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Supply chain information systems strategy: Impacts on supply chain performance and firm performance

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ABSTRACT

This paper examines the relationship between supply chain (SC) strategy and supply chain information systems (IS) strategy, and its impact on supply chain performance and firm performance. Theorizing from the supply chain and IS literatures within an overarching framework of the information processing theory (IPT), we develop hypotheses proposing a positive moderating effect of two supply chain IS strategies – IS for Efficiency and IS for Flexibility – on the respective relationships between two SC strategies – Lean and Agile, and supply chain performance. Based on confirmatory analysis and structural equation modeling of survey data from members of senior and executive management in the purchase/materials management/logistics/supply chain functions, from 205 firms, we validate these hypotheses and show that the IS for Efficiency (IS for Flexibility) IS strategy enhances the relationship between Lean (Agile) SC strategy and supply chain performance. We also show a positive association between supply chain performance and firm performance, and a full (partial) mediation effect of supply chain performance on the relation between Agile (Lean) SC strategy and firm performance. The paper contributes to the supply chain literature by providing theoretical understanding and empirical support of how SC strategies and IS strategies can work together to boost supply chain performance. In doing so, it identifies particular types of supply chain IS application portfolios that can enhance the benefits from specific SC strategies. The paper also develops and validates instruments for measuring two types of SC strategies and supply chain IS strategies. For practice, the paper offers guidance in making investment decisions for adopting and deploying IS appropriate to particular SC strategies and analyzing possible lack of alignment between applications that the firm deploys in its supply chain, and the information processing needs of its SC strategy.

1. Introduction

A critical aspect of successfully managing the supply chain lies in measuring and monitoring information about its key operational and performance parameters (e.g. inventory, delivery schedules and lead times) (Gunasekaran and Ngai, 2004). It is therefore important for a firm to adopt information systems (IS) that are aligned to its supply chain, that is, adopt IS that facilitate the particular processes of its supply chain and provide information about parameters that assess specific goals of its particular supply chain (SC) strategy. Practice-based commentary provides instances of both success and failure of firms in achieving such alignment. For example, Wal-Mart's adoption of IS for materials management, ordering, and RFID-based inventory-tracking has enabled real-time demand forecasting and inventory management, leading to higher inventory turnover and reduced inventory costs. These applications have thus supported the company's low cost SC strategy. On the other hand, Nike's $100 million deployment of supply chain software failed to prevent significant inventory shortages and excesses in its supply chain (McLaren et al., 2004), largely as a consequence of lack of fit of the application with its supply chain objectives. Examples such as these clearly suggest the importance of aligning information systems that are deployed in the supply chain with the goals and objectives of the supply chain itself (Shah et al., 2002).

Why are some firms successful at such alignment whereas others are not? One important reason is lack of adequate analysis regarding whether benefits from a particular application address the specific information processing and management control needs of the supply chain (Gunasekaran and Ngai, 2004; Richmond et al., 1998). For instance, if minimizing inventory or achieving leanness is a key objective of the supply chain, what kind of applications should be adopted by a supply chain member

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firm to support leanness in its processes? Or, which applications are required for effectively addressing the information processing requirements emanating from the objective of inventory minimization? Appropriate fit between supply chain and IS thus requires a basis for analyzing how information processing needs of particular types of supply chains can be supported by specific IS applications.

We examine the moderating relationships between SC strategies (i.e. particular types of strategic goals and objectives that supply chains can have) and supply chain IS strategies (i.e. particular IS applications portfolio profiles for the supply chain), and their associated effects on the supply chain performance (i.e. supply chain flexibility, integration and customer responsiveness) and firm performance (i.e. how well a firm achieves its market-oriented and financial goals). In particular, theorizing from the supply chain and IS literatures, we develop hypotheses proposing that positive moderating relationships between two distinct SC strategies (Lean and Agile) and two respective supply chain IS strategies (IS for Efficiency and IS for Flexibility) are associated with enhanced performance of the particular supply chain and that of the focal firm. Validation of the framework with confirmatory analysis of survey data from senior executives in supply chain/materials management/procurement roles from 205 manufacturing firms shows that IS for Efficiency and IS for Flexibility positively moderate the relationship between Lean SC strategy and Agile SC strategy, respectively, and supply chain performance. The theoretical implication is that IS for Efficiency and IS for Flexibility reinforce the supply chain benefits from Lean SC strategy and Agile SC strategy, respectively, and also facilitate improved firm performance.

To situate the paper's contribution, we note here that firstly, the literature has developed classifications of SC strategies (Fisher, 1997; Lee, 2002; Vonderembse et al., 2006), without explaining the associated implications for adopting supporting information systems. Therefore it is largely deficient, in offering a theoretical understanding of how particular IS can support the information processing requirements of processes associated with specific types of supply chains, or how or why specific SC strategies should be aligned with relevant IS strategies. Our study addresses this conceptual gap by offering a theoretical and empirical basis for analyzing the benefits of different types of IS applications to supply chains. It shows that *particular* types of information systems application portfolios when *associated* with different types of SC strategies, can enhance supply chain and firm performance. Secondly, existing studies describe the impact of information technology (IT) *in general* on *individual* supply chain aspects such as supply chain integration (Shah et al., 2002; McLaren et al., 2004; Rai et al., 2006), procurement-related activities and supplier relationships (Premkumar et al., 2005; Subramani, 2004; Sanders, 2008). This paper builds on and extends these studies by considering the *broader* aspect of the nature of the supply chain (i.e. SC strategy), and identifying the relevant *set of applications* (i.e. IS strategy) that would enhance its impact on supply chain performance. Based on these observations, we submit that the paper contributes to the literature by suggesting that appropriate fit between SC strategy and supply chain IS strategy leads to improved supply chain performance, to the best of our knowledge, one of the first studies to theoretically and empirically examine such alignment. Thirdly, it offers validated instruments for measuring SC strategy and supply chain IS strategy of a firm and supply chain performance.

For supply chain and operations management practitioners, the study demonstrates the importance of adopting and implementing those IS applications that fit the particular type of the supply chain. We provide guidance to managers for acquiring and deploying *appropriate* applications in the supply chain, for a specific supply chain strategy. In doing so we provide a basis for understanding which IS applications should be developed/purchased and implemented, for specific supply chains. That is, the paper offers a framework by which supply chain and operations managers can analyze investment decisions with regard to the deployment of IT in the supply chain.

The paper is set out as follows. First, we provide theoretical background from IS and supply chain literatures. Next, we develop the research model and hypotheses. We then describe methods and findings, followed by interpretations, contributions and limitations.

