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Implementation of a responsive supply chain strategy in global complexity: The case of manufacturing firms

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ABSTRACT

Although a responsive supply chain is an integral part of order-winning manufacturing strategies, it has not been clear how firms build a responsive supply chain in global manufacturing environments. Built upon a synthesis of the existing literature and relevant theories, this paper presents a research model that defines the drivers, strategy, and practices of a responsive supply chain and the performance outcomes. This paper is one of the rare empirical studies that identify key variables relevant to the implementation of a successful responsive supply chain. The effective implementation of a responsive supply chain requires a careful definition of a responsive supply chain strategy in terms of the product range, and the frequency and innovativeness of the product offerings. Firms also need to provide key implementation practices (i.e., sharing of information with customers, collaboration with suppliers, use of advanced manufacturing technology) to achieve pull production to achieve responsiveness to the market. This study also suggests that the key contextual factors that influence the extent of implementation of a responsive supply chain strategy are mostly the size of firms, industry characteristics, and customer and supplier bases, rather than the location of manufacturing firms. This paper shows that the effective implementation of a responsive supply chain strategy involves the integration of inter-organizational resources (i.e., socio-relational and techno-process integration) across the global supply chain to enhance pull production capabilities.

1. Introduction

In an era of worldwide economic downturn, a global supply chain is fraught with greater demand uncertainty, higher risk, and increasing competitive intensity. As such, the success of global manufacturing activities often hinges on a manufacturing firm's flexibility in terms of its ability to adapt its supply chain to dynamic changes in customer needs and preferences. Since such flexibility can be enhanced by increased access to real-time customer information throughout the supply chain, many leading-edge manufacturing firms have attempted to enrich their customer information sources and share real-time customer information with their supply chain partners. Thus, the main principle of supply chain management (SCM) is that firms must become more customer-centric, information-intensive, and flexible. This is referred to henceforth as “responsive” SCM. Responsive SCM is different from traditional SCM in that the former aims at increasing customer bases and long-term profitability through agile demand planning, whereas the latter has focused heavily on increasing cost-saving opportunities through improved efficiency in outsourcing, production planning, and logistics processes. Although improved efficiency throughout the end-to-end supply chain can enhance a firm's competitiveness, it will not necessarily make the firm an order winner. The rationale is that improved efficiency alone will not help the firm differentiate its products from those of its competitors.

For example, auto parts makers that won accolades for efficient manufacturing have suffered from hyper-competition and have gone bankrupt due to their failure to make their operations more flexible (Hugos, 2007). Similarly, Motorola's market share in the U.S. cell phone industry plummeted from 60% in 1994 to 31% in 1998 and then to 16% in 2002 due to its lack of responsiveness to the growing customer demand for digital technology (Finkelstein, 2003). To make it worse, Motorola in 2008 laid off 150 research and development (R&D) staff in its attempt to reduce product development costs and was criticized by its customers for uninspired hand-set lineups that contributed to further losses in its revenue and market share in the cell phone industry (Deffree, 2008). As these examples illustrate, the efficiency-based supply chain often presumes that customer demand is predictable or stable. However, this assumption often does not hold for highly

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customized and short life cycle products such as toys (Wong et al., 2006); semiconductors (Donk and Vaart, 2007), fashionable apparel (Brun and Castelli, 2008; Storey et al., 2005), personal computers (Kapuscinski et al., 2004), consumer electronics (Catalan and Kotzab, 2003), and automobiles (Holweg, 2005). Indeed, Lee (2004) observed that efficiency-based, cost-saving supply chains tend to be more vulnerable to unanticipated shifts in customer demand than do responsive supply chains. Similarly, Porter (1996) argued that efficiency-based, cost-saving supply chains might lead firms to concentrate on short-term gains instead of long-term profitability and thus such firms might be reluctant to invest in new product development and technological innovations more suited to changing customer needs and preferences.

As an alternative to the efficiency-based supply chain, Heikkilä (2002), Reichhart and Holweg (2007), and Gunasekaran et al. (2008) have examined a responsive supply chain that can better cope with today's demand oscillation. However, the influence of a responsive supply chain strategy on a firm's performance has yet to be tested empirically. To initiate such empirical research, this paper attempts to make the following contributions: First, this paper conceptualizes a responsive supply chain and clarifies its role in improving strategic advantages from a focal company perspective. Second, this paper constructs an integrative research framework that captures the essence of a responsive supply chain based on a synthesis of prior studies. Third, this paper empirically assesses the impacts of a responsive supply chain strategy on a firm's performance and subsequent competitiveness.

To put it simply, a responsive supply chain focuses on market responsiveness as a core element of the supply chain processes. It aims to increase customer value throughout the supply chain. To elaborate, the main objectives of a responsive supply chain are (1) to improve agility in order to enhance responsiveness to customer demands. In other words, the responsive supply chain aims at providing customers with the right product at the right time in the right place by utilizing point-of-sales information; (2) to increase flexibility in order to respond to changing customer demands by streamlining and centralizing the supply chain planning processes including new product development and market expansion; (3) to reduce risk by removing the potential sources of supply chain bottlenecks and disruptions. In this paper, we will examine how significantly a responsive supply chain strategy influences the level of information sharing with end-customers, the development of collaborative practices with suppliers, the use of advanced manufacturing technology, and the pull production strategy that has been employed as a way to improve manufacturing efficiency.

2. Theories of responsive supply chain management

Over the last two decades, supply chain management (SCM) has risen to prominence due to its emphasis on long-term strategic benefits including strategic alliances (or business linkages) among a network of business organizations (Hong et al., 2009b; Brown and Bessant, 2003; Storey et al., 2006). Acknowledging the strategic focus of supply chains, a number of researchers have examined the different roles that strategy plays in improving supply chain efficiency. Among these researchers, Fisher (1997) observed that product characteristics influenced demand variability, while lead time dictated the type of supply chains that shaped different forms of supply chain strategy. More recently, the paradigms of build-to-order production and rapid-fire order fulfillment have been presented as a viable strategy that helps to improve supply chain responsiveness to volatile demand (Gunasekaran and Ngai, 2005; Reichhart and Holweg, 2007; Holweg, 2005; Sharif et al., 2007). This stream of research aims to understand the front end of the demand side better and then to make the supply chain effective through extensive, proactive information sharing with customers (Sharif et al., 2007). In fact, a clear understanding of customer demand through proactive information sharing with customers allows a manufacturing firm to better understand the dynamics of changing customer demand and then gives such a firm more incentives to collaborate with its suppliers to reduce demand uncertainty (Holweg and Pil, 2001; Holweg et al., 2005). Such proactive interaction with customers and suppliers eventually enables a manufacturing firm to streamline its production process from downstream to upstream in the supply chain, thereby making its pull production process seamless.

