21**	–

Note: **Correlation is significant at the 0.01 level (two-tailed)

Steps	Variables	Supplier performance		
		1	2 (1)	2 (2)
<i>(a) Direct model</i>				
1	Number of employees	0.22*	0.22*	0.20*
	Annual sales	−0.03	−0.08	−0.07
2 (1)	Electronic linkages		0.18**	
2 (2)	Intra-organizational ICT			0.10
	R^2	0.04	0.07	0.05
	Adj R^2	0.03	0.06	0.04
	F	6.45**	7.64***	5.00**
	Change in R^2	0.04	0.03	0.01
	Change in F	6.45**	9.66**	2.06
<i>(b) Information sharing and cooperative relationship as mediators of electronic linkages</i>				
1	Number of employees	0.22*	0.22*	0.17
	Annual sales	−0.03	−0.08	−0.08
2	Electronic linkages		0.18**	0.07
3	Information sharing			0.19*
	Cooperative relationship			0.05
	R^2	0.04	0.07	0.1
	Adj R^2	0.03	0.06	0.09
	F	6.45**	7.64***	6.91***
	Change in R^2	0.04	0.03	0.03
	Change in F	6.45**	9.66**	5.50**

Notes: Sobel test statistics = 3.13; p -value = 0.001. Standardized regression coefficients are reported.
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table IV.
Results of
regression analyses
(direct model
and mediation)

		Supplier performance				Supply chain performance	
Steps	Variables	1	2	3	4		
(a) Intra-organizational ICT as moderator on the relationship between information sharing and supplier performance							
1	Number of employees	0.22*	0.17	0.16	0.20*	815	
	Annual sales	−0.03	−0.06	−0.08	−0.10		
2	Information sharing (IS)		0.25***	0.24***	0.24***		
3	Intra-organizational ICT (intra-ICT)			0.06	−0.13		
4	Intra_ICT × IS				0.25***		
	R ²	0.04	0.10	0.10	0.13		
	Adj R ²	0.03	0.09	0.09	0.11		
	F	6.45**	11.05***	8.48***	9.08***		
	Change in R ²	0.04	0.06	0.00	0.03		
	Change in F	6.45**	19.49***	0.81	10.47***		
(b) Intra-organizational ICT as moderator on the relationship between cooperative relationship and supplier performance							
1	Number of employees	0.22*	0.18*	0.17	0.20*		
	Annual sales	−0.03	−0.04	−0.06	−0.08		
2	Cooperative relationship (CR)		0.17**	0.16**	0.19**		
3	Intra-organizational ICT (intra-ICT)			0.06	−0.06		
4	Intra_ICT × CR				0.18**		
	R ²	0.04	0.06	0.07	0.08		
	Adj R ²	0.03	0.06	0.06	0.07		
	F	6.45**	7.26***	5.66***	6.02***		
	Change in R ²	0.04	0.02	0.01	0.02		
	Change in F	6.45**	7.26***	0.85	7.08**		
Notes: Standardized regression coefficients are reported. * <i>p</i> < 0.05; ** <i>p</i> < 0.01; *** <i>p</i> < 0.001						Table V. Results of regression analyses (moderation)	

Table IV(b) shows the results for the impact of electronic linkages. $H2a$ and $H2b$ are tested following the approach suggested by Baron and Kenny (1986). First, electronic linkages have significant relationships with information sharing ($\beta = 0.52$, $p < 0.001$) and cooperative relationship ($\beta = 0.27$, $p < 0.001$). Second, information sharing has a significant positive effect on supplier performance ($\beta = 0.19$, $p < 0.05$). However, cooperative relationship does not have a significant relationship with supplier performance ($\beta = 0.05$, ns). Therefore, $H2b$ is rejected. Finally, with regard to information sharing, the results show that adding the mediator in the regression significantly reduces the effect of electronic linkages, as is confirmed by the Sobel test. The change in β -coefficient from significant to insignificant ($\beta = 0.07$, ns) shows that information sharing fully mediates the effect of electronic linkages. Thus, $H2a$ is supported.

Table V present the results regarding the moderation effect of intra-organizational ICT. Table V(a) shows that the interaction effect between intra-organizational ICT and information sharing with supplier performance is significant ($\beta = 0.25$, $p < 0.001$), which supports $H3a$.

