Electronic commerce applications for supply chain integration and competitive capabilities

An empirical study

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Abstract

Purpose – The purpose of this paper is to empirically examine the impacts of supplier- and customer-oriented electronic communication technologies (ECTs) (electronic data interchange (EDI) and internet-based) on supply chain integration and manufacturing competitive capabilities (flexibility and quality).

Design/methodology/approach – The research model is based on resource-based view of technology use, ECTs, and supply chain management literature. Data from 711 international manufacturing firms International Manufacturing Strategy Survey (IMSS IV) are analyzed using exploratory factor analysis and structural equation modeling to test the proposed relationships.

Findings – The results suggest: the importance of applying two specific ECTs (EDI and internet-based) for both supplier and customer integration; and the direct impact of supplier integration and customer integration on manufacturing competitive capabilities.

Research limitations/implications – Except for perceptual biases inherent to survey methodology, this research provides rich implications on ECTs (particularly, EDI and internet-based) on supply chain integration and manufacturing competitive capabilities.

Practical implications – The findings of this research provide practical management insights on ECTs investment and deployment practices. Creation and delivery of values require effective integration of technologies for key performance outcomes across suppliers, customers and internal business processes.

Originality/value – This paper fills the research gap by presenting a research model and empirically validates how ECTs impact on quality and flexibility based on rich empirical data of 711 firms of manufacturing firms.

Keywords Communication technologies, Supply chain management, Competitive strategy, Electronic commerce, Electronic document delivery, Operations management

Paper type Research paper

1. Introduction

Increasingly, researchers recognize the strategic importance of integrating suppliers, manufacturers, and customers (Bagchi and Skjoett-Larsen, 2005; Zailani and Rajagopal, 2005; Power, 2005). Lambert and Cooper (2000) define the essence of supply chain management (SCM) as integration of information flows, product flows and multiple business processes throughout the value chain. Supply Chain Operations Reference model recommend five business processes (i.e. plan, source, make, delivery, and return) be strategically linking suppliers and customers to manufacturers. Effective integration of suppliers into supply chains through business processes (e.g. product development and commercialization) is a key factor for manufacturing firms in achieving reliable

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supply chain performance and thus competitive advantages (Ragatz *et al.*, 1997; Koufteros *et al.*, 2005; Lee *et al.*, 2007).

In this current environment of global market turbulence companies compete based on their network capabilities that include both suppliers and customers. Changing customer demands in the marketplace require effective information flows through the supply chains (Lambert and Cooper, 2000; Gunasekaran *et al.*, 2002). Information and communication technologies such as electronic data interchange (EDI) and the internet with its world wide web (WWW) have significantly increased the efficiency and effectiveness of supply chain communication and coordination (Gunasekaran and Ngai, 2004). Rai *et al.* (2006, p. 226) note a critical aspect of SCM as "a digitally-enabled inter-firm process capability" that require coordination of activities across functional units, geographic regions, and network partners. In this context, effective supply chain integration requires strategic selection and implementation of appropriate information systems, vendor, standards (e.g. XML, EDIFACT, etc.), and platform (e.g. internet-based, EDI, etc.) (Sarkis and Talluri, 2004). Electronic communication technologies (ECTs) may provide opportunities for organizations to expand their global market scope (Gunasekaran and Ngai, 2004).

However, the effect of ECTs on supply chain performance is not necessarily clear and straightforward. Craighead and Shaw (2003) emphasize a critical role of ECTs on SCM. SCM council estimates that optimization of tasks (e.g. inventory levels, competitive costing, financing/payment, and forecasting needs) can save an entity 6 percent of its total revenue (Boubekri, 2001). ECTs enable the collaboration in a supply chain more effective in terms of real-time speed information, connectivity, and information transparency (Boubekri, 2001; Golicic *et al.*, 2002; Gunasekaran *et al.*, 2002; Cassivi *et al.*, 2005).

In view of an increasing role of information and communication technologies across organizations in supply chains, information systems researchers have recognized a growing research need for benchmarking practices in terms of performance outcomes (e.g. flexibility, quality, and cost savings) (Li *et al.*, 2006). Implementation of such ECTs is costly (Jajaraman, 2002). Studies show conflicting results in regard to the effect of information technologies on SCM performance outcomes (Kanakamedala *et al.*, 2003). Mahadevan (2000) suggest careful evaluation of the actual impact of investment of these technologies on interorganizational performance outcomes. Rai *et al.*'s (2006) in particular investigate how IT creates performance gains for firms in a SCM context through organizational capabilities. Nonetheless, further empirical validations are needed in the context of IT-enabled supply chain.

Given the importance of electronic information and communication technologies to supply chain integration, and its heavy investment requirements but limited empirical studies, especially at a large-scale level, the paper aims to examine the impacts of supplier- and customer-oriented ECTs (EDI and internet) on supply chain integration to yield manufacturing competitive capabilities (flexibility, and quality). This study investigates the following research questions:

RQ1. Do ECTs (EDI and internet) enhance supply chain integration and manufacturing competitive capabilities?

RQ2. Does supply chain integration (supplier and customer) impact manufacturing competitive capabilities?

Research framework and concepts are drawn from the literature streams of resource-based view of technology use, ECTs, information systems, and SCM. The remainder of this paper is organized as follows. The next sections introduce the literature review, a research model and hypotheses. The research methodology is described and the findings are presented in the Section 4. The last part of this paper presents implications and summarizes the key contributions.

2. Literature review

In this section, we review literature of ECTs (particularly, EDI and internet), supply chain integration, and manufacturing competitive capabilities.