2.1. *The order winner and order qualifier framework*

Hill (2000) stressed that the purpose of manufacturing strategy should not be limited to operational efficiency but, rather, should be extended to the creation of strategic advantages by reflecting on market volatility and trends. This can be made possible by meeting both order-qualifying and order-winning criteria (Hill, 2000). To meet order-qualifying and order-winning criteria, management needs to determine the specific domains of its manufacturing system (Hill, 2000; Slack and Lewis, 2002). Five domains are identified by Skinner (1965, 1985): (1) plant and equipment; (2) production planning and control; (3) labor and staffing; (4) product design and engineering; and (5) organization and management. Slack and Lewis (2002) rework the content of manufacturing strategy into four areas: (1) capacity; (2) supply networks; (3) process technology; and (4) development and organization. These four areas involve structural and infrastructural issues. In this reworking, a structural domain is defined as “the physical arrangement and configuration of the operation's resources,” such as the physical size and location of operations, while an infrastructural domain is referred to as “the activities that take place within the operation's structure,” such as process technology (Slack and Lewis, 2002). Thus, the ultimate aim of management is to match “the performance of an operation's resources with the requirements of its markets” (Slack and Lewis, 2002).

Mason-Jones et al. (2000) extended the concepts of order winners and order qualifiers to the supply chain context. These authors regarded order qualifiers as market qualifiers and order winners as critical differentiators. They observed that firms striving for a lean supply chain regarded quality and reliability as market qualifiers, while low price was viewed as an order winner. Similarly, firms stressing supply chain agility tended to view quality and reliability as market qualifiers, while regarding lead time as an order winner. In these authors' argument, what differentiates the agile supply chain from the lean supply chain is the increased velocity of supply chain operations. Their view was shared by Aitken et al. (2005), who underscored the importance of supply chain agility for winning orders. Aitken et al.'s study also recognizes the order winner and order qualifier framework proposed by Hill (2000) as the important aspect of supply chain strategy. In particular, as Fig. 1 displays, direct linkage to a responsive supply chain strategy using the order winner and order qualifier framework is relevant to both responsive and lean supply chain strategies.

Since this framework reflects market status as it was until the late 1990s, it is not up to date. In the 21st century, the competition has become more intense and technology development has been accelerated. As a result, the product development life cycle has been shortened and product variety has been increased considerably. Customers go beyond acceptable quality and ask for more innovative and eye-catching products. For example, Apple captured the hearts of its customers by introducing innovative, fashionable products such as iPod, iTune, iPhone, and iPad. Likewise, Nintendo transformed the landscape of competition in the video game market and broadened its customer bases by

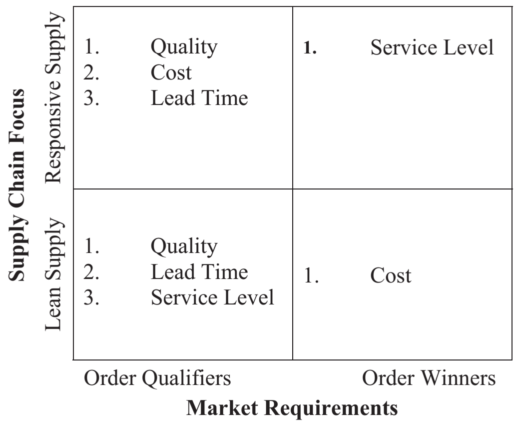

Fig. 1. Order winners and market qualifiers as the determinants of supply chain focus.
(*Source*: Adopted from Mason-Jones et al. (2000)).

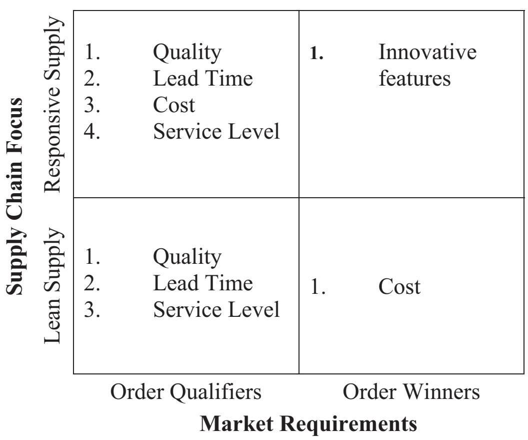

Fig. 2. Updated order winners and market qualifiers as the determinants of the supply chain strategy.
(*Source*: Adapted from Mason-Jones et al. (2000)).

constantly introducing new versions of an innovative product, Wii. These examples demonstrate that order winners have begun to prioritize product innovation and diversity over price bargains and reliability. Thus, the framework shown in Fig. 1 should be updated by changing the order winning principle as shown in Fig. 2.

Fig. 2 recognizes the innovative feature as an order-winning criterion. As illustrated by Figs. 1 and 2, the order winner and order qualifier framework can reflect the shifts in customer demand and preferences over time and thus can be utilized to develop a responsive supply chain strategy.

2.2. *The resource-based view*

The resource-based view (RBV) is useful for describing the role of strategic resources and capabilities within the firm and its network (Barney, 2000). Tangible resources (e.g., facilitators and technologies) and intangible capabilities (e.g., interorganizational relationships, infrastructures, and process skill-sets) are both critical in enabling firms to implement a responsive product strategy across the supply chain (Cousins and Menguc, 2006). Since a responsive supply chain often requires cross-organizational product development, coordination mechanisms among diverse supply chain partners are essential (Hong et al., 2009a). Thus, a responsive supply chain necessitates higher levels of interactive communications with both upstream suppliers and downstream customers. These communications can be facilitated by the supply chain partners' information technology infrastructure, internal organizational structure, and manufacturing capabilities (Song and Nagi (1997); Sharif et al., 2007).

2.3. *The essence of a responsive supply chain strategy*

Most of the SCM literature to date has focused on the improvement of operational efficiency in sourcing, manufacturing, and logistics through the utilization of mathematical and simulation models (Min and Zhou, 2002). To fill the void left by prior SCM research, a few attempts have been made to conceptualize supply chain strategy and formulate it in such a way that it can help firms increase their competitiveness in today's dynamic, uncertain, and risky business environments. As shown in Fig. 3, to make a supply chain strategy successful, the supply chain strategy should be closely aligned with corporate strategy as it shapes supply chain practices. Supply chain practices solidly built upon a supply chain strategy can enhance the firm's and its supply chain partners' business performance and thus their competitiveness.

In response to the need for a viable supply chain strategy, Fisher (1997) proposed two distinctive supply chain strategies: (1) an efficient strategy; and (2) a strategy that is responsive with respect to the type of products: functional and innovative. Further extending the strategic framework developed by Fisher (1997), Mason-Jones et al. (2000) categorized supply chain strategies into three different types: lean, agile, and leagile. To elaborate, a lean supply chain strategy aims to develop a value stream from the suppliers to the final customers in order to eliminate all kinds of buffering cost in the supply chain and to ensure a stable schedule in production in order to improve process efficiency and then maintain the competitive advantage through economies of scale in a stable and predictable marketplace. On the other hand, an agile supply chain strategy aims to develop a flexible and reconfigurable network with partners to share competences and market knowledge in order to ensure survival and prosperity in a fluctuating market environment by achieving a rapid response to market changes. A leagile supply chain strategy, which combines some elements of both lean and agile strategies, utilizes make-to-stock/lean strategies for high volume, stable demand products, while using make-to-order/agile strategies for everything else. Thus, a leagile supply chain strategy can provide flexible production capacity to meet surges in demand (e.g., seasonal demand) or unexpected requirements, while using postponement strategies for "platform" products that are made to forecast, and then assembled and configured upon final customer orders (Christopher and Towill, 2001; Goldsby et al., 2006).

