DIXIÈME RENCONTRE INTERNATIONALE DU GERPISA
TENTH GERPISA INTERNATIONAL COLLOQUIUM

La coordination des compétences et des connaissances dans l'industrie automobile
Co-ordinating competencies and knowledge in the auto industry

6-8 Juin 2002 (Palais du Luxembourg, 15, rue Vaugirard, 75006 Paris, France)

THE EFFECTS OF IT ON SUPPLY CHAIN PERFORMANCE: INFORMATION SHARING, KNOWLEDGE CREATION, AND COORDINATION

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INTRODUCTION

Electronic Supply Chain Design (e-SCD) is a supply chain design to integrate and coordinate suppliers, manufacturers, logistic channels, and customers using information technology (IT) [3]. e-SCD is a process to build an electronic Supply Chain Network (e-SCN) for transactions among supplier-manufacturer-retailer-customer in virtual space using IT. The concept and characteristics of e-SCD is explained in [3]. The e-supply chain makes it easier and less costly to manage suppliers [4]. IT can link all activities in a supply chain into an integrated and coordinated system that is fast, responsive, flexible, and able to produce a high volume of customized products at low cost.

In a previous study [3], a new model was proposed to explain how an electronic network evolves from a network for simple data exchange in to a space for knowledge creation and supply chain coordination. This study is an extension of the study [3]. The goals of this study are 1) to empirically test the model with more refined measures, and 2) to examine the impact of e-SCD on the performance of supply chains. The impact of IT on supply chain performance such as sales, profit, and modularization and systemization of products were also empirically tested. The survey in the previous study was modified and refined and used for the survey.

THE EFFECTS OF E-SCD IN SUPPLY CHAIN

Gurbaxani and Whang [5] argue that IT in an organization has multiple roles: a) it increases scale efficiencies of the firms operations; b) it processes basic business transactions; c) it collects and provides information relevant to managerial decisions and even makes decisions; d) it monitors and records the performance of employees and function units; e) it maintains records of status and change in the fundamental business functions within the organization and maintains communication channels. Although these roles are in the context of organization, it is expected that IT will also affect supply chains in a similar fashion. The effects of e-SCD are conceptualized along three dimensions – linkage effect, brokerage effect, and integration effect [5]. These effects are expected to change the capability and performance of a supply chain. In the following sections, the three effects of e-SCD are discussed further and it is explored how they are related to the framework for knowledge creation.

Linkage effect of e-SCD

Linkage effect of e-SCD is an instant gain due to the electronic transaction and electronic information sharing. Once a network for B2B transactions takes place, the efficiencies between manufacturers and suppliers increase instantly because they can exchange information and process transactions electronically. The cost savings by direct linkage such as EDI have been shown in past studies [6]. Another short-term effect is the new competition among the suppliers. The network will enable the manufacturer to search alternatives for current suppliers, which will intensify the competition among the suppliers. The competition will press down the procurement costs of the manufacturer in the short-term.

Involvement of suppliers

Customized investments of the suppliers transform the e-SCN from a network for simple information exchange into a network for customized product development. The customized investment means the customization in site, physical, and human assets [7]. The customized investment is an indicator of involvement. Involvement refers to “the implicit or explicit pledge to continue the relationship between the transaction parties” [8]. Dyer [9] showed that the customized investments of Japanese automobile suppliers increased their involvement because of the increased switching costs.

The importance of ‘site asset specification’ (physical location) has generally decreased due to the advancement of communication technologies. However, the physical location is still important for customized product design and production process engineering. Especially, when the product is a system product that requires continuous coordination in design phase, it is most efficient when engineers are collocated [10] [11]. An empirical study [12] found that information distortion was decreased when the engineers from manufacturer and suppliers design the product together, increasing the quality of the product. As the customized investment and suppliers' involvement increases, the e-SCNs will evolve from a network for electronic data exchange into a network for information sharing and integration. The latter was referred to as "Knowledge-sharing network" by Dyer and Nobeoka [13]. The knowledge-sharing network enables the coordination of the network at whole supply chain level.

