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Impact of eBusiness technologies on operational performance: The role of production information integration in the supply chain

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Abstract

While the information technology (IT) literature is mixed regarding the direct benefits of eBusiness technologies on performance, the impact of such technologies on supply chain practices remains largely an unexplored area of research. We hypothesize that while there may be no direct benefit of eBusiness technologies on performance, these technologies might support customer integration and supplier integration in the supply chain, which in turn might impact operating performance.

To examine our hypotheses, we collected data from respondents who focused their responses to a single major product the process that manufactures it, a significant customer, and an important supplier. Our analyses showed that there was no direct benefit of eBusiness technologies on performance; however these technologies supported customer integration and supplier integration. Further, supplier integration was found to positively impact cost, quality, flexibility, and delivery performance; however there was no relationship between customer integration and performance. Consequently, there is a relationship between eBusiness technologies and supplier integration that leads to better performance. Further, there is an interactive effect between customer integration and supplier integration that supports the notion that firms that have both forms of integration, supported by eBusiness technologies, significantly outperform the others.

Keywords: eBusiness technologies; Customer integration; Supplier integration; Operational performance; Supply chain management

1. Introduction

With the advent of new eBusiness technologies, firms have engaged in initiatives that link supply chain processes across enterprises to create efficiencies and gain a competitive edge. The thrust of investment in eBusiness technologies is to create a seamless integration of entities in a supply chain, which calls for the sharing of accurate and timely information and the coordination of activities between business entities. Distorted information from one end of a supply chain to the other can lead to exaggerated order swings causing tremendous inefficiencies (Lee et al., 1997).

Despite the widespread adoption of eBusiness technologies, it is not clear whether eBusiness technologies have a direct affect on supply chain performance. Certainly, firms invest in eBusiness technologies with the presumption that they will facilitate supply chain integration and that performance will improve. Executives consider ''supply chain planning,'' ''linkages with customers,'' and ''linkages with suppliers'' to offer the greatest operational improvement opportunities, all of which are the capabilities most often transformed by eBusiness

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technologies in supply chain initiatives (D'Avanzo et al., 2003). Unfortunately, managerial expectations for these technologies have exceeded actual performance (Poirier and Quinn, 2003). Further, while the payoff from investing in information technologies has been a subject of long standing academic research and intense discussion, no clear conclusion has resulted. Payoffs from IT have been and continue to be open to debate in the literature, where it is called the ''IT paradox'' (Brynjolfsson and Yang, 1996). Largely due to the nature of the research designs employed, this stream of research has not definitively attributed the impact of individual technologies on organizational performance (Lee and Barua, 1999; Devaraj and Kohli, 2003). A direct linkage between eBusiness technologies and supply chain performance still remains an elusive entity. Thus, the first critical research question that this study seeks to address is ''Do eBusiness technologies have a significant impact on supply chain performance?''

One possible reason for the dissatisfaction with the performance of eBusiness technologies on the part of supply chain executives is that technology solutions were selected before certain process improvements were made, thereby diluting the paybacks for these investments (Poirier and Quinn, 2003; Zhu and Kraemer, 2002). A potential remedy may be the development of processes to improve integration, which can enhance relationships with distribution channel partners (Johnson, 1999) or cultivate supplier capabilities (Krause et al., 1998). To realize these benefits, firms use eBusiness technologies to engage in information sharing and other forms of collaboration between customers and suppliers that address the issues of production planning and scheduling of their products. We will refer to this specific form of integration as *production information integration*. New eBusiness technologies facilitate quick information sharing between downstream and upstream partners and enable companies like Dell Computer to ''trade inventory for information'' (Milgrom and Roberts, 1988; Dell, 1999). Capturing and sharing real-time information has become essential to improving supply chain performance. Timely information sharing helps speed up decision making and often results in shorter lead times and smaller batch sizes (Cachon and Fisher, 2000). In addition to information sharing, eBusiness technologies also facilitate the collaboration of supply chain entities. Examples include jointly developing demand forecasting (Koloczyc, 1998; Aviv, 2001) and vendor-managed inventory (VMI), also referred to as direct shipment or automatic replenishment (Buzzell and Ortmeyer, 1995; Cetinkaya and Lee, 2000; Kulp et al., 2004). Conceivably, if eBusiness technologies for production planning and scheduling do not have a direct effect on firm performance, they may have an *indirect* effect on performance via their impact on the processes developed for supplier and customer production information integration. This possibility has not been addressed in the literature. Thus, our second research question is ''Does production information integration constitute an important link in the pathway from eBusiness technology to supply chain performance?''

As indicated by Kauffman and Walden (2001), much of the existing eBusiness literature still relies heavily on case studies and anecdotes, with few empirical studies to measure Internet-based initiatives or gauge the scale of their impact on firm performance. Thus, there is a paucity of scientific analysis that clearly establishes the impact of eBusiness technology on strategic measures (Mukhopadhyay and Kekre, 2002). Since the evidence of both the success and failure of eBusiness initiatives has been generally anecdotal, we use a rigorous survey methodology in this paper to answer the two research questions. Specifically, we developed a set of hypotheses based on the literature to empirically test the pathway from eBusiness technology to performance, mediated by information integration. A unique aspect of our data set is that the respondents were asked to focus on their major product, the specific process that manufactures that product, the most important customer for the product, and the most important supplier for parts or components for the product. All data for the production information integration and performance variables were gathered in that context, which allowed the respondents to be specific about the value chain.

2. Literature and hypotheses

Our overarching premise is that eBusiness technologies add value to supply chain operations by enhancing production information integration. The focus of this paper is to provide insight into how firms can realize the benefits of those technologies. In this section we develop three constructs and a set of theory-based hypotheses on the role of eBusiness technologies in supply chain performance. These hypotheses are supported by three theories: resource-base view theory, the relational view theory, and the theory of swift and even flow, which will be discussed later. We performed an extensive survey of the literature that spanned the three areas pertinent to this study: eBusiness capabilities, production information integration, and operational performance. Table 1 is a concise summary of the representative references categorized by the three constructs mentioned above.

