Information Technology Implementation in Supply Risk and Performance†

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<Abstract>

This study is to investigate the impact of information technology implementation on supply chain risk and performance. It focuses on how information technology adoption affects supply risk as well as performance. It collected one hundred fifty nine responses from supply executives and supply and purchasing managers of U.S manufacturing firms by applying a survey methodology. The research results provide empirical evidence that the use of information technology in the supply chain mitigates supply risk and improves performance. More importantly, information technology adoption involves three aspects: inbound and outbound communications, internal communications and administration and finally, mitigation of supply risks and improved performance via order taking and procurement. This research emphasizes the importance of IT implementation in supply risk management. It also points out how information technology adoption facilitates the impact of information technology in risk mitigation in the supply chain and in performance. Thus, supply and purchasing managers need to consider IT implementation and adoption when establishing their risk mitigating strategies within the supply chains.

Key Words: Information Technology (IT), supply risk, performance, technology adoption, communications

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Ⅰ. Introduction

Recently, information technology has emerged as a very important tool in supply chain management due to its many advantages. Previous literature indicates that the adoption of information technologies is growing steadily and consistently (Caniato *et al.*, 2009). More importantly, implementing information technology makes a significant impact on firm strategy and firm performance. Firms as well as supply chain members adopt information technology due to various purposes, leading to various benefits in the supply chain. One of the most significant impacts of information technology in the supply chain is to have the supply chain members share their information, resulting in real time collaboration and integration. It also offers visibility, improvement on inventory management, production planning and decision making in the supply chain (Kearns and Lederer, 2003; Mabert and Venkataramanan, 1998, Grover and Malhotra, 1997).

Adding to the role of information technology on enabling supply chain members to share information and promote collaboration, IT engenders evolution within the supply chain. Croom categorized IT impact in the supply chain into five categories: improving access to customers and market, customer relationship management, operations process management support, such as ERP, supply activities integration and material management improvement (Croom, 2005).

Moreover, one of the most important reasons in adopting information technology in the supply chain is the positive impact on firm performance. Investment in IT SCM systems is positively associated with firm performance (Dehning *et al.*, 2007). The utilization of IT has improved the operational performance of large apparel firms by shortening the lead times (Jin, 2006). Using IT also improved the dyadic cooperation, resulting in a positive effect on operational performance (Johnson *et al.*, 2007). IT is also an essential component for improving reverse logistics performance (Olorunniwo and Li, 2010).

On the other hand, previous literatures reveal conflicting results regarding the impacts of IT on performance as well as on the supply chain. Implementing IT does not lead to consistent consequences on improving performance, which is referred to as “productivity paradox” (Lim et al., 2004; Sriram and Stump, 2004). Sanders (2007) summarized various reasons as to why productivity paradox occurred in previous literatures: failure of management (Dos Santos and Sussman, 2000), ineffective execution of IT (Stratopoulos and Dehning, 2000), measurement issues on performance (Bharadwaj *et al.*, 1999), time difference between actual IT investment and performance measurement (Deveraj and Kohli, 2000), difference between actual area and the studies where were resulted (Sriram and Stump, 2004), and finally indirect impacts (Wen *et al.*, 1998).

While prior studies provide arguable results regarding the impact of IT in the supply chain, this study investigates the impact of IT in the context of supply chain risk management. In

supply chain risk management, information sharing and collaboration within the supply chain have been emphasized as a proper risk mitigating strategy. The research of Christopher and Peck (2004) points out the importance of supply chain collaboration and information exchange within supply chain networks in setting up risk mitigating strategies (Christopher and Peck, 2004). Information technology plays a significant role in supply chain management by promoting information sharing in the supply chain and improving coordination between supply chain partners (Small, 1999; McAfee, 2002). Therefore, this study examines the mitigating impact of IT in supply risk. In addition, in order to provide empirical evidence for the positive influence of IT on performance, this research also investigates the relationship between IT implementation and firm performance.

Many previous management information systems literatures discuss IT adoption at the individual level. With regards to IT adoptions, the technological acceptance model (TAM) has received much attention as one of the well-established theory in individuals' technology adoption. However, this research applies an organizational level approach in adopting information technology in the supply chain. More importantly, this research divides IT implementation in the supply chain into two categories, IT adoption and IT impact, in order to investigate how IT implementation affects supply risk as well as firm performance. By dividing the implementation into two categories, this study provides significant evidences and attempts as to how IT plays a critical role in mitigating the supply risk and improving firm performance.

The contributions of this study are two-fold. First, it provides empirical evidences as to how IT implementation in the supply chain helps to mitigate supply risks and improve performance. Utilizing IT can be a good strategic decision for managers to set up a risk mitigating strategy in the supply chain. Second, IT adoption in the organization also generates positive impacts on reducing supply risk and improving performance. Additionally, impacts of IT implementation promote information sharing and frequent communications in the supply chain, leading to foundations for strong relationships in the supply chain.