2.1 Electronic communication technologies

An electronic commerce application is a combination of IT hardware and software that intends to facilitate business processes (Kalakota and Whinston, 1996). Kalakota and Whinston (1996) classify electronic commerce application into four types:

(1) *Communication*. EC is the deliverer of information, products/services or payments over telephone lines, computer networks or any other electronic means.

(2) *Business process*. EC applications that enhance the automation of business transaction and work flows.

(3) *Service*. EC applications that address the desire of firms, consumers, and management to cut service costs while improving quality of goods and increasing speed of service delivery.

(4) *Online*. EC applications that provide the capacity to buy and sell products and information on the internet as well as other online services.

Some of the typical ECTs include phone, fax, EDI, electronic mail, and the internet (Gunasekaran *et al.*, 2002).

Among these diverse ECTs the focus of this research is EDI and the internet. EDI is an inter-organizational system that includes:

> [. . .] the movement of business documents electronically between or within firms in a structured, machine-retrievable, data format that permits data to be transferred, without re-keying, from a business application in one location to a business application in another location (Hansen and Hill, 1989, p. 403).

EDI is computer-to-computer exchange of business documents without human intervention. EDI can handle high-volume transactional traffic between companies and enables them to exchange precisely formatted business orders, payments, or even engineering drawings, electronically via a direct communication linkage (Gunasekaran *et al.*, 2002). EDI allows a private network of large firms to be electronically connected in the areas of the back end information exchanges (e.g. invoice exchange, order documents, and inventory management). In contrast, the internet has surpassed EDI in information sharing capabilities and cost beyond these predefined organizational boundaries (Chopra *et al.*, 2001).

Internet is a global system of interconnected computer networks that interchange data by using the standardized internet protocol suite (IP). It is a hardware and software infrastructure that provides connectivity between computers through copper wires, fiber-optic cables, wireless connection, and other technologies linkages. The internet carries various information resources and services such as electronic mail, online chat, file transfer, file sharing, etc. internet-enabled supply chain integration is regarded as a strategic competitive weapon because of its potential contribution for effective information sharing at relatively low transaction costs (Sanders, 2007). The three main characteristics of the internet are open standard, public network, and wide connectivity in SCM (Zhu and Kramer, 2005). According to a survey by Lancioni *et al.* (2000), 90 percent of the respondents report that they use internet for their supply chain business activities. Internet-based communication and information technologies improve the efficiency of supply chain through real-time information on critical information requirements (e.g. inventory details, shipment status, and product availability). Thus, firms may achieve more effective network coordination, product and services visibility and responsiveness to customer demands in global market places (Chen and Paulraj, 2004; Devaraj *et al.*, 2007).

2.2 Supply chain integration

Integration of internal functions aims for performance enhancement. Historically, many US firms implemented a high degree of vertical integration for their competitive advantages (Hayes and Wheelwright, 1984). A primary goal of integration is to bring various functions in a company and work together for common business purposes (Das *et al.*, 2006). With an increasing level of outsourcing practices firms look for beyond such tight vertical integration for their sustainable competitive advantages (Hayes *et al.*, 2005). In this new business environment, effective integration across supply chains require both:

(1) internal integration across functions within a single organization; and

(2) external integration through coordination linkages between organizations (suppliers-manufacturers-customers) (Pagell, 2004).

According to Swink *et al.* (2007) classify external integration into supplier integration (integration that occurs between suppliers and manufacturers) and customer integration (integration that occurs between manufacturers and customers). Devaraj *et al.* (2007) view demand-oriented integration in terms of sharing of real-time point-of-sales data, sales forecasts, customer profiling, and customer relationship management while supply oriented integration from the standpoint of inventory ordering policies, inventory levels and master production schedules. Therefore, effective integration in supply chains requires both supplier integration for the supply side customer integration for the demand side.

2.3 Manufacturing competitive capabilities

Skinner (1969) suggests that firms take manufacturing capabilities in the form of cost, quality, and time as a source of their competitive advantages. Stalk *et al.* (1992, p. 62) emphasize that competitive capabilities "distinguish a company from its competitors in the eyes of its customers." Competitive capabilities are also expressed to describe as intended potential capabilities (Hayes and Wheelwright, 1984; Roth and van de Velde, 1991), realized capabilities (Roth and van de Velde, 1991), or order winner and qualifier comparative capabilities (Hill, 1994). These researchers consistently suggest four key dimensions of competitive capabilities as cost, delivery, quality, and flexibility (Ward *et al.*, 1996; Souza and Williams, 2000).

Electronic commerce and information systems literature have also investigated extensively on the impact of digitally-enabled SCM on cost and delivery performance (Chen and Pauraj, 2004; Devaraj *et al.*, 2007; Frohlich and Westbrook, 2002; Li *et al.*, 2006; Park and Yun, 2004; Power and Sohal, 2002; Rosenzweig *et al.*, 2003). Electronic commerce communication technologies such as EDI and internet-based technologies enable organizations to access information faster, easier, and at real time. Thus, they allow faster processing speed, greater accuracy, reduced production lead time, reduced production costs, reduced transaction cost, increased delivery speed, and increased delivery reliability (Chen and Pauraj, 2004; Devaraj *et al.*, 2007; Frohlich and Westbrook, 2002; Li *et al.*, 2006; Park and Yun, 2004; Power and Sohal, 2002; Rosenzweig *et al.*, 2003). A research by Devaraj *et al.* (2007) attempts to study cost, quality, flexibility, and delivery as the benefits of using e-business technologies to support supply chain integration. Nevertheless, instead of considering these outcomes as four individual constructs, the authors operate them as four dimensions (four item measurements) of operational performance construct. A research gap exists in regard to empirical validations on how ECTs impact two critical dimensions of competitive capabilities (i.e. flexibility and quality). Thus, the focus of this paper is to present a research model that investigates the role of ECTs on quality and flexibility constructs and empirically validates based on 711 manufacturing firms worldwide.