Table 1
Constructs and supporting literature

	Key references
eBusiness capabilities	
EBUSCUST	
(1) Customer buying online	Frohlich and Westbrook (2002), Lancioni et al. (2000), Mukhopadhyay and Kekre (2002) and Zhu et al. (2004)
(2) Customer configuration/customization	Barua et al. (2004), Pflughoeft et al. (2003), Ranganathan et al. (2004) and Zhu and Kraemer (2002)
(3) Customer online order tracking	Barua et al. (2004), Chen and Paulraj (2004), Frohlich and Westbrook (2002) and Zhu and Kraemer (2002)
EBUSPUR	
(4) Find/select suppliers	Barua et al. (2004), Pflughoeft et al. (2003), Zhu and Kraemer (2002) and Zhu et al. (2004)
(5) Online purchasing/auctions	Barua et al. (2004), Poirier and Quinn (2003), Ranganathan et al. (2004) and Zhu and Kraemer (2002)
EBUSCOLL	
(6) Web-based EDI	Frohlich and Westbrook (2001), Hill and Scudder (2002), Mukhopadhyay and Kekre (2002) and Zhu and Kraemer (2002)
(7) Collaboration on forecast, schedule, and replenishment	Barua et al. (2004), Frohlich and Westbrook (2002) and Hill and Scudder (2002)
(8) Advanced planning and scheduling (APS)	Barua et al. (2004), Frohlich and Westbrook (2002) and Poirier and Quinn (2003)
Production information integration	
(1) Sales forecast	Barua et al. (2004), Cachon and Lariviere (2001), Frohlich and Westbrook (2001), Krajewski and Wei (2001) and Lee et al. (1997)
(2) MPS	Barua et al. (2004), Frohlich and Westbrook (2001), Krajewski and Wei (2001) and Lancioni et al. (2000)
(3) Inventory	Barua et al. (2004), Frohlich and Westbrook (2001), Krajewski and Wei (2001), Lee et al. (1997) and Zhu and Kraemer (2002)
(4) Collaboration on net requirements	Barua et al. (2004), Cachon and Lariviere (2001), Krajewski and Wei (2001), Lee et al. (1997) and Zhu and Kraemer (2002)
(5) Supplier automatically replenishes inventory (VMI)	Buzzell and Ortmeyer (1995) and Lee et al. (1997)
Operational performance	
(1) Percent returns	Frohlich and Westbrook (2001), Poirier and Quinn (2003) and Rosenzweig et al. (2003)
(2) Percent defects	Frohlich and Westbrook (2001) and Rosenzweig et al. (2003)
(3) Delivery speed	Buzzell and Ortmeyer (1995), Chen and Paulraj (2004), Frohlich and Westbrook (2001) and Frohlich and Westbrook (2002)
(4) Delivery reliability	Buzzell and Ortmeyer (1995), Chen and Paulraj (2004), Poirier and Quinn (2003) and Rosenzweig et al. (2003)
(5) Production costs	Chen and Paulraj (2004), Frohlich and Westbrook (2001), Frohlich and Westbrook (2002), Poirier and Quinn (2003), Rosenzweig et al. (2003) and Zhu and Kraemer (2002)
(6) Production lead time	Buzzell and Ortmeyer (1995), Frohlich and Westbrook (2001), Ranganathan et al. (2004) and Rosenzweig et al. (2003)
(7) Inventory turns	Frohlich and Westbrook (2001), Ranganathan et al. (2004) and Zhu and Kraemer (2002)
(8) Flexibility	Chen and Paulraj (2004) and Rosenzweig et al. (2003)

2.1. eBusiness capabilities

eBusiness capability is the ability of a firm to use Internet technologies to share information, process transactions, coordinate activities, and facilitate collaboration with suppliers and customers. Clearly, traditional modes of communication such as phone and fax are still used by many firms to do business with customers and suppliers. Nonetheless, we focus on eBusiness technologies because so little is known about their impact on performance (Devaraj and Kohli, 2003; Mukhopadhyay and Kekre, 2002). In addition, many firms are using the Internet to do business in their supply chains. Ninety percent of the respondents in a survey reported in Lancioni et al. (2000) used the Internet in some part of their supply chain program. Although some firms have successfully integrated eBusiness technologies into their traditional bricks-and-mortar business models, many others still struggle with implementing and justifying eBusiness initiatives (Barua et al., 2000). The potential benefits for supply chains, however, are significant. Organizations use the web to improve customer relations by providing easier access to information, developing more flexibility to respond to customer information requests, and speeding up the transaction time to shorten product cycles (Lederer et al., 2001). Information technology has vast potential to facilitate collaborative planning among supply chain partners by sharing information on demand forecasts and production schedules (Chen and Paulraj, 2004). Through the Internet, information technology also enhances supply chain efficiency by providing real-time information regarding product availability, inventory levels, shipment status, and production requirements (Radstaak and Ketelaar, 1998; Lancioni et al., 2000; Chen and Paulraj, 2004).

Boone and Ganeshan (2001) indicate that the relationship between information technology implementation and productivity is determined in part by the use of technology. Information technology that becomes a part of the production process is associated with productivity improvements, unlike information technology that only documents or collects information. The mere institution of traditional EDI no longer results in strategic benefits to the supply chain; advancements such as fully integrated order-processing systems or electronic invoicing systems are also required (Mukhopadhyay and Kekre, 2002). The Internet, however, has enhanced traditional EDI systems by making them more flexible and affordable to smaller businesses (Lancioni et al., 2000; Zhu and Kraemer, 2002; Zhu et al., 2004). Nonetheless, many firms have gone beyond the confines of EDI and incorporated a multitude of Internet-based technologies to facilitate the connections between customers and suppliers.

Our eBusiness capability construct includes a broad set of technologies that are being used by firms to manage their supply chains. Table 1 shows the eight technologies we address in this study. While many more technologies exist, this set is based on the literature of the research and practicing communities and relates nicely to the types of technology most firms are acquiring to advance their supply chain competency: inventory planning and optimization, web-based applications, advanced planning and scheduling, and e-procurement systems (Poirier and Quinn, 2003). We classify the eight eBusiness technologies into three categories depending on their focus. The first category of technologies focuses on the demand side, which we call EBUSCUST, and relates to allowing customers to order online, configure or customize products online, and check the status of orders online. The second set of technologies focuses on the supply side, which we call EBUSPUR, and addresses the capability of the company to find and select suppliers online and purchase material through online auctions. Finally, the third set of technologies focuses on collaboration with customers or suppliers, which we call EBUSCOLL, and relates to web-based EDI, forecasting, inventory replenishment, and scheduling capabilities. Our eBusiness capability construct focuses on those technologies that conceivably relate to production information integration, which is the focus of this study.

2.2. Production information integration

Our production information integration construct embodies the nature of the information that is shared between entities in a supply chain and supported by the collaborative efforts that result in improved production information accuracy. Information sharing can be divided into demand oriented and supply oriented information sharing. Demand-oriented information sharing includes the sharing of real-time point-of-sales data, sales forecasts (Cachon and Lariviere, 2001; Aviv, 2001), customer profiling, and customer relationship management (Frohlich and Westbrook, 2002). Supply-oriented integration includes inventory ordering policies, inventory levels (Gavirneni et al., 1999) and master production schedules (Narasimhan and Das, 2001; Lancioni et al., 2000; Frohlich and Westbrook, 2001). Firms vary in the intensity of their production information integration depending upon the degree of Internet-based demand integration and the degree of Internet-based supply integration in their strategy. These strategies can range from little or no Internet-based integration to total integration from customers to suppliers (Frohlich and Westbrook, 2002; Straub et al., 2004).