Going one step further, Lee (2002) put forward a demand and supply uncertainty framework that produces four types of supply chain strategies: efficient, risk-hedging, responsive, and agile, as summarized in Table 1. A firm may pursue efficient supply chains when a market is mature and competitive advantage is achieved primarily through low cost and high productivity. Firms employ an efficient supply chain strategy to manufacture quality products efficiently and to provide customers with reliable services. A risk-hedging supply chain strategy can be used when a supply chain is fraught with risk and uncertainty. In addition to the retail industry, hydro-electric power and some food producers provide examples of this category (Lee, 2002; Boone et al., 2007). To leverage supply uncertainties, a firm would increase buffer stocks for its core products and attempt to share the cost of the safety stock with its supply chain partners.

In general, a responsive supply chain strategy is suitable for firms that offer a variety of innovative or customized products tailored to specific customer demands and taste (Fisher, 1997). To accommodate customers' fluctuating demands, this strategy may postpone the final assembly/manufacture of a product until the demand becomes known. The fashion apparel, computer, and music CD industries often use this strategy (Lee, 2002). Though

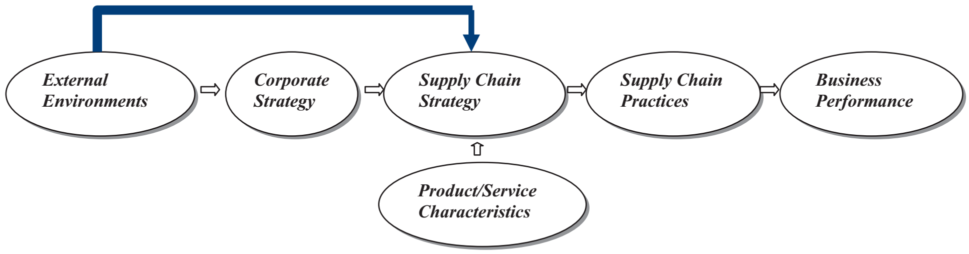

Fig. 3. Supply chain strategy and its role in business performance.
(*Source*: Adapted from Fisher (1997) and Huang et al. (2002)).

Table 1
Types of supply chain strategies.
(*Source*: Adapted from Lee (2002), and Vonderembse et al. (2006)).

Category	Efficient supply chain	Risk-hedging supply chain	Responsive supply chain	Agile supply chain
Supply uncertainty	Low	High	Low	High
Demand uncertainty	Low	Low	High	High
Definition	An ESC aims at achieving the highest cost efficiencies in the supply chain through the elimination of waste or non-value added process.	An RHSC aims at sharing risks of supply disruption through pooling and sharing resources.	An RSC aims at being rapidly adaptive to changes in customer needs and market volatility.	An ASC aims at being responsive and context-specific to customer needs, while the risks of supply shortages or disruptions are hedged by pooling inventory or other capacity resources.
Focus	Highest cost efficiencies in the supply chain.	Cost-efficiency and hedging the risk of supplier disruptions.	Adaptability to rapidly changing customer needs.	Market-oriented and has the capacity to meet a wide variety of market niches simultaneously.
Product type	Functional	Functional	Innovative	Innovative
Competitive priorities	Cost and quality	Cost, flexibility, quality	Speed, flexibility	Speed, flexibility, innovation
Supplier relationship	Transaction-based	Relation-based	Time-based	Partnership-based

somewhat similar to a responsive supply chain strategy, an agile supply chain strategy is the most flexible and the most market-driven strategy among the four categories of supply chain strategies. An agile supply chain strategy aims at increasing flexibility and enabling velocity to adjust promptly to volatile market conditions and to unpredictable sources of supply. Thus, an agile supply chain strategy focuses on fast market responses and quick new product development, while minimizing supply disruptions by streamlining information flows across the supply chain. The firms that exploit an agile supply chain strategy can be found in the high-end personal computer and semiconductor industries.

Within the four supply chain strategy framework described above, the present research focuses on the responsive supply chain strategy and examines a number of strategic variables that have been impacted by a responsive supply chain strategy from a focal company standpoint. For the purpose of this study we have identified six variables, which are summarized in Table 2.

3. Development of hypotheses

To identify the factors that are essential for the successful implementation of a responsive supply chain strategy, we develop a number of hypotheses and then test their validity using empirical data. In the following section, theoretical justifications for these hypotheses are provided in detail.

3.1. The responsive supply chain and information sharing with customers

The identification of a strategy can be carried out in various ways. Some researchers have taken a resource-based view, examined the capabilities of firms that are characterized by a specific supply chain strategy (McKone-Sweet and Lee, 2009; Coates and McDermott, 2002), and developed a typology from this. Another way to distinguish strategies is to examine competitive priorities (Hayes and Pisano, 1994; Lamming et al., 2000; Slack and Lewis, 2002). Fisher (1997) argued that an efficient supply chain strategy is suited to functional products while a responsive strategy is suited to innovative products. The competitive priorities for this responsive supply chain consist of innovation, flexibility, and frequent new product offerings (Fisher, 1997; Mason-Jones et al., 2000; Lee, 2002; Vonderembse et al., 2006).

To sustain such competitive priorities, the responsive supply chain strategy often rests on the manufacturer's ability to coordinate its production plans with its customers through information sharing (Banerjee et al., 2012; Roh et al., 2011). Since the acquisition of accurate and timely demand information enables firms to mitigate the bullwhip effect emanating from the erroneous prediction of end-customers' demand, firms with a responsive supply chain strategy can enhance supply chain visibility, which helps them exploit built-to-order production schedules (Forrester, 1961; Holweg and Pil, 2001; Sharif et al., 2007). As such, firms with a responsive supply chain strategy are likely to increase the extent of information sharing with their end-customers. To consider this likelihood, we posit the following hypothesis:

Hypothesis 1. Firms implementing a responsive supply chain strategy will exhibit a higher level of information sharing with customers.

3.2. The responsive supply chain and collaboration with suppliers

Holweg et al. (2005) pointed out that the idea of sharing information with suppliers alone will not make a responsive supply chain successful. To enhance supply chain visibility, they

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Table 2
Constructs, definition, and literature base.

Variables	Definition	Literature
Responsive supply chain strategy	Strategic determination of major customer requirements in terms of range, frequency, and innovativeness of product offerings	Gunasekaran and Ngai (2005), Hill (2000) Slack and Lewis (2002), Christopher and Towill (2001), Hayes and Pisano (1994), Lamming et al. (2000)
Information sharing with customers	The extent of use of electronic tools with key and strategic customers for access to vital information, collaboration, and service arrangements	Da Silveira et al. (2001), Sharif et al. (2007), Olhager (2002), Gunasekaran et al. (2008), Caniato et al. (2009), Youn et al. (2012a)
Collaboration with suppliers	The extent of coordinate planning decisions and flow of goods and physical interactions with key and strategic suppliers	Zirger and Maidique (1990), Brown and Eisenhardt (1995), Holweg (2005), Holweg et al. (2005), Huang et al. (2002), Liao et al. (2010)
Advanced manufacturing technology	The extent of operational activities performed by automated technologies for loading/unloading, guided vehicles, and storage-retrieval systems	Idris et al. (2008), Hugos (2007), Lei et al. (1996), Song and Nagi (1997), Sim (2001), Tracey et al. (1999)
Pull production	The degree to which specific action programs, related to reducing batches, to reducing setup time, and to the use of Kanban systems, are undertaken	Hopp and Spearman (2004), Cheng and Podolsky (1993), Koufteros et al. (2007)
Responsiveness to market	The reported operational performance results in terms of time to market, delivery speed, delivery dependability, and manufacturing lead time	Gunasekaran et al. (2008), Reichhart and Holweg (2007), Holweg and Pil, 2001, Holweg (2005), Heikkilä (2002)

