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Integration of supply chain IT and lean practices for mass customization

Benchmarking of product and service focused manufacturers

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Abstract

Purpose – The purpose of this paper is to examine the use of specific supply chain information technologies (IT) for e-commerce, e-procurement, and enterprise resource planning (ERP), when implementing lean practices to achieve mass customization (MC) performance. The study further investigates how these technologies may be deployed differently in product and service focused contexts. "Best practices" of high performing MC firms are also explored.

Design/methodology/approach – Survey method was employed to collect data from 711 firms in 23 countries. Exploratory factor analysis was employed to establish simple factor structure and construct validity. Hierarchical multiple regression was used to analyze relationships between lean practices, IT use, and MC performance in aggregated and bifurcated samples of product and service focused manufacturers. *T*-tests were used to examine differences between the practices employed by high and low MC performers.

Findings – Findings suggest that lean practices can reasonably predict MC performance. In this context, of lean practices, e-commerce and e-procurement reasonably predict MC performance. ERP is not shown to predict MC performance. Results suggest that e-commerce use is a better predictor of performance than e-procurement or ERP for service focused manufacturers. E-commerce and e-procurement appear to be reasonable predictors of MC performance in product manufacturers, while ERP is not. "Best practices" related to lean practices, e-commerce, e-procurement, and ERP emerge among high MC performers.

Originality/value – This paper describes what is believed to be the first study to examine these three IT approaches in the context of lean practices and supply chain MC performance. This paper also contributes to the growing interest in differences among product and service focused manufacturing firms. Finally, specific "best practices" are provided to add value for practitioners.

Keywords Supply chain management, Quality improvement, Best practice, Communication technologies, Electronic commerce, Lean production

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1. Introduction

Owing to rapidly changing, uncertain customer demands and significant technological advancements, competition has shifted beyond the firm level to center on the performance of a firm's entire supply chain (Vonderembse *et al.*, 2006). In this environment, integration for information sharing between suppliers and customers across the entire supply chain and the ability to produce mass customized (MC) offerings for customers are critical issues facing an increasing number of firms (Akkermans *et al.*, 2003). While few products could be delivered on a MC platform previously, recent advancements, such as the internet, have made this a viable alternative for many products (Kaplan and Haenlein, 2006). Recently:

> [...] many companies offer highly customized products in a wide range of categories, including computers, sneakers, vitamins, cars, golf clubs, eyeglasses, garden design, cosmetics, and greeting cards (Wind, 2001, p. 39).

This need for MC performance even extends to service focused firms and has become a routine practice in industries such as advertising (Salomon, 1999) and insurance (Kaplan and Haenlein, 2006).

Firms often implement improvement practices such as lean as they strive to develop the supply chain responsiveness necessary for MC (Reichhart and Holweg, 2007). MC techniques from lean can help a firm to drive down costs (Smith and Rupp, 2003), and increase flexibility and customer responsiveness (Sahin, 2000). In this way, lean is a key enabler or platform for MC (Alfnes and Strandhagen, 2000). Such a platform requires information sharing and as such, firms have recognized great promise for the use of information technologies (ITs) to manage transactions within the firm and across the supply chain. This has led to the belief that e-commerce and MC will emerge as a primary operations style during the next decade (Jiao and Helander, 2006).

However, MC represents a significant challenge for most industries (Yassine *et al.*, 2004). Scholars have reported numerous operational problems realized by MC firms, such as higher manufacturing costs and extended delivery times (Ahlstrom and Westbrook, 1999; Zipkin, 2001; Salvador *et al.*, 2004; Squire *et al.*, 2006). It appears that perhaps in MC, the installation of these new process technologies alone is often insufficient for success (Kakati, 2002). Yet, the extant body of literature offers little in the way of insight regarding the implementation of these MC practices; practices which firms have found difficult to apply (Huang *et al.*, 2008). A clear need exists to explore the intersection of managerial practices and IT use (Tu *et al.*, 2004), a paucity even more evident in regard to empirical studies (Silveira *et al.*, 2001).

Therefore, the purpose of the current study is to explore the impact IT can have on the relationship between supply chain practices and performance. Specifically, this study examines the use of e-commerce for customer integration, e-procurement for supplier integration, and enterprise resource planning (ERP) technologies for business process management, when using lean practices to achieve enhanced MC performance. At a granular level, this study embraces the burden of informing the research question:

> *RQ1.* Which IT technologies are most impactful in achieving MC when implementing lean?

Further, given the wide spread adoption of MC among both product and service focused firms, and the key differences between them, this study extends to explore how these

technologies may be deployed differently in the juxtaposition of product and service focused contexts. It specifically informs a second research question:

RQ2. How do product and service focused firms use supply chain technologies differently to achieve supply chain MC performance?

Finally, the practices of high MC performers are examined, pointing to best practices or benchmarks with regard to lean practices and IT use for MC. As such, this study informs an important practical question:

RQ3. What are the best practices used by leading firms to achieve MC?