Quality is a very complex and rich construct. Garvin (1984) provides a well-known framework for measuring quality of manufactured product that is a multidimensional construct with eight dimensions including performance, features, reliability, conformance, durability, serviceability, aesthetics, and perceived quality. Various researchers suggest multiple dimensions of quality in terms of product performance, services outcomes, customer satisfaction, and employee processes and morale (Bettman, 1993; Goodman *et al.*, 1994; Juran, 1993; Ward *et al.*, 1996; Sebastianelli and Tamimi, 2002). For the purpose of this study, we adopt four critical dimensions of quality in terms of product quality and reliability, customer services and support, employee satisfaction, and environmental performance.

Similarly, flexibility is a multidimensional concept as well. Sethi and Sethi (1990) develop a list of 11 dimensions for flexibility construct. These dimensions are machine flexibility, material handling flexibility, operational flexibility, process flexibility, product flexibility, routing flexibility, volume flexibility, expansion flexibility, program flexibility, production flexibility, and market flexibility. According to Souza and Williams (2000), some dimensions of flexibility are strategic in nature and others are tactical in nature. This hierarchical nature of manufacturing flexibility is also noted with terms such as primary (strategic) and secondary (tactical) (Watts *et al.*, 1993). Souza and Williams (2000) further classify primary flexibility dimensions into externally-driven dimensions (toward meeting the market needs of the firm) and internally driven dimensions (toward operational activities of the manufacturing function). In this paper, we approach flexibility in terms of volume and mix in that they are two critical indicators of strategic flexibility. The definitions and references for all six constructs under this study are summarized in Table I.

Constructs	Definitions	References
Supplier-oriented ECTs	Supplier-oriented ECTs are combination of IT hardware and software such as EDI and the internet that are used to facilitate business activities between suppliers and manufacturers through some type of electronic medium	Kalakota and Whinston (1996), Gunasekaran *et al.* (2002) and Gunasekaran and Ngai (2004)
Customer-oriented ECTs	Customer-oriented ECTs are combination of IT hardware and software such as EDI and the internet that are used to facilitate business activities between customers and manufacturers through some type of electronic medium	Kalakota and Whinston (1996), Gunasekaran *et al.* (2002) and Gunasekaran and Ngai (2004)
Supplier integration	Supplier integration is the extent to which suppliers and manufacturers coordinate decisions related to inventory management, collaborative planning, forecasting, replenishment, and the flows of physical resources	Pagell (2004), Koufteros *et al.* (2005), Das *et al.* (2006), Lee *et al.* (2007) and Swink *et al.* (2007)
Customer integration	Customer integration is the extent to which customers and manufacturers coordinate decisions related to inventory level, production planning, demand forecasting, order tracking, and products delivery	Pagell (2004), Koufteros *et al.* (2005), Das *et al.* (2006), Lee *et al.* (2007) and Swink *et al.* (2007)
Quality	Quality is the extent to which a product or service meets and/or exceeds customer's expectations, conformance to specifications, and other excellence requirements	Garvin (1984), Bettman (1993), Goodman *et al.* (1994), Juran (1993), Ward *et al.* (1996) and Sebastianelli and Tamimi (2002)
Flexibility	Flexibility is the ability to change the level of output of a manufacturing process and to produce a number of difference combinations of products to meet the market needs of the firm	Sethi and Sethi (1990), Watts *et al.* (1993) and Souza and Williams (2000)

Table I.
Construct definitions

3. Theory development

3.1 ECTs and supply chain integration

Rapid deployment of technologies has impacted changes in business environment since 1990s. D'Aveni (1994) called marketplace "hyper-competitive" in that firms wrestle with world-wide competitors who are able to offer products and services faster, cheaper, and higher quality. Such multiplying options of product and services allow customers to be more demanding and discriminating and firms struggle to respond to these changing customer requirements (Ellinger *et al.*, 1997). Toward the end of 1990s, competition patterns switch from firm versus firm to supply chain versus supply chain. Global Supply Chain Forum defines SCM as "[…] the integration of key business processes from end-user through original suppliers that provides products, services, and information that add value for customers and other stakeholders" (Lambert and Cooper, 2000).

Supply chain literature thus recognizes two major flows in a supply chain: product flows and information flows (Craighead and Shaw, 2003).

While effective supply chain integration is considered as a key factor to gain competitive advantage (Bowersox and Closs, 1996), firms have not been able to fully integrate their supply chains. According to Thomas (1999), although 90 percent of North American manufacturers believe that SCM is very important to their companies' success, fewer than 10 percent of firms rate their management of supply chain activities as "world class." Successful examples of supply chain integration like Dell and Cisco suggest that an extensive data management and effective information sharing requires the use of information communication technologies (ECTs) (Zhou and Benton, 2007). With this in mind, the relationship between supply chain integration and ECTs in the context of SCM is shown in Figure 1.