2. Theoretical background

The theoretical background informing this paper draws from the information processing view of the firm (Galbraith, 1973). Exemplified by the information processing theory (IPT), this view looks at organizations as information processing entities that collect, analyze, and coordinate information in order to make operational and strategic decisions. Design of processes then, should address information processing capabilities that support information requirements for decision-making. This can be either through structural means such as rules, procedures and lateral communication mechanisms or through the application of IS. Applying the IPT to supply chain processes, emerging research (Schoenherr and Swink, 2012) shows that integration of external (i.e. supplier and customer facing) processes leads to improved supply chain performance and that integration of internal (i.e. intra-firm logistics, operations and supply chain management) processes positively moderates this relationship. In this study we draw from the IPT to suggest that the information required to implement particular SC strategies represents the supply chain's *information processing needs*. Supply chain IS strategy encompasses different applications applied to supply chain processes and thus represents its *information processing abilities*. That is, the supply chain IS strategy of the focal firm provides the infrastructure or vehicle, with which its SC strategy can be most effectively translated into performance. We thus argue that matching particular SC strategies (i.e. supply chain *information processing needs*) with appropriate supply chain IS strategies (i.e. supply chain *information processing abilities*) will enhance the benefits from those SC strategies.

2.1. Supply chain strategy and supply chain information systems strategy

The SC strategy reflects the "nature" of the particular supply chain and establishes its specific objectives and goals (Lee, 2002; Fisher, 1997). Classifications of SC strategies suggest that supply chains can be predominantly focused on cost efficiencies and leanness, on flexibility and quick response, or on a contingent mix of both. A number of such classifications (e.g. Vonderembse et al., 2006; Lee, 2002) describe efficient supply chains, risk-hedging supply chains, responsive supply chains, and agile supply chains. In this paper, we will focus on two distinct SC strategies—Lean and Agile SC strategies. A "Lean" SC strategy is one aimed at creating a cost efficient supply chain, with a focus on reducing inventory lead times and waste (Wang et al., 2004; Vonderembse et al., 2006). This strategy works well where demand is relatively stable and predictable, and product variety is low (Qi et al., 2009). An "Agile" SC strategy is aimed at achieving flexibility and adaptability in the face of changing customer needs and competitive environments through quick, dynamic and continual response (Gunasekaran et al., 2008; Lin et al., 2006). Table 1 summarizes differences between Lean and Agile SC strategies.

Table 1
Supply chain strategy: Lean and agile.

Supply chain strategy	Lean	Agile
Objective	Focuses on cost reduction and incremental improvements for existing products Focuses on elimination of waste and non-value added activities across the supply chain	Tracks and understands customer requirements by interfacing closely with the market Aims to produce in any volume (and not just the optimal capacity utilization volume) and deliver simultaneously to a wide variety of markets Provides customized products at short lead times (i.e. focuses on responsiveness)
Inventory strategy	Generates high inventory turnover and minimizes inventory through the supply chain	Deploys significant stocks of parts to tide over unpredictable market requirements
Lead time focus	Shortens lead-time only so long as doing so does not increase delivery or inventory costs	Reduces lead times to customer specifications and requirements
Manufacturing focus	Maintains high average capacity utilization rate	Deploys excess/buffer capacity to ensure that raw material/components are available to manufacture the product according to market requirements
Product design strategy	Reduces the cost of production	Produces to modular designs, by using a limited number of basic components and processes that can be assembled into different products

Table 2
Information systems strategy for the supply chain: IS for Efficiency and IS for Flexibility.

Type of IS strategy (for the supply chain)	Typical applications portfolio	Description
IS strategy for Efficiency—use of IS for operational support of intra- and inter-organizational supply chain processes	Operational Support Systems and Inter-organizational Systems. Examples: ERP, EDI, e-Procurement systems and intra- and inter-organizational process automation applications	IS are primarily used to monitor and control day-to-day operations in the supply chain, to facilitate operational efficiency
IS strategy for Flexibility—use of IS for market flexibility and quick strategic decisions	Market information systems and strategic decision support systems. Examples: demand forecasting, production scheduling, market analysis and CRM applications	IS are primarily used to monitor product and market trends and respond quickly to changes in them by appropriately deciding on production schedules and delivery lead times

The IS strategy of a firm is its "*long-term, directional plan which decides what to do with information technology*" (Earl, 1989). The nature of the IS strategy is manifest in the portfolio of applications that the firm deploys and in the firm's stance toward IS. Conceptualizations of IS strategy reveal two distinct types, one that is oriented towards using IS for operational efficiency through a conservative stance and the other towards using IS for agility and effectiveness in the marketplace, through an innovative mode (Sabherwal and Chan, 2001; Chen et al., 2010). Accordingly, Sabherwal and Chan (2001) describe IS for Efficiency IS strategy and IS for Flexibility IS strategy. The first represents a portfolio of applications that supports operational and cost efficiency, economies of scale, and standardization and the second characterizes a portfolio that supports innovation and enables new market opportunities. They also mention a third IS strategy, IS for Comprehensiveness, that encompasses characteristics of the first two. Given that IS for Efficiency and IS for Flexibility are the two distinct IS strategies, we focus on these two in this paper.

The "IS for Efficiency" strategy is oriented toward operational support of intra and inter-organizational efficiencies. Applied to the supply chain, the IS for Efficiency strategy would include workflow automation systems, electronic data interchange systems, and transaction processing systems (e.g. enterprise resource planning and procurement software), for monitoring and controlling day-to-day intra- and inter-firm processes. Such systems would facilitate operational efficiency in the supply chain by registering transactions, making information about them easily available, structuring intra and inter-firm workflows around standard activities and using standard protocols to facilitate information exchange between them. "IS for Flexibility" refers to an IS strategy that focuses on enabling the firm to achieve market flexibility and quick strategic decision support. Applied to the supply chain, this IS strategy is characterized by an applications portfolio that typically includes market information systems and strategic decision support systems. The former facilitate demand analysis and selection of strategic alternatives in the context of the firm's (changing) products and markets. The latter help in identifying appropriate production schedules, stocking levels and lead times, in response to such changes. Table 2 summarizes the two types of supply chain IS strategy. We henceforth refer to supply chain IS strategy as simply "IS Strategy."