argued that supply chain collaboration should precede information sharing practices. Collaboration with suppliers deepens suppliers' insights into customer value and makes it possible to embark on co-innovation in terms of components or parts (Flint et al., 2011). Indeed, Youn et al. (2012b) observed that close collaboration with suppliers tends to precipitate the development of innovative products. Thus, a focal company in a given supply chain needs to encourage the early involvement of its suppliers in new, innovative product design and development. Early supplier involvement in innovative product development requires the focal company to better understand its suppliers' capabilities (e.g., suppliers' design, manufacturing, and financial capabilities) and then leverage them to increase its responsiveness (Hong et al., 2004, 2009a; Szwejczewski, et al., 2005; Oh and Rhee, 2008; Tomino et al., 2009). For example, Bang and Olufsen (B&O) successfully developed its new mobile phone with technological support from its supplier, Samsung, after B&O established an effective collaborative relationship with the supplier. As illustrated above, since mutual cooperation between the focal company and its suppliers should precede early supplier involvement, the establishment of collaborative relationships with suppliers is essential for formulating a responsive supply chain strategy. Therefore, it is hypothesized that

Hypothesis 2. Firms implementing a responsive supply chain strategy will exhibit a higher level of collaboration with their suppliers.

3.3. The responsive supply chain and advanced manufacturing technology

A responsive supply chain strategy calls for a more demand-oriented manufacturing strategy that is characterized by diversified product lines, mass customization, and quicker customer response time. Effective responses to increasing environmental uncertainty require manufacturers to enhance flexible manufacturing technologies as a source of competitive advantage (Sim, 2001; Zhang, et al., 2006). In fact, Liu et al. (2011) found that firms equipped with advanced manufacturing technology tend to create a greater absorptive production capacity and multiple production capabilities. In light of the above discussion, firms need to leverage advanced manufacturing technology such as automated parts loading, automated guided vehicles, and automated storage and retrieval systems, which are useful for helping firms reduce market response time, improve manufacturing flexibility, speed up new product development, and ensure the continuous flow of products (Kaplan, 1990; Idris et al., 2008). Therefore, we posit the following hypothesis:

Hypothesis 3. Firms implementing a responsive supply chain strategy will adopt a higher level of manufacturing technology.

3.4. Information sharing with customers and collaboration with suppliers

With growing market uncertainty in a time of global financial crisis, flexibility and responsiveness become the most significant dimensions (Gerwin, 1993; Holweg, 2005). The successful development of this responsive supply chain strategy requires timely and accurate information regarding customer demand patterns and changing needs. Due to the layers involved in a supply chain that may hamper visibility, demand information in the downstream supply chain should be transmitted on a real-time basis to the upstream supply chain partners such as suppliers and original equipment manufacturers (OEMs). A firm's capability to share and transmit such information among its supply chain partners is known to be essential for facilitating supply chain agility and flexibility (Da Silveira et al., 2001). The use of information technology (IT) such as electronic data interchange (EDI) makes the information flow across the supply chain smooth and transparent. In particular, real-time demand information, which reduces uncertainty, helps to reduce inventory levels, backorders, and upstream demand variations (Sharif et al., 2007; Olhager, 2002). Furthermore, Lau et al. (2010) have found that customers can become sources of innovative ideas and thus facilitate innovative product development. Considering these managerial benefits of information sharing, supply chain partners will be encouraged to perform more collaborative practices that will foster an organizational culture of mutual trust and cooperation. Thus, we postulate the following hypothesis:

Hypothesis 4. The more information sharing practices a firm performs with strategic customers, the more collaborative practices the firm will engage in with strategic suppliers.

3.5. Collaboration with suppliers and the use of advanced manufacturing technology

Studies conducted by both Zirger and Maidique (1990) and Brown and Eisenhardt (1995) indicated that internal collaboration within an organization (e.g., between marketing and manufacturing) often helped the organization develop a more rational plan and subsequently succeed in developing new products.

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In particular, the process of developing new products opens a space for a variety of supply chain partners with different expertise, knowledge, and perspectives that will foster a culture of collaboration among them. This cultural transformation resulting from collaborative supply chain practices can increase the chance of experimenting with advanced manufacturing technology.

Indeed, Lei et al. (1996) discovered a strong correlation between a firm's organizational flexibility with regard to collaboration and its exploitation of advanced manufacturing technologies. Similarly, Rahman et al. (2009) confirmed the positive influence of a manufacturer-supplier relationship on the adoption of advanced manufacturing technology. That is to say, a firm that is composed of modular structures and open communication systems flexible enough to build collaborative relationships with its suppliers and customers is more likely to be receptive to organizational learning and consequently will be open to the use of new technology. With the basic technology infrastructure in place, such a firm is highly likely to develop and use more advanced manufacturing technologies such as automated parts loading/unloading, automated guided vehicles, and automated storage-retrieval systems than its stand-alone counterpart without any established supplier/customer partnership. Therefore, it is hypothesized that

Hypothesis 5. The more a firm collaborates with its suppliers, the higher the level of advanced manufacturing technology it will operate.

3.6. *Information sharing with customers and pull production*

Song and Nagi (1997) observed that IT use is strongly correlated with manufacturing flexibility. The rationale is that the use of IT such as a point-of-sale system (POS) and electronic data interchange (EDI) enhances supply chain visibility and thus increases timely access to demand information (Claudio and Krishnamurthy, 2009). Easy access to demand information will allow the firm to adopt a flexible production schedule in accordance with fluctuating demand patterns. Since a flexible production schedule is a prerequisite to a pull production system, IT use can dictate the success of a pull production system. In fact, Koufteros et al. (2007) found that manufacturing firms communicating more frequently with their internal and external customers were able to implement pull production more successfully. For instance, as an external customer demands a change, the manufacturing firm needs to be aware of such a change well in advance so that it can produce the right product at the right time for the customer. Similarly, internal customers such as the firm's workers on the shop-floor can immediately address a potential production problem based on the information already available to the shop-floor so that they can maintain an uninterrupted flow of materials throughout the supply chain. A case in point is Boeing's pull production system, which replaced its “batch and queue” production configurations with aligned, single-piece manufacturing principles based on real-time demand information. In batch and queue (push) production systems, Boeing's production schedule relied heavily on written reports available from each workshop that were rarely read by the workers and thus created many bottlenecks and unbalanced workloads due to limited supply chain visibility. To correct this, Boeing exploited visual control systems that allowed its workers instantly to recognize the need for process improvement and to share such needs with other workers throughout the manufacturing processes through internal information sharing efforts. These efforts, for instance, did not allow rejection tags to go beyond one problem area. Likewise, information sharing practices should precede the pull production system, since uninterrupted material flow and flexible production are essential for the successful implementation of the pull production system. In other words, information sharing practices predicated on IT use can boost the efficiency of the pull production system. Therefore, we posit the following hypothesis:

Hypothesis 6. The higher the level of information sharing practices a firm utilizes, the higher the level of pull production the firm will achieve.