Ⅱ. Related Literatures

Technology adoption model focuses on technology adoptions at the individual level, especially in the e-commerce area (Ha and Stoel, 2009). Few studies, including the research of Autry *et al.* (2010) applied TAM at the organizational level. This study also utilizes information technology adoption at the organizational level primarily due to two reasons. First, IT adoption in the supply chain is decided by the top management. Therefore, a decision in IT adoption and implementation affects the whole organization as well as all of the members in the supply chain. Hence, this study examines IT adoptions and impacts on the supply chain in the executive managers' perspective at the organization level. Second,

IT adoptions and impacts are considered as one unit or group. Specifically, this study regards IT adoptions and impacts as collections of individuals' IT adoptions. Therefore, this research investigates the relationship between information technology adoption and supply risk as well as performance at the organizational level.

Although information technologies have been receiving increasing attention in supply chain management, studies of information technology usage in the supply chain have not been discussed heavily yet. More importantly, the role of information technology in supply chain risk management has not been discussed yet in literatures. In previous literature reviews, the usage of information technology in the supply chain focuses on improving the coordination and collaboration among supply chain members as well as enhancing firm performance.

This study defines information technology as uses of information technology which is employed in inter-organizational context to link customers, suppliers, business partners and employees in business transactions, customer service, intranet, extranet, data interchange and supply chain (Subramini, 2004; Wu et al., 2003). Prior studies discuss the benefits of implementing information technology in the supply chain in the perspective of coordination and collaboration. Information technology enables suppliers and buyers to establish a strong coordination in production, such as inventory planning, forecasting in demand and scheduling (Feeny, 2001). The research of Vickery *et al.* (2003) also supports evidences that a direct relationship exists between information technology and supply chain coordination in the automobile industry. For improvement in the current process, IT provides empirical evidences leading to positive impacts on coordination. More importantly, IT usage engenders a positive impact on strategic and operation coordination directly, leading to suppliers' operational and strategic benefits (Sanders, 2008).

The impact of information technologies have been investigated in improving firm performance. Information technologies provide organizations with a wide range of benefits, such as savings in transaction costs, inventory reduction and the establishment of communication networks between buyers and suppliers (Min and Galle, 1999; Deeter-Schmelz *et al.*, 2001). Information technology also enables firms to collect and analyze real-time information thereby resulting in enhanced collaboration among firms (Vakharia, 2002).

Wu *et al.* (2003) assessed the impact of firm characteristics, competitive environment and the intensity of information technology adoption on performance. It was shown that performance was improved due to IT-based communication and internal administration, but not online order taking and e-procurement. The study of Johnson *et al.* (2007) presented the findings from a study of drivers and the outcomes of information technology use in the supply chain. Transactional technologies were subdivided into dyadic cooperation and price determination. Significant differences were found between the two dimensions in terms of their overall levels of adoption, with dyadic coordination being the most widely adopted. Finally, information

technologies targeted at reducing the dyadic coordination costs, which were found to lead to improved financial performance.

In Devaraj *et al.* (2007), it was shown that there was no direct benefit of information technologies on performance; however, these technologies supported both customer integration and supplier integration. Furthermore, supplier integration was found to positively impact cost, quality, flexibility and delivery performance. Sanders (2008) supports the notion that the use of information technologies positively affects intra-org, inter-org collaboration and performance. Information technologies also positively influence intra organizational collaboration with indirect positive impacts on organizational performance.

Ⅲ. Research Model and Hypothesis

Prior studies have suggested many strategies for mitigating supply chain risks. Braunscheidel and Suresh introduced the supply chain agility approach in order to deal with supply chain disruptions by emphasizing the fact that supply chain agility provides organizations with the ability for quick response and changes toward disruptions in the supply chain (Braunscheidel and Suresh, 2009). The study of Chopra and Sodhi (2004) introduced strategies on how organizations can mitigate risk, such as increasing the capacity, responsiveness, inventory, flexibility and capability and acquiring many suppliers. Christopher and Lee (2004) also suggested strategies on the steps for eliminating supply chain risks. Accurate information needs to be accessible to all supply chain members, and then they need to be quickly informed for response as well as recoveries. The research of Craighead *et al.* (2007) presented two mitigation capabilities: recovery capability and warning capability, which requires interactions and coordination between supply chain entities for speed recovery from disruptions and detection of potential disruptions. Christopher and Peck (2004) emphasized the importance of supply chain collaboration, such as information sharing in supply chain networks for risk mitigating strategies.

The study of Faisal *et al.* (2006) listed eleven enablers of supply chain risk mitigation with tier structural models. Collaborative relationships, information sharing and trust among supply chain partners promoted interactive relationships. Knowledge regarding various types of risks in a supply chain influenced cooperate social responsibility and strategic risk planning, affecting risk sharing in the supply chain. Finally, all of these impacts on the previous tiers affected continual risk assessment analysis and agility in the supply chain. Juttner *et al.* (2003) introduced four mitigating strategies; avoiding high risk by dropping specific products and geographical markets with unreliable supply, utilizing contingency plans for controlling various risk sources, encouraging cooperation in the supply chain, such as information sharing and joint plans, and flexibility in the supply chain.

Kleindorefer and Saad (2005) presented ten principles of risk mitigating strategies: mitigating its own risk in the supply chain as a focal firm,

diversification in sourcing options, strong incentives and collaboration in the supply chain network, prevention strategy, not too much dependence on extreme leanness and efficiency, contingency plans, collaborative information sharing, risk assessment, agility and flexibility in supply chains and finally, quality management. Using a case study of Ericsson, Norman and Johnson (2004) emphasized a proactive approach, that is, collaboration with suppliers in supply chain risk management.