2.2. Relationship between supply chain strategy and information systems strategy

Recent studies have focused on effects associated with use of IS in supply chains. There is evidence that supply chain coordination and integration are facilitated by the use of integrated information technologies (Vickery et al., 2003) and IT integration capabilities (Rai et al., 2006), and lead to improved firm performance. Shah et al. (2002) suggest that supply chain practices such as supply chain integration, and initiatives such as building long-term strategic relationships with suppliers, require extensive use of EDI and web-based interchange; and thus the support of inter-organizational information systems. Arguing that supply chains at different levels of integration and coordination require different levels of technology integration, they propose a conceptual framework suggesting that a high (low) level of supplier integration must be matched with a high (low) level of IT integration in order to achieve superior supply chain performances. Premkumar et al. (2005) examine procurement-related information processing needs (from uncertainties in the product market environment and supplier relationships) and information processing capabilities (through the deployment of electronic procurement applications), and use Galbraith's (1973) IPT to show that aligning the two enhances supply chain performance. Thus, it is increasingly being recognized that the design of supply chains should include consideration of corresponding and specific information processing requirements and accompanying implications for deploying particular IS. This is typically referred to as "*the strategic planning of IS in supply chain*" (Gunasekaran and Ngai, 2004). The supply chain literature however is largely deficient in frameworks that might facilitate such analysis. Similarly, the IS literature, although rich in discussion on business strategy—IS strategy alignment (Chan et al., 1997; Sabherwal and Chan, 2001), fails to offer conceptual frameworks and empirical studies in the area of SC strategy and IS strategy alignment.

The focus of this paper is thus to examine different SC strategies and offer an organizing framework to assess the moderating relationship of IS strategies that would enhance their effectiveness vis-à-vis enhanced supply chain and firm performance. Specifically we propose that given a particular SC strategy, a specific IS strategy would positively moderate the relationship between that strategy and supply chain performance and therefore would be associated with enhanced supply chain performance. Noting that improved supply chain performance is associated with enhanced firm performance, we thus suggest that IS strategy positively influences the relationship between a firm's supply chain strategy and the performance of its supply chain. We expand on these arguments and present our hypotheses in the next section.

3. Hypotheses development

The model presented in Fig. 1 depicts our hypothesized relationships between SC strategy, IS strategy, supply chain performance, and firm performance. Specifically, we propose that the relationship between a particular SC strategy and supply chain performance would be enhanced or positively moderated by an appropriate IS strategy. That is, (1) IS for Efficiency would reinforce the relationship between a Lean SC strategy and supply chain performance, and (2) IS for Flexibility would strengthen that between the Agile SC strategy and supply chain performance. We also suggest that supply chain performance would be associated with improved performance of the firm. We next describe the rationale for the proposed relationships. Our key arguments are summarized in Table 3.

3.1. Hypotheses H1a and H1b: moderating effect of IS strategy (IS for efficiency and IS for Flexibility) on the relationship between SC strategy (lean and agile SC strategy) and supply chain performance

The Lean SC strategy requires appropriate and timely intra- and inter-organizational communication of information about inventories, capacities, delivery plans, and exceptions, within the framework of just-in-time (JIT) principles. The IS for Efficiency strategy improves internal and inter-organizational operational efficiencies through applications that enable day-to-day coordination internally, among the firm's departments, and externally, with customers and suppliers. For example, using ERP-enabled workflows to co-ordinate materials' ordering between purchasing and production functions can result in lower raw material inventory. ERP software is typically used to execute integrated workflows across supply chain functions such as procurement and production planning. Research shows that the use of ERP results in more productive

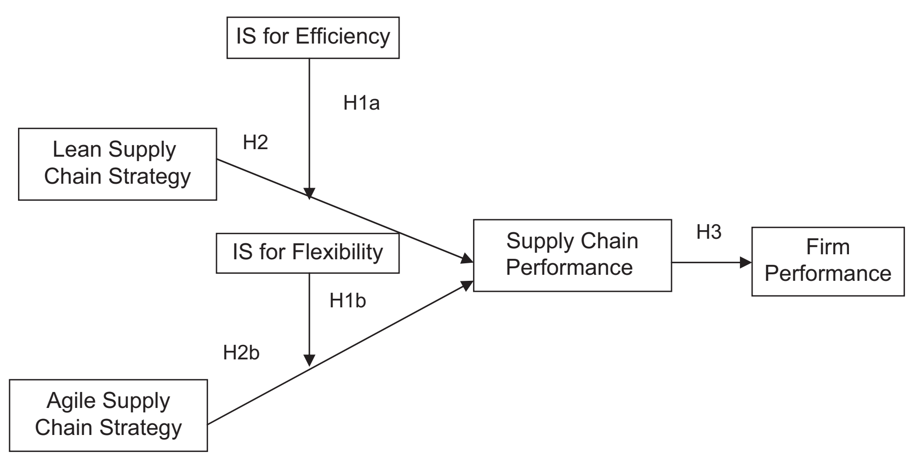

Fig. 1. Research model and hypotheses.

Table 3
Relationship between SC strategy (Lean and Agile SC strategies) and IS strategy (IS for Efficiency and IS for Flexibility).

Relationship between supply chain strategy and IS strategy	Requirements/characteristics of the particular supply chain strategy	Examples of support from corresponding IS strategy
Lean SC strategy—IS for efficiency	• High inventory turnover • High manufacturing utilization rate • Low cost • On time delivery	Inter and Intra-organizational Operational Systems. • ERP • RFID-based inventory tracking applications facilitate inventory and labor cost reduction, efficient inventory management and improved supply chain visibility (Wal-Mart) (Roh et al., 2009). • EDI applications facilitate cost savings, by enabling coordination and communication of production and delivery information between the focal firm and its suppliers.
Agile SC strategy—IS for flexibility	• Short lead times • High level of inventory • Production in different volumes • Capacity cushion • Quick delivery • Fast responses • Modular design	Market information systems and strategic decision making systems. • Market Information Systems help in tracking customer preferences, facilitating fast response in terms of new product offerings. • Zara's supply chain deploys applications for real time monitoring of customer demand and communication between its stores and production/design facilities, allowing Zara to make new products available to stores in just 15 days (Lee, 2004; Ferdows et al., 2004).

and error-free processes due to improved availability of operational data that is required for day-to-day control of operations. It also leads to lower procurement costs for maintenance-repair-order (MRO) type standardized products (Bendoly and Schoenherr, 2005). Further, it can help organizations implement "best practice" workflow templates that represent efficient and low-waste processes (Bendoly and Jacobs, 2004; Bendoly and Schoenherr, 2005). Similarly, connecting the production planning systems of a focal firm with the order entry system of its suppliers through a transaction-oriented B2B system or through EDI is expected to lead to better co-ordination of inventory and deliveries, reducing the amount of inventory in process and the turnaround time for new orders. The presence of operational and inter-organizational systems as indicated by the IS for Efficiency IS strategy is thus, as described in Table 3, expected to further accentuate the impact of the Lean SC strategy on supply chain performance, by increasing the extent of information integration and synchronicity in operational decisions, both of which represent information processing requirements of the Lean SC strategy.