These research questions serve to motivate a review of the relevant literature in Section 2.0 and the theoretical underpinnings of the hypothesized relationships under study in Section 3.0. This will be followed by a discussion of the research methods including data analysis in Section 4.0 and finally the conclusion and implications of the study in Section 5.0.

2. Literature review

The term "mass customization" was introduced by the seminal work of Davis (1987) in his book, *Future Perfect.* The concept initially gained favor in the marketing discipline from the work of Kotler (1989), before Pine (1993) ported it into operations management (OM). In the context of OM, MC refers to the ability to rapidly produce customized offerings with quality and costs similar to those achieved by the mass production approach (MacCarthy *et al.*, 2003) and is a central concern in both product and service firms (Hart, 1995; Zipkin, 2001). While OM practitioners have found MC to be a popular means of satisfying the diverse needs of the current customer-oriented market (Du *et al.*, 2003; Dai *et al.*, 2006; Heizer and Render, 2006), it represents a new operations paradigm that challenges firms by increasing uncertainties in their operating environment and potentially causing negative cost, quality, and speed outcomes (Huang *et al.*, 2008). This causes many firms to attempt to redesign their operational strategy and supply chain practices to reduce uncertainty and provide the better speed and flexibility required to manage variations and market uncertainty (Alfnes and Strandhagen, 2000). As such, great synergy can exist between MC and continuous improvement (Pine *et al.*, 1993).

Sahin (2000) discusses lean among several continuous improvement approaches to such operational redesigns. Womack *et al.* (1990) introduce lean, describing it as a set of principles and techniques designed to eliminate waste in the manufacturing process. Goldman *et al.* (1995) characterized lean by continuous improvement efforts, first time quality conformance, elimination of waste, and flexible production. As such, lean has emerged as a popular practice in supply chain management (Naylor *et al.*, 1999; Christopher and Towill, 2000; Chen and Paulraj, 2004; Li *et al.*, 2005).

Krafcik (1988) explores the type of equipment necessary for lean and suggests that it is different from mass production and should be simple, reliable, and flexible. In a complementary way, some scholars suggest that automation equipment should be minimized as it can be accompanied by machine complexity, less flexibility and is often the source of downtime (Edwards, 1996). Other scholars investigate and suggest similarities and overlap between lean and other operational supply chain approaches such as just-in-time (JIT) (Alfnes and Strandhagen, 2000) and agility (Sahin, 2000). Alfnes and Strandhagen (2000) suggest that lean/JIT provides simplified rapid flows of

information and material that are well coordinated by front-line employees to meet real demand, a necessary capability for MC. In addition to flexibility outcomes, scholars have also suggested that lean models can help reduce fixed and marginal costs, also a key requirement of MC (Smith and Rupp, 2003).

In developing a conceptual model for MC, Alfnes and Strandhagen (2000) discuss the importance of information flow in the context of lean operational approaches, suggesting that tools are developed that enable effective communication among supply chain partners as well as coordination of business processes. This is owing to the notion that MC is better achieved when firms work closely with dependable suppliers (Tu *et al.*, 2001), as well as their customers (Piller *et al.*, 2004). In this way, MC is a performance outcome of the firm's supply chain management efforts. IT tools for supply chain management might be used for e-commerce to facilitate downstream supply chain activities such as sales to customers (Brynjolfsson and Smith, 2000), e-procurement to facilitate upstream activities such as purchases from suppliers (de Boer *et al.*, 2002), and ERP to manage internal supply chain activities such as inventory flows and control business processes (Francis, 2008).

To the authors' knowledge these three IT approaches have not been empirically tested in the context of lean for MC, however, other scholars have investigated their use during operational improvement programs, or for MC in different contextual circumstances (i.e. product development). For example, Rabinovich *et al.* (2003) studied enterprise wide information systems in the context of operational practices for MC, suggesting that JIT leads to improved inventory performance. Tan and Vonderembse (2006) studied IT use during product development and found a positive relationship between internal systems such as CAD use and product development performance and cost. In studying customer information integration, Lee *et al.* (2000) suggest that the type of customer interactions necessary for MC require that IT can handle the subsequent intensity and complexity efficiently. In studying suppliers, Yassine *et al.* (2004) found that in general, information integration with suppliers is beneficial for MC. With regard to ERP, Yao and Carlson (2003, p. 95) suggest that:

> For agile production it appears essential that an on-line, real-time data capture system provide the status and location of production lots, components, [and] subassemblies for schedule control.

While these studies provide useful, empirical findings contributing to the MC and/or IT literature, none directly inform the research questions under study here, providing a holistic view of the use of e-commerce, e-procurement, and ERP for MC.

Other non-empirical, conceptual studies suggest that benefits can be derived from the use of e-commerce, e-procurement, and ERP in the context of MC. For example, Ghiassi and Spera (2003) describe a software system designed to enable synchronized supply chain collaboration, an element the authors posit as essential for MC. A key benefit of such a system is supply chain visibility, as:

> Enterprises must have end-to-end visibility into demand levels, supply sources, production capacities, inventory quantities, and distribution capabilities to [. . .] [respond to customers' needs] in a MC business model (Ghaissi and Spera, 2003, pp. 20-21).