In the broad concept of supply chain risk, this study focuses on the supply side of supply chain risk by identifying sources in the supply chain risk. Due to a lack of clear distinctions of risk mitigating strategies between supply chain risk and supply risk, this study applies very similar approaches, leading to discussions regarding supply risk mitigating strategies. Similar to supply chain risk management literatures, the research proposed that close buyer-supplier relationships and sharing risk mitigation plans were key factors of minimizing supply risks (Zsidisin *et al.*, 2000). In the toy industry, Johnson suggested risk mitigating strategies in the supply: outsourcing with flexible partners, information sharing and diversifications among suppliers (Johnson, 2001). The research of Harland *et al.* (2003) also presented similar strategies in supply risk management strategies by promoting collaboration in the supply chain and implementing a supply network risk strategy. The study of Jiang et al (2009) discovered that buyers should work with suppliers in order to improve the labor conditions, resulting in reducing supply risks.

Previous literature has suggested a variety of supply chain risk mitigating strategies, which emphasizes in promoting collaboration, information sharing and flexibility. Among supply chain practices, adopting information technology is a very effective tool for performing these strategies. Many studies indicate that the use of information technology in supply chains helps supply chain members to establish coordination leading to collaboration and information and flexibility among supply chain networks. Burgess pointed out the role of IT in integrating supply chain members, resulting in customer satisfaction improvement by saving costs (Burgess, 1998). Ragatz et al. (1997) also presented that IT helped to speed up the information flow as well as establish partnerships in the supply chain. More importantly, IT positively affects the coordination relating to both relationship commitment and relationship magnitude in the supply chain (Kent and Mentzer, 2003; Golicic and Mentzer, 2006). The use of IT for improving the current processes in the supply chain had a positive and direct impact on operational coordination and IT use for new development in the supply chain, which also positively and directly affected strategic coordination (Sanders, 2008). Based on this finding, this study proposes that the use of IT helps supply chain members to establish coordination and promote collaboration as well as information sharing and flexibility in the supply chain, leading to minimize the probability and magnitude of the supply disruption risk. Thus, this research proposes hypothesis 1:

H1: Information technology use in the supply chain mitigates supply risks.

Previous literatures consistently portrayed that integration in the supply chain improves firm performance (Vickery *et al.*, 2003;Ward and Zhou, 2006). Maintaining a good relationship with suppliers can improve the performance (Lee, 2013). In addition, coordination in the supply chain also generates benefits for firms in the supply chain (Saeed *et al.*, 2005). Information technology in the supply chain promotes integration as well as coordination in the supply chain, resulting in improving firm performance. IT can also be applied in the reverse logistics such that it can improve the reverse logistics performance measure by satisfaction and profit margins (Olorunniwo and Li, 2010). IT is considered as an essential component to achieve effectiveness in the supply chain (Gunasekaran and Ngai, 2004). IT dependency is also positively associated with the business relationship connected with IT (Jeon, Jeong and Min, 2013). IT utilization in the U.S. apparel supply chain also positively affects operational performance (Jin, 2006). Other studies also examined the impacts of IT in an indirect perspective. Subrami (2004) examined the positive impacts of IT in the supply chain as first order benefits by going through the business process and domain knowledge specificity. Sanders (2008) also investigated the positive impacts of IT in the supply chain as first order benefits by going through operational and strategic coordination. This study investigates the direct impacts of IT use in the supply chain on performance. Thus, we propose hypothesis 2:

H2: IT use in the supply chain positively affects performance.

Information technologies have emerged as a very important tool to increase collaboration in the supply chain. Information technology's characteristics and IT usage attitude also affect information technology interactions (Yoon, 2013). However, very few studies discussed information technology adoption in the supply chain, particularly at the organizational level, which explains a linkage between individual user's technology adoption and actual implementation. Thus, this study explores how organizational information technology adoptions affect supply risk as well as performance. IT cultivated the communication process between suppliers and customers. By inbound and outbound communi-cations in the supply chain, all members are able to exchange the flow of information. IT enforces communications and information exchange between suppliers and customers (Cagliano *et al.*, 2003). Communications by IT are considered as a prerequisite for effective collaboration by sharing critical information in the supply chain networks (Sandberg, 2007). By adopting IT, communications with suppliers and buyers help information to flow seamlessly and enable an exchange of data in the supply chain in order to achieve integration within the supply chain (Webster *et al.*, 2006). In Devaraj *et al.* (2007), information integration with suppliers conducted by IT positively affected the operational performance; however, information integration with customers did not have any significant impact on the operational performance. More importantly, the study of Fawcett *et al.*

(2007) pointed out that the connectives of the supply chain networks in information sharing improved the various dimensions of performance. Wu *et al.* (2003) also indicated that IT adoption in communications with suppliers and customers positively influenced performance. IT adoption in communications with suppliers and customers not only promotes collaboration in the supply chain by sharing information, but also directly or indirectly improves performance. Therefore, this research proposes the following two hypotheses:

H3: IT adoption in inbound and outbound communications mitigates supply risks.

H4: IT adoption in inbound and outbound communications in the supply chain positively affects performance.