Wal-Mart is a good example to demonstrate how the IS for Efficiency IS strategy facilitates a Lean SC strategy. By way of inter-organizational applications, Wal-Mart provides real-time point-of-sale data to major suppliers (e.g. Proctor and Gamble) through integrated satellite-based communication systems, thus facilitating a continuous view of inventory replenishment requirements. It analyzes long-term ordering and inventory trend data to deploy systems that provide decision guidance to suppliers with regard to safety stock and order quantities. The use of RFID-based inventory tagging and tracking increases accuracy of inventory records. The combined effect of these applications is to reduce inventory-on-hand, safety stock levels and inventory loss/pilferage, thus improving efficiencies in and reinforcing the benefits of leanness in the supply chain (Shah et al., 2002, Roh et al., 2009; Ketikidis et al., 2008).

Based on the above arguments, we hypothesize that:

H1a. IS for Efficiency IS strategy positively moderates the relationship between the Lean SC strategy and Supply Chain Performance.

The notion of agility in supply chains can be recognized as a strategy for increasing flexibility in production and delivery processes. In terms of information processing support, the Agile SC strategy requires the firm to analyze data on customer trends, competitor action, and product-market strategic options. Puckridge and Woolsey (2003) explain how the IS for Flexibility strategy can support the requirements of an agile supply chain thus, "*Requiring supply chains to become agile* (i.e. *have the ability to respond rapidly to unpredictable changes in the market*) *also requires the same agility in the organization's IT capabilities*." Market information systems, for example, can bolster supply chain agility by facilitating quick observation, analysis and response in the context of changing customer and market demand. Strategic decision support systems facilitate corresponding entry and exit decisions for new or existing product-markets. Additionally, the presence of inter-organizational systems facilitates information sharing for collaboration with partners and for co-ordination of response strategies and activities (Gunasekaran et al., 2008; Kim et al., 2011). We thus expect that the IS for Flexibility IS strategy will enhance the positive association between the Agile SC strategy and supply chain performance. Table 3 provides a summary of the logic for this association.

Zara, the Spanish clothier known for rapid design and worldwide delivery of new fashion, provides a good example of how alignment between the IS for Flexibility IS strategy and the Agile SC strategy enables better execution of agility and leads to increased supply chain flexibility (Lee, 2004; Ferdows et al., 2004). Zara's ability to design, produce, and make available a new garment in stores worldwide in just 15 days, hinges on three kinds of IS. First, it uses a combination of wireless handheld tools and networks to acquire and upload market and customer data from its stores and the field to product managers in its central design office. Second, collocated groups of designers and product managers collaborate and use decision-making systems that analyze this data, to determine new designs and order quantities. Third, Zara uses applications to facilitate exchange of information between the firm and its suppliers, for communication and coordination in the context of distribution and delivery of raw cloth and finished garments (Ferdows et al., 2004). Zara's ability to execute the Agile SC strategy and maintain a flexible supply chain thus is critically dependent on its IS for Flexibility IS strategy.

Based on the above arguments and example, we hypothesize that:

H1b. IS for Flexibility IS strategy positively moderates the relationship between the Agile SC strategy and Supply Chain Performance.

3.2. Hypotheses H2a and H2b: relationships between lean and agile SC strategies and supply chain performance

The Lean SC strategy focuses on efficiently managing the supply chain by eliminating waste and employing continuous improvement techniques, thus improving the quality of parts, reducing delivery times and minimizing inventory. This strategy involves the focal firm working in a collaborative mode with suppliers on key operational parameters such as inventory levels and lead times, to implement practices such as mass-production and just-in-time (Qi et al., 2009; Thun, 2010). By eliminating excess inventory and improving the quality of parts, the supply chain is able to reduce set-up time, adjust capacity, enhance product quality and respond quickly to the customer. As a result supply chain performance is enhanced (Wang et al., 2004; Vonderembse et al., 2006). A higher degree of leanness is thus expected to be associated with better supply chain performance. The agile supply chain has a higher capacity for effectively adapting to changes in customer demand and preferences (Qi et al., 2009; Vickery et al., 1999). It does so by, for example, implementing capacity buffers to handle market uncertainties, which increases its responsiveness (Qi et al., 2009, 2011). Lee (2004) argues that agility in the supply chain can help it respond quickly to changes in customers' demand, handle the uncertainty in the market more effectively, and deliver a higher level of product customization. We therefore hypothesize that:

H2a. The Lean SC strategy is associated with higher levels of Supply Chain Performance.

H2b. The Agile SC strategy is associated with higher levels of Supply Chain Performance.

3.3. Hypothesis H3 (relation between supply chain performance and firm performance)

Gunasekaran et al. (2001) and Beamon (1998), define supply chain performance as its overall efficiency and effectiveness. Beamon (1999) suggests three aspects for measuring supply chain performance, namely, resources measurement (generally efficiency), output measurement (generally, customer satisfaction), and flexibility (how well the system reacts to uncertainty). Similarly, Gunasekaran et al. (2001) suggest that supply chain performance should be evaluated in terms of manufacturing and inventory costs, responsiveness to changes in delivery requirements and integration with partners. Following these descriptions, we define supply chain performance as its flexibility, integration, and customer responsiveness. Supply chain flexibility is the extent to which supply chain partners effectively and quickly adapt to changes in the market (Vickery et al., 1999). Supply chain integration is the extent to which activities, communication, and decision-making in the supply chain are coordinated together (Stock et al., 2000; Narasimhan and Jayaram, 1998). Responsiveness to customers is the extent to which supply chain partners respond in a timely manner to customers' needs and wants (Narasimhan and Jayaram, 1998; Chen et al., 2004).

Firm performance refers to how well a firm achieves its market and financial goals and objectives. Following previous studies from the supply chain literature (e.g. Li et al., 2006); we measure the performance of the focal firm through perceived accounts of its market share, sales and overall competitive position. A positive association between supply chain performance and firm performance has been generally supported. For instance, supply chain integration increases the efficiency with which information is transmitted in the supply chain (Rai et al., 2006; Zhang et al., 2006), thus improving firm performance by reducing inventory levels and costs, and by increasing on-time delivery (Vonderembse and Tracey, 1999). Similarly, there is a high correlation between supply chain flexibility and firm performance because the ability of the supply chain to adapt to changes will positively impact the firm's ability to introduce and deliver products that are likely to meet changing demand (Sanchez and Perez, 2005; Vickery et al., 1999). A number of studies have shown that the ability of the supply chain to produce and deliver products in response to customer needs results in superior performance for firms who are part of the supply chain (Vickery et al., 2003; Chen et al., 2004). Therefore, we hypothesize that:

H3. Supply Chain Performance is positively associated with Firm Performance.