Similarly, Dai *et al.* (2006) suggest that a three-dimensional software application can enable consumers, partners, distributors, and suppliers to share product requirements and ideas leading to better efficiency and precision in a MC environment. In exploring

the use of IT for MC, Helander and Jiao (2002) provide several important observations in the context of this study. First, synergy exists between IT and MC. Second, it is beneficial to consider a holistic view of the entire value creation chain encompassing suppliers, manufacturers, and customers. Finally, there is an:

> [. . .] emphasis on the re-engineering of domain-specific workflows and business models underlying conventional e-commerce [IT] infrastructure (Helander and Jiao, 2002, p. 723).

This final observation from Helander and Jiao (2002) sheds light on the use of IT in the context of MC as a support mechanism of process improvement programs such as lean. This is consistent with (Ghaissi and Spera, 2003, p. 23) who observe that:

> [. . .] these [IT] systems were developed using principles of business process re-engineering [such as lean], the goal of which is to instill "industry best practices" by implementing process controls that would ensure efficiency and repeatability.

Two key observations emerge from the literature review. First, MC requires the flexibility and efficiency which results from streamlined, improved supply chain processes. In this way, lean "constitutes a platform for MC" (Alfnes and Strandhagen, 2000, p. 116). Second, advancements in IT now enable customers, suppliers, and focal firm employees to directly participate and interact in value creation, as is the case with Dell Computer where suppliers are electronically notified of the unique product features selected by customers, and respond accordingly (Helander and Jiao, 2002). In this way, IT serves to support the exploitation of the flexibility and efficiency resulting from lean process improvements. The ability to use e-commerce, e-procurement, and ERP technologies has thus served as the impetus for a shift in thinking regarding value creation, placing greater emphasis on the linkages and interactions between customers, suppliers, and focal firm employees who work together to co-create value (Normann and Ramirez, 1993).

3. Theory development and hypotheses

3.1 Value co-creation theory

Porter (1985) developed the value chain concept as a means of explaining how value creation occurs in a firm's offerings and can lead to consequential competitive advantage. The value chain concept describes the activities which create margin and provides a basis to explore how those activities can be facilitated (i.e. outsourced or in collaboration with other actors) (Gehmlich, 2008). In Porter's (1985) value chain, the unilateral role of the focal firm is emphasized as the customer is placed outside of the value creation process (Prahalad and Ramaswamy, 2004). This follows a traditional view of supply chain interactions as each company maintains a specific position in a linear, discrete value chain with suppliers adding value to inputs upstream, while the focal firm contributes specific value to the product prior to sending it downstream to customers (Normann and Ramirez, 1993). This is consistent with the mass production approach to operations and is characterized much differently from MC (Prahalad and Ramaswamy, 2004).

A contemporary theoretical approach for explaining MC, referred to as value co-creation, emphasizes the focal firm's role in the development of a value creation systems comprised of "suppliers, business partners, allies, and customers [who] work together to co-produce value" (Normann and Ramirez, 1993, p. 66). With regard to the customer, Toffler (1970) discusses this as a transformation of the role of the consumer into a co-producer or "prosumer," a concept critical to MC (Piller *et al.*, 2004). Put another

way, value co-creation emphasizes a shift in the customer's role from that of value consumption to value creation (Normann and Ramirez, 1993). It follows that the interactions facilitated by IT connectivity between customers, suppliers, and focal firm employees enable the supply chain to "respond to a high variety [of customer] requirements and orders within the constraints of cost, schedule, and quality" (Helander and Jiao, 2002, p. 717). Thus, value co-creation is capable of explaining the phenomenon of MC by linking the interactions among customers, suppliers, and focal firm employees with customized products that are exactly what customers want (Zhang and Chen, 2008).

Value co-creation provides a theoretical explanation for MC in that the active role of the customer enables a firm to digest order information and exploit upstream supply chain flexibility developed within and outside the firm to deliver specialized products matching each customer's desires. As firms strive to develop these value creation systems, it is often beneficial or necessary that they improve their operational practices and integrate information sharing among the key actors of this system. Therefore, exploration of this intersection of lean practices and supply chain integration through the use of IT for MC is the focus of this study and is shown in Figure 1.