Collaborative planning efforts must be considered along with information sharing to get a complete picture of production information integration. One of the most often cited initiatives firms put in place to enhance supply chain performance is collaborative planning with key customers/suppliers (Poirier and Quinn, 2003). One such form of collaborative planning is VMI, which has been shown to be positively related to manufacturer's margins (Kulp et al., 2004). Conceivably, information sharing gives firms a first step in supply chain integration; however, it is the capability for collaboration that separates the most successful firms from the rest of the pack.

Integration with supply chain partners is reflected by the five measures that are included in our production information integration construct, shown in Table 1. Demand forecasts from the customer provide suppliers more visibility to plan for capacity and material requirements (Lee et al., 1997; Frohlich and Westbrook, 2001). Further, sharing master production schedules with suppliers reduces forecast uncertainty and enables more detailed production quantity and timing (Lancioni et al., 2000; Wei and Krajewski, 2000; Krajewski and Wei, 2001). In addition, when a supplier has access to the customer's inventory status, more precise replenishment production and shipment can be scheduled.

A company invests in eBusiness technologies to facilitate more information sharing and collaboration with either its suppliers or its customers in the value chain. Web-based technologies that process purchase orders and track or expedite shipments are often cited as critical integration tools (Frohlich and Westbrook, 2002; Chen and Paulraj, 2004; Barua et al., 2004). Thus, we expect that eBusiness capability will have a positive influence on production information integration. Further, as Frohlich and Westbrook (2001, 2002) point out, integration efforts can take place with customers and/or suppliers. Consequently, our production information integration construct applies to customers separately from suppliers, which we will refer to as customer integration and supplier integration, respectively. This discussion leads to the following hypotheses, all being equal.

Hypothesis 1. eBusiness capability influences the degree of customer integration.

Hypothesis 1a. EBUSCUST has a positive influence on the degree of customer integration.

Hypothesis 1b. EBUSPUR has a positive influence on the degree of customer integration.

Hypothesis 1c. EBUSCOLL has a positive influence on the degree of customer integration.

Hypothesis 2. eBusiness capability influences the degree of supplier integration.

Hypothesis 2a. EBUSCUST has a positive influence on the degree of supplier integration.

Hypothesis 2b. EBUSPUR has a positive influence on the degree of supplier integration.

Hypothesis 2c. EBUSCOLL has a positive influence on the degree of supplier integration.

2.3. Operational performance

There is growing empirical evidence suggesting that higher levels of integration along the supply chain are associated with greater potential benefits. Armistead and Mapes (1993) use five items to measure strength of integration, including the extent of shared ownership of master production schedules and the level of information system integration. The results of their study indicated that increasing the level of integration does increase operating performance in quality, cost, delivery time, and flexibility. Using data from 215 North American manufacturing firms, Narasimhan and Jayaram (1998) propose that supply chain integration impacts external customer responsiveness and internal manufacturing performance via the key linkage between sourcing and degree of manufacturing goal achievement. Johnson (1999) shows that strategic integration results in enhanced economic rewards for the customer (distributor) firm. Based on the data from 57 tier-1 automotive suppliers, Vickery et al. (2003) found that customer service fully mediates the relationship between supply chain integration and firm performance. There was no significant direct relationship to firm performance from supply chain integration, or from integrated information technology.

While most studies in the literature focus on either the supply side or the demand side of integration, Frohlich and Westbrook (2001) address the question ''Is it more important to link with suppliers, customers, or both?'' Among the industrial goods manufacturers they surveyed, the firms with the greatest degree of integration, with both suppliers and customers, had the strongest performance improvement. In addition, firms that participated in the survey had a stronger degree of integration with their suppliers than with their customers in the following integrative activities: access to planning systems, sharing production plans, and knowledge of inventory mix/levels. In a separate but related study, Frohlich and Westbrook (2002) further distinguish web-based demand chain integration from supply chain integration. They report that manufacturing and services firms adopting both the demand integration and supply integration had the highest operational performance in delivery time, transaction costs, profitability, and inventory turnover. Ranganathan et al. (2004) found significant positive associations between the benefits realized from web technologies and both internal assimilation and external diffusion of such technologies to suppliers.

Rosenzweig et al. (2003) introduce supply chain integration intensity as a proxy variable for Frohlich and

Westbrook's (2001) "arc of integration." Their study involves a sample of 238 consumer products companies dominated by market leaders. They found no empirical evidence to support a direct effect between integration intensity and sales growth or customer satisfaction. Rather, it appears that the benefits of integration must first be translated into operational capabilities, such as product quality, delivery reliability, process flexibility, and cost. In other words, these operational capabilities mediate the relationship between supply chain integration and multiple measures of business performance. Our operational performance construct, shown in Table 1, also includes measures for cost, quality, delivery, and flexibility. Therefore, based on the above arguments, we propose the following hypotheses.

Hypothesis 3. A higher degree of customer integration leads to improved operational performance.

Hypothesis 4. A higher degree of supplier integration leads to improved operational performance.

2.4. Underlying theoretical support

While the above discussion provides support for our research model, our study of the relationships between eBusiness capabilities, production information integration, and operational performance is grounded on three theories: resource-based view (RBV), relational view, and theory of swift and even flow. While the first two theories have a basis in strategic management, the third one is rooted in operations management literature. The resources-based view (RBV) is based on the notion that a firm's performance is founded on its unique resources and capabilities that are hard to imitate, such as resource heterogeneity and immobility (Wernerfelt, 1984; Barney, 1991; Peteraf, 1993). In the context of RBV, studies have shown that the ability of a firm to develop and exploit new technologies and organizational processes, including eBusiness capabilities, will lead to sustainable competitive advantages (Mata et al., 1995; Teece et al., 1997; Straub and Klein, 2001; Zhu and Kraemer, 2002; Zhu, 2004). RBV provides the underlying foundation for the development of our eBusiness construct because this construct describes a firm's capability in eBusiness, which may be applied in a host of ways other than production information integration.

From the perspective of the relational view, a firm's critical resources may span its boundaries and be embedded in inter-firm resources and relationships (Dyer and Singh, 1998). This view takes the position that RBV tends to focus on the resources housed within a firm and, hence, overlooks the network of relationships in which the firm is embedded (Powell et al., 1996; Dyer, 1996, 1997). While the RBV theory tends to focus on the firm and understanding its competitive advantage from a resource perspective, the relational view theory focuses on the dyad or network relationships and processes (Straub et al., 2004; Chen and Paulraj, 2004). In this research, our production information integration construct is grounded on the relational view because we focus on a major product and its manufacturing process. We then investigate the intensity of integration specific to the product and process between the respondent firm and its customer, and between the respondent firm and its supplier, respectively.