4. Methods and analysis

This study was executed in 4 phases: (1) Questionnaire development and pilot study, (2) Large-scale data collection, (3) Confirmatory analysis for reliability, convergent validity and discriminant validity and (4) Hypothesis testing through structural equation modeling analysis. We describe each of the phases below.

4.1. Questionnaire development and pilot study

We developed instruments to measure the two types of SCM Strategy and IS Strategy, for which previous studies (e.g. Sabherwal and Chan, 2001; Swafford et al., 2006) and our discussions in Section 2 formed the basis for the initial items. The instruments to measure supply chain performance and firm performance were adopted from previous studies (Li et al., 2005, 2006).

Content validity was done in two steps. First, the items were reviewed by two academicians and six practitioners to comment on clarity and appropriateness. Based on their feedback, we adjusted them for the pilot study. The pilot study was conducted using the Q-sort method. The Q-sort method pre-assesses convergent and discriminant validities of constructs by asking different "judges" to sort (place) the items into various construct categories. We used three criteria for evaluating the Q-sort results (Moore and Benbasat, 1991; Cohen, 1960): level of inter-judge agreement (the number of items that judges agree to place into a certain category), hit ratio (how many items the judges place in the appropriate and intended category), and Cohen's Kappa coefficient agreement (proportion of joint judgment in which there is agreement on placing an item in a particular category, after eliminating chance agreements).

Three rounds of Q-sort were conducted, with two judges in each round. In the first, two senior supply chain managers of a major automobile firm participated. The hit ratio score averaged 79%, the inter-judge raw correct agreement score averaged 65%, and Cohen's Kappa score averaged 63%, all of which are considered low. After making changes to the items based on the results/feedback from the first Q-sort round, 8 items were eliminated and others were modified. A second Q-sort round involved two senior purchasing managers from a manufacturing company. The second Q-sort results were: 93% for the hit ratio, 89% for the inter-judge raw correct agreement, and 87% for Cohen's Kappa. Although these results are considered excellent, careful inspection of the items placement ratio for each construct yielded some problems, notably a placement ratio of 71.4% for the construct IS for Efficiency. Hence a third Q-sort round was conducted, after rewording and eliminating appropriate items. Two senior purchasing managers from a manufacturing firm were judges in the third round. The hit ratio score averaged 98%, the inter-judge raw correct agreement score 95%, and Cohen's Kappa coefficient 95%, all of which represent an excellent level of agreement for the judges. The questionnaire as represented by the items at the end of the third round was used for large-scale data collection. All items were measured on Likert-type scales with response option ranging from 1 (strongly agree) to 6 (not applicable).

4.2. Large-scale data collection

The unit of analysis is at the level of the focal firm. Senior executives (directors, vice presidents and senior managers) from purchasing/production/supply chain functions were chosen as the respondents. We used a list of 3129 executives from these functions, working in a randomly selected sample of manufacturing firms in the United States having more than 200 employees and $10 million in sales revenue. Restrictions on size were intended to account for the fact that small organizations are unlikely to acquire or use sophisticated information systems in their supply chains. Data was collected through a web-survey in two rounds. 205 completed surveys were returned, representing a response rate of 6.6% which is comparable to other recent studies on supply chain management (Li et al., 2005, 2006).

The sample characteristics of the respondents are given in Tables A1, A2 and A3 in the Appendix. Table A1 shows that most of the respondents are senior managers, Table A2 that most of the respondents are from purchasing/procurement functions, and Table A3 that the majority of the organizations in the study are manufacturing organizations. The "other" category is considered as retail, distribution, logistics, design, and overhaul/repair organizations.

4.3. Analysis for reliability, convergent validity and discriminant validity

4.3.1. Non-response bias

Non-response bias between the two rounds of respondents was assessed using the Chi-square test to evaluate differences in number of firm employees, annual firm sales, and job title between them. We did not find any significant difference between the two groups along these three criterions, indicating that non-response bias is not a major concern for this study. The first group had 77 responses, the second, 128.

4.3.2. Assessing convergent validity and reliability

Corrected item total correlation (CITC) analysis, as shown in Table 4 was used to conduct item purification for each construct. For the Agile SC strategy construct, two items were removed after two rounds of CITC. For the IS for Flexibility, one item was removed after one round. For the remaining items, all scores are higher than the threshold of 0.5. The constituent items and the mean, standard deviation, and reliability (using Cronbach Alpha) of all the constructs, after purification are shown in Table 4. All Cronbach Alpha values are above 0.7, suggesting good reliability (Nunnally, 1978).

Table 4
Items, corrected item total correlation, alpha, mean, and standard deviation for each construct.

Item code		Survey item	CITC	Alpha	Mean	Standard deviation
Lean supply chain (LSC)				**0.77**	**2.23**	**0.68**
LSC1	Our supply chain	Manages inventory by delivering what we need	**0.51**			
LSC2		Provides standardized products	**0.54**			
LSC3		Reduces any kind of waste	**0.53**			
LSC4		Adopts quality practices as per our requirements	**0.65**			
LSC5		Manages quality as per our requirements	**0.69**			
LSC6		Inspects products frequently	**0.57**			
Agile supply chain (ASC)				**0.81**	**2.54**	**0.73**
ASC1	Our **supply chain**	Responds effectively to changing requirements of design	**0.59**			
ASC2		Responds quickly to customization requirements	**0.65**			
ASC3		Can handle changes in product design	**0.75**			
ASC4		Customizes our products by adding feature models as per our requirements	**0.73**			
ASC5		Maintains a higher capacity buffer to response to volatile market	**0.71**			
Information systems strategy for efficiency (ISSE)				**0.86**	**2.6**	**1.01**
ISSE1	The Information Systems (IS)	Improve the efficiency of operation between our suppliers and us	**0.73**			
ISSE2	applications we acquire/	Manage inventory between our suppliers and us	**0.74**			
ISSE3	develop help us to	Manage material requirements planning of our facility	**0.66**			
ISSE4		Manage production control between our suppliers and us	**0.76**			
ISSE5		Coordinate (production and information) efficiently across suppliers and product lines	**0.76**			
Information systems strategy for flexibility (ISSF)				**0.85**	**3.01**	**1.05**
ISSF1	The Information Systems (IS)	Introduce new product(s) and/or service(s) in our market(s)	**0.78**			
ISSF2	applications we acquire/	Monitor changes in our market condition	**0.68**			
ISSF3	develop help us to	Respond to changes in the market	**0.80**			
ISSF4		Change the design of our product(s)	**0.65**			
Supply chain performance (SCP)				**0.83**	**2.57**	**0.94**
SCP1	Our **supply chain**	Is able to handle nonstandard orders	**0.64**			
SCP2		Is able to meet special customer specification requirements	**0.68**			
SCP3		Is able to produce products characterized by numerous features options, sizes and colors	**0.60**			
SCP4		Is able to rapidly adjust capacity so as to accelerate or decelerate production in response to changes in customer demand	**0.73**			
SCP5		Is able to rapidly introduce large numbers of product improvements/variation	**0.60**			
SCP6		Is able to handle rapid introduction of new products	**0.60**			
SCP7		Has fast customer response time	**0.73**			
SCP8		Is characterized by a great amount of cross-over of the activities of our firm and our trading partners	**0.68**			
SCP9		Is characterized by a high level of integration of information systems in our firm	**0.73**			
SCP10		Has short order-to-delivery cycle time	**0.71**			
Firm performance (FP)				**0.92**	**3.69**	**0.89**
	On a scale of 1–6, please indicate the choice that accurately reflects your firm's overall performance					
FP1	Market share		**0.78**			
FP2	Return on investment		**0.79**			
FP3	The growth of market share		**0.75**			
FP4	Growth in return on investment		**0.81**			
FP5	Profit margin on sales		**0.71**			
FP6	Overall competitive position		**0.80**			