From a network for data exchange to a space for knowledge creation

e-SCD will have more profound effects in mid to long term. As an e-SCD is more utilized, the participants invest and involve more in the supply chain. As the participants invest and involve more in the supply chain, they share more knowledge and coordinate more of their activities to optimize the whole supply chain. This will have more fundamental effects in those industries such as automobile industry where 'tightly coupled' product development and manufacturing among the firms in the supply chain is critical for success.

Knowledge creation cycle in supply chains

The electronic linkage makes it possible to overcome time, space, and relationship limitations in a network through electronic communication and electronic information integrations. Malone et al. [1] suggest that there are three main effects of electronic market – electronic communication, brokerage, and integration. *Electronic communication effect* refers to the fact that IT allows faster and cheaper communication. *Electronic brokerage effect* means that electronic markets play, by electronically connecting many different potential suppliers quickly, the role of broker – reduce the need for buyers and suppliers to contact a large number of alternative partners individually. *Electronic integration effect* refers to tighter coupling of the processes of information creation and use. In other words, buyers and suppliers can create common information or common interpretation of data [1].

In another stream of research, Nonaka [2] coined the concept of "knowledge creation cycle," which shows how simple information transfers in an organization evolves into information sharing/integration and ultimately into knowledge for coordinating value chain activities. They posit that there are two types of knowledge – knowledge that can be explained and documented (explicit knowledge) and knowledge that is difficult to explain or document (tacit knowledge). According to Nonaka's knowledge creation cycle, people in an organization make their tacit knowledge explicit (*externalization*), combine tacit knowledge to create new knowledge (*combination*), learn and acquire knowledge (*internalization*), and sometimes they acquire tacit knowledge directly from the person who has it by hanging around with him/her (*socialization*) [2]. Nonaka's framework implies that the knowledge in an organization can be effectively transferred and leveraged when those four types of knowledge transfer processes are actively taking place.

Information exchange

Malone et al.'s three main effects of electronic market have similarities with Nonaka's four processes of knowledge creation. Networking provides a mechanism for transferring information, knowledge, and technology [14]. The electronic communication effect refers to easier information exchange due to IT. Easier information exchange will enable people in an e-SCN codify more information in order to communicate with others. For example, as companies utilize Internet more and more, probably they will have to convert more information into electronic file or database to share it with people outside their organization. In this case, e-SCN promotes codification and documentation of the information that has been considered as 'tacit' in the past. This process is similar to Nonaka's '*externalization*.'

Information brokerage

The information transferred through e-SCNs is stored in databases and becomes available to the participants of the supply chain. As more information is available, people in organizations will be able to combine and merge it to create more value. This is the "electronic brokerage effect" [1] and also Nonaka's "*combination*" process through which explicit knowledge is combined with other explicit knowledge [2].

Information integration

In the network, the transferred/combined information is integrated through dynamic learning processes. This is the "electronic integration" and also Nonaka's "***internalization***" and "***socialization***" processes [2]. Internalization refers to the process through which explicit knowledge is transmitted to others and they learn it to create their own tacit knowledge. Socialization is the process through which tacit knowledge is transmitted to others and becomes their own tacit knowledge. In the information integration process, some "data mining" is usually done on the collected data to find and create valuable information, which is a process of converting information into knowledge. As Malone et al. [1] argued, buyers and suppliers work together in the 'integration' process to create common understandings or interpretations on the data.