Finally, our study is also grounded in the operation management theory of swift and even flow (Schmenner and Swink, 1998). The theory holds that the swifter and more even the flow of materials through a process, the more productive that process is. Thus, productivity for any process rises with the speed by which the material

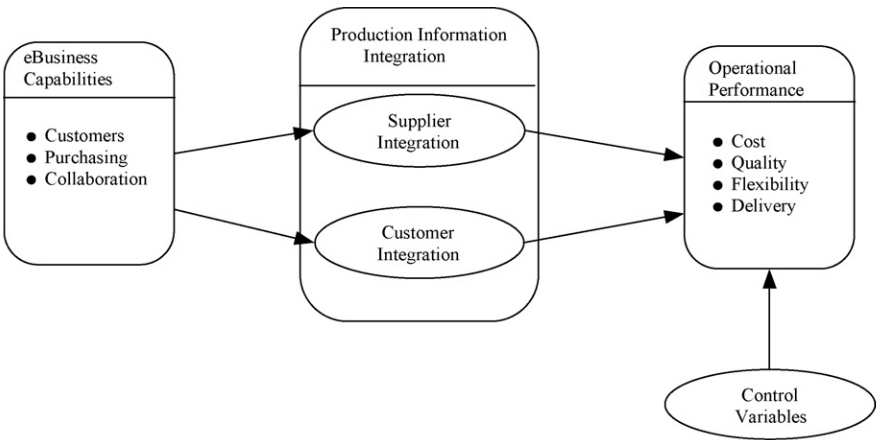

Fig. 1. Hypothesized model.

flows through the process, and falls with the increases in the variability associated with the flow. We postulate that strong eBusiness capabilities will lead to better production information integration with both the supplier and the customer. As a result, materials will flow through the supply chain more swiftly and evenly and bring forth improved operational performance.

Based on this discussion, Fig. 1 shows the hypothesized model.

3. Research design

3.1. Survey development

The survey was created in several stages. Initially, we developed questions involving eBusiness capabilities, production information integration, and operating performance based on the literature (see Appendix A). Next, we asked eight managers to take the survey and give us their suggestions for improvement and clarity. Finally, as a result of that pre-test, we made a number of changes to the instrument.

3.2. Sample

The target audience for the survey was selected from the following industries and SIC codes: computer components and peripherals (SIC 357), printed circuit boards and semiconductors (SIC 367), electronic equipment and supplies (SIC 369), and automotive bodies and parts (SIC 371). These SIC codes are within the ranges of recent supply chain studies (Dyer, 1996, 1997; Krause et al., 1998; Narasimhan and Das, 2001; Zhu and Kraemer, 2002; Chen and Paulraj, 2004). We used a stratified random sample of companies to ensure coverage of the target industries. The contact information was obtained from a professional database. To ensure that the respondent had expertise to accurately respond to the questions, we focused the survey on senior managers as key informants with titles such as 'Vice President,' 'Manager,' or 'Director', and with functional areas of expertise such as 'Operations', 'Production', or 'Manufacturing'. Key informants were used to obtain all of the data used in this study for several reasons. First, operational performance data at the plant level is generally not available from any source other than company records which is privy only to key persons in the organization. Further, many of the questions in the survey required adequate knowledge about the eBusiness capability, information sharing in the supply chain, and performance. It is more likely that a limited number of individuals in the plant rather than somebody selected at random in the plant would generally have an adequate knowledge of, or access to, this information. Under these conditions, key informants are commonly used to obtain the necessary data and enhance the likelihood of valid and reliable data (Huber and Power, 1985). Although key informants can provide reliable data as discussed above, consistent with prior research in operations management using key informants, inter-rater reliability cannot be assessed.

The data collection process resulted in 120 usable responses. After accounting for undelivered surveys and incomplete responses, we obtained a useable or effective response rate of 8.4%. A priori, a low response rate was anticipated due to the length of the survey and the fact we focused on top-level managers (Pflughoeft et al., 2003). Nevertheless, the proportions among the SIC codes in the 120 usable responses were close to the proportions in the surveys that were mailed out. This sample size is in comparable range with other respected empirical studies (Krause et al., 1998; Kulp et al., 2004). In general, the absolute size of the sample is more important than the proportion of the population sampled (Black, 1999; Fowler, 1993). Consequently, to ensure that our sample size was adequate, we used Verma and Goodale (1995) guidelines for computation of statistical power; for a medium effect sample size, the power is greater than 0.90 at a significance level of 0.05. The computation of statistical power yielded a value of 0.91.

3.3. Respondent profile

About 55% of the responses came from companies with less than 250 employees (small), 18% from companies with between 250 and 500 employees (medium), and the remaining 27% from large companies more than 500 employees. In terms of the distribution of responses from the various industries, about 49.2% of the responses were from the automotives industry and the remaining 50.8% from the electronics and computer industry. The percentages of the industries within the sample distribution are very close to the percentages of the surveys that were originally mailed out. There was no statistical difference between the distribution of responses and the sample distribution at a 5% level of significance.

As a test of non-respondent bias, we compared the responses of early respondents with those that were collected from respondents by telephone solicitation (non-respondents in the first round). A statistical test of the comparison between the two groups for the constructs employed in this study yielded no significant difference.

3.4. Measures

3.4.1. Construct validation

Appendix A provides the scale items and the exploratory factor analysis (EFA) factor loadings of the items utilized in this study.

3.4.1.1. eBusiness capabilities. Our construct for eBusiness capability has three categories as shown in Table 1: EBUSCUST, EBUSPUR, and EBUSCOLL. We examined the statistical properties of the scales in several ways. First, we performed a principal component factor analyses to examine if the underlying factor pattern for the eBusiness capabilities construct was consistent with the three categories mentioned above. The factor loadings using Varimax rotation are shown in Appendix A. All the items relating to eBusiness capabilities separate out into the three categories discussed above. A factor analysis of the constructs indicated that all items load onto a single factor with all factor loadings greater than 0.679, which are substantially above the minimum requirements of 0.40 (Nunnally and Bernstain, 1994; Gefen et al., 2000). Also there were no cross-loadings of any items on more than one component. In Table 2 we present evidence of this in terms of the factor loadings of the eight items of eBusiness capabilities. The eigen values are 2.093, 1.953, and 1.372. An examination of the factor loadings, eigen values, as well as scree plots provided robust evidence of a three-factor solution to the eBusiness capabilities scale. Taken together, this is preliminary evidence of the convergent and divergent validity of the scales for eBusiness capabilities. The cumulative percent of variance extracted by this factor structure was 67.8%.

We next examined the reliabilities of these scales as indicated by Cronbach's alpha. The reliabilities for EBUSCUST, EBUSPUR, and EBUSCOLL were 0.72, 0.70, and 0.76, respectively, which is considered higher than the recommended threshold (Nunnally, 1978).

Table 2
eBusiness capabilities—factor loadings

	Component		
	1	2	3
Item 1	.154	**.816**	.013
Item 2	-.081	**.740**	.127
Item 3	.134	**.752**	.081
Item 4	.115	.139	**.780**
Item 5	.117	-.035	**.839**
Item 6	**.679**	.136	.050
Item 7	**.888**	.006	.103
Item 8	**.847**	.063	.153

3.4.1.2. Supplier integration. The items employed in the construct for supplier production information integration (SUPINTEG) are extracted from the literature as shown in Table 1. A factor analysis of the items measuring supplier integration revealed a single factor solution with factor loadings in excess of 0.65 for each item. The percent of variance explained was 55.8%. Further, Cronbach's alpha for the reliability of the scale was 0.80.