4.3.3. *Assessing discriminant validity*

Table A4 in the Appendix shows the results of Component Based Analysis conducted using PLS. The factor loading for each item on its intended construct is higher than its cross-loading for all other constructs, indicating good discriminant validity. The inter-construct correlations and average variance extracted (AVE) values are shown in Table A5 in the Appendix. The square root of the AVE for each construct is greater than the correlation of the construct to the all other constructs, showing further evidence of discriminant validity (Chin, 1998).

4.3.4. *Assessing common method bias*

Since we collected data from a single respondent from each firm, we tested for common method bias using Harman's single factor test. The results of this test suggests that when taking all the items for the 6 constructs into an exploratory factor analysis, no one general factor accounted for the majority of the variances explained, which suggests that common method bias is not a major concern in this study (Podsakoff et al., 2003).

Table 5
PLS structural equation modeling results.

Hypothesis	Relationship	Type	Beta-coefficient	*T*-coefficient	Significant
H2a	LSC-SCP	Direct	0.131	3.7	Yes
H2b	ASC-SCP	Direct	0.135	2.7	Yes
H1a	LSC*ISSE	Moderation	0.182	2.9	Yes
H1b	ASC*ISSF	Moderation	0.169	2.3	Yes
H3	SCP-FP	Direct	0.182	7.3	Yes

4.4. *Hypothesis testing*

We tested for our research hypotheses using Structural Equation Modeling analysis with PLS software. The *T*-statistic and standardized path (Beta coefficient) values were used to assess respectively,

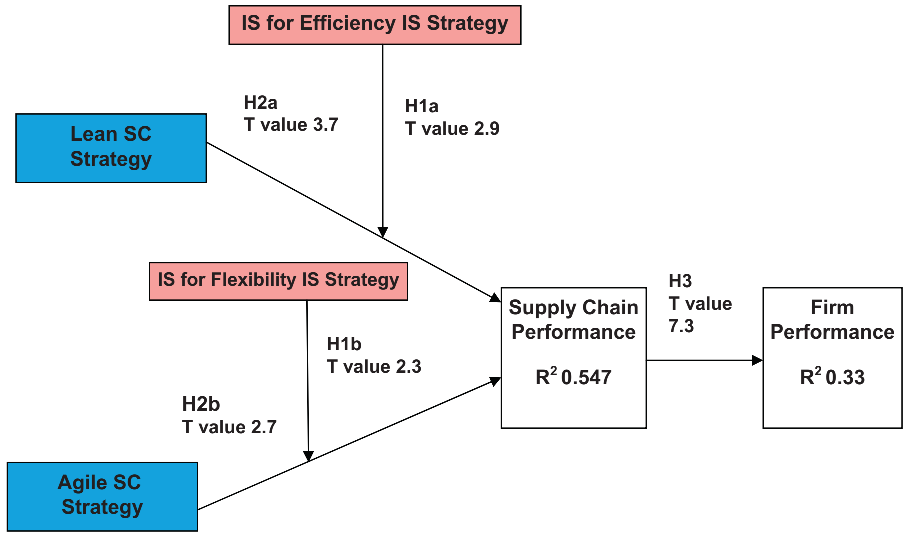

Fig. 2. Results of the structural model. * *Note*: Each construct is a latent variable having the corresponding items described in Table 4. The respective items for each construct have not been depicted in this figure for purposes of simplicity.

the significance and strength of each relation. The R^2 values were used to examine the impact of independent variables on dependent variables. Bootstrapping was used to generate the *T*-statistic with 205 cases and 1000 repetitions and the path weighting scheme technique was used to calculate the standardized coefficient (Beta coefficient) and R^2. The results are shown in Table 5 and Fig. 2.

5. Contribution and implication

The study makes a number of contributions. First, it theoretically explains and empirically demonstrates how and why specific IS strategies can be gainfully aligned with different types of supply chains, thus introducing a contingency view in the relationship between the nature of IS deployed in the supply chain and type of supply chain. Past studies (Gunasekaran and Ngai, 2004) investigating relationships between SC strategy and supply chain performance suggest that in general, effective deployment of IS into supply chains is associated with improved performance. Our results extend these by showing that specific SC strategies require the adoption of *corresponding* IS strategies such that they can more significantly impact supply chain performance. While the use of IS in the supply chain has been found to deliver supply chain performance benefits in general (e.g. (Rai et al., 2006; Subramani, 2004), acknowledgment of contingency in the relationship between the nature of applications and type of supply chain has been missing. This paper addresses that gap.

We first note that the R^2 of supply chain performance = 0.547, indicating that a significant amount of variance explained is explained by the two SC strategies and the moderating effects of the two IS strategies. Hypothesis H1a is significant (*t*-coefficient = 2.9), implying that IS for Efficiency positively moderates the relationship between Lean SC strategy and supply chain performance. This means the IS for Efficiency strategy facilitates improved supply chain performance from the Lean SC strategy. In particular then, if a focal firm is planning to create leanness or cost efficiency in its supply chain, then the firm should also adopt applications indicated by the IS for Efficiency strategy in its supply chain, such as transaction processing systems, intra- and inter-organizational workflow applications, and applications that help coordinate and improve operational information sharing with suppliers. The fit (interaction) between these two strategies is associated with better supply chain performance and improved firm performance. Hypothesis H1b is significant (*t*-coefficient = 2.3), indicating that the IS for Flexibility IS strategy positively moderates the relationship between an Agile SC strategy and supply chain performance. The Agile SC strategy is found to exist in product-market environments that are relatively dynamic and possibly requiring frequent re-orientation of supply chain resources. IS on the other hand, take time to develop, configure and implement. It is important to note there that for agile supply chains, appropriate IS applications may therefore be required to be deployed relatively quickly and in a manner capable of frequent and easy re-configuration in concert with changing environmental conditions. Implementation details and issues might thus be an important factor in the ability of the Agile SC strategy to appropriate benefits from the IS for Flexibility IS strategy.