The grey oval provides an illustration of the context of the study; the relationship between lean practices and MC performance. This is a relevant starting point in establishing the model given that firms in pursuit of MC must first develop flexible and efficient processes (Alfnes and Strandhagen, 2000) prior to benefiting from IT. Consider the likelihood for MC success if a supply chain operated with rigid and inefficient processes. If this were the case, IT might improve information flow, but performance would likely continue to suffer as the supply chain was unable to respond to the unique needs of customers communicated through IT systems. This is consistent with previous scholars who suggest that lean practices influence performance, and serve to mediate the relationship between IT and performance (Fullerton *et al.*, 2003; Vickery *et al.*, 2003; Ghiassi and Spera, 2003; Ward and Zhou, 2006). Further, while the literature suggests the importance of e-commerce, e-procurement, and ERP in this relationship, it does not imply any interaction effect among the three uses. As a matter of fact, Ghiassi and Spera (2003) suggest that while firms may use IT to manage their external supply chain (e.g. e-commerce and e-procurement), many firms have not yet adopted such IT in running their businesses (e.g. ERP). Therefore, the impact of e-commerce use, e-procurement use, and ERP use are tested individually in the context of lean processes used to achieve MC. At a macro level, this provides the opportunity to test the impact of these technologies on the relationship between supply chain practices and performance.

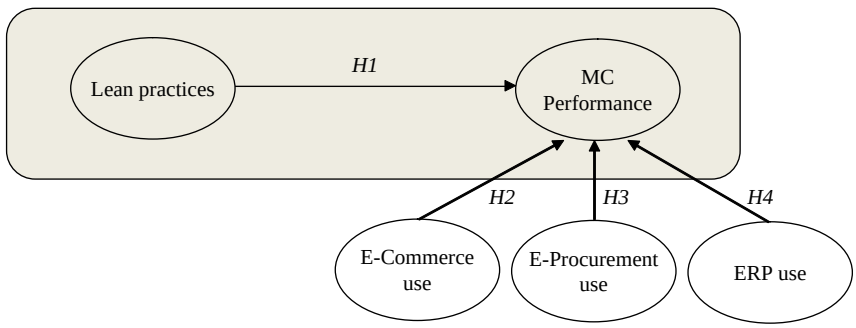

Figure 1.
Research framework

3.2 Lean practices

Lean practices represent an important dimension or practice within the domain of supply chain management (Naylor *et al.*, 1999; Christopher and Towill, 2000; Chen and Paulraj, 2004; Li *et al.*, 2005). This is likely owing to the notion that many firms have increased flexibility and competitiveness by implementing the lean principles developed at Toyota (Womack and Jones, 1996). Lean's fundamental purpose is to increase profits by lower costs through greatly reducing or eliminating waste in a firm's supply chain activities such as excessive stocks or workforce (Alfnes and Strandhagen, 2000). This is accomplished through the achievement of balanced, synchronized single piece pull production, empowerment of employees, continuous improvement, reduced set up and lead times and minimized automation technologies (Sahin, 2000). Considering this, the present study conceptualizes lean practices as the extent to which a firm engages in activities to eliminate waste and achieve cost reduction in the internal supply chain through flexibility, worker empowerment, and process simplification (Table I). This is manifested in the firm through the implementation of a lean organizational model (e.g. reducing the levels of management), implementing continuous improvement programs (e.g. kaizen), increased delegation and knowledge of the workforce, and increased work force flexibility (e.g. job sharing and variable working hours) (Womack and Jones, 1996; Alfnes and Strandhagen, 2000; Sahin, 2000).

3.3 Mass customization performance

MC as a concept is simple, providing personalized offerings at affordable prices (Duray, 2002). Put another way, "MC requires companies to provide personalized products and services at mass production prices" (Pham *et al.*, 2008, p. 695). While simple, it has taken many scholarly contributions to develop a workable definition of the concept (Kaplan and Haenlein, 2006), the majority of which place focus squarely on the customer. This focus is clear as early as Pine (1993) who provided that mass customizers:

> [. . .] develop, produce, market and distribute goods and services with such variety that nearly everyone finds exactly what they want at a price they can afford (Alford *et al.*, 2000, p. 100).

Many other authors have gone on in a similar fashion to discuss MC products as "created to customers' specifications" (Ettlie and Ward, 1997, p. 36), or as "one-of-a-kind," "custom products," which can include "customized services" (von Hippel, 1998, p. 631-2). Zipkin (2001) and Ahlstrom and Westbrook (1999) view MC products or services as those individually tailored or customized on a large-scale. Pine *et al.* (1995, p. 105) submit that "customization means manufacturing a product or delivering a service in response to a particular customer's needs, and MC means doing it in a cost-effective way." Finally, Hart (1995, p. 36) suggests a "practical definition: the use of flexible processes and organizational structures to produce varied and often individually customized products and services." In addition to flexible processes, MC benefits from coordination and working with suppliers (Tu *et al.*, 2001; Yassine *et al.*, 2004) and customers (Piller *et al.*, 2004) across the supply chain. Thus, this study views MC as an outcome of effective supply chain management, and synthesizes the work of the aforementioned authors in a fashion consistent with the original spirit of Pine (1993), to define MC performance as the extent to which a firm develops, produces, markets and distributes goods and services with such variety that downstream customers in the supply chain find exactly what they want at a price similar to mass produced products. Given this, MC performance is