3.4.1.3. Customer integration. Similar to the construct for supplier integration, our construct for customer production information integration (CUSINTEG) taps into the information sharing that takes place between the firm and its customers. The items for this construct were derived from the literature as shown in Table 1. The items loaded onto a single factor with factor loadings in excess of 0.67, providing evidence of the unidimensionality of the scale. The percent of variance explained was 53.4%. Reliability of this scale as assessed by Cronbach's alpha was 0.78.

3.4.1.4. Performance. Operational performance is typically assessed along the dimensions of cost, quality, flexibility, and delivery (Vickery et al., 1993; Miller and Roth, 1994; Devaraj et al., 2004). The cohesiveness of the items measuring operational performance was very high; all items loaded onto a single factor with factor loadings greater than 0.61. The percent of variance extracted was 57.3%. The reliability of the scale for performance was also very high (Cronbach's alpha of 0.89). Thus, we treat operational performance as a unidimensional construct in our analyses.

3.4.1.5. Control variables. We controlled for two variables that can also conceivably affect performance—type of industry and size of the firm (Zhu et al., 2004; Rosenzweig et al., 2003; Zhu and Kraemer, 2002; Frohlich and Westbrook, 2002). Respondents to our survey were from the automotive and computers/electronics industries. Thus, we used an indicator variable to depict the industry classification in our estimation models. Further, we also had information on the size of the firm (small—less than 250 employees, medium—between 250 and 500 employees, and large—greater than 500 employees). We used two indicator variables to capture the effect of the firm size on performance.

3.4.2. Confirmatory factor analysis

Structural equation modeling was used to perform a confirmatory factor analysis (CFA) for the measurement model. CFA allows for tests to be conducted for unidimensionality, convergent validity, and divergent validity of the scales employed in the study. Consistent with extant literature in eBusiness technologies (Zhu and Kraemer, 2002) we use EFA to develop the constructs and CFA to confirm their properties.

3.4.2.1. Unidimensionality. Unidimensionality is the extent to which empirical measures (indicators) are strongly associated with each other and represent a single concept. Tests for unidimensionality indicated that the factor loadings associated with constructs were statistically significant ($p \leq 0.01$).

3.4.2.2. Convergent validity. Convergent validity is the extent to which varying approaches to construct measurement yield same results (Campbell and Fiske, 1959). The value for the Bentler–Bonentt coefficient Δ (Bentler and Bonentt, 1980) was 0.91, indicating strong convergent validity.

3.4.2.3. Discriminant validity. Discriminant validity assesses the extent to which a concept and its indicators differ from another concept and its indicators (Bagozzi et al., 1991). To test discriminant validity, we compare two CFA models: one in which the correlation of a pair of constructs is constrained to equal 1.0 (model-a), and another in which the correlation is free to vary (model-b). The chi-square difference test checks the statistical significance of the statistic (chi-a minus chi-b) at $p < 0.01$ (Venkatraman, 1989). A statistically significant value of (chi-a minus chi-b), with a threshold of 32.0, demonstrates that the two constructs under consideration are distinct. This procedure is repeated for all pairs of scales in the instrument. For each pair of constructs, the chi-square test was statistically significant ($p \leq 0.01$) providing support for discriminant validity of constructs in all the measurement models.

3.4.2.4. Criterion validity. Criterion validity is the extent to which the items predict a set of criteria of interest. One way to assess this is to estimate the correlation between items used in the study with other measures that attempt to capture the same or similar criteria. As one example to illustrate criterion validity, we examined the correlation between the performance measures for delivery speed and delivery reliability with an objective measure of delivery performance (% products delivered on time) that was not used in this study. The correlation coefficients were 0.59 and 0.61 and very highly significant ($p < 0.001$). Another check examined the correlation between production lead time performance and an objective measure of manufacturing lead time in days. Again, the correlation was highly significant with a correlation coefficient of 0.27 and $p < 0.001$.

3.4.3. Bias

One of the potential sources of bias in survey research is common method variance. One of the procedures used to test for evidence suggesting the presence, or absence, of common method bias in a data set is the Harman's one-factor test (Podsakoff and Organ, 1986). An exploratory factor analysis was performed on the variables of interest. If a single factor is obtained or if one factor accounts for a majority of the covariance in the independent and criterion variables, then the threat of common method bias is high. We performed such a factor analysis by combining the independent and dependent variables and did not observe a single factor structure that explained significant covariance. This suggests that common method bias may not be a cause for concern in our sample.

Another source of potential bias is the use of subjective data. According to Miller et al. (1997), two criteria where subjective data may be reliable and valid are: (a) questions do not require recall from distant past, and (b) informants are motivated to provide accurate information. We promised confidentiality of data and highlighted the usefulness of the project. Further, we believe that respondents would try to respond as accurately as possible since we mailed a benchmarking report after the data were collected. Therefore, we minimized distortions in subjective data obtained from key informants.

Given that the constructs employed in the study demonstrated good statistical properties, we proceeded to test the hypothesized research model shown in Fig. 1.

4. Results

We present descriptive statistics and the correlation matrix in Table 3. The correlations and descriptive statistics refer to the average of the items reflecting each construct. Structural Equation Model (SEM) analysis has been widely applied in the operations management, social sciences, and marketing literature. Researchers have recognized the advantages of SEM as a second-generation technique (Zhu and Kraemer, 2002; Pflughoeft et al., 2003; Carr and Pearson, 1999; Narasimhan

Table 3
Descriptive statistics and correlations

	Mean	Standard deviation	1	2	3	4	5	6
1. EBUSCUST	1.808	1.029	1.000					
2. EBUSPUR	2.358	1.211	0.226**	1.000				
3. EBUSCOLL	2.469	1.222	0.328***	0.273***	1.000			
4. SUPINTEG	3.992	1.587	0.080	0.153*	0.315***	1.000		
5. CUSINTEG	3.402	1.404	0.088	0.193**	0.318***	0.247***	1.000	
6. PERFORM	4.925	1.219	−0.028	−0.049	0.081	0.396***	−0.049	1.000

* Significant at 0.10 level.
** Significant at the 0.05 level.
*** Significant at 0.01 level.

and Jayaram, 1998). The SEM consists of two parts—the measurement model and the structural model. The measurement model (discussed earlier) assesses the adequacy of the measures used for theoretical constructs employed in the study. The structural model, on the other hand, specifies the relationship between constructs. Effectively, the SEM methodology incorporates these two aspects to ascertain the fit between the variance–covariance matrix observed in the sample data and that implied by the theoretical or research model.