3.7. *Collaboration with suppliers and pull production*

Supply chain collaboration with strategic suppliers increases a firm's responsiveness to market changes (Holweg et al., 2005). This increased responsiveness is due to supply chain collaboration that increases customization capability and the extent of knowledge sharing and communication (Rahman et al., 2009). In general, a manufacturing firm can deal with market dynamics better when its suppliers and customers complement it, thereby giving it greater leeway to deal with various market changes. For instance, a vendor-managed inventory (VMI) program supported by the firm's suppliers can help reduce its inventory level, which is necessary to make the pull production system work. Another example that illustrates the positive impact of supplier collaboration on pull production such as just-in-time (JIT) production is the strategic partnership between John Deere and its key supplier, the R and B Machining and Grinding Company, which helped John Deere increase manufacturing flexibility and then successfully utilize lean manufacturing tools and techniques essential for pull production by reducing the cycle time from weeks to hours (American Technical Publisher, 2003). As such, we develop the following hypothesis:

Hypothesis 7. The more a firm collaborates with its suppliers and customers, the higher the level of pull production the firm will achieve.

3.8. *The use of advanced manufacturing technology and pull production*

Heikkilä (2002) observed that advanced manufacturing technology contributed significantly to the enhancement of competitive edge. In addition, Stalk (1988) discovered that advanced manufacturing technology could increase a firm's manufacturing flexibility, as evidenced by the success of some Japanese firms such as Toyota. Toyota's success, in part, stemmed from the effective use of advanced manufacturing technology such that manufacturing flexibility could reduce changeover time and thus facilitate time-based manufacturing practices such as just-in-time production systems. Since pull production is predicated on manufacturing flexibility, advanced manufacturing technology can dictate the efficiency and effectiveness of pull production.

In addition, competence in advanced manufacturing technology reflects a firm's ability to increase mass customization and product innovation. For example, LG Electronics recently leveraged its advanced design competence in cellular phone products and accessories to take a significant market share away from its rivals such as Nokia, Samsung, and Motorola. As a matter of fact, thanks to its advanced design competence, LG's market share in the cellular phone industry soared from 6.4% in January 2008 to 8.6% in March 2008 (Moon, 2008). This success can be further explained by the organization information processing theory developed by Daft and Lengel (1986), suggesting that the use of advanced manufacturing technology increases the firm's manufacturing flexibility and improves its resilience in the changing marketplace. In particular, the managerial benefits of advanced

Table 3
Profile of respondents.

Region	n	(%)	Industry by ISIC	n	(%)	Size	N	(%)
Asia/Pacific	110	19.7	28: Fabricated metal	214	38.3	Small	317	56.7
Europe	317	56.7	29–30: Machinery	130	23.3	Medium	113	20.2
North America	47	8.4	31–32: Electronics	108	19.3	Large	124	22.2
South America	71	12.7	33: Medical/Optical	21	3.8	Missing	5	0.9
Middle East	14	2.5	34–35: Automotive	83	14.8			
			36: Miscellaneous	3	0.5			
Total	559	100		559	100		559	100

manufacturing technology will be greater when the development of products becomes more complex and product demands are unpredictable (Jassawalla and Sashittal, 1999; Hong et al., 2004). Since such complex product development often calls for pull production, we posit the following hypothesis:

Hypothesis 8. The higher the level of advanced manufacturing technology a firm uses, the more extensively the firm will utilize pull production.

3.9. Pull production and responsive market outcomes

Under pull production, products are made only when customers request them, not before; thus, pull production enhances responsiveness throughout the supply chain. In other words, if production changes or problems occur in the upstream part of the supply chain, the downstream processes will be shut down, thereby preventing the accumulation of inventory throughout the downstream part of the supply chain (Cheng and Podolsky, 1993; Hopp and Spearman, 2004). By reducing fluctuations in the work-in-process inventory level, pull production can shorten the cycle time and thus increase responsiveness to market demand (Hopp and Spearman, 2004). In addition, pull production is known to facilitate mass customization, which, in turn, enhances a firm's responsiveness to the market (Tu et al., 2001). Thus, we posit the following hypothesis:

Hypothesis 9. The more extensive the use of pull production, the greater the responsive market outcomes will be.

4. Research methods

4.1. Sample

To test the series of hypotheses developed in the previous section, empirical evidence was drawn from the International Manufacturing Strategy Survey (IMSS). IMSS aims at examining the patterns of international manufacturing practices. Since 1992, it has contained empirical data from various manufacturing firms representing more than 20 countries, and it has been updated every four years. The particular set of data used in this research is IMSS-IV, which yielded data on 751 manufacturing units from 24 countries around the world in 2005. In order to administer the process of data collection in different countries, a research group developed a standard questionnaire and translated it into different languages after ensuring that the translated version conveys the same meaning as the standard one. Included in the survey are nine manufacturing industries with ISIC codes ranging from 28 to 36, which represent metal products, semi-conductor, electrical machinery, precision instrument, automotive, and other transport industries. Initially, operations or manufacturing managers were contacted to ascertain their willingness to participate in the survey, and the response rate varied across countries—with a minimum response rate of 20%, which meets the requirement for a positive assessment of mail survey results (Malhotra and Grover, 1998). The survey instrument was designed based on the method suggested by Dillman (1978). Over the years, papers using IMSS I–IV have been published extensively in the supply chain management literature (see, e.g., Voss and Blackmon, 1998; Cagliano et al., 2006; Yang et al., 2011).

It is important to note that 192 incomplete responses out of 751 were excluded, resulting in usable data on 559 manufacturing units. Table 3 summarizes the profile of respondents by region, industry, and employment scale. The majority of the responses (56.7%) are from European countries, while the responses from the Asia/Pacific area and South America are the next largest in number. The ISIC codes show that the responses varied from fabricated metal to automotive companies. In terms of the number of employees, small and medium companies accounted for a majority of the responses, while large companies represented 22.2%.

4.2. Measures

Measures for each construct were chosen from the literature survey, and Table 4 reports the items employed in the current study. To select items that assess the responsive supply chain strategy, the past literature regarding responsive supply chains was examined (Fisher, 1997; Mason-Jones et al., 2000; Christopher and Towill, 2001; Heikkilä, 2002; Lee, 2002; and Gunasekaran et al., 2008), and the items were chosen from the IMSS V survey. The measurement items for information sharing with customers stem from studies by Olhager (2002), Sharif et al. (2007), and Caniato et al. (2009). The measurement items for collaboration with suppliers come from Holweg et al. (2005) and those for advanced manufacturing technologies from Lei et al. (1996). The items for pull production were extracted from Koufteros et al. (2007) and those for responsiveness to the market from Reichhart and Holweg (2007).

The assessment of rigorous reliability and validity followed the selection of relevant items. Afterward, to evaluate the focal constructs, exploratory factor analysis (EFA) was first executed using SPSS 18.0. Also, to test the uni-dimensionality of each construct and then assess the internal consistency of the construct, we used Cronbach's alphas (Cronbach, 1951). In general, a principal component analysis with Varimax rotation and mean substitution ensures uni-dimensionality. The acceptable loading limits should be greater than 0.60 for an exploratory study (Nunnally, 1978). Based on the EFA, items were removed from further analysis due to significant cross-loading on multiple factors.