Table I.
Conceptual definitions of the variables under study

Variable	Definition	Scholarly references
Lean practices	The extent to which a firm engages in activities to eliminate waste and achieve cost reduction in the internal supply chain through flexibility, worker empowerment, and process simplification	Womack and Jones (1996), Alfnes and Strandhagen (2000), Sahin (2000) and Li *et al.* (2005)
Mass customization (MC) performance	The extent to which a firm develops, produces, markets and distributes goods and services with such variety that downstream customers in the supply chain find exactly what they want at a price similar to mass produced products	Pine (1993), Pine *et al.* (1995), Alford *et al.* (2000), Tu *et al.* (2001) and Pham *et al.* (2008)
E-commerce use	The extent to which a firm uses internet tools to support sales, distribution, and downstream supply chain customer service processes	Brynjolfsson and Smith (2000), Cagliano *et al.* (2003) and Turowski (2002)
E-procurement use	The extent to which a firm uses the internet in the purchasing process to support upstream supply chain sourcing, product selection (i.e. use of on-line catalogues), tendering, and order tracking and fulfillment	de Boer *et al.* (2002), van Weele (1994) and Cagliano *et al.* (2003)
Enterprise resource planning use	The extent to which a firm uses software applications to access pertinent data or information used to monitor events and material flows across a supply chain, which provide direct insight into the status of orders, inventory, and shipments	Vitasak (2005), Bradley (2002), Francis (2008) and AberdeenGroup (2006)

manifested through competitive manufacturing lead times, delivery speed, unit manufacturing costs, and mix flexibility (Pine, 1993; Pine *et al.*, 1995; Tu *et al.*, 2001; Pham *et al.*, 2008).

MC performance is not easily achieved, however (Yassine *et al.*, 2004). Barnett *et al.* (2004, p. 626) suggest that this may be in part owing to the notion that MC requires a "reduction in lot size and the increase of model variety [. . .][having] a negative impact on resource efficiency." Therefore, MC performance often benefits from lean practices and their consequent "reduced lot sizes, flexible equipment and skilled operators to quickly change from one small batch to the next thereby minimizing WIP," and optimizing resources (Yao and Carlson, 2003, p. 96).

In addition to resource efficiencies, "MC involves responsiveness to customers' changing demands, and requires performance and flexibility improvement" (Alfnes and Strandhagen, 2000, p. 111). Lean practices are effective in addressing these requirements as lean results in shorter production cycles and thus speeds delivery time (Yao and Carlson, 2003). One way in which this is achieved is through the use of visual controls (*or kanban*), creating tight linkages among suppliers, customers enabling them to interact to co-create value (Prahalad and Ramaswamy, 2004; Alfnes and Strandhagen, 2000). As such, lean practices result in higher productivity and customer responsiveness (Edwards, 1996; Krafcik, 1988; Womack *et al.*, 1990; Sahin, 2000). Thus, scholars believe that "lean production constitutes a platform for MC" (Alfnes and Strandhagen, 2000, p. 116).

The consistent focus of MC on the customer as well as the acknowledged need for production flexibility (AberdeenGroup, 2006) is consistent with value co-creation theory and its nonlinear, continuous view of the supply chain as comprised of a network of suppliers and customers interacting with the focal firm in the development of a value creation system (Prahalad and Ramaswamy, 2004). Owing to the changes in operational practices required by the MC approach as well as the improvements in flexibility and cost that have been shown by lean practices (Pine *et al.*, 1993), this study hypothesizes the following:

H1. Lean practices are positively related to MC performance.

3.4 E-commerce use

Firms that seek innovation outcomes and competitive performance are increasingly relying upon IT and communications technologies to improve responsiveness (Sambamurthy *et al.*, 2003). This is particularly true regarding customer and marketing IS interfaces (Sabherwal and Chan, 2001). Scholars such as Brynjolfsson and Smith (2000) have described these e-commerce technologies as lending support to sales, distribution and customer service processes (Cagliano *et al.*, 2003). Others describe e-commerce technologies to include auctions, exchanges, catalogues, on-line marketplaces, and e-collaboration tools (Kalakota, 2000; Kaplan and Sawhney, 2000; Wise and Morrison, 2000). In a broad sense, "e-commerce uses computer networks and the internet to buy and sell products, services and transmit information" (Helms *et al.*, 2008). Consistent with this literature, the present study defines e-commerce use as the extent to which a firm uses internet tools to support sales, distribution, and downstream supply chain customer service processes (Table I). Consequently, e-commerce use is manifested through the firm's efforts to manage customer interactions (e.g. for sales and distribution) through the use of electronic tools for content or knowledge management, order management/tracking,

sharing information about request for quotations (RFQs), access to catalogues, and auctions (Brynjolfsson and Smith, 2000: Cagliano *et al.*, 2003; Turowski, 2002).