Similar to how communications with suppliers and customers enhance efficiency in the supply chain, effective communications inside organizations are expected to generate positive effects. Internal coordination developed integration within the firms, leading to cross-functional teams (Ko and Kincade, 1998). Prior literatures also point out the significance of internal communications among functional teams. Cross functional communications provide strong support for the sourcing strategy (Chen and Paulraj, 2004). Functional coordination between functional teams of the firm improved the customer satisfaction level as well as the responsiveness in the supply chain (Chen *et al.*, 2004). Strong inter-functional communications help to establish a smooth line of communications between teams and to understand other functions easily (Sanders, 2007). IT plays a critical role in promoting internal communications and administration. By providing informational support in the firm, the production schedule and operational planning reduced the work-in-process inventory and increased capacity utilization (Vaart and Donk, 2008: Gunasekaran *et al.*, 2004). In addition, IT improved the support process, such as human resources function, resulting in the reduction of Selling, General and Administrative expenditures (Dehning *et al.*, 2007). IT also helps to promote intra organizational collaborations. Sanders empirically found out that IT positively influenced intra organizational collaborations that also have a positive impact on organizational performance (Sanders, 2007). Finally, the research of Wu *et al.* (2003) provided empirical evidences as to how IT adoption on internal communications and internal administration positively affected in increasing efficiency and developing a relationship in the supply chain. Based on the above discussion, IT adoptions in internal communications and internal administrations encouraged cross-functional team performances as well as efficiencies in the supply chain. Therefore, this study presents these two hypotheses:

H5: IT adoption in internal communications and internal administrations mitigates supply risks.

H6: IT adoption in internal communications and internal administrations in the supply chain positively affects performance.

Information technologies transformed order taking and procurement processes into a new era in the supply chain. By adopting IT in order taking and procurement, supply chain members performed good procurement practices,

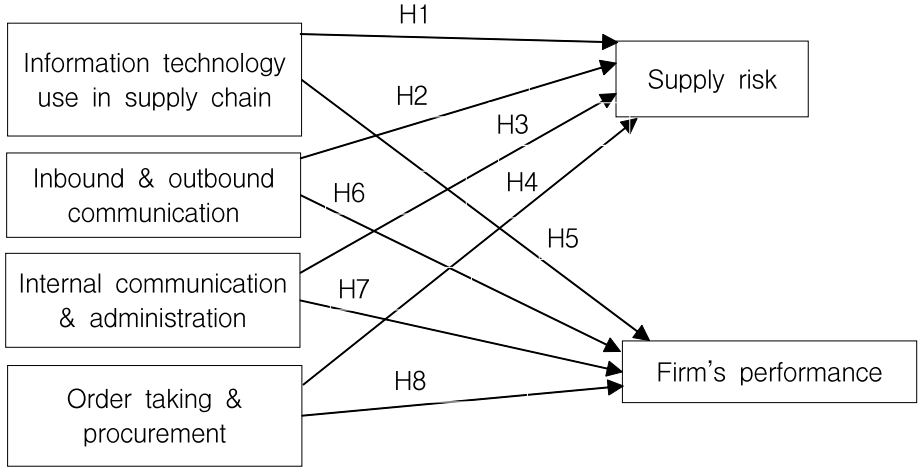
developed trust with partners, shared useful information and maintained high quality of communications (Archer *et al.*, 2008). Smart (2005) also presented many benefits of IT adoption in order taking and procurement by attracting both suppliers and customers and encouraging integration in the supply chain. Croom (2005) also summarized IT in order taking and procurement: improving customer service, information flow and financial performance. Devaraj *et al.* (2007) presented interesting results as to how IT indirectly influenced performance by supplier integration. Adoption in IT provided two main advantages: transaction costs and integration in the supply chain, resulting in improved performance (Johnson *et al.*, 2007). Power *et al.* (2010) also summarized the benefits of order taking and procurement in IT: leading to interactions between suppliers and customers, cost savings and positive impact on performance with other factors. In their study, Wu *et al.* (2003) proposed that adoptions of IT in order taking and procurement would increase efficiency, improve sales performance and customer satisfaction and enhance the relationship in the supply chain. Based on the previous literatures, IT adoptions in order taking and procurement are expected to improve the relationship between supply chain network as well as performance in the supply chain.

Therefore, this study establishes two hypothesis below:

H7: IT adoption in order taking and procurement mitigates supply risks.

H8: IT adoption in order taking and procurement in the supply chain positively.

Figure 1 describes our research model



<Figure 1> Research model

Ⅳ. Methodology

This research applied the survey methodology for data collection. Based on prior literatures, instruments of survey measurements were developed. Table 1 describes all survey

items with a summary of construct measurements as well as references. A total of thirty one items are used for measuring the usage of information technology. Among the forty three items, six items are used for measuring IT use in supply chain relationships. Ten items measure inbound and outbound communications by the IT adoption level in the supply chain. Eight items measure internal communications and internal administrations by the IT adoption level in the organization. Seven items are used for measuring IT adoption in order taking and procurement. In order to measure the supply risk that represented the probability and magnitude of the disruption risk in the supply chain, six items are used. The performance was measured with nine items of three dimensions: financial, operational and supply chain performance. The performance is measured by comparing firm's financial, operational and supply chain performance with industry average such as return on assets and average profits. All these measurements used a seven-point Likert scale.