This fit is expressed using measures of goodness-of-fit index (GFI). It is standard practice to report several measures of GFI. The measures we report are goodness-of-fit index (GFI) (Bentler and Bonentt, 1980), adjusted goodness-of-fit index (AGFI) (Bagozzi and Yi, 1988), comparative fit index (CFI) and normed fit index (NFI) (Bentler and Bonentt, 1980), and the root mean square error of approximation (RMSEA) (Steiger, 1990). Values higher than 0.90 for GFI, CFI, and NFI are indicative of a good fit (Gefen et al., 2000), while AGFI values higher than 0.80 suggest a good fit of the hypothesized model. For RMSEA, a value less than 0.1 is considered a good fit, and a value less than 0.05 is considered a very good fit of the data to the research model (Gefen et al., 2000; Steiger, 1990).

We implemented the structural equation modeling using LISREL 8.50. The fit indices for each model are listed in Table 4. Another advantage of the SEM methodology is that it enables us to test competing models. We tested the hypothesized model with another competing model. According to the discussion of the resource-based view in Section 2.4, it is plausible that firms with eBusiness capabilities might in general have better performance, regardless of the production information integration achieved by eBusiness. Thus, we tested a model with a direct impact of eBusiness capabilities on performance. We call this model the Direct Effect model.

Table 4
Model statistics

Model	Chi-square/d.f.	GFI	AGFI	CFI	NFI	RMSEA
Hypothesized model	1.33	0.95	0.90	0.93	0.88	0.05
Direct Effect model	2.36	0.94	0.86	0.89	0.82	0.09

The results for the hypothesized model indicate a good fit between the variance–covariance matrix of the data and that implied by the model. This is indicated by the measures of fit (GFI, AGFI, CFI, and NFI) all above the threshold values for a good model. The results in Table 4 suggest that the hypothesized model fits better than the Direct Effect model. A more detailed examination of the additional paths between eBusiness capabilities and performance in the Direct Effect model indicates that none of the three dimensions of eBusiness capability were significantly associated with performance. Thus, we find evidence that there is no direct impact of eBusiness capabilities on performance. A firm that has a high degree of eBusiness capability is not necessarily experiencing better performance. Our results indicate that the ways in which these firms leverage their eBusiness capabilities is what determines if they also experience superior performance. This finding also responds to the IT literature on the paradox or the lack of impact of IT investment on performance (e.g., Hitt and Brynjolfsson, 1996; Porter, 2001; Vickery et al., 2003; Devaraj and Kohli, 2003).

Next, we examined the relationships between constructs hypothesized in the earlier section. Fig. 2 presents a graphical representation of the SEM models with their regression coefficients for each construct. We observe support for the general idea that eBusiness capabilities affect the extent to which firms integrate production information with their suppliers. Hypotheses 1b and 1c are supported by the data; EBUSPUR and EBUSCOLL positively influence the degree of supplier

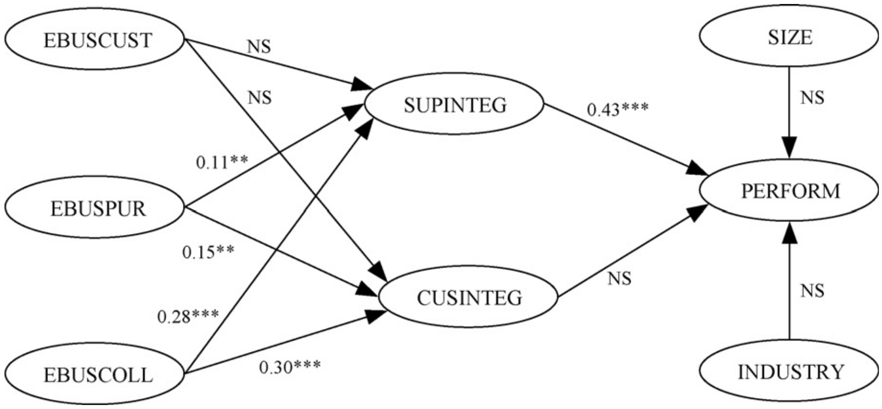

Fig. 2. Results of Structural Equation Model. ***Significant at 0.01 level; **significant at the 0.05 level; NS, not significant.

integration. However, there is no support for Hypothesis 1a. Thus we observe support for Hypothesis 1 along two of the dimensions of eBusiness capabilities—purchasing and collaborative capabilities.

Similar to the above set of relationships, there is support for the general idea that eBusiness capabilities affect the extent to which firms integrate production information with their customers. Hypotheses 2b and 2c are supported by the data; EBUSPUR and EBUSCOLL positively influence the degree of customer integration. However, similar to the results for supplier integration, Hypothesis 2a was not supported. The underlying dimension of eBusiness capability that relates to customer online ordering capability was not linked to supplier integration or customer integration. We discuss these results in greater detail in Section 5.1.

The relationship between supplier production integration and firm performance was highly significant, lending strong support for Hypothesis 3. However, an interesting and counter-intuitive result was that the relationship between customer integration and performance was not statistically significant (Hypothesis 4). While supplier production information integration was viewed as positively affecting performance, a similar result was not true for customer production information integration. We investigate this phenomenon in greater detail in Section 5.2.

Finally, we included indicator variables to control for the size of the company as well as the type of industry. The control variables were not statistically significant, but their inclusion in the model lends credibility to our results that after controlling for the size and industry type we still observe significant relationships between the constructs employed in the study.

5. Discussion

This study addresses two important questions about the role of information technology in supply chain management: (1) do eBusiness technologies have a significant impact on supply chain performance? (2) Does production information integration constitute an important link in the pathway from eBusiness technology to supply chain performance? Based on our results, we can say that eBusiness technologies do impact the production information integration in a supply chain. Further, supplier integration affects the operational performance of the firm. However, some results were surprising and need further analysis. In particular, we did not expect the EBUSCUST variable to drop out of the model. We also did not expect the lack of an association between customer integration and operational performance. Finally, as supplier integration had such an important effect on operational performance, we did an analysis to find out which performance measures were the most affected by it. We discuss these results next.

5.1. eBusiness effects

Our analysis indicated that eBusiness capability, assessed along the dimensions of customer ordering capability, purchasing capability, and supply chain collaboration capability, has no direct effect on operational performance. This result simply emphasizes the fact that having any capability is ineffective unless the firm also has the systems and processes in place to leverage the capability (Poirier and Quinn, 2003; Zhu and Kraemer, 2002). From a supply chain perspective, the capability for customer integration and supplier integration are the keys to achieving improved operational performance with eBusiness technologies. Both types of integration require methods, procedures, and processes that go far beyond the mere capability to interact with customers over the Internet. However, it was unexpected to see that customer ordering capability (EBUSCUST) was not associated with either of the integration constructs. There are two possible reasons for not observing these relationships in our original sample. First, it is conceivable that this is a transient phenomenon and a large percentage of the firms represented by our sample have not yet incorporated the customer ordering capability. As firms mature in the use of the Internet, we could see many more of them developing customer ordering capabilities and, if so, that capability should support the firm's production information integration efforts. Second, it is conceivable that the predominance of the target population, represented by our sample, consists of firms that do not use (or need) customer ordering capability. Assessing which if any of these possibilities for customer ordering capability is present would be a useful future investigation.