According to Gunasekaran and Ngai (2004, p. 270), ECTs are electronic commerce applications such as EDI, the internet, and WWW. These technologies are "[. . .] like a nerve system for supply chain management." ECTs support supply chain integration by facilitating information flow and allowing valuable information to be available "[. . .] at the right place, at the right time, and in the right hands of people" (Fawcett *et al.*, 2008, p. 37). Zhou and Benton (2007) emphasize the importance of effective information sharing in enhancing supply chain initiatives, including vendor managed inventory, continuous replenishment program, collaborative forecasting and replenishment, and efficient customer response. Increasingly, an effective use of ECTs is critical for supply chain integration (Golicic *et al.*, 2002; Gunasekaran *et al.*, 2002; McGaughey, 2002; Power and Sohal, 2002; Gunasekaran and Ngai, 2004; Cassivi *et al.*, 2005; Fawcett *et al.*, 2008).

Volkoff *et al.* (1999) make it clear that the systems must fit within the organizational requirements of the supply chain members. In addition, Bakker *et al.* (2008) suggest that the adoption of electronic commerce applications should match with firms' contextual factors such as organizational characteristics (internal context) and supply chain structural characteristics (external context). In reality, no single application is capable for the wide use throughout diverse entities of the supply chain. Sarkis and Talluri (2004, p. 319) suggest that "the selection of an appropriate system, vendor, platform, and media are necessary" for successful supply chain integration. A great deal of efforts for supply chain integration requires the development of standardized electronic commerce applications or effective communications among a variety of standards with varying levels of abstraction across organizations in a supply chain. Literature also suggests that the use of ECTs is different:

- between suppliers and manufacturers (i.e. supplier integration) and; and
- between customers and manufacturers (i.e. customer integration).

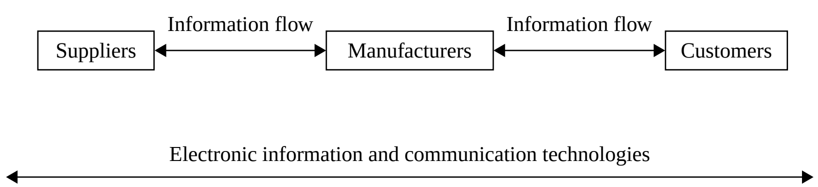


Figure 1.
Supply chain integration and ECTs in SCM and electronic commerce literature

Therefore, in this research, we study the impacts of ECTs on suppliers and customers separately. We hypothesize that the higher usage of electronic ECTs by the supply chain members will affect positively the success of supply chain integration:

H1a. Higher usage of customer-oriented ECTs is positively related to the higher level of customer integration.

H1b. Higher usage of supplier-oriented ECTs is positively related to the higher level of supplier integration.

Figure 2 shows the research model that proposes the specific relationships between:

- customer-oriented ECTs (*H1a*) and supplier-oriented ECTs and supplier integration (*H1b*);
- supplier integration and competitive capabilities (i.e. flexibility and quality) (*H2a* and *H2b*);
- customer integration and competitive capabilities (i.e. flexibility and quality) (*H3a* and *H3b*);
- supplier-oriented ECTs and two aspects of competitive capabilities (i.e. flexibility and quality) (*H4a* and *H4b*); and
- customer-oriented ECTs and competitive capabilities (i.e. flexibility and quality) (*H5a* and *H5b*).

3.2 Supply chain integration and manufacturing competitive capabilities

According to Swink *et al.* (2007), strategic fit theory, information processing theory, and the knowledge-based view of organization all suggest that supply chain integration lead to superior manufacturing competitive capabilities. Strategic integration helps organizations to match resource deployments with customer demands and thus

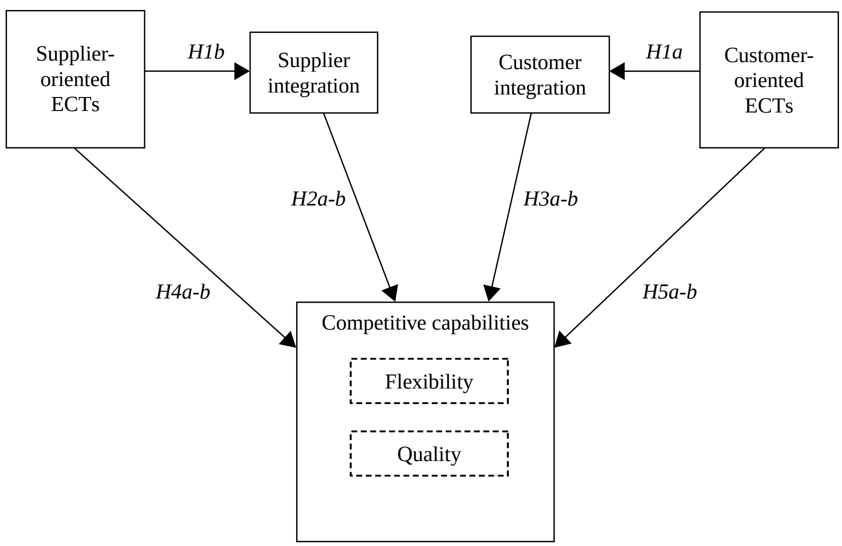


Figure 2.
Model of ECTs for supply chain integration and manufacturing competitive capabilities

achieving a fit between manufacturing competitive capabilities and the market environment. Information processing perspective suggests that IT-enabled supply chain integration allows rich communications among manufacturing decision makers (e.g. manufacturers, suppliers, and customers). These communications enable firms to anticipate and respond faster and better to changes in customers' demand, new markets, and technological opportunities which then also result in superior manufacturing competitive capabilities.