In order to increase the reliability as well as the quality of the survey instruments, we had an interview with a group of experts in the supply chain management and received feedbacks and comments on the measurements of survey questions. After reflecting on experts' opinions, we conducted a pilot study with a total of 32 responses. By reflecting the results of pilot study, we dropped five items of survey questions and improved the clarity of the survey questions. After modifying and finalizing all survey items with precious feedbacks from professionals in supply chain management, the survey was sent to 622 executives as well as supply and purchasing managers in U.S. firms. They were the members of Institute of Supply Management, especially in Buffalo, New York area. One hundred fifty-nine members participated in completing this survey, making the response rate to be 25.56 %. The respondents were primarily from manufacturing industries. The firm characteristics of the responders are presented in table 3.

This research applied the partial least squares (PLS) technique for analyzing the survey data in order to establish both measurement for constructs and structural models of the research model (Wold, 1989). In addition, PLS does not have to be restricted with assumptions regarding distribution and sample size (Haenlein and Kaplan, 2004; Falk and Miller, 1992). Thus, this research use PLS for overcoming the sample size, 159 responses. More importantly, lack of strong theoretical background on our research model is one of reason in applying PLS. Using partial least squares, the convergent and discriminant validity as well as reliability were examined, which were presented in table 1 and 2. Factor loadings for all measurement items are also presented in table 4.

V. Results

1. Measurement Model

For establishing an acceptable reliability of

measurement items, the factor loadings of all construct indicators must be greater than 0.7 (Fornell and Larker, 1981). This research also uses the value of Cronbach's α in order to assess reliability. All factor loadings of measurement indicators presented strong reliability and all Cronbach's α score of the constructs were greater than 0.7, showing acceptable reliability. By using the composite reliability as well as the average variance extracted (AVE), a convergent validity test was conducted. To provide good internal consistency, the values of composite reliability have to be greater than 0.7 (Hulland, 1999). Regarding AVE, the proportion of the average variance between constructs and indicator variables must be above 0.5 (Chin, 1998). All loadings of measurement constructs are greater than 0.7, which is acceptable; furthermore, no significant cross loadings are found, providing evidences of scale unidimensionality (Chin, 1998). Table 1 included all measures of factor loadings, Cronbach's α, CR and AVE. In table 2, this research examined the discriminant validity by confirming that the values of the square root of AVE have to be greater than the correlations of the variables, following the suggestions of Fornell and Larker (1981). Therefore, the values of the diagonal elements appear to be greater than those of the off-diagonal elements in table 2 (Fornell and Larker, 1981; Hulland, 1999).

<Table 1> Constructs measurements summary: Reliability

Item Description (Reliability, Cronbach's α, CR, AVE)	Factor Loadings
Information technology use in the supply chain relationship (anchors: 1 = minimal use to 7 = significant use; (Subramani 2004, Boynton and Zmud 1994), Cronbach's α = 0.955, CR = 0.948, AVE = 0.871	
The extent to which you use specific IT-based support for order processing, invoicing and setting accounts with your suppliers	0.822
The extent to which you specific IT-based support for exchange of shipment and delivery information with your suppliers	0.866
The extent to which you use specific IT-based support for managing warehouse stock and inventories with your suppliers	0.924
The extent to which you use specific IT-based support for understanding trends in sales and customer preferences with your suppliers	0.895
The extent to which you use specific IT-based support for investigating your functions (design and manufacturing) with your suppliers' service organization	0.917
The extent to which you use specific IT-based support for leveraging your firm's expertise to create new business opportunities with your suppliers	0.903
Information technology adoption in the supply chain (anchors: 1 = did not adopt at all to 7 = Adopt very extensively; (Wu et al. 2003)	
Inbound and Outbound Communications, Cronbach's α = 0.917, CR = 0.921, AVE = 0.818	
Send suppliers with regular updates about new product plans and other new developments within our supply chain	0.883
Provide specific online information about product specifications that our suppliers must meet	0.818
Share product and inventory planning information with our suppliers	0.907
Permit suppliers to directly link up to our databases (via ERP systems)	0.852

Provide customers with general information about our supply chain	0.889
Allow customers to locate and send information to appropriate contacts within our supply chain	0.925
Send customers regular updates about new products and other developments within our supply chain	0.876
Provide solutions to customer problems	0.947
Provide after-sale services to our customers	0.919
Provide information in response to consumer questions or requests	0.933
Internal Communications and Internal Administration, Cronbach's α = 0.888, CR = 0.903, AVE = 0.778	
Facilitate internal communication between employees in different departments and different locations	0.857
Regularly update employees about developments within our supply chain	0.922
Facilitate discussions and feedbacks on various issues of importance to our supply chain	0.944
Manage projects within our supply chain	0.918
Coordinate new product development teams	0.872
Perform financial and managerial accounting	0.825
Provide reimbursements and manage payrolls	0.833
Manage employee benefits	0.817
Order taking and Procurement, Cronbach's α = 0.825, CR = 0.811, AVE = 0.754	
Accept orders electronically from customers	0.936
Accept payments electronically from customers	0.899
Allow customers to track and inquire about their orders electronically	0.929
Search and locate potential suppliers online	0.855
Place and track orders with suppliers electronically	0.936
Allow suppliers to submit bids online	0.839
Use online marketplaces to source suppliers	0.901
Performance (anchors: 1 = well below industry average to 7 = well above industry average; Yeung, 2008; Devaraj, Krajewski, and Wei 2007; Sezen 2008), Cronbach's α = 0.925, CR = 0.947, AVE = 0.801	
Average return on assets	0.926
Average profit	0.883
Production lead time	0.907
Deliver reliability	0.822
Ability to respond to and to accommodate periods of poor supplier performance	0.874
Customer response time	0.856
Supply risk (anchors: 1 = extremely low to 7 = extremely high; Ellis, Henry and Shockley, 2010; Zsidisn 2003), Cronbach's α = 0.875, CR = 0.923, AVE = 0.736	
It is highly unlikely that we will experience an interruption in supplies from our suppliers	0.926
There is a high probability that our suppliers will fail to provide supplies to us	0.889
We worry that suppliers may not provide suppliers as specified within our purchase agreement	0.855
An interruption in supplies from our suppliers would have severe negative financial consequences for our business	0.801
Suppliers' inability to provide supplies would jeopardize our business performance information system sophistication	0.877
We would incur significant costs and/or losses in revenue if our suppliers failed to provide supplies with legal liabilities	0.913