To better understand the effect, the regression equations were rearranged into simple regression of information sharing on supplier performance, with given conditional values of intra-organizational ICT ($M + 1SD$; $M - 1SD$) (see Figure 1). In a situation with low intra-organizational ICT, information sharing is insignificantly related to supplier performance (simple slope test: $\beta = 0.11$, ns), while in a situation with

high intra-organizational ICT, intra-organizational ICT is positively related to supplier performance (simple slope test: $\beta = 0.41$, $p < 0.001$).

Finally, as Table V(b) shows, the interaction between intra-organizational ICT and cooperative relationship with supplier performance is significant ($\beta = 0.18$ $p < 0.05$), which is consistent with *H3b*. Here, the same additional analysis was performed as in the case of information sharing (see Figure 1). Cooperative relationship is found to be insignificantly related to supplier performance (simple slope test: $\beta = 0.08$, ns) in a situation with low intra-organizational ICT application, while cooperative relationship is positively related to supplier performance in a situation with high intra-organizational ICT application (simple slope test: $\beta = 0.32$, $p < 0.01$).

In summary, all hypotheses are supported except for *H2b*. In other words, although no support is found for the mediating effect of cooperative relationship for electronic linkages, the main idea of this paper is supported that the mechanisms through which intra- and inter-organizational ICT and supply chain integration jointly improve supplier performance are different.

Conclusion and discussion

The aim of this paper is to investigate the role of different types of ICT in improving supply chain performance, focussing on one important element: supplier performance. Specifically, it aims to understand the differences in the relationship between electronic linkages and intra-organizational types of ICT and supply chain practices in affecting supplier performance. The paper provides evidence that both electronic linkages and intra-organizational ICT are crucial for increasing supplier performance, but that their roles differ substantially. Those differences are manifest in how each of the two types of ICT relates to supply chain integration. More specifically, information sharing and cooperative relationship mediate the positive effect of electronic linkages (representing inter-organizational ICT) on supplier performance. In other words, electronic linkages lead to more supply chain integration which in turn improves supplier performance. In contrast, intra-organizational ICT moderates the effect of the two supply chain practices on supplier performance. These findings help to understand the mixed results reported in the literature with respect to the relationships between ICT and supply chain performance in general and the role of supply chain integration in that relationship. Specifically, our results show that different types of ICT relate to SC performance through different mechanisms. It seems likely that measuring ICT as a mixture of different types, as has been done in previous research, might obscure the real effects of each individual type of ICT. The results confirm that both mediation and moderation models are useful to explain the performance effects of types of ICT, as suggested in Zhang *et al.* (2011).

Figure 1.
Interaction effects

The above findings are in line with our expectations. However, the interaction effects for intra-organizational ICT deserve-specific attention. Upon closer inspection, it appears that Figure 1 displays a surprising effect. For low levels of SC integration (either information sharing or cooperative relationship) it appears that organizations reach a higher supplier performance if the level of intra-organizational ICT is low than if the level of intra-organizational ICT is high. Only if SC integration increases, supplier performance for low and high levels of intra-organizational ICT are almost equal (for information sharing) or the performance for high levels of intra-organizational ICT exceeds the supplier performance that can be reached under low levels of intra-organizational ICT (for cooperative relationship). In addition, the figure also shows that there is no effect of increased cooperative relationship and information sharing in the case of low levels of intra-organizational ICT. This suggests that, as argued earlier, high-quality information is indeed an important condition for effective supply chain practices and thus being an enabler (Hald and Mouritsen, 2013), but at the same time that the use of systems like ERP might in fact be a constraining factor. It might decrease performance in the supply chain unless increased use of intra-organizational ICT is accompanied with a high level of integrative practices. These findings suggest that unsatisfactory performance outcomes of implementation of MRP/ERP systems might be partly attributed to insufficient SC integration. Nurmilaakso (2007) characterizes this as a mismatch between a high internal ICT level with a low level of supply chain integration. This also empirically supports the conceptually derived propositions by Hald and Mouritsen (2013) and extends them beyond the single organization. Similarly, Bloom *et al.* (2014) find different effects of different types ICT within organizations. The present study extends that finding to the supply chain level. These findings seem to be important for practice as well. In contemporary business practice having intra-organizational ICT such as a MRP/ERP-system is more or less a standard practice for many suppliers and often a requirement to qualify as a supplier for major buyers. Our findings suggest that this will not automatically improve supplier performance, but that it forms a solid base on which integrative practices can be built that will improve that performance. The findings are in line with the general RBV argument and empirically support arguments of Wu *et al.* (2006) and Fawcett *et al.* (2011). Just investing in and using ICT can be easily mimicked by competitors: ICT is a valuable but not a rare resource. However, the way ICT is used and bundled with other intangible resources, such as coordinated and collaborative SC strategies, creates inimitable performance advantages through ICT-enabled unique value-creation.