A growing body of SCM literature has also reported a positive association between the level of integration (with suppliers and customers) and manufacturing competitive capabilities. Lee *et al.* (2007) indicate that supplier integration is a strategic priority for achieving supply chain reliable performance. Other empirical studies validate the direct and positive impacts of supply chain integration on productivity, flexibility, and quality (Rosenzweig *et al.*, 2003; Droge *et al.*, 2004; Swink *et al.*, 2005, 2007). Ettlie and Reza (1992) suggest that:

- tight customer integration impacts new system flexibility positively and; and
- such effective communication among supply chain partners allows manufacturing firms to produce products with the consistent quality features.

Other authors also tested the impacts of supply chain integration on new product development (Koufteros *et al.*, 2005). Kim (2006) found that in firms with higher level of internal and external integration, supply chain integration has a direct influence on firm performance. Therefore, we posit that the higher supply chain integration level will positively impact firms' flexibility and quality dimension of manufacturing competitive capabilities:

H2a. Higher supplier integration is positively associated with higher flexibility.

H2b. Higher supplier integration is positively associated with higher quality.

H3a. Higher customer integration is positively associated with higher flexibility.

H3b. Higher customer integration is positively associated with higher quality.

3.3 ECTs and manufacturing competitive capabilities

There are multiple benefits from using ECTs. For instance, these tools are expected to make the flow of goods transparent and allow the integration of different functional areas within an organization such as marketing, purchasing, manufacturing/scheduling, logistics/transportation, and network optimization (Boubekri, 2001). Furthermore, Lee *et al.* (1997) point to the relevance of information exchange in reducing "bullwhip" effect.

Benefits of EDI have been empirically studied by a few researchers. For example, Mukhopadhyay *et al.* (1995) assessed the business value of EDI and found that EDI enabled effective use of information to coordinate material movements between manufacturers and suppliers, thus resulting in cost savings and inventory reduction. Likewise, Mohsen (1997) assert that EDI help firms reducing inventories, fostering JIT management, promoting engineering interchange, and improving work scheduling. In many cases, companies that have successfully implemented EDI have reported general benefits such as expedited purchasing processes, reduced transaction cycle times, higher inventory turnovers, faster response times, and overall improved service (Boudette, 1989).

While fewer in number, there are other studies that discuss the benefits of internet applications to organizations. For instance, Ovalle and Marquez (2003) propose that collaborative planning among supply chain partners utilizing internet and other low access cost applications can lead to inventory reduction of 10-50 percent for each of the supply chain members. Others speculate the benefits of internet applications in:

- shortening procurement cycles through the use of on-line catalogues, ordering, and payment;
- reducing development cycles and accelerating time-to-market through collaborative engineering, product, and process design, regardless of the location of participants;
- gaining access to world-wide markets at a fraction of traditional costs;
- reducing cost of communications and speeding up communication that have potentially positive impacts on manufacturing, marketing, inventory, and purchasing;
- enhancing closer relationship with customers and suppliers; and
- increasing alternative sales channels and opportunities to tap new markets or markets niches (Gunasekaran *et al.*, 2002).

Gunasekaran *et al.* (2002) also indicate that using electronic bidding, assemblers such as IBM and Boeing can get sub-assemblies 15-20 percent less expensive than before and up to 80 percent faster.

According to the resource-based view (RBV), a firm's IT investments enable it to develop unique electronic commerce capabilities and affect its overall electronic commerce effectiveness (Zhu, 2004). At the first glance, these ECTs can be considered as commodity since they are readily available in the marketplace. Nevertheless, scholarly advocates of RBV for electronic commerce technologies argue that by removing the barriers of system incompatibilities, the integration of new technologies into an organization's electronic commerce systems makes it possible to build a unique corporate platform for launching these applications. This uniqueness can be valuable, rare, inimitable, and non-substitutable and thus the IT assets evolve from commodity assets to become strategic assets of the firm.

Using RBV, many other authors have supported IT as a potential source of sustained competitive advantage (Craighead and Shaw, 2003). Authors such as Mata *et al.* (1995) and Bharadwaj *et al.* (1999) stress the impacts of IT on firms' competitive capabilities. Recent studies in IS research suggest that outstanding firms exploit IT resources for the development of new organizational capabilities which further enhance their sustainable competitive advantages (Devaraj *et al.*, 2007; Rai *et al.*, 2006; Teece *et al.*, 1997). Based on RBV of technologies, we hypothesize that higher usage of ECTs will influence positively competitive capabilities:

H4a. Higher usage of supplier-oriented ECTs is positively associated with higher flexibility.

H4b. Higher usage of supplier-oriented ECTs is positively associated with higher quality.

H5a. Higher usage of customer-oriented ECTs is positively associated with higher flexibility.

H5b. Higher usage of customer-oriented ECTs is positively associated with higher quality.

4. Research methodology

In this section, we discuss our data collection process and move from the theoretical domain to the operational domain. We start with the operationalization of the constructs using exploratory factory analysis approach then proceed to test the hypotheses using structural equation modeling Analysis of Moment Structures (AMOS 7.0).

4.1 Data collection

Empirical data from IMSS IV were used for testing our hypotheses. IMSS IV data were collected under the fourth study (2005) by a global research project. Data were collected by national research groups within the global network using same questionnaire, approaching similar types of companies, and targeted product manager to fill in the questionnaire. In nations where English is not commonly used, the questionnaire was translated into the local language by research coordinators, typically a full-time university faculty in the areas of operations and SCM, thus ensuring reliable translation by someone familiar with the concept of business and operations strategy practices. The International Manufacturing Strategy Survey is an international co-operative research network of research groups. All research groups participating in the network collected data in their own country. The network has existed since 1990 and has conducted four rounds of similar survey as of 2005.