If carried out successfully, the organizations in an e-SCN will be able to share and create knowledge through the information exchange, brokerage, and integration cycle. There is another requirement for successful knowledge creation in e-SCN. For a successful knowledge sharing and transfer, especially for tacit knowledge, trust and involvement between the sender and receiver is important. Sometimes, people can learn others' tacit knowledge by observing and assimilating those who they want to learn. This requires high level of trust and involvement from both parties. In the "knowledge creation cycle," involvement would be a moderating variable of the sharing/integrating of the transferred information and it is also a necessary condition of participation and motivation. Without involvement, an e-SCN is simply a network for mechanical data exchanges and critical information such as product development, inventory, contract, etc is not shared. Dyer and Nobeoka [13] found that valuable information was shared in a network when the suppliers were actively participating. Therefore, involvement of participants is crucial for B2B e-SCNs to evolve from electronic linkage into electronic coordination.

The effect of "knowledge sharing network" on supply chain coordination.

Toyota has a system to increase its suppliers' involvement, share valuable knowledge, and prevent free riders in its supply chain [13]. It was found that in the Toyota system, the suppliers were developing a "dynamic learning capability" that improved their competitive capabilities. This type of network – a network where manufacturers and suppliers are highly involved in the interactions and learning – is referred to as "knowledge sharing network." The effects of knowledge sharing network on the coordination of supply chain and product customization are as follows.

Savings in procurement and transaction costs

Technology, know-how, and human resource integrated through e-SCNs increase efficiency (alignment effect). Alignment effect is the efficiency increase by aligning material specification, low cost suppliers, and leveraging of volume scale. The information integration effect also saves costs of information search, evaluation, transaction, and administration [1]. Despite the required investment in specialized assets for B2B e-SCNs [15], savings in transaction cost can be obtained. Studies on the US and Japanese automobile companies found that Japanese companies had lower transaction costs in spite of their higher relationship-specific investments [16]. The lower transaction costs of Japanese companies were because of the economies of scale and economies of scope due to the repeated transactions with a small number of suppliers, wide range of information exchange/sharing to reduce the information asymmetry, long-term performance orientation, and investments in the co-specialized assets. Therefore, if e-SCNs lead to a similar transaction relationship, transaction cost savings will be possible.

Alleviation of the "bull-whip effect" and lower inventory

The "bull-whip effect" occurs due to the time lag between demand and order and the differences of the demand and order amount [17]. Bull-whip effect is amplified as it goes upstream of the supply chain farther from market [10]. Electronic information integration can reduce the "bull-whip effect" because the participants can access demand information faster and information distortion or delay is reduced.

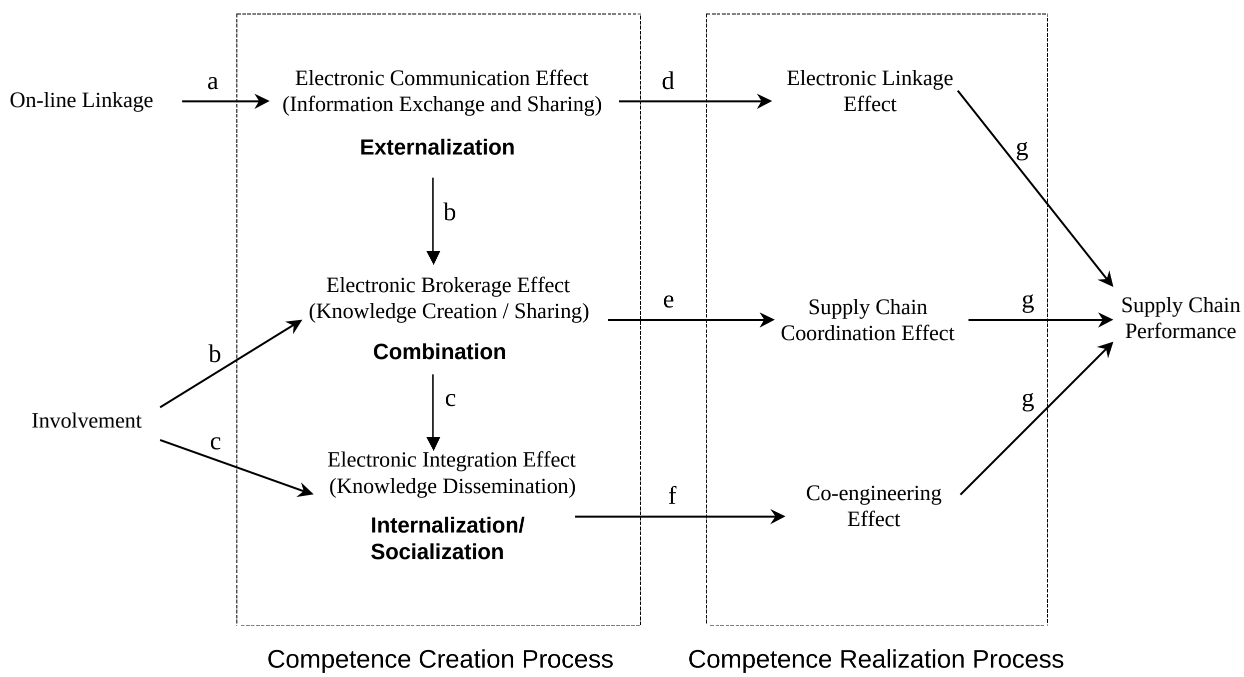
The effect of R&D support and co-engineering.