The use of e-commerce can be very attractive for firms as Brynjolfsson and Smith (2000) suggest that the internet is more efficient than traditional transaction methods and enables firms to access larger markets of new customers. A wide variety of customers can now be reached online, as not only do 87 percent of teens engage in e-communication, but also 69 percent of men between the ages of 18-34 state that they cannot live without the internet (www.itfact.biz) (Zhou and Benton, 2007). Start up costs and return on investment are often not prohibitive, as the Aberdeen Group reports that 21 percent of retailers expect to realize revenue from their on-line customer tools within a matter of weeks following implementation. It is not surprising then that many firms now offer online product customization websites, for example, www.dell.com; www.idtown.com; www.cannondale.com (Jiao and Helander, 2006), and www.schwab.com (Helms *et al.*, 2008).

In the context of MC, success hinges upon understanding and responding to the unique and rapidly changing needs of the customer. E-commerce can create a linkage to the customers (Helms *et al.*, 2008). It can contribute to an environment that enables customers to communicate their purchasing needs to the focal firm and through participation in the value creation process receive the unique offerings that they desire. In this way, the customer can become integrated into the firm's value creating processes, an essential element of value co-creation (Piller *et al.*, 2004). This can be the case for simple as well as complex products. For example, "the case of Oracle is different [in that the product is very complex, however] a customer will design a network server" (Helander and Jiao, 2002, p. 719). Oracle then manufactures to the customers specification in concert with components provided by suppliers. This type of customer involvement has been shown to enhance the ability of the firm in customization by enabling the customer to co-create value in the product (Zhang and Chen, 2008). Further, this type of e-commerce integration allows the firm to capitalize on its responsiveness and flexibility (Helms *et al.*, 2008) developed from lean practice implementations (Peters and Saidin, 2000). Thus, this study hypothesizes the following:

H2. E-commerce use is positively related to MC performance when using lean practices.

3.5 E-procurement use

The principle of pull production is one key element of lean practices as relates to MC (Alfnes and Strandhagen, 2000). Pull production and single piece flow enable a firm the flexibility and customer responsiveness necessary for MC. A firm's pull production capability can be enhanced by IT integration with suppliers. For example, Dell receives customers order information directly (through e-commerce) and shares it on a real time basis with its suppliers making their pull production system more effective (Zhou and Benton, 2007). In this way, business-to-business (B2B) e-procurement systems are used to manage standardized data exchange between companies to enable the responsiveness necessary for MC (Helms *et al.*, 2008).

van Weele (1994) provided a conceptual definition for e-procurement as using Internet technology during the various stages of the purchasing process. Cagliano *et al.* (2005) defined e-procurement as IT support of sourcing, procurement, tendering, and order fulfillment processes. Others scholars describe it in specific terms as the use of

electronic catalogue systems, electronic marketplaces and auctions, and intelligent agent applications (Smeltzer and Ruzicka, 2000; Croom, 2000). Finally, de Boer *et al.* (2002) while working within the general framework of van Weele (1994), specified six forms of e-procurement to include electronic maintenance, repairs, and operations, web-based ERP, e-sourcing, e-tendering, e-reverse auctioning, and e-informing. Synthesizing this previous literature, the current study conceptualizes e-procurement use (as described in Table I) as the extent to which a firm uses the internet in the purchasing process to support upstream supply chain sourcing, product selection (i.e. use of on-line catalogues), tendering, and order tracking and fulfillment. E-procurement use is manifested in a firm through the use of electronic tools to communicate RFQs, content and knowledge management, access to catalogues (Smeltzer and Ruzicka, 2000; Croom, 2000), order management/tracking (Cagliano *et al.*, 2006) and auctions with key suppliers (de Boer *et al.*, 2002).

The use of e-procurement technologies can create access to a wider base of suppliers by mitigating geographic boundaries. In this way, the firm can choose from the best suppliers to participate in the value creation process (Normann and Ramirez, 1993). That said, not only does e-procurement open access to more and better suppliers, but it also can improve the effectiveness and efficiency of the interaction with which suppliers participate. For example, interactive web-based systems allow suppliers to share ideas and knowledge with employees from the focal firm and customers which improves the accuracy of compliance with customer requirements and efficiency (Dai *et al.*, 2006). Online order taking, a key feature of e-procurement, improves economic efficiencies by connecting buyers with seller. In doing so, it is an enabler of firm changes which support MC by facilitating dialogue and interactions of buyers and sellers in co-creation (Prahalad and Ramaswamy, 2004), providing greater flexibility, efficiency, and responsiveness (Helms *et al.*, 2008). This kind of information sharing facilitates value co-creation and is of utmost importance in achieving supply chain performance (Zhou and Benton, 2007), allowing a firm to exploit the use of lean practices (AberdeenGroup, 2006). Thus, this study hypothesizes the following:

H3. E-procurement use is positively related to MC performance when using lean practices.