<Table 2> Corelation Matrix: Discriminant Validity

		IT adoption in supply chain				
Variable	ITS	IOC	ICIA	OTP	SR	PER
ITS	(0.933)					
IOC	0.369	(0.904)				
ICIA	0.447	0.115	(0.882)			
OTP	0.258	0.401	0.002	(0.868)		
SCR	0.354	0.331	0.226	0.299	(0.858)	
PER	0.398	0.010	0.217	0.252	0.196	(0.895)

ITS: Information technology use in the supply chain relationship, IOC: Internal and outbound communications, ICIA: Internal communications and internal administration, OTP: Order taking and procurement, SR: supply risk, PER: Financial, operational and supply chain performance

* The number in parenthesis is the square root of AVE.

<Table 3> Firm characteristics of respondents

Industry	No.	Firm Size (annual sales)	No.
furniture and fixtures	15	< 50 million $	28
chemical and allied products	17	51million $ - 100 million $	24
rubber and plastic products	19	101 million $ - 250 million $	30
stone, clay, glass and concrete products	18	251 million $ -500 million $	27
primary and fabricated metal products	12	501 million $ - 1 billion $	29
automobile and its relating products	26	More than1 billion dollars	21
computing and electronic equipments and components	25	Unanswered	0
transportation and machinery items	14	Total	159
analyzing and controlling instruments	11		
Unanswered	2		
Total	159		

2. Main Effects

In order to examine the main effects, the partial least square technique was used to establish the structural model. First of all, this study conducted a bootstrap resampling procedure for testing the stability of the estimates (Chin et al., 2003) and for developing robust confidence interval level (Chin, 1998).

The research results confirm that use of information technology in supply chain negatively affects supply risks, supporting hypothesis 1: information technology use in supply chain mitigates supply risks. The result presents a statistically significant relationship with a path coefficient of -0.325 and a t-score of 2.99 at a 0.01 level of significance. The result also supports hypothesis 2: IT use in the supply chain positively affects performance. There is a statically significant positive relationship between information technology use in the supply chain and performance with

a path coefficient of 0.218 and a t-score of 2.75 at the 0.01 level of significance.

The research result empirically supports hypothesis 3: IT adoption in inbound and outbound communications mitigates supply risks with a path coefficient of -0.299 and a t-score of 3.04 at the 0.01 level of significance. Hypothesis 4: IT adoption in inbound and outbound communications in the supply chain positively affects performance was also supported with a path coefficient of 0.188 and a t-score of 2.03 at the 0.05 level of significance.