As e-businesses in e-SCNs evolve, co-engineering for modularization and customized product development advances and the cost savings become larger. Specialized investment and involvement will push co-design and co-engineering in the network further. The co-engineering infrastructures enable the firms in the supply chain to provide customized products, without significant sacrifice of costs and efficiency, based on customers' characteristics, needs, and requests.

A model on the effects of e-SCD

Based on the previous study [3] and discussions above, a model for the effect of electronic linkage and coordination, shown in Figure 1, was developed. The direct effect of online linkage is electronic communication effect that brings electronic linkage effect. Electronic communication effect evolves into electronic brokerage effect if the organizations in a supply chain involves. Electronic brokerage effect, if augmented by involvement, evolves into electronic integration effect. Electronic brokerage effect will help entities in a supply chain coordinate their activities (supply chain coordination effect) and electronic integration effect will augment learning and collaboration between organizations in a supply chain (co-engineering effect). The three effects – electronic linkage, supply chain coordination, and co-engineering effect – will have effects on supply chain performance.

Figure 1. - A Model for the Impact of IT on Supply Chain Performance



The three effects of IT, and also corresponding knowledge creation processes, create competencies of supply chains. If those processes do not take place in a supply chain for some reason, low level of involvement for example, the supply chain will not be able to create competencies. It may remain as a network just for data exchange. Once those processes are performed well, the supply chain will be able to materialized their competencies through the three effects – electronic linkage effect, supply chain coordination effect, and co-engineering effect. Through these three effects, the competences created in the ‘competence creation process’ are realized.

EMPIRICAL STUDY

The model in Figure 1 was tested using an empirical data set. The relationships from ***a*** to ***g*** were tested using the data collected from suppliers in the automobile industry in Korea. The operational variables shown in Table 2 were developed based on previous studies and the validity was tested in a pilot test.

Data collection

The data were collected from major suppliers of two automobile companies in Korea. A total of 150 questionnaires were mailed out and some responses were collected through face-to-face interviews. The number of final responses was 70 (response rate = 46.7%). Collected questionnaires were checked by the researchers to filter out any invalid responses. A total of 67 responses were used in the final data analysis after discarding 3 invalid responses. The descriptive statistics of the respondents are shown in Table 1.