3.6 Enterprise resource planning use

Delivering products and services that meet the individual needs of customers requires internal as well as external integration (Tracey, 2004). As this integration is realized, multiple functional areas (i.e. marketing and manufacturing) work in a collaborative way to enhance communication and knowledge sharing which in turn allows improved responsiveness (Hong *et al.*, 2005). ERP software can be employed for such integration, as a "comprehensive transaction management system that integrates many kinds of information processing abilities and places data into a single database" (Akkermans *et al.*, 2003, p. 285). Such systems can coordinate data from different business processes such as purchase order management, accounting, and human resources, previously stored separately, into a single system. In doing so, ERP systems can improve transparency or visibility across the supply chain, reducing information distortions and improving information velocity by improving information delays (Akkermans *et al.*, 2003).

Vitasak (2005) describes software (ERP) applications as those which enable firms to have visibility over and monitor events which impact inventory and material flows across the supply chain and provide estimates of material arrival times. Additionally, this visibility provides access to relevant data related to logistics and supply chain regardless of the location of such data in the supply chain. Bradley (2002) suggests that such systems should provide unencumbered insights into the precise status of inventory and orders across the supply chain. Finally, Francis (2008, p. 182) synthesizes the work of previous authors to provide a detailed description of the visibility which results from ERP type systems as:

> The identity, location and status of the entities transiting the supply chain, captured in timely messages about events, along with the planned and actual dates/times for these events.

This study reconciles the work of these previous scholars to define ERP use in Table I as the extent to which a firm uses software applications to access pertinent data or information used to monitor events and material flows across a supply chain, which provides direct insight into the status of orders, inventory, and shipments. ERP use is manifested in a firm's use of ERP to manage purchasing and supply management (purchasing), production planning and control of materials (manufacturing planning), sales management (customers orders), and distribution (and other supply chain activities) (AberdeenGroup, 2006).

Supply chain managers consistently rank the visibility created by ERP systems as a top challenge today (Francis, 2008). This is particularly important in the context of MC as information from the supply chain must be monitored and acted upon to facilitate an appropriate and rapid response (Peters and Saidin, 2000). This requires an enterprise model or high-level map that guides the execution of non-automated activities (Haeckel and Nolan, 1993). As such ERP use enables the coordination of business processes spanning both functional areas as well as supply chain tiers, facilitating communications which underpin the co-creation of value (Normann and Ramirez, 1993; Prahalad and Ramaswamy, 2004). In the context of MC, Turowski (2002) suggests that such ERP systems allow for the internal integration of customer information such as desired color or performance product characteristics into production planning and control. This allows managers to track and deploy resources from within as well as outside the firm to exploit efficiency and flexibility developed from lean practices, co-create value, and enable response to customer demands. On the other hand, the absence of a formal production planning and control system can have negative consequences on MC performance including long customer order lead times and poor utilization of resources (Barnett *et al.*, 2004). Thus, this study hypothesizes the following:

H4. ERP use is positively related to MC performance when using lean practices.

3.7 Product and service focused firms

Given this study's examination of product and service focused firms in a juxtaposed MC context, it is necessary to discuss some of the key differences between these firms (Pitt *et al.*, 1999; Peters and Saidin, 2000). Two significant distinctions between the provision of products and services are perishability and inseparability (Rathmell, 1966; Kaplan and Haenlin, 2006). As such, services cannot be inventoried *per se,* and are instead consumed in the moment of production (perishability) (Sundbo, 2002). As a result, the customer is a co-producer, involved in the production and delivery process

and therefore inseparable from key activities involved in value creation (Kelley *et al.*, 1990).

This co-producer role leads customers to not evaluate service solely on the outcome, but rather to consider the process of service delivery (Chen *et al.*, 1994). Pine and Gilmore (1999) with regard to MC, suggest that service experiences are most memorable when the customer actively engages in the service, making it possible for service focused firms to customize each service experience to meet the unique needs of the customer.

Firefly is an example of one such service focused firm. They offer simple products such books, CDs, and DVDs while using MC in the creation of the customer experience (Pitt *et al.*, 1999). Firefly creates virtual networks where customers can purchase and provide opinions about books, films, or music. Firefly then uses this customer information to construct a profile of those preferences that is constantly updated as additional information is provided by customers. This information is useful in many ways. First, it helps to create a customized experience for each individual customer as they enjoy a webpage populated with individualized content. Second, each customer's profile can allow Firefly to notify them of other products that they may find of interest. Third, customer data can be aggregated and correlated, allowing Firefly to release recommendations about new products. In this way, customers participation actually extends beyond a co-creator of value in their own service to result in the production of value for Firefly in the form of salable information (Pitt *et al.*, 1999; Normann and Ramirez, 1993; Prahalad and Ramaswamy, 2004).

E-commerce serves as a linchpin in the creation of customer value for service focused firms owing to its ability to capture a customer's preferred service characteristics and incorporate them into future transactions. The result is that the focus of these firms shifts to rest nearly solely on the customer and facilitation of their interactions. Service focused firms also realize the benefits from lean as is evidenced by the growing presence of lean practices among this group, but they may differ in the deployment of IT. As Peters and Saidin (2000) suggest, MC in a service focused setting benefits from the characteristics of the service offerings, as opposed to offerings in a product focused setting. Given this, the present study hypothesizes the following:

H5. E-commerce use is more positively related to MC performance in service focused firms using lean practices than are e-procurement use or ERP use.