Hypothesis H2a is significant (*t*-coefficient = 3.7), indicating that lean SC strategy improves supply chain performance. Lean SC strategy allows the supply chain to minimize inventory and reduces time required for activities, such as setup, thus enabling economic production of small batch quantities, and enhancing flexibility in the supply chain (Vonderembse et al., 2006). Additionally, the lean SC strategy requires the supply chain partners to coordinate and collaborate for conjoint problem solving with respect for eliminating waste, lowering costs and increasing efficiency (Thun, 2010; Qi et al., 2009). This leads to higher integration across the supply chain as many suppliers participate in strategic alliances and joint ventures to cut costs and achieve incremental improvement in products design Hypothesis H2b is significant (*t*-coefficient = 2.7), implying that the greater the extent of agility in its supply chain, the better the supply chain performs. Agile SC strategy requires a dynamic, context-specific, and aggressively changing supply chain; it allows the supply chain to interface with customers and quickly adapt to future changes. As a result, the supply chain can provide products at varying volumes and deliver to varying market demands.

Previous studies have explored the relationship between supply chain performance and firm performance. The key argument here is that if the supply chain performs well (that is, has accomplished integration, is flexible to market changes, or is responsive to customer requirements), then the focal firm will benefit in terms of improved performance in the context of price, quality, and delivery times of its products (Li et al., 2006). We find that hypothesis H3 is significant (with *t*-coefficients = 7.3) supporting findings from prior research (e.g. Vickery et al., 2003; Chen et al., 2004; Kim, 2009) relating SC strategy, supply chain performance, and firm performance.

To further explore the impact of SC strategy on supply chain performance and firm performance, we examined post-hoc, the mediation effects of supply chain performance on the relationships between the Lean and Agile SC strategies and firm performance. As a first step we observed a significant direct effect of Lean and Agile SC strategies on firm performance without the presence of the mediating variable, i.e. supply chain performance. We then inserted supply chain performance as the mediating variable between Lean and Agile SC strategies and firm performance. We found that supply chain performance *fully* mediated the relationship between Agile SC strategy and firm performance (*T*-coefficient of the Agile SC-firm performance link=0.29, Agile SC-supply chain performance link=3.7 and supply chain performance–firm performance link=2.37, all path coefficients positive). This shows two things. One, that superior firm performance is contingent upon superior supply chain performance, in firms that aim to be responsive to fast changing customer needs. This is because rapid introduction and delivery of new products, which are measures of supply chain performance, are also key aspects of firm success, given the fast changing and quickly obsolescent products that are usually associated with agile supply chains. Two, the matching presence of the IS for Flexibility strategy (to boost the positive relationship between Agile SC strategy and supply chain performance) is *especially* important because enhancing supply chain performance is *critical* to improving firm performance, given the full mediation effect. We also found that supply chain performance *partially* mediated the relationship between Lean SC strategy and firm performance (*T*-coefficient of the Lean SC-firm performance link=2.4, Lean SC-supply chain performance link=4.66, and supply chain performance–firm performance link=2.37, all path coefficients positive). This indicates that in addition to boosting firm chain performance indirectly through a positive impact on supply chain performance, the Lean SC strategy can directly enhance firm performance. This is possibly due to the general emphasis of such supply chains on operational and cost efficiencies and benefits, which ultimately contribute to financial performance. These post-hoc results provide intriguing and important insights on the impact of SC strategies on firm performance, and as such we believe they highlight an interesting contribution that deserves further study.

Second, our results call for attention to the need for fit between the focal firm and its suppliers in terms of IS sophistication and capabilities. For example, recent firm activities in the RFID domain, exemplified by RFID-based tracking by Wal-Mart and its suppliers (Roh et al., 2009), show that when a focal firm invests in supply chain applications, it is important to consider whether the technology capabilities of suppliers allow for similar adoption in their operations. This study provides a theoretical basis for identifying specific areas where IT sophistication of suppliers may need to be upgraded, depending on the particular SC strategy. For example then, the Lean SC strategy may require adoption of inter-organizational operational and transaction processing applications along the supply chain, which would entail different kinds of IS investments and IS adoption on the part of suppliers, from that implied by the Agile SC strategy which requires adoption of decision support and market intelligence applications.

Third, the study develops and validates measures for the four constructs measuring SC strategy and IS strategy, allowing for researchers to use and build on these measurements in future research.

Supply chains are becoming increasingly complex, and their effective management increasingly requires intelligent and appropriate information processing. Yet, with the glut of IS available for deployment in supply chain processes, supply chain practitioners are often hard pressed to analyze which of these would bring the greatest benefits. For practitioners, then, our results reveal the importance of deploying applications in the supply chain that support the *particular* SC strategy. For instance, if a focal firm's goal is to primarily cut costs along its value chain, not only is the Lean SC strategy required, to achieve this goal, but it is also necessary to acquire appropriate applications (e.g. EDI, ERP). Or, if a particular SC strategy is supported by inter-organizational applications, our findings alert supply chain managers to the need for assessing applications'/standards' compatibility with, and IS sophistication of, their suppliers. That is, unilateral or one-sided adoption of the suggested applications may not be an effective facilitator for implementing the particular SC strategy. As an extension then, the study also proposes a decision-framework for supply chain managers of a focal firm to identify, based on the primacy of the SC strategy, particular classes of applications that their suppliers might need to adopt, and if required, areas in which they might need to enhance their technology maturity.

6. Limitations and future research

Notwithstanding its contributions, there are several limitations to this study. First, a single respondent from each participating firm was asked questions about SC issues dealing with strategy, and applications. Although a majority of respondents were senior executives (of the level of Directors and Vice Presidents) in supply chain functions such as purchasing, it is rare for one person in an organization to supervise the entire supply chain. There is thus the possibility of associated bias in the responses to the survey questions. As suggested by Vachon and Klassen (2006), our attempt has been to minimize this bias by selecting members of executive and senior management in functions relevant to the supply chain, who it is expected, would have reasonable accuracy of perception and understanding of the firm's strategies relating to the supply chain and deployment of IS in the supply chain. Moreover, from Table A2, 43% of our respondents were responsible for more than one supply chain function in their firms, suggesting that they would be familiar with the domains addressed by the survey questions.