Table 1. - Descriptive statistics of respondents

		Percentage (n = 67)
Annual Sales (in USD)	Less than $5 mil.	27.7%
	$5 mil. – $10 mil.	21.3%
	$11 mil. – $50 mil.	38.3%
	Over $51 mil.	12.8%
Have Joined e-SCN Since	Before 1996	9.3%
	1996-1997	25.9%
	1998-1999	40.7%
	2000-2001	24.1%

Methodology

The constructs of the model in Figure 1 were measured using operational variables developed in previous studies [3]. A ‘1 to 7 scale’ system was used for the operational variables. The reliability of the operational variables was tested by Cronbach α coefficients. In exploratory studies such as this study, the threshold of Cronbach α coefficient is usually set to 0.6 [18]. In this study, the operation variables that have Cronbach α coefficient lower than 0.6 were discarded. The final operation variables of the constructs are shown in Table 2. Factor analysis method was used to group the operational variables. The factor scores, except those constructs that have only one operational variable, were used as the final measure for the construct.

Table 2. - Operational variables of the model

Constructs		Operational Variables	Cronbach α
Electronic Information Linkage		Degree of utilization at electronic order processing	N/A
Electronic Information Exchange		Extent of information exchange on transaction status	0.884
		Extent of information exchange on new products	
		Extent of information exchange on purchase confirmation	
		Extent of information exchange on sales	
		Extent of information exchange on inventory	
		Extent of information exchange on bidding status	
		Extent of information exchange on other things	
Electronic linkage effects	Quality of Information	Timeliness of the shared information	0.921
		Reliability of the shared information	
		Sufficiency of the shared information	
		Usefulness of the shared information	
		Error reduction	
		Ease of complicated data management	
	Cost and Time Effect	Cost savings in document processing	0.933
		Cost savings in negotiations	
		Cost savings in information search	
		Cost savings in payment and transaction closing	
		Cost savings in information acquisition	
		Time savings in information exchange	
		Faster transaction processing	
		Shorter new product development cycle	
		Reduction of lead-time	

SuiteTable 2. - Operational variables of the model

Electronic Brokerage Effect	Inventory reduction in supply chain using the shared information Improved coordination of material flow using the shared information Improved coordination of activities in supply chain Savings in time and cost for supply chain coordination Easier partner switching in case of emergency Fast response to emergencies	0.937
Involvement	Importance of the relationship Intention to sustain the relationship Perceived value of the relationship	0.917
Electronic Integration Effect	Learning of fast product development from partners Learning of customized product development from partners Learning of new technology from partners Learning of product design from partners	0.884
Supply Chain Coordination	Better demand forecasting Better observance of customer needs and preferences Better observance of market size Better observance of changes in market-share	0.919
Co-engineering	Improved capability to design products that customers want Improved capability to design parts Improved capability of suppliers to develop parts independently Faster product development Developing more competent products Decreased part defect rates Improved manufacturability More effective resource allocations for product development Closer collaboration between R&D and manufacturing Better application of advanced technologies	0.966

Table 3 shows the dependent variables used in this study. Supply chain performance was measured by quantitative measures such as sales, profit, cost savings and product modularizations. Product modularization refers to the extent to which suppliers assemble the products before they supply them. Product modularization is an important indicator of how much an automobile manufacturer is ready for customization. If the products of an automobile manufacturer are highly modularized, it is very likely that the company will be able to customize their products with less difficulty.

Table 3. - Dependent variables

Constructs	Operational Variables	Cronbach α
Sales	Effect on sales growth	N/A
Profit	Effect on profit increase	N/A
Cost Savings	Cost savings in procurement due to online bidding Cost savings in transaction processing Manufacturing cost savings Inventory cost savings Cost savings from better coordination between manufacturer and suppliers Cost savings due to product competence	0.948
Product Modularization	Effect on modularization in 1 year Effect on modularization in 3 years	0.862

Analysis results

Regression analyses were conducted to test the relationships in Figure 1. The regression analysis results are summarized in Table 4 and Figure 2. As shown in the table, most regression coefficients are significant at α = 0.01 level. The regression results can be summarized as follows.