5.2. Production information integration

The lack of a relationship between customer integration and operational performance seems to defy intuition. Certainly, the practitioner literature would have us believe that receiving production information from a customer and collaborating on future schedules and vendor-managed inventories should have a positive effect on performance. Nonetheless, our results lead us to believe otherwise. Frohlich and Westbrook (2002) showed that firms integrating both customers and suppliers perform better than firms integrating only one or the other. That concept could also apply here, however the twist in our study is that customer integration, as measured by specific information flows and collaborative efforts with customers, does not by itself relate to performance. While the independent impact of supplier integration might exist, what might be even more significant is the combined or interactive effect of supplier and customer integration. To examine this conjecture, we test the statistical significance of the interaction term in the model. To estimate the interaction effects, we first employ the more established practice of estimating an ordinary least squares regression (OLS) with the interaction term captured as the product of the two types of integration. Results of the OLS regression with performance as the dependent variable are shown in Table 5. As can be observed, the impact of the interactive effect of supplier and customer production integration is highly significant lending support to the notion that firms that exhibit both forms of integration outperform the others significantly. Further evidence of the significance of the interaction term is also observed as the increase in R-square after its inclusion. The R-square value increased from 18.6% to 26.9% after we included the interaction term.

We assessed multicollinearity issues that pose a threat to the validity of the analyses. An examination of the variance inflation factors (VIFs) indicated that all VIFs were less than 2. These are significantly less than the threshold of 10 that is commonly viewed as indicative of multicollinearity. Further, we also looked at Belsley–Kuh–Welsch indices (Belsley et al., 1980) to reconfirm that we did not have multicollinearity problems.

Finally, following Ping (1995) we estimated the interaction term within the context of a structural equation modeling framework and found statistical support for the significance of the interaction between customer and supplier information integration. In the interests of brevity, we did not report the details of this analysis.

Fig. 3 takes this analysis one step further. We categorized the firms into high or low customer

Table 5
Interactive effect of customer integration and supplier integration

Independent variables	Dependent variable performance
Interaction between supplier and customer	0.29^{***}
Supplier	0.39^{***}
Customer	−0.11
Size 1	0.003
Size 2	−0.05
Industry	−0.07
R-square of model	26.9%
F-statistic	6.92^{***}

*** Significant at the 0.01 level.

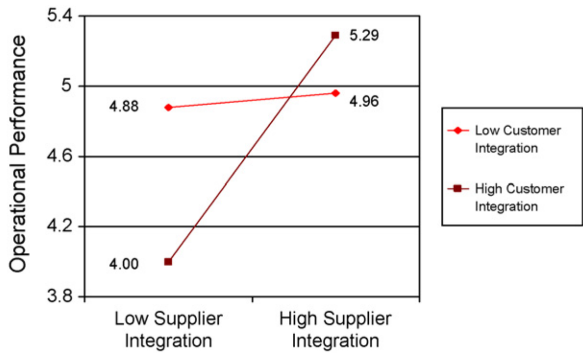

Fig. 3. Interaction effect on performance.

integration intensity and high or low supplier integration intensity depending on the firm's scores relative to the median score for each construct. The operational performance score is the average of the firms in each quadrant.

Two groupings have statistically significant differences in their operational performance at the 0.05 level of significance: firms with high supplier integration and high customer integration (5.29) versus firms with low supplier integration and high customer integration (4.00); and firms with high supplier integration and low customer integration (4.96) versus firms with low supplier integration and high customer integration (4.00). Firms with low customer integration and high supplier integration do not experience operational performance significantly better than firms that have low customer integration and low supplier integration. Apparently, if customer integration is left at a low level, most of the gains in performance can be achieved with low levels of supplier integration. The largest benefit comes when both customer integration and supplier integration are at high levels. The synergistic effects of both forms of integration combine to produce the best outcome. However, why does a firm with low supplier integration and high customer integration have such poor performance? A possible answer resides in the anticipated benefits of the Internet capability, which has been shown to be a driver for supply chain integration (Frohlich and Westbrook, 2002). The level of customer expectation rises relative to performance once a firm has established a capability to interact with customers via the Internet. Indeed, this level of expectation could translate to the firm's management as they evaluate their own operational performance; they expect more of the process because the customer expects more. The actual performance, nonetheless, could be limited because the firm has not established an adequate level of supplier integration. While we agree that both forms of production information integration are best, our data indicate that developing high levels of customer integration without first establishing supplier integration can result in lower levels of perceived operational performance. This finding is consistent with a recent study by Barua et al. (2004) who posit that the supplier-side ‘‘digitization’’, the online transactions and information exchanges, serves as a prerequisite for digitization on the customer-side. Without increasing supplier-side digitization, a firm may over-promise customers and then fail to deliver.

5.3. Impact of supplier integration on performance

The structural equation analyses and the OLS regression analyses outlined above use an aggregate measure of performance as the dependent variable. This is due to the statistical properties of the scale for performance supporting a unidimensional construct. From a managerial perspective, it would be useful to discover which measures have the strongest relationship to supplier integration. To address this issue, we conducted a one-way ANOVA with the items comprising the performance scale as the dependent variables and supplier integration as the independent variable.

The results of the one-way ANOVA are shown in Table 6. As can be seen all the dimensions considered in the performance scale are statistically significant (at the 0.05 level of significance). In decreasing order of significance, the dimensions that are related to supplier integration are delivery reliability, delivery speed, production costs, percent products returned by customer, production lead time, flexibility of the process, percent defects during production, and inventory turns. That is, dimensions of performance related to aspects of delivery timing, cost, and quality problems discovered by the customer have a stronger relationship with supplier integration than the other dimensions.

Table 6
One-way ANOVA results

Performance measure	*F*-statistic	Significance (*F*-statistic)
Percent product returned by the customer	2.851	0.000
Percent defects during production	2.465	0.001
Delivery speed	3.021	0.000
Delivery reliability	3.247	0.000
Production costs	2.881	0.000
Production lead time	2.713	0.000
Inventory turns	1.733	0.026
The flexibility of the process	2.538	0.000

6. Contributions and future research

6.1. Key findings and managerial implications

The results of this study provide insights into the design of effective value chains. A key finding is that eBusiness capability supports customer and supplier integration efforts. Our eBusiness capability construct focused on specific supply chain technologies that supported customer ordering, purchasing, and collaboration between customers and suppliers. Firms should invest in eBusiness capabilities if they want to enhance their production information integration intensity. Nonetheless, firms should not try to justify investments in eBusiness technologies on the basis of their immediate impact on operational performance. To achieve operational performance advantages, the firm must also have the processes and procedures in place to use those capabilities.