Following this adjustment, three methods were used to verify convergent validity. First, a test of internal consistency reliability using Cronbach's coefficient alphas was performed. The test revealed that Cronbach's coefficient alphas ranged from 0.71 to 0.88, which exceeds 0.60, the threshold value suggested by Nunnally (1978). Second, confirmatory factor analysis (CFA) with the maximum likelihood method was used to assess and validate the revised constructs and scale properties as summarized in

Table 4
Measurement model and descriptive statistics.

Constructs and items		Std. loadings	t-values	Mean	Std. dev.
Responsive supply chain strategy (α:.79)					
Consider the importance of the following attributes in winning orders from your major customers. (1=least important, 5=most important)					
RPS1	Wider product range	0.65	–	3.37	0.99
RPS2	Offer new products more frequently	0.89	13.66	3.22	1.15
RPS3	Offer more innovative products	0.70	13.65	3.57	1.10
Information sharing with customers (α:.88)					
Indicate to what extent you use electronic tools (Internet or EDI based) with your key/strategic customers. (1=no adoption, 5=highest level of adoption)					
ISC1	Data analysis (audit and reporting)	0.76	–	2.71	1.29
ISC2	Access to catalogues	0.58	13.55	2.85	1.31
ISC3	Order management and tracking	0.77	18.44	3.02	1.39
ISC4	Content and knowledge management	0.87	21.09	2.64	1.27
ISC5	Collaboration support services	0.86	20.82	2.74	1.28
Collaboration with suppliers (α:.76)					
How do you coordinate planning decisions and flow of goods with your key/strategic suppliers? (1=no coordination, 5=highest coordination)					
CS1	Require supplier(s) to manage or hold inventories of materials at your site (e.g., Vendor Managed Inventory, Consignment Stock)	0.76	–	2.61	1.26
CS2	Collaborative Planning, Forecasting, and Replenishment	0.71	13.96	2.83	1.14
CS3	Physical integration of the supplier into the plant	0.70	13.54	1.87	1.10
Advanced manufacturing technology (α: .76)					
To what extent is the operational activity in your plant performed using the following technologies? (1=no use, 5=highest use)					
AMT1	Automated parts loading/unloading	0.62	–	2.36	1.37
AMT2	Automated guided vehicles (AGVs)	0.78	13.96	1.51	1.03
AMT3	Automated storage-retrieval systems (AS/RS)	0.80	13.55	1.62	1.06
Pull production (α: .71)					
Indicate degree of the following action programs undertaken over the last three years and planned efforts for the coming three years. (1=no action, 5=highest degree of action)					
PP1	Undertaking actions to implement pull production (e.g., reducing batches, setup time, using Kanban systems, etc.) for the last 3 years	0.87	–	2.90	1.19
PP2	Planned effort to implement pull production (e.g., reducing batches, setup time, using Kanban systems, etc.) within next the next 3 years	0.64	6.98	3.42	1.23
Responsiveness to market (α: .81)					
How has your operational performance changed over the last three years? (1=deteriorated more than 10%, 5=improved more than 50%)					
ORM1	Time to market	0.61	–	2.84	0.87
ORM2	Delivery speed	0.89	14.31	3.01	0.93
ORM3	Delivery dependability	0.73	13.40	3.04	0.92
ORM4	Manufacturing lead time	0.63	12.09	2.80	0.88

Note: standardized coefficients are significant at $^*p<0.001$. statistics: Chi-square/d.f. 292.57/155=1.89; GFI=0.95; AGFI=0.93; NFI=0.94; CFI=0.97; IFI=0.97; RMSEA=0.04 (0.033, 0.047).

Table 4. With the exception of the measurement scale for "access to catalogues," the scale reliability coefficients are above the commonly accepted standard of 0.60 suggested by Nunnally (1978) and Fornell and Larcker (1981).

The measurement model confirmed the presence of six unique constructs. Since the Chi-square fit index alone cannot determine a satisfactory fit between the structural equation model and the data, other fit statistics including the Chi-square/degree of fit ratio, the comparative fit index (CFI), and the root mean square of approximation (RMSEA) were examined. To elaborate, the Chi-square/degree of freedom ratio of 1.89 falls into the recommended range of 3 to 1 (Bollen and Long, 1993). Also, the CFI, the single most important index according to Bentler (1990) because it accounts for sample size bias, is 0.97, exceeding the suggested value of 0.90 (Byrne, 2001).

Furthermore, the RMSEA value of 0.042 is less than the suggested limit of 0.08 for good model fit (Browne and Cudeck, 1993) with 90% confidence level ranging from 0.033 to 0.050. RMSEA has been recognized as one of the most informative indicators of the model fit, because it considers the error of the approximation in population and is sensitive to the number of estimated parameters in the structural equations modeling (SEM) (Byrne, 2001). All of the factor loadings in the CFA model are greater than.5 with the smallest *t*-values being 6.98. Judging from these results, convergent validity was deemed to be ensured.

Table 5 shows descriptive statistics and inter-correlations among variables. To assess discriminant validity, both the average variance extracted (AVE) and composite reliability were calculated and compared with squared correlations. Discriminant validity was established when the AVE value and composite reliability were greater than the squared correlations between a specific construct and other constructs in the model (Fornell and Larcker, 1981; Ewing and Napoli, 2005).

In Table 5, the AVE values are greater than the squared correlations, verifying the evidence of discriminant validity. To verify the presence of a common method bias, additional analysis was conducted following the suggestions made by Podsakoff et al. (2003). When a common method bias was found to be present, a less complex model such as a single-factor model produced a fit as good as that of the more complex model. The six factor model proposed in this study produced a significantly better fit for the data than the single factor model, verifying that the common method bias is not a serious issue.

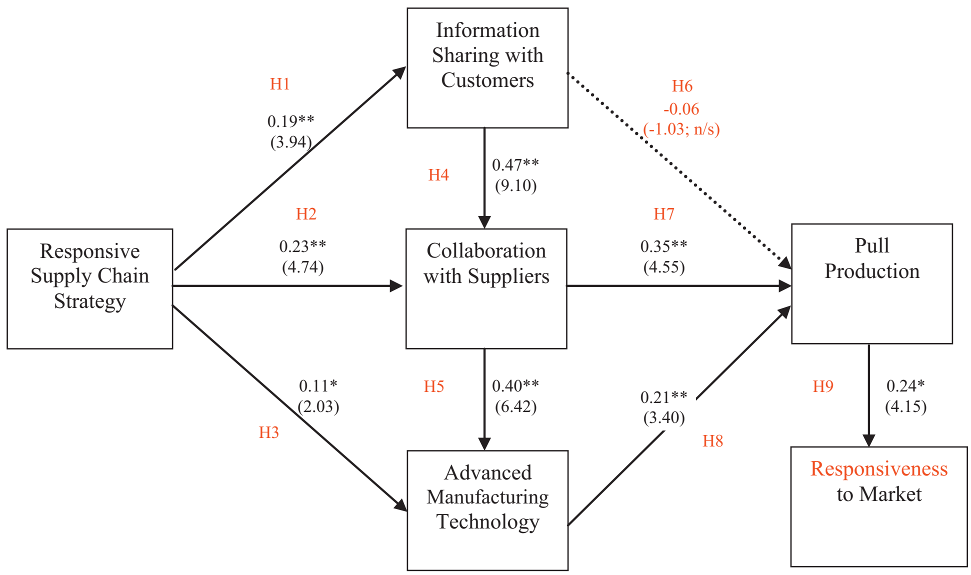
4.3. Results of the use of a structural equation model

A structural equation model (SEM) was used to test the nine hypotheses postulated earlier. SEM is known to be useful for testing the relationships between latent variables and validating

Table 5
Descriptive statistics and inter-correlations.