Figure 2. - Summary of Test Results

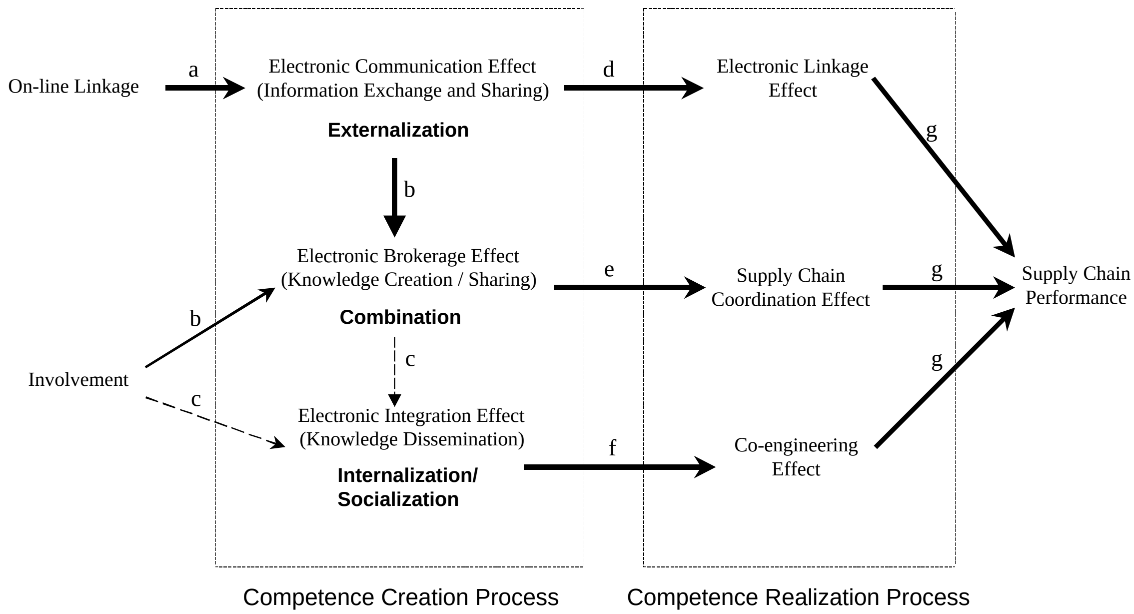


Table 4. - Results of Regression Analyses

Relationship in the Model	Dependent Variable	Independent Variable	Std. Coeff.	Regression Coeff.	Regression Std. Error	t value
a	Electronic Communication Effect $R^2 = 0.588$	Constant		-2.248	0.382	-5.882***
		On-line Linkage	0.767	0.483	0.078	6.203***
b	Electronic Brokerage Effect $R^2 = 0.462$	Constant		0.004	0.161	0.025
		Involvement	0.263	0.292	0.163	1.794*
		Electronic Communication Effect	0.629	0.691	0.161	4.285***
c	Electronic Integration Effect $R^2 = 0.038$	Constant		0.293	0.186	1.579
		Involvement	-0.171	-0.126	0.191	-0.660
		Electronic Brokerage Effect	0.198	0.139	0.182	0.763
d	Electronic Linkage Effect (Quality of Information) $R^2 = 0.060$	Constant		0.104	0.216	0.482
		Electronic Communication Effect	0.244	0.260	0.211	1.235
d	Electronic Linkage Effect (Time / Cost of Information acquisition) $R^2 = 0.610$	Constant		-0.090	0.139	-0.065
		Electronic Communication Effect	0.781	0.832	0.136	6.127***
e	Supply Chain Coordination Effect $R^2 = 0.308$	Constant		-0.032	0.109	-0.299
		Electronic Brokerage Effect	0.555	0.593	0.118	5.038***
f	Co-engineering Effect $R^2 =$	Constant		0.221	0.093	2.369**
		Electronic Integration Effect	0.613	0.481	0.095	5.088***
g	Supply Chain Performance (Systemization) $R^2 = 0.211$	Constant		-0.127	0.179	-0.709
		Electronic Linkage Effect (Quality of Information)	0.364	0.376	0.171	2.198**
		Electronic Linkage Effect (Cost/time of Information acquisition)	0.200	0.215	0.188	1.143
		Supply Chain Coordination Effect	0.362	0.368	0.165	2.232**
		Co-engineering Effect	0.180	0.251	0.242	1.037