During the fourth survey of IMSS, 711 plant managers or manufacturing executives from 23 countries completed the questionnaire. All firms included in the study are classified as manufacturers according to International SIC code standards. Firms were contacted prior to mailing to assess participation interest. The questionnaire was then sent to plant managers or manufacturing executives in a sample of manufacturing units with more than 100 employees. The response rate was varied across country with the lowest of 25 percent which reasonably meets scholarly standards for survey method research.

The companies in the database represent traditional manufacturing and assembly industries, including the metal engineering, electronics, automotive, and semiconductor sectors. The database is purposefully biased towards high-performing companies as these companies are the ones that we can learn most of, in terms of the practices they deploy and how these practices help them achieve and sustain high-performance levels. In addition, the survey is primarily targeted at medium and large sized companies, which are companies with more than 50 employees. Table II presents geographical distribution and average company size of the sample by country.

4.2 Construct validity

The perceptual measures of supplier-oriented ECTs, customer-oriented ECTs, supplier integration, customer integration, flexibility, and quality constructs used in this study were selected according to the purpose of the research. Moreover, all measures were well supported by respective literature as discussed earlier. Items were submitted to exploratory factor analysis for construct validity. Factor loadings greater than

Table II.
Geographical distribution and average company size

Region	Number of respondents	Country	Number of respondents	Average company size
East Europe	75	Estonia	21	250
		Hungary	54	519
West Europe	145	Belgium	32	561
		Germany	18	995
		Ireland	15	586
		The Netherlands	63	376
		UK	17	137
North Europe	135	Denmark	36	425
		Norway	17	119
		Sweden	82	488
South Europe	68	Greece	13	510
		Italy	45	535
		Portugal	10	205
North America	61	Canada	25	289
		USA	36	663
South America	90	Argentina	44	300
		Brazil	16	2,704
		Venezuela	30	446
Australia/New Zealand	54	Australia	14	60
		New Zealand	30	110
Asia	38	China	38	2,520
Turkey/Israel	55	Israel	20	89
		Turkey	35	838
Total	711		711	619

0.50 are considered significant (Hair *et al.*, 1995). A scale with good internal consistency should have all items load on one factor (Mora-Monge *et al.*, 2006). A total of seven factors emerged from the factor analysis with oblimin rotation method. Most factor loadings above 0.65, which are considered to be generally high. All items loaded on their respective factors as shown in Table III. The cumulative variance explained by eight factors was 62.6 percent, which is considered as acceptable. Cronbach's coefficient alpha is popularly used to assess the degree of internal consistency within a particular scale. In general, alpha values of 0.6 or higher are considered to be acceptable (Churchill, 1979, Boyer *et al.*, 1997). As shown in Table III, all scales have alpha scores that are higher than 0.70. Overall, the measures have good reliability and validity. According to Schwab (1980), convergent can be established by the high-factor loadings and low cross loading (under 0.40). Therefore, factors show evidence of good convergent validity. Unidimensionality is the extent to which empirical measures are strongly associated with each other and represent a single concept. Tests for unidimensionality indicated that factor loadings associated with constructs were all statistically significant ($p \leq 0.01$). Factor loading and cross loadings are shown in Table IV.

4.3 Path analytic model

Descriptive statistics and the correlation matrix are presented in Table V. Structural models were specified based on hypothesized paths of theoretical model and analyzed using AMOS 7.0. Model-data fit was evaluated based on multiple fit indexes. The χ^2-statistics is perhaps the most popular index to evaluate the goodness of fit of

Item	SI	CI	SEECT	Factor CEECT	*F*	*Q*
Supplier integration (*SI*) ($\alpha = 0.704$)[a] (*scale: 1– none, 5– high*)						
How do you coordinate planning decisions and flows of goods with your key/strategic suppliers						
Require supplier(s) to manage or hold inventories of materials at your site (e.g. vendor managed inventory, consignment stock)	0.841					
Collaborative planning, forecasting, and replenishment	0.781					
Physical integration of the supplier into the plant	0.667					
Customer integration (*CI*) ($\alpha = 0.772$) (*scale: 1– none, 5– high*)						
How do you coordinate planning decisions and flow of goods with your key/strategic customers						
Share inventory level knowledge		−0.810				
Share production planning decisions and demand forecast knowledge		−0.639				
Order tracking/tracing		−0.763				
Agreements on delivery frequency		−0.694				
Supplier-oriented electronic ECTs (*SEECT*) ($\alpha = 0.866$) (*scale: 1– none, 5– high*)						
Indicate to what extent do you use electronic tools (internet or EDI based) with your key/strategic suppliers for the following						
Scouting/pre-qualify			0.768			
Auctions			0.591			
RFx (request for quotation, proposal, and information)			0.814			
Data analysis (audit and reporting)			0.727			
Order management and tracking			0.643			
Content and knowledge management			0.719			
Collaboration support services			0.692			
Customer-oriented electronic ECTs (*CEECT*) ($\alpha = 0.866$) (*scale: 1– none, 5– high*)						
Indicate to what extent do your key/strategic customers use electronic tools (internet or EDI based) with you for the following						
RFx (request for quotation, proposal, and information)				−0.702		
Data analysis (audit and reporting)				−0.746		
Access to catalogues				−0.763		
Order management and tracking				−0.755		
Content and knowledge management				−0.764		
How has your operational performance changed over the last three years (scale: 1– deteriorated more than 10 percent, 2– stay about the same, 3– improved 10-30 percent, 4– improved 30-50 percent, 5– improved more than 50 percent)						
Flexibility (*F*) ($\alpha = 0.729$)						
Volume flexibility					0.860	
Mix flexibility					0.804	

(*continued*)

Table III. Factor loading and reliability

Table III.