Another unexpected finding is that cooperative relationship does not mediate the effect of inter-organization ICT on supplier performance. To better understand this result, also a model was tested with cooperation as the only mediator. In that case, cooperative relationship mediates the relationship between inter-organizational ICT and supplier performance. However, if information sharing is added to the model, the mediating role of cooperative relationship becomes insignificant. There is a high and significant correlation between information sharing and cooperative relationship (0.58, $p < 0.01$). These findings seems to suggest that increases in cooperation will enhance information sharing, as suggested by Cheng (2011) among others, refuting the argument of Li and Lin (2006) and Tortoriello *et al.* (2011) that information sharing is an intermediate step toward the establishment of more complex and significant forms of cooperation. The findings also indicate the complex interrelationships between different aspects/dimensions of supply chain integration as indicated by Van der Vaart and Van Donk (2008). Further studies can explore models that incorporate both aspects

of supply chain integration and their relationship. Taking together the separate results for the mediation of cooperative relationship and information sharing and the above discussion, it is evident that supply chain practices mediate the effect of electronic linkages (representing inter-organizational ICT) on supplier performance.

Two important academic implications can be derived from this study. First, this study provides support for the idea that distinguishing intra- and inter-organizational ICT helps to acquire a better understanding and assessment of the contribution of ICT to supplier performance improvement. Specifically, it is important to understand that each of the two types of ICT has a distinctive role and that understanding these roles will help to make – each type of – ICT more effective. Earlier research has distinguished between mediating and moderating models in the relationship between ICT and SCM, but without linking those models to different types of ICT and the different underlying mechanisms for each type of ICT. Based on the results of this study, future research should distinguish between intra- and inter-organizational ICT to avoid confusing effects of ICT as have been reported in the past (see Zhang *et al.*, 2011).

Second, the present study confirms that a number of the concepts proposed and developed in the RBV can be translated and employed in the context of ICT and SCM. Specifically, the notions of distinguishing internal- and external-oriented resources and employing the concept of bundles of resources are worthwhile. Applying those concepts in this study provides insight in the different underlying mechanisms through which both internal and external ICT resources contribute to the performance improvement in a supply chain relationship. Additionally, it is explored how different bundles of resources lead to a competitive advantage. It is confirmed that organizational resources such as supply chain practices interrelate with ICT, but that the specific way in which a bundle of ICT and organizational resources turns out to be effective differs for inter-organizational and intra-organizational ICT. The use of inter-organization ICT (electronic linkages) simply leads to more supply chain integration which in turn improves performance, whereas intra-organizational ICT improves the quality of information and as such acts as a condition for effective supply chain integration. Together, this provides a framework grounded in the RBV-theory for understanding the role of ICT resources and it proves the value of ICT through empirical verification.

Our study provides also an aid for managers to rethink their ICT strategy in the context of SCM and performance improvement. Stated simple, for inter-organizational ICT direct effects on improving supply chain performance might be expected. However, when investing in intra-organizational ICT it is actually possible that supply chain performance will not improve and additional efforts are needed to engage into additional supply chain integrating practices for improving the coordination and collaboration with supply chain partners.

Limitations and further research

This study investigates the separate effects of intra- and inter-organizational ICT, without investigating possible interaction between these two types of ICT and supply chain processes. Future research might seek to explore the mechanisms that explain the mutual effects of supply chain integration and both types of ICT on performance. Such research might also address another possible limitation of this paper by incorporating other aspects of supply chain integration than the two supply chain practices that were investigated here, for example communication or trust. A possible limitation might be that we base our findings on Chinese manufacturers only. Although earlier studies also

reported on what is considered to be the manufacturer of the world, extension to other countries might provide additional insights. Finally, this paper only considers the impact of ICT and integration on service performance. Of course, ICT and integration also have an impact on other performance measures, such as supply chain costs, return of investment or market share. Therefore, it is relevant to extend this research and include the effects of ICT and SCM on various other performance measures.

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Corresponding author

Xuan Zhang can be contacted at: zhangxuan818@163.com

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