	Construct	Mean	Std. dev.	1	2	3	4	5	6
1	Responsive supply chain strategy	3.39	.90	0.80[a], [0.57][b]					
2	Information sharing with customers	2.79	1.07	.034[c]	0.88, [0.60]				
3	Coordination with suppliers	2.44	.96	.066	.173	0.76, [0.52]			
4	Advanced manufacturing technology	1.83	.96	.027	.077	.101	0.78, [0.54]		
5	Pull Production	3.16	1.07	.035	.016	.076	.060	0.63, [0.47]	
6	Operational responsiveness to market	2.92	.71	.037	.056	.082	.049	.027	0.81, [0.52]

[a] Composite reliabilities are on the diagonal.
[b] Average variances extracted are on the diagonal in brackets.
[c] Squared correlation.



Note: standardized coefficients are significant at ** p<0.01, * p<0.05.
Model fit: Chi-square/d.f. 353.674/161=2.197; GFI= 0.94; AGFI= 0.92; NFI= 0.92; CFI= 0.96; IFI= 0.96; RMSEA= 0.046 (0.040, 0.053).

Fig. 4. Structural model results.

structural models (Chin, 1998). As recommended by Hu and Bentler (1995), multiple fit criteria are considered to rule out measurement biases in the SEM. The fit indices are similar to those reported in the CFA model and indicate a good model fit (Chi-square/degree of freedom = 2.197, CFI = 0.96, and RMSEA = 0.046) as shown in Fig. 4. Given the overall sound assessment of the measurement model, our next step in data analysis focused on testing the hypotheses. Fig. 4 displays the directions and significances of the hypothesized relationships among the constructs. As shown in Fig. 4, all but Hypothesis 6 were supported by the test results. A rejection of the hypothesized link between information sharing with customers and pull production defies conventional wisdom. However, despite this lack of support for a direct effect, information sharing with customers still influences pull production indirectly; its indirect effects are 0.17 (i.e., 0.47×0.35) and 0.04 ($0.47 \times 0.40 \times 0.21$).

4.4. Contextual analysis

To further investigate the responsive supply chains strategy (RSCS) in manufacturing firms, three contexts were chosen for contextual analysis. The first context is market dynamics. According to Fisher (1997), an efficient supply chain strategy is suitable for functional products while a responsive supply chain is appropriate for innovative products. Market dynamics reflect the characteristics of the market: a declining demand may represent the market for functional products, whereas a growing demand may reflect the market for innovative products. A customer base also plays an important role in understanding a responsive supply chain strategy. In a small customer base, it is easier to implement a responsive supply chain strategy, but a larger customer base makes it difficult to implement that strategy due to diverse customer needs and requirements. By the same token, it is expected that a responsive supply chain strategy can be implemented more successfully in a small supplier base than in a large one Table 6.

Table 6
Chi-square difference test.

	Chi-square	Degree of freedom	*p*-value	Invariant?
Unconstrained	853.968	564		
Fully constrained	933.852	644		
Number of groups		6		
Difference	79.884	80	0.482	Yes

A figure of one hundred suppliers and one hundred customers is selected as a threshold for dividing the groups into two categories (in terms of smaller and larger numbers of suppliers/customers) for two reasons. First, Goffin et al. (1997) reported that the average number of suppliers in various industry sectors in the

Table 7
Contextual analysis (unstandardized coefficient and *t*-values).

Relationship	Total sample	Market dynamics		Customer base: < =or > 100		Supplier base: < =or > 100	
	(n=559)	Declining (n=310)	Growing (n=240)	Small (n=295)	Large (n=206)	Small (n=275)	Large (n=237)
RSC→ ISC	0.29(3.94)	0.25(2.73)	0.27(2.18)	0.4(4.02)	0.22(1.6)	0.22(2.16)	0.37(2.76)
RSC→ CS	0.35(4.74)	0.41(4.04)	0.26(2.4)	0.21(2.28)	0.49(3.51)	0.33(3.49)	0.32(2.43)
RSC→ AMT	0.14(2.03)	0.18(1.93)	0.14(1.3)	0.13(1.46)	0.23(1.66)	0.04(0.46)	0.38(2.76)
ISC→ CS	0.46(9.1)	0.41(5.49)	0.47(6.82)	0.5(7.19)	0.4(5.14)	0.45(6.55)	0.53(6.27)
CS→ AMT	0.36(6.42)	0.17(2.59)	0.48(5.27)	0.4(5.23)	0.28(2.99)	0.35(4.53)	0.39(4.26)
ISC→ PP	−0.06(−1.03)	−0.02(−0.22)	−0.11(−1.19)	−0.01(−0.17)	−0.13(−1.32)	−0.09(−1.05)	−0.09(−0.86)
CS→ PP	0.36(4.55)	0.41(4.6)	0.21(1.59)	0.25(2.29)	0.5(3.87)	0.4(3.75)	0.31(2.28)
AMT→ PP	0.24(3.4)	0.16(1.73)	0.38(3.44)	0.24(2.53)	0.14(1.32)	0.13(1.39)	0.34(2.91)
PP→ RM	0.13(4.15)	0.14(3.41)	0.06(1.55)	0.16(2.96)	0.04(1.15)	0.09(2.27)	0.13(2.77)
Fit indices	Chis./d.f.:2.2	Chis./d.f.:1.58	Chis./d.f.:1.47	Chis./d.f.:1.85	Chis./d.f.:1.47	Chis./d.f.:1.69	Chis./d.f.:1.45
	CFI:.96 IFI:.96	CFI:.96 IFI:.96	CFI:.96 IFI:.96	CFI:.94 IFI:.94	CFI:.95 IFI:.95	CFI:.95 IFI:.95	CFI:.96 IFI:.96
	TLI:.95 RMSEA:.046	TLI:.95 RMSEA:.043	TLI:.96 RMSEA:.44	TLI:.93 RMSEA:.054	TLI:.94 RMSEA:.048	TLI:.94 RMSEA:.05	TLI:.95 RMSEA:.044

UK declined gradually from 1991 to 1995. In another study, it was shown that companies have seen on average a 17% supplier reduction in the UK and Germany. The 21st century has witnessed a more drastic supplier base reduction (Dedrick et al. 2008). Unfortunately, the most recent data on average numbers of suppliers are unavailable in the literature. Thus, this study examined the number of suppliers in the survey, and the result showed that while there are firms with more than 1000 suppliers and 1000 customers (the largest number of suppliers was 100,000), small firms tend to have less than 100 suppliers and 100 customers. Second, the decision to use 100 suppliers/customers as a threshold was also guided by the feasibility of dividing the sample in half. Selecting 100 suppliers/customers as a threshold also presents an opportunity to compare the two samples and examine possible differences between them. While information about the nominal number of suppliers may not yield information about the number of strategic or active suppliers of a company, it sheds light on the complexity of the supply chain that a firm has to deal with. For this reason, the number of suppliers is selected as one of the contextual variables and included in the analyses.