SuiteTable 4. - Results of Regression Analyses

g	Supply Chain Performance (Modularization) $R^2 = 0.158$	Constant		-0.069	0.181	-0.378
		Electronic Linkage Effect (Quality of Information)	0.317	0.327	0.174	1.879*
		Electronic Linkage Effect (Cost/time of Information acquisition)	0.102	0.109	0.191	0.573
		Supply Chain Coordination Effect	0.319	0.323	0.167	1.929*
		Co-engineering Effect	0.123	0.170	0.244	0.698
g	Supply Chain Performance (Sales) $R^2 = 0.417$	Constant		3.439	0.150	22.925***
		Electronic Linkage Effect (Quality of Information)	0.313	0.445	0.155	2.879***
		Electronic Linkage Effect (Cost/time of Information acquisition)	0.350	0.476	0.147	3.231***
		Supply Chain Coordination Effect	0.343	0.478	0.152	3.151***
		Co-engineering Effect	0.402	0.583	0.159	3.677***
g	Supply Chain Performance (Profit) $R^2 =$	Constant		3.679	0.155	23.686***
		Electronic Linkage Effect (Quality of Information)	0.281	0.396	0.160	2.477**
		Electronic Linkage Effect (Cost/time of Information acquisition)	0.320	0.432	0.153	2.835***
		Supply Chain Coordination Effect	0.355	0.489	0.157	3.116***
		Co-engineering Effect	0.358	0.515	0.164	3.136***

* Significant at α = 0.1 level ** Significant at α = 0.05 level *** Significant at α = 0.01 level

First, electronic linkage between the suppliers and automobile manufacturers increases exchange of information. The information exchanged between partners is about transaction processing, new product, purchasing, sales, and inventory. Second, if the involvement of the participants is high and the contact between suppliers and automobile manufacturers is intensive, the exchanged information is shared and transformed into valuable information. Third, information sharing increases the extent of coordination/co-engineering – collaborative programs and effective divide of roles – among the firms in the supply chain. Fourth, learning in supply chain promotes co-engineering among partners in a supply chain. Finally, electronic linkage, supply chain coordination, and co-engineering affects supply chain performance.

Interestingly, IT has a significant impact on sales, profit, and modularization, but not on cost savings. There was not significant relationship between electronic brokerage effect and electronic integration effect. Probably, there are other variables that affect electronic integration of information. This needs to be examined further in future research.

CONCLUSIONS

In this study, it was shown that e-SCD has significant effects on the supply chain coordination and collaboration. This implies that e-SCD can be an effective management tool to deliver customized products with right timing and price.

The result of this study has several implications for future electronic supply chain study. First, the impact of IT on supply chain is more on knowledge sharing and product development rather than cost savings through electronic data exchange. Efficient customization can be achieved by transforming the e-SCN into a “knowledge-sharing network” through the information intermediation and integration effects.

Second, the empirical results show that the involvement of suppliers is one of the most critical factors for an e-SCN to evolve into a “knowledge-sharing network.” The result implies that firms need to carefully develop trust-building mechanisms, such as fair profit allocation rules, to develop mutually trusting relationships. If e-SCD destructs the relationship between manufacturer and its suppliers, then the B2B e-SCN would become a simple medium to exchange transaction data and search for low price commodity goods.

Third, electronic supply chain network affect supply chain performance in sales, profit, and modularization capability. The effect on direct cost savings is weaker than the effects on sales, profit, and modularization capability. This implies that fundamental impact of IT on supply chain performance can be achieved when the network is evolves from a network for data exchange into knowledge sharing space.

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