Item	SI	CI	SEECT	Factor CEECT	*F*	*Q*
Quality (Q) (α = 0.747)						
Product quality and reliability						0.662
Customer service and support						0.709
Employee satisfaction						0.794
Environmental performance						0.737

Note: [a]Cronbach *α* reliability coefficients

Table IV.
Factor loading and cross loading

Items	SI	CI	Constructs SEECT	CEECT	*F*	*Q*
SI1	0.841	0.029	−0.032	−0.070	0.031	−0.057
SI2	0.781	−0.046	−0.037	−0.110	0.080	−0.097
SI3	0.667	−0.054	0.119	0.090	−0.032	0.167
CI1	0.022	−0.810	0.030	0.017	0.089	−0.098
CI2	−0.092	−0.639	0.042	−0.225	0.046	0.086
CI3	0.001	−0.763	−0.049	−0.057	−0.090	0.031
CI4	0.144	−0.694	0.068	0.062	−0.003	0.071
SEECT1	−0.054	0.056	0.768	0.024	0.040	−0.117
SEECT2	0.127	−0.014	0.591	0.077	−0.004	0.029
SEECT3	−0.094	0.082	0.814	−0.029	0.095	−0.066
SEECT4	−0.024	−0.016	0.727	−0.156	0.074	−0.023
SEECT5	0.027	−0.090	0.643	−0.120	−0.036	0.045
SEECT6	0.054	−0.074	0.719	−0.042	−0.097	0.156
SEECT7	0.069	−0.137	0.692	−0.042	−0.117	0.142
CEECT1	−0.048	−0.125	0.151	−0.702	−0.027	−0.013
CEECT2	0.096	0.183	−0.024	−0.746	−0.110	0.104
CEECT3	−0.002	−0.194	−0.018	−0.763	0.052	−0.040
CEECT4	0.055	−0.067	0.099	−0.755	0.082	0.014
CEECT5	0.035	−0.087	0.071	−0.764	0.089	−0.028
F1	0.014	−0.055	−0.038	−0.015	0.860	0.067
F2	0.081	0.058	0.066	0.023	0.804	0.118
Q1	−0.080	−0.116	−0.070	−0.009	0.107	0.662
Q2	−0.001	0.107	0.025	−0.069	0.087	0.709
Q3	0.040	−0.043	0.002	0.073	−0.014	0.794
Q4	0.021	0.023	0.044	−0.056	0.018	0.737

Table V.
Descriptive statistics and correlations

	Mean	SD	1	2	3	4	5	6
1. SI	2.352	0.873	1					
2. CI	3.182	0.936	0.302*	1				
3. SEECT	2.575	0.861	0.321*	0.378*	1			
4. CEECT	2.729	0.994	0.338*	0.498*	0.550*	1		
5. *F*	3.048	0.767	0.196*	0.176*	0.165*	0.158*	1	
6. *Q*	2.836	0.628	0.256*	0.264*	0.218*	0.248*	0.443*	1

Note: *Significant at: 0.01 level

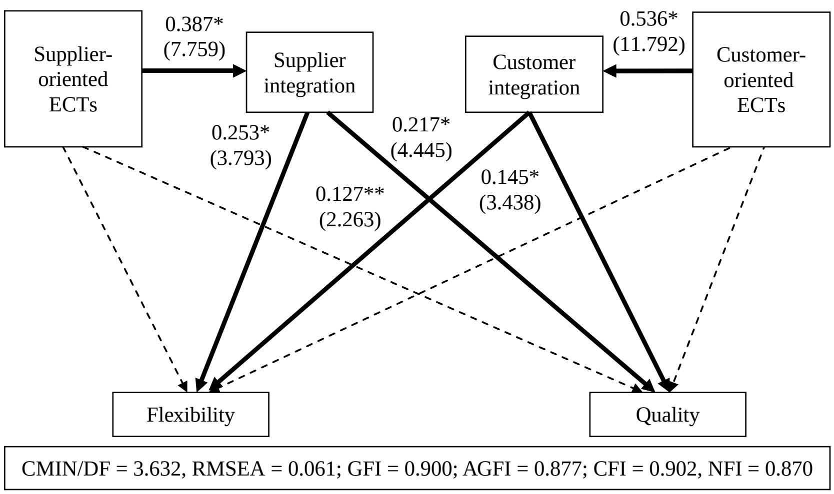
the model. It measures the differences between the sample covariance and the fitted covariance. However, this index has some disadvantages. The χ^2 index is sensitive to sample size and departures from multivariate normality. That is why, researchers have been turning to multiple fit criteria as suggested by Bollen and Long (1993) to reduce any measuring biases inherent in different measures. Some of the measures of overall model fit that are being used regularly by researchers are the goodness of fit index (GFI), the adjusted goodness of fit index (AGFI), comparative fit index (CFI), the root mean square error of approximation (RMSEA), and normed fit index (NFI) (Bagozzi and Yi, 1988; Bentler and Bonentt, 1980). GFI, AGFI, CFI, and NFI, scores in the 0.80-0.89 range are generally interpreted as representing reasonable fit; scores of 0.90 and above represent good fit (Chau, 1997). RMSEA values range from 0 to 1, with smaller values indicating better models; values below 0.05 signify good fit (Bryne, 1989).

The results of submitting our models to AMOS are shown in Figure 3. All of the fit indices (i.e. CMIN/DF, GFI, AGFI, CFI, NFI, and RMSEA) are reasonably comparable to the threshold and thus indicate that the model has reasonably good fit.