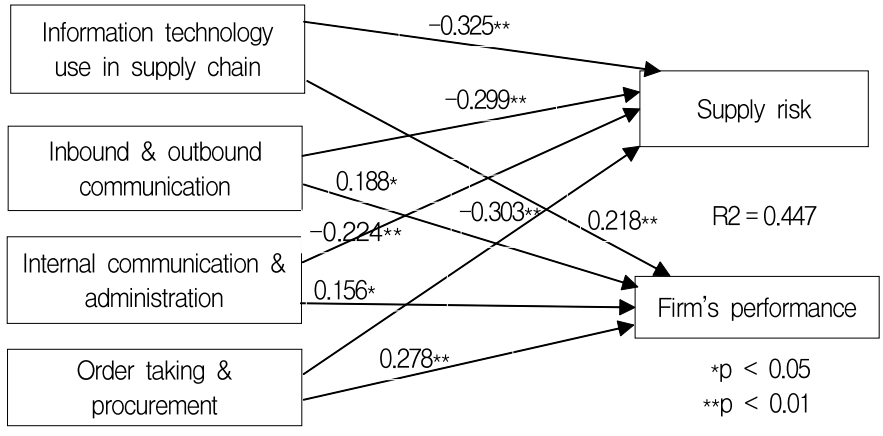
<Table 4> Factor Loadings

	ITS	IOC	ICIA	OTP	SR	PER
ITS1	**0.822**	0.103	0.451	0.277	-0.002	0.367
ITS2	**0.886**	0.222	0.333	0.296	0.047	0.332
ITS3	**0.924**	0.541	0.101	0.314	0.300	0.214
ITS4	**0.895**	0.232	0.004	0.257	0.157	0.471
ITS5	**0.917**	0.359	0.002	0.003	0.155	0.412
ITS6	**0.903**	0.289	0.274	0.001	0.335	0.003
IOC1	-0.014	**0.883**	0.354	0.144	0.432	0.448
IOC2	0.357	**0.818**	0.444	0.001	-0.320	0.115
IOC3	0.366	**0.907**	-0.301	0.222	0.147	0.258
IOC4	0.229	**0.852**	0.353	0.210	0.447	0.336
IOC5	0.249	**0.889**	0.321	0.220	0.101	0.410
IOC6	0.352	**0.925**	0.267	0.448	0.427	0.141
IOC7	0.159	**0.876**	0.347	0.154	0.257	0.236
IOC8	0.339	**0.947**	0.335	0.387	0.002	0.201
IOC9	0.421	**0.919**	0.326	0.215	-0.107	0.270
IOC10	0.333	**0.933**	0.355	0.478	0.338	0.234
ICIA1	0.123	0.254	**0.857**	0.371	0.099	0.357
ICIA2	0.447	0.266	**0.922**	0.277	0.154	0.229
ICIA3	0.299	0.398	**0.944**	0.210	0.324	0.235
ICIA4	0.396	0.274	**0.918**	0.214	0.365	0.399
ICIA5	0.413	0.278	**0.872**	0.488	0.002	0.200
ICIA6	0.358	0.300	**0.825**	0.456	0.102	0.083
ICIA7	0.385	0.256	**0.833**	0.259	0.426	0.002
ICIA8	0.257	0.147	**0.817**	0.048	0.354	0.084
OTP1	-0.200	0.214	0.007	**0.936**	0.364	0.225
OTP2	0.344	0.442	0.463	**0.899**	0.125	0.179
OTP3	0.264	0.339	0.201	**0.929**	0.274	0.501
OTP4	0.299	0.352	0.247	**0.855**	-0.014	0.337
OTP5	0.210	0.467	0.336	**0.936**	0.147	0.269
OTP6	0.335	0.471	0.222	**0.839**	0.177	0.288
OTP7	0.148	0.255	0.310	**0.901**	0.247	0.313
SCR1	0.112	0.157	0.366	0.178	**0.926**	0.387
SCR2	0.154	0.339	0.228	0.454	**0.889**	0.140

SCR3	0.241	0.288	0.366	0.447	**0.855**	0.409
SCR4	0.308	0.254	0.226	0.333	**0.801**	0.441
SCR5	0.101	-0.004	0.088	0.177	**0.877**	0.324
SCR6	0.225	0.321	0.117	0.147	**0.913**	0.222
PER1	0.277	0.084	-0.012	0.460	0.335	**0.926**
PER2	0.103	0.222	0.007	0.422	0.254	**0.883**
PER3	0.339	0.366	0.001	0.259	0.301	**0.907**
PER4	0.441	0.240	0.235	0.338	0.332	**0.822**
PER5	0.225	0.337	0.229	0.104	0.201	**0.874**
PER6	0.314	0.222	0.117	0.299	0.312	**0.856**

Our research results provide empirical evidences as to how IT adoption in internal communication and administration in the supply chain mitigates supply risk, supporting hypothesis 5. We found a statistically significant negative relationship between internal communication and administration and supply risk with a path coefficient of -0.224 and a t-score of 2.88 at the 0.01 level of significance. The results also support hypothesis 6: IT adoption in internal communications and internal administrations in the supply chain positively affects performance with a path coefficient of 0.156 and a t-score of 1.99 at the 0.05 level of significance.

For hypothesis 7: IT adoption in order taking and procurement mitigates supply risks, the research result provides a statistically significant negative relationship between these two constructs with a path coefficient of -0.303 and a t-score of 2.83 at the 0.01 level of significance. Our research result also support hypothesis 8: IT adoption in order taking and procurement in the supply chain positively affects performance. We found a statistically positive relationship between the two constructs with a path coefficient of 0.278 and a t-score of 2.79 at the 0.01 level of significance. Figure 2 describe our research results.



<Figure 2> Research Results

VI. Discussion and Conclusion

This research investigates how the use of information technology and its adoptions in the supply chain affects supply risks as well as performance. In addition, it divides IT technology adoptions into three aspects: communications with suppliers and customers, communications and administration within the firm and procurement process. More importantly, this study establishes three dimensions of performance by measuring three aspects: financial, operational and supply chain performance.

This research makes meaningful contributions for both academics and practitioners. In previous literatures, the technology adoption is applied at the individual level. However, this research applies it at the organizational level and provides empirical evidences as to how IT adoptions affect the mitigation of supply risks and performance improvement at the firm level. More importantly, there was a lack of empirical literature on supply chain risk management, especially on the use of IT in supply chain risk management. This research empirically demonstrates that information technology implementation is considered as one of the risk mitigating strategies in the supply chain. It also provides meaningful directions in supply chain management literatures; improving the adoption level on IT develops more positive impacts on mitigating supply risks. Additionally, IT use and its adoptions in the supply chain positively influence all three dimensions of firm performance: financial, operational and supply chain performance.

This study contributes to filling the gap by empirically validating the impact of information technology and its adoption in supply chain risk management. Although prior literatures introduces various risk mitigating strategies in supply chain risk management, all of the strategies are mostly solutions, suggestions and recommendations, with very few studies conducting empirical validations (Juttner *et al.,* 2003). This study also provides managerial implications as to how purchasing and supply managers in the field utilize information technology in mitigating supply risks and improving performance.