Second, there is the possibility of Common Methods bias, from the same person responding to the dependent and independent variables in our research model. In this context, the empirical absence of Common Methods bias as reported in tests in Section 4, suggests a high probability that the use of a single respondent did not induce a bias in our results.

Third, the responses, capturing various aspects of the supply chain from the point of the perceptions and understanding of a single/focal manufacturing firm, may not reflect prevailing actualities for all firms in the supply chain. For instance, different firms along the supply chain may have different levels of automation. Indeed it is difficult to capture the complexities and nuances of the entire supply chain from the point of view of one organization. Lai et al. (2004) suggest collection of data from firms across suppliers in the supply chain as means to address this difficulty. That our study does not do so, is a limitation.

Future research could investigate the fit between SC strategy and IS strategy in different industries. It is quite possible that industry specific patterns of particular SC strategy—IS strategy alignment exist. In industries where demand is relatively stable or predictable, such as retail, low technology manufacturing or industrial goods manufacturing, the "lean-efficiency" combination may prevail. The "agile-flexibility" fit is expected to be particularly relevant in industries that are given to short product life cycles and continual technology developments, such as high fashion, personal computing equipment and mobile communications devices. Research investigating such patterns would yield insights about industry-specific templates of how SC strategy can be gainfully aligned with IS strategy.

Supply chains are becoming increasingly complex, and the plethora of IT applications available increasingly sophisticated. That notwithstanding, there has been scant academic attention on understanding how or why specific applications are likely to

Table A.1
Job title of respondent firms.

Job Title	Number of firms	Percentage
Senior Managers	113	55
Directors and VP's	89	43
CEO/President	3	2

Table A.2
Job function of respondent firms.

Job function[a]	Number of firms	Percentage
Corporate executive	27	13
Purchasing/procurement	157	77
Manufacturing/production	43	21
Distribution	30	15
Transportation	31	15
Sales	6	3

[a] *Note*: In some cases, one company represented multiple sample points since the responding person was responsible for more than one function in the firm; the calculation of the percentage is based on the total sample size of 205. 43% of the respondents were responsible for more than one function in the firm.

Table A.3
Industry category of respondent firms.

Industry category	Number of firms	Percentage
Manufacturing	170	83
Process industry	3	1
Service	7	3
Others	25	12

Table A.4
Component-based analysis: Loadings on intended construct and cross loadings.

	LSC	ASC	ISSE	ISSF	SCP	FP
LSC1	**0.79**	0.17	0.15	0.03	0.07	−0.12
LSC2	**0.74**	0.1	0.11	0.14	0.17	−0.18
LSC3	**0.77**	0.1	0.09	−0.02	0.08	−0.11
LSC4	**0.86**	0.42	0.27	0.13	0.23	−0.03
LSC5	**0.85**	0.46	0.26	0.13	0.24	−0.01
LSC6	**0.80**	0.31	0.33	0.17	0.33	−0.06
ASC1	0.42	**0.93**	0.11	0.16	0.32	0.04
ASC2	0.50	**0.93**	0.16	0.22	0.32	0.02
ASC3	0.19	**0.79**	0.15	0.27	0.26	0.03
ASC4	0.14	**0.82**	0.17	0.27	0.27	0.04
ASC5	0.15	**0.77**	0.19	0.23	0.26	0.04
ISSE1	0.25	0.1	**0.79**	0.31	0.21	0.23
ISSE2	0.20	−0.01	**0.81**	0.33	0.30	0.26
ISSE3	0.35	0.18	**0.78**	0.33	0.37	0.13
ISSE4	0.28	0.17	**0.81**	0.42	0.38	0.21
ISSE5	0.23	0.17	**0.82**	0.43	0.40	0.12
ISSF1	0.10	0.1	0.36	**0.88**	0.25	0.13
ISSF2	0.09	−0.05	0.42	**0.83**	0.07	0.13
ISSF3	0.17	0.02	0.47	**0.79**	0.17	0.07
ISSF4	0.19	0.35	0.37	**0.89**	0.35	0.15
SCP1	0.24	0.20	0.31	0.24	**0.75**	0.05
SCP2	0.38	0.37	0.39	0.19	**0.77**	0.04
SCP3	0.19	0.33	0.24	0.25	**0.77**	0.17
SCP4	0.24	0.15	0.37	0.22	**0.79**	−0.04
SCP5	0.19	0.22	0.25	0.21	**0.76**	−0.03
SCP6	0.12	0.2	0.27	0.27	**0.78**	0.11
SCP7	0.32	0.09	0.40	0.27	**0.82**	0.06
SCP8	0.17	0.03	0.36	0.25	**0.78**	0.15
SCP9	0.26	0.16	0.29	0.28	**0.82**	0.21
SCP10	0.26	0.09	0.55	0.30	**0.79**	0.10
FP1	−0.05	−0.03	0.22	0.09	0.12	**0.81**
FP2	−0.11	0.1	0.21	0.16	0.21	**0.90**
FP3	−0.14	−0.07	0.23	0.04	0.07	**0.80**
FP4	0.15	0.03	0.17	0.15	0.16	**0.91**
FP5	0.2	0.03	0.25	0.20	0.15	**0.82**
FP6	0.11	0.07	0.19	0.11	0.08	**0.83**

Table A.5
Correlation of constructs and the AVE.

Construct	LSC	ASC	ISSE	ISSF	SCP	FP
LSC	**0.81**					
ASC	0.383**	**0.86**				
ISSE	0.235**	0.15*	**0.84**			
ISSF	0.201**	0.175*	0.15*	**0.76**		
SCP	0.246**	0.449**	0.24**	0.156*	0.**84**	
FP	−0.12	−0.042	0.11	0.189*	0.28**	**0.72**

Note: Diagonal elements in (bold) are the square root of the average variance extracted (AVE) between the constructs and their measures. Off diagonal elements are correlations between constructs. For discriminate validity, AVE should be greater than off-diagonal elements.

** Correlation is significant at 0.001.

* Correlation is significant at 0.05.

benefit particular types of supply chains. This paper shows that the IS strategy of the firm with respect to its supply chain applications portfolio, when appropriately matched with its SC strategy, can reinforce the latter's positive effects and deliver a boost to the performance of the supply chain. The paper delivers theoretical extensions to current academic discourse on the supply chain—IS interface. For practice, the paper offers a generalizable basis to understand information processing needs and corresponding applications that can be gainfully deployed, for different types of supply chains.

Appendix A

See Tables A.1–A.5.

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