It is necessary to check whether the measurement model holds across the six groups. The Chi-square test comparing the unconstrained and fully constrained models shows that the *p*-value for the Chi-square difference test is greater than the significance level, 0.05, suggesting that the factor structures are invariant (Arbuckle, 2005).

For comparative purposes, un-standardized coefficients are reported in Table 7. Interesting results emerged in the contextual analysis. First, the impact of a responsive supply chain strategy varies depending on the context. In the overall model, its impact is strong on information sharing with customers, collaboration with suppliers, and advanced manufacturing technologies. However, in the context of a growing market, its impact on AMT is not significant (*t*-value is 1.30). This result suggests that, in an innovative product market, firms exert an effort to understand customers through information sharing and reflect the changes in the supply chain by building up collaborative relationships with their suppliers. The insignificant impact of RSC on AMT may be due to the fact that, in a growing market, many companies put out new products and this creates uncertainty with respect to AMT. The size of the customer base and the supplier base also plays a considerable role in the implementation of a responsive supply chain strategy. When customers and suppliers both number more than 100, firms face challenges in grasping customers' needs. Thus, firms with larger customer and supplier bases tend to utilize ISC, CS, and AMT actively. However, firms with smaller customer and supplier bases tend to use AMT to a lesser degree.

Second, pull production is enhanced by increased collaboration with suppliers and advanced manufacturing technology, not by information sharing with customers. It is surprising to see that information sharing with customers has no direct impact on pull production in any of the three contexts referred to above. Collaboration with suppliers plays the most significant role in increasing pull production. This result highlights the importance of managing collaborative relationships with suppliers to reflect changes in customer demand. As suggested by Holweg et al. (2005), collaboration with suppliers allows a firm to effectively absorb demand oscillation.

Third, pull production may not always lead to quicker responses to the market. The contextual analysis revealed that pull production did not play a statistically significant role in enhancing responsiveness to the market in two situations: (1) a growing market; and (2) a market with a large customer base. This is surprising, because pull production is meant to increase responsiveness to the market. However, when the market is growing and the customer base is large, pull production seems to be less effective in increasing responsiveness to the market.

5. Concluding remarks

To conclude, it is worth noting the major implications of the study results. The results ~~indicates~~ that multi-dimensional integrations represent one of the most important characteristics of a responsive supply chain strategy. First, a responsive supply chain strategy implements socio-relational integration with strategic suppliers and customers. In today's customer-centric global business environments, a traditional supply chain strategy, which stresses only cost-efficiency and stability, faces serious challenges that need to be surmounted. As a viable alternative, this paper proposes a responsive supply chain strategy that can enhance the focal company's responsiveness/adaptability to rapidly changing customer demands, while adding value to customers by reducing waste throughout the supply chain. Previous research (Lee, 2002, 2004) on supply chain strategy emphasizes product innovativeness and a stable supply process as a key to supply chain success. This paper, on the other hand, has found that proactive information sharing with strategic customers and suppliers is another important driver for the success of a responsive supply chain. This finding is somewhat consistent with that of earlier studies (Lau et al., 2010; Zhao, et al., 2011), indicating that making connections with strategic customers and suppliers through a knowledge sharing network and relationship commitment is an integral part of a responsive supply chain strategy for the focal company. That is

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to say, to make the supply chain more responsive, managers of OEMs need to develop an open-communication channel with strategic suppliers and customers as a foundation for real-time information sharing and then need to clarify points of contact among an OEM and its suppliers/customers to ensure constant flows of updated information about market dynamics and demand patterns. A catalyst for such a channel may include the EDI, RFID, ERP, and Extranet.

Second, a responsive supply chain strategy utilizes both socio-relational integration (with strategic suppliers and customers) and techno-process integration (with advanced manufacturing and pull production). To verify this, the present study investigated how significantly a responsive supply chain strategy influences advanced manufacturing technology and pull production (i.e., manufacturing technology and process integration). As evidenced by the study results, a responsive supply chain encourages the focal company (e.g., an OEM) to share end-customer demand information with its customers and foster collaborative relationships with its suppliers (i.e., relational integration). Also, a responsive supply chain strategy tends to facilitate the use of advanced manufacturing technology and pull production (i.e., technology-process integration). In other words, the present study discovered that a focal company tends to attain pull production through socio-relational and techno-process integration. This finding reaffirms the strategic importance of a long-term partnership with a firm's suppliers to the successful implementation of JIT manufacturing and confirms the need for advanced manufacturing technology as a prerequisite to JIT manufacturing. As such, it is recommended that managers of OEM in a JIT mode should focus on relationship building with their suppliers and consider setting aside a budget for experimenting with advanced manufacturing techniques including robotics, CAD, CIM, and optimized production technology (OPT) to fine-tune its pull production strategy.

Third, a responsive supply chain strategy integrates socio-relational and techno-process integration toward time-based performance outcomes. A primary goal of a responsive supply chain strategy is to enhance the responsiveness of the focal company to market dynamics through proactive information sharing with its customers, collaboration with its suppliers, and the use of advanced manufacturing technology. This study's finding supports the importance of multi-level integration for a responsive supply chain strategy. Such integration differs from stand-alone efficiency-focused, technology-based, or process-constrained integration. This finding implies that, as a way to maximize the benefit potential of a responsive supply chain strategy, managers of the focal company should ensure the existence of multiple stages of supply chain integration involving the company's own internal units, customers, and suppliers. That is to say, the involvement of all three supply chain partners in the formulation of a responsive supply chain strategy can create synergistic effects and thus further enhance time-based performance outcomes, whereas stand-alone, one-dimensional integration constrains such outcomes.

Although this study offers the aforementioned new insights into responsive supply chain strategy, it has several limitations. For instance, it has not explored or tested the possibility that a responsive supply chain strategy will lead to improved market responsiveness and better mass-customization capability by leveraging pull production. Another limitation of the current research is the exclusion of some constructs such as the focal company's financial performance and supply chain performance, which can be used to assess the positive impacts of a responsive supply chain strategy on cost-efficiency and lead time reduction.

Given these limitations of the current study, the following research agenda items are suggested for further studies. First, this paper does not empirically test all four supply chain patterns (i.e., efficient, risk-hedging, responsive, and agile) in detail. Further elaboration of multiple dimensions of various types of supply chains is worth pursuing. Future research may consider how firms effectively respond through their supply chains to changing market requirements (e.g., increasing emphasis on greening initiatives and sustainability), while identifying and incorporating emerging supply chain practices. Second, additional research may also examine the connection between supply chain performance and financial performance beyond the focal company perspective. As more portions of value creation and delivery occur in the supply chain outside of a focal company, supply chain research needs to define, assess, and measure the upstream and downstream processes more realistically in terms of their performance implications. Third, in view of the growing complexity associated with products and services, the sampling frame of this study can be extended to include other industries beyond those in the nine ISIC codes examined here. Longitudinal studies may also examine the diverse patterns of responsive supply chain strategy. Finally, future research may include other constructs such as the degree of market dynamics and the level of competitive intensity in the global marketplace and examine their effects on the development of appropriate supply chain strategies. In a nutshell, this study defines critical variables for a responsive supply chain strategy and such a strategy's dynamic impacts on supply chain outcomes.

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