4.4 Research findings

Statistical results supports the positive relationships between supplier-oriented ECTs and supplier integration (*H1a*), between customer-oriented ECTs and customer integration (*H1b*), between supplier integration and flexibility and quality (*H2a*, *H2b*), and between customer integration and flexibility and quality (*H3a*, *H3b*). However, hypotheses *H4a*, *H4b*, *H5a*, and *H5b* were all not supported which indicate that using ECTs only will not result into better operational performance in flexibility and quality. Table VI presents the findings of the structural model.

The results of this study provide insights into designing effective ECTs-enabled supply chain integration for better flexibility and quality in manufacturing. A key finding is that ECTs (particularly, EDI and internet) support both supplier and customer integration efforts. While ECTs assist information sharing and integration activities



Notes: $*p \leq 0.001$, $**p \leq 0.05$; dashed line - not supported; bold line - supported

Figure 3.
Path analytical model of ECTs for supply chain integration and manufacturing competitive capabilities

Table VI. Summary of SEM statistical findings

Relationships	Model 1
Supplier-oriented ECTs → Supplier integration	*H1a* – supported (+)
Customer-oriented ECTs → Customer integration	*H1b* – supported (+)
Supplier integration → Flexibility	*H2a* – supported (+)
Supplier integration → Quality	*H2b* – supported (+)
Customer integration → Flexibility	*H3a* – supported (+)
Customer integration → Quality	*H3b* – supported (+)
Supplier-oriented ECTs → Flexibility	*H4a* – not supported
Supplier-oriented ECTs → Quality	*H4b* – not supported
Customer-oriented ECTs → Flexibility	*H5a* – not supported
Customer-oriented ECTs → Quality	*H5b* – Not supported

at both strategic and operational level between manufacturers and suppliers, they are still mainly used for operational integration activities between manufacturers and customers. Besides, in order to achieve operational performance advantages in flexibility and quality, firms must have clear processes and procedures to achieve supplier and customer related information integration for the effective use of ECTs. Therefore, mere investment on ECTs without clear strategic priorities of supply chain integration may not achieve desirable goals of competitive capabilities in terms of flexibility and quality performance.

5. Contributions and future research

5.1 Research contributions

Several contributions of this paper are stated in this section. First, the proposed model is based adequate literature reviews. Variables are defined and measured with high level of internal and external validity. This research model also examines the both aspects of supply chain integration (i.e. supplier- and customer-based ECTs) and two dimensions of competitive capabilities (i.e. flexibility and quality).

Second, this empirical test is based on the data of 711 manufacturing firms of 23 countries. Very few papers ever tested the impacts of electronic information and communication technologies (supplier- and customer-oriented EDI and internet uses) on supply chain integration and manufacturing competitive capabilities (flexibility and quality). The rich characteristics of this data (large-scale, multi-industry, and multi-country) enhance the generalizability of the research findings. The limited extant body of empirical literature studying the impact of ECTs on the SCM and performance outcomes such as flexibility and quality.

Third, the research findings extend the previous findings. Rai *et al.* (2006) found that integrated IT infrastructure enable firms to develop a higher-order capability of supply chain process integration (information, materials, and financial flow integration) and IT-enabled supply chain integration capability results in significant and sustained firm performance gains. However, this paper investigates dynamic interrelationships between the uses of EDI and internet, supply chain integration (external integration with supplier and customer), and firm performance outcomes (manufacturing competitive capabilities, particularly flexibility and quality) with much larger respondents from multiple countries. The results suggest noticeable patterns among manufacturing firms around the world in regard to supply chain integration. An effective supply chain integration requires integration of suppliers and customers through the selective uses of ECTs. Managerial implications are quite significant in that firms may start implementation of supply chain integration step-by-step with the available technologies.

In addition, the results support the notion that ECTs are "at best production-assistant technology, rather than production technologies" (Park and Yun, 2004). In another words, ECTs cannot produce value for firms unless they are used to assist and improve the operations of organizational and supply chain members' activities. Firms must develop a capability for supplier and customer integration to realize the benefits of ECTs. Therefore, it is critical to acquire, manage, maintain, operate, and integrate them accordingly to organizational and supply chain business and manufacturing processes.

Finally, the respondents of this research are mostly from the large pools of firms that are reputable for their business practices (i.e. best practices). We thus expect that our findings may be useful for a benchmarking purpose for many firms that consider investment and deployment of new technologies for sustainable competitive advantages.

5.2 Limitations and future research

No empirical study is without limitation. Several limitations should also be taken into considerations. The first limitation rests with the sample population. Limited responses in each of participating country may reduce the degree of generalizability to country-wide. Except for perceptual biases inherent to survey methodology, this research provides rich implications on ECTs (particularly, EDI and internet-based) on supply chain integration and manufacturing competitive capabilities. While ECTs are implemented in various industry sectors, manufacturing as well as service (e.g. finance and banking), this research used data collected from traditional manufacturing and assembly industries and thus the authors can only generalize the results to the metal engineering, electronics, automotive, and semiconductor sectors. Other research methods such as comparative studies across industries, case studies can broaden and deepen knowledge of the phenomena, especially for bench marking purpose. In business-to-business supply chain, there are many tiers of suppliers and customers. Future research may address the issue of how deep the integration should go and what kind of ECTs would be more beneficial as ECTs can require expensive investments that may not be affordable by small- and medium-sized companies. It would be worthy to explore further how firms should manage and deploy specific ECTs with suppliers and customers in regard to organizational size (e.g. small vs large organizations) as this study's database only presented medium and large sized companies' statistics.

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