A second key finding is that operational performance, which affects the customer's perception of the quality of the business relationship with the firm, can *best* be improved by intensifying the production information integration with customers and suppliers. This implies that increased exchanges of information such as sales forecasts, master production schedules, and inventory levels should result in better operational performance. In addition, firms should increase their collaboration with customers and suppliers regarding production requirements and move more toward vendor-managed inventory arrangements.

A third key finding relates to the approach that should be used in designing an effective supply chain. Often there are budgetary considerations that limit firms from doing everything at once. When referring to production information integration, our study has indicated that it is best to develop supplier integration *before* customer integration, with the goal to have both in place for maximum operational performance. By first developing supplier integration the firm establishes the capability to meet the performance expectations of its customers before engaging in customer integration.

Finally, while supplier integration positively affects all dimensions of operational performance, it appears to have its greatest impact on delivery timing, costs, and quality.

6.2. Research contributions

The significance of these findings resides in three research contributions of this study. First, the model we tested bridges the work of several other studies and verifies some general findings. Zhu and Kraemer (2002) found that aggregate measures of firm performance such as total sales and profit margins are too remote to be significantly associated with e-commerce capability. In our study, we also found that eBusiness capability is not directly associated with operational performance; however it is mediated by production information integration, which is related to operational performance. Rosenzweig et al. (2003) showed that supply chain integration intensity is associated with competitive capabilities (which we call operational performance) and that competitive capabilities are associated with positive business performance. The present study has shown that supplier integration and customer integration have an interaction effect that is more highly associated with operational performance than either taken alone. Finally, Frohlich and Westbrook (2002) proposed four web-based supply chain integration strategies that incorporate different degrees of demand integration (which we call customer integration) and supply integration and showed that they are linked to operational performance. We have also shown that various combinations of production information integration lead to varying levels of performance. However, our study has separated the web capability from specific forms of production information integration to show the role that eBusiness capabilities play in the integration efforts. Consequently, a major contribution of the study is that it is the first study of supply chain integration that addresses the effects of eBusiness capability, production information integration, and operating performance in one theoretical framework.

Second, our findings indicated that eBusiness capabilities, by themselves, do not directly impact operational performance. Firms must develop a capability for customer and supplier integration to realize the benefits of the new eBusiness technologies. In addition, supplier integration should be at a high level before customer integration is developed if both capabilities cannot be developed simultaneously. Customer integration by itself does not directly affect operational performance and must be implemented with supplier integration to realize its full potential.

Finally, we developed new supply chain constructs for eBusiness capability, customer integration, and supplier integration. Following the suggestions of Rosenzweig et al. (2003), our measures include technology capabilities and specific tactics for supplier and customer integration that allow us to better capture the nature of those constructs and their affect on supply chain performance.

6.3. Limitations and future research

No empirical study is without limitations. To be fair, some of these limitations are true for cross-sectional survey research in general. First, while the hypothesized model represents our best predictions based on the arguments articulated in the section on hypothesis development, no causal claims can be made from our results due to the cross-sectional nature of the data employed in the study. Future studies might examine the relationships proposed here in greater detail and over time to provide support for a causal perspective. The second issue relates to our ability to generalize the results to other industries. Strictly, we can generalize our results to the automotive, computers, and electronics industries. In addition, our sample had 73% of firms in the small to medium (SME) size category. While our ''size'' control variable was not significant, it is conceivable that the results may be more reflective of SMEs. This may have had an influence on the results we had for the EBUSCUST construct, which we found to have no affect on the integration variables for the complete sample. Nonetheless, we believe there are interesting insights for industries that have similar demographics and supply chain and technology practices. A third limitation is that some of our results might be a function of the timing of the survey. Specifically, the lack of support for eBusiness technologies relating to customer ordering capabilities might be due to the vast majority of companies in our sample not having implemented that technology at this point in time. However, this might change in the years to come, which implies that the relationship between customer-oriented eBusiness technologies and production information integration and consequently performance might be different than what we observed. Again, we believe this offers an opportunity to examine relationships hypothesized in this study as these technologies mature and find greater acceptance and implementation in organizations.

The topic of supply chain integration is still in its infancy. This study included only first tier suppliers to the respondent firm. Future research should address the issue of how deep the integration should go. Information exchanges and collaborative efforts could extend to second and third tier suppliers, however we do not know if those efforts would result in significant differences in operational performance. Further, the role of manufacturing process capability remains to be explored. For example, it is conceivable that manufacturing process flexibility is another mediating variable for eBusiness capability. Research could also explore the differences between SMEs and large firms in the relationships between eBusiness capabilities and production information integration. There are many opportunities for future research in this area.

Appendix A. Appendix of survey items (with factor loadings)

A.1. eBusiness capabilities

Responses range from 'Not Implemented' to 'Fully Implemented'.

The following items relate to my company's eBusiness capabilities in general:

1. Allow customers to order products online (0.816).
2. Allow customers to configure or customize products online (0.740).
3. Allow customers to check the status of their orders online (0.752).
4. Find and select suppliers online for commodity components (0.780).
5. Purchasing materials through online auctions (0.839).
6. Support web-based EDI (0.679).
7. Enable collaboration with suppliers or customers on forecasting, scheduling, or replenishment online (0.888).
8. Support advanced planning and scheduling (APS) for optimizing supply chain performances (0.847).

A.2. Supplier production information integration

Responses ranged on a seven-point Likert scale from 'Strongly Disagree' to 'Strongly Agree':

1. My company provides the following information items to the supplier:
   a. Sales forecast (0.651).
   b. Master production schedule (0.791).
   c. The inventory status (0.809).
2. My company collaborates with the supplier to jointly develop the net requirements of the component that the supplier will need to deliver (0.723).
3. My company authorizes the supplier to automatically replenish the inventory of the component (0.747).

A.3. Customer production information integration

Responses ranged on a seven-point Likert scale from 'Strongly Disagree' to 'Strongly Agree':

1. The customer provides the following information about its final product to my company (if the customer is a retailer, then the final product is the same as the product you supply):
   a. Sales forecast (0.708).
   b. Master production schedule (0.788).
   c. The inventory status (0.761).
2. The customer collaborates with my company to jointly develop the net requirements of the product that my company supplies (0.714).
3. The customer authorizes my company to automatically replenish the inventory of the product my company supplies (0.678).

A.4. Operational performance

Please rate the performance of the *Process* along the following dimensions:

Responses for the above questions ranged on a seven-point Likert Scale from 'Not Very Good' – 'Average' – 'Very Good':

1. Percent product returned by the customer (0.619).
2. Percent defects during production (0.776).
3. Delivery speed (0.865).
4. Delivery reliability (0.839).
5. Production costs (0.718).
6. Production lead time (0.818).
7. Inventory turns (0.644).
8. The flexibility of the process to accommodate changes to shipping schedules within the *effective lead time* of the product without the use of safety stock (0.742).

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