While information technology is regarded as one of the powerful components in mitigating supply risk and improving performance, there was a lack of prior literature that set up the relationship between IT use and IT adoptions in the supply chain and supply risk. Thus, this research attempts to investigate the association between information technology and its adoption and supply risks. It fills the gap in the literatures that IT use in the coordination of the supply chain promotes collaboration based on the future study of Sanders (2007). It also divides information technology into two categories: IT usage and adoption in the supply chain relationship affecting supply risk as well as performance. This study empirically confirmed that the use of IT and IT adoption in the supply chain mitigate supply risks and improve performance. This research applied IT usage and adoptions in the context of supply chain risk management. Therefore, it contributes to providing strong empirical results regarding

the positive role of IT adoption in supply chain risk management. This research also contributes to the perspective that managers need to recognize the importance of information technology usage as well as IT adoption in establishing risk mitigating strategies and implementing improved performance in the supply chain. More specifically, when managers and top management teams set up strategies in supply chain management, they should consider information technology implementation and adoption within their organizations for the success of risk mitigation as well as for performance improvement. If the organization effectively adopts IT, their IT implementation promotes collaborations, frequent communications and effective transactions with their suppliers, resulting in positive impacts on mitigating supply risks and progressing performance.

Our research results empirically support that IT use in the supply chain decreases supply risks. In our study, supply risk is measured with the probability and magnitude of supply chain disruption risk. Information technology plays a significant role in the supply chain by enhancing the relationship between suppliers and buyers, enabling buyer firms to interact very close with suppliers, and finally generating collaboration with suppliers. Therefore, information technology improved supply chain members to react quickly toward any disruptions. Supply chain members could work together to minimize the magnitude of supply chain disruptions, leading to reduction in the damage of the supply chain even if supply disruptions occur. Hence, supply and purchasing managers consider information technology as an effective supply chain practice for mitigating supply risks. More importantly, information technology use in the supply chain not only mitigates supply risk but also improves performance. With the benefits that IT generates in the supply chain, there is also a positive impact on firm performance. Thus, it added the operations management literatures that IT use in the supply chain relationship improves the financial, operational and supply chain performance from the future research direction of Sanders (2008).

Previous literatures discuss IT in the supply chain. However, this study focuses on adopting IT in the supply chain at the organization level. By adopting IT in inbound and outbound communications, it encourages frequent communication with suppliers and customers as well as being able to share real time information in the supply chain. With the adoption of IT in internal communications and internal administration, it promotes cross-functional team activities as well as communications among teams or departments within the firm, reduces the paper-work in the organization and improves efficiency. Finally, by adopting IT in order taking and procurement, it saves transaction costs, develops a capacity of tracking inventories, improves efficiency and raises transparency in the order process. All of these factors, which benefit from adopting information technology in three areas, contribute to the mitigation of supply risks and improve the financial, operational and supply chain performance. If managers can

find a way of improving the IT adoption, organizations can achieve both effective communications within organizations as well as supply chain networks along with efficient order process in the supply chain.

However, this study has some limitations similar to other empirical studies. First, this research receives surveys from only a single respondent within each firm, although the respondent is in a high rank to properly answer all of the survey questions. Second, the single firm is considered a focal firm, or a buyer firm in the supply chain representing a buyer perspective. In order to overcome these two imitations, future studies can be planned to distribute surveys to both multiple supply and purchasing managers and multiple marketing and sales managers in applying both buyers' and suppliers' perspectives.

This research can be extended in various ways. Based on the fact that this research focuses on the manufacturing industry in supply chain risk management, future research can be applied in the service industry, such as the healthcare and financial industry. Moreover, it needs to consider the cultural impact in other countries. Due to a different perspective of e-business technology adoption in supply chain risk management, a future research can compare the cultural differences between Korea and the USA as to how purchasing and supply managers think about technology adoption in e-business technology. Finally, another future study can be applied in an inbound perspective where the focal firm would be the suppliers.

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요 약

공급위험과 성과를 위한 정보 기술 실행

김민균* · 채상미**

본 연구는 공급위험과 성과에 대한 정보기술시행의 영향을 조사한다. 또한 정보기술도입이 공급위험뿐만 아니라 성과에 어떻게 영향을 주는 지 중점을 둔다. 본 연구는 미국 제조업체 구매 및 공급 관련 임원과 경영자들로부터 백오십구 매의 설문지를 수집했다. 본 연구 결과는 공급사슬에서 정보기술 사용이 공급위험을 완화 시키고 경영 성과를 향상시킨다는 실증을 제공한다. 더 중요한 것은 정보기술 도입을 세 분야 (인바운드 아웃바운드 의사소통, 내부의사소통 및 관리, 주문 관리 및 구매)로 나누어 연구되었다. 따라서 본 연구는 공급사슬위험관리에서 정보기술수행의 중요성과 정보기술도입이 위험 완화와 경영성과향상을 활성화 시키는데 큰 역할을 한다는 것을 강조한다. 그래서 공급과 구매 관리자들이 공급 위험 완화 전략 수립 시 정보기술 도입 및 활용을 고려해야만 한다는 필요성을 제시한다.

핵심주제어: 정보기술, 공급위험, 성과, 기술도입, 의사소통

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