Firms that provide more complex products (i.e. personal computers) often tend to maintain more of a product focus. Take Dell as an example. They rely heavily on information sharing to enhance supply chain practices (Zhou and Benton, 2007). Through e-commerce, Dell receives orders directly from customers and in a real time automated fashion, shares that order information with the appropriate suppliers. The experience is rich for customers as they have the ability to access pricing and product information, subsequently customizing their orders. Dell's e-procurement systems at the same time notifies suppliers enabling them to better manage inventories and improve responsiveness, especially those with long lead times. In this system, Sony's logistics system is linked to Dell, permitting coordinated direct shipments from Sony to Dell's customers. ERP systems can be used to track orders and coordinate billing, staffing, and activities potentially impacted by the order fulfillment process. As such, the balanced and highly integrated use of IT in developing their value creation system (connecting suppliers, customers, and Dell employees) (Normann and Ramirez, 1993) can

enhance lean practices and MC performance (Zhou and Benton, 2007). Thus, this study hypothesizes the following:

H6. E-commerce use, e-procurement use, and ERP use are all positively and equally related to MC performance in product focused firms using lean practices.

4. Research methods and data analysis

4.1 Data collection

Data were collected to test the hypothesized relationships during the 2005 International Manufacturing Strategy Survey (IMSS) Version IV, a global research project. The IMSS was started in 1992 with the purpose of collecting manufacturing strategy data in a global context. In countries where English is not commonly used, the survey instrument was translated into the local language by academic research coordinators, in most cases a full-time university faculty in the areas of operations and supply chain management. This ensures a reliable translation by someone familiar with both the concept of business and operations strategy practices. Additional information about the survey instrument and data collection procedure of IMSS can be found in Voss and Blackmon (1998), Frohlich and Westbrook (2001) and Cagliano *et al.* (2005).

National research groups worked within the global network using a standard questionnaire to collect data. In total, 711 plant managers or manufacturing executives completed a standard survey instrument, from firms employing more than 100 employees, from 23 countries throughout the Asian Pacific, European, North American, and South American Regions. Specific industries included:

- fabricated metal products;
- machinery and equipment;
- office, accounting, and computing equipment;
- electrical machinery;
- radio, television, and communication equipment;
- medical, precision, and optical instruments;
- motor vehicles, trailers, and semi-trailers;
- other transportation equipment; and
- other miscellaneous manufactured products.

All of the firms qualify as manufacturers per their SIC code. Firms were contacted prior to mailing to assess participation interest. The response rate varied by country, but the lowest was 25 percent, which comfortably meets scholarly standards for survey method research.

4.2 Measures

All of the item measures were theorized and supported in previous scholarly literature as discussed earlier and displayed in Table I. The items were selected as appropriate measures of the variables under study for lean practices, e-commerce, e-procurement, supply chain visibility, and supply chain performance in accordance with the purpose of this study (Cagliano *et al.*, 2006). Exploratory factor analysis was employed as it is an

appropriate method for identifying simple factor structure among many variables (Hair *et al.*, 2006).

The items displayed in Table II were analyzed collectively using SPSS 15.0. This produced a total explained variance of 60.9 percent, and a Kaiser-Meyer-Olkin value of 0.851, indicating an appropriate number of factors present in the model (Hair *et al.*, 2006) to explain the phenomenon under study and to provide evidence of sampling accuracy. Factor loadings were generated using Principle Components Analysis extraction method and Varimax rotation method (Mora-Monge *et al.*, 2006). The number of factors was not specified in the analysis. This revealed a simple factor structure showing five factors, all demonstrating eigenvalues > 1.

All factors loadings were above 0.5, demonstrating convergent validity (Bagozzi and Yi, 1988). Most of the factor loadings exceeded 0.7 which Hair *et al.* (2006) considers indicative of well defined structure. Two motivations led the authors to retain the items with factor loadings below 0.7. First from a statistical perspective, it is recommended that researchers should design studies that achieve a minimum statistical power level of 80 percent (Hair *et al.*, 2006). Statistical power is influenced by sample size. Specifically, a factor loading of 0.3 for a sample size of 350 achieves 80 percent statistical power, whereas a factor loading of 0.55 is required for a sample of 100 to achieve the same statistical power of 80 percent (Hair *et al.*, 2006). Therefore, factor loadings below 0.3 are capable of producing sufficient statistical power (>80 percent) in the present study, given the large sample size ($n = 711$). While none of the factor loadings in this study fall in the 0.3 range, some values are below 0.7 which is a commonly accepted cutoff standard among more typical sample sizes. This leads to the second motivation for retaining these items in the study. Hair *et al.* (2006, p. 128) suggests that researchers "should realize that extremely high loadings (0.80 and above) are not typical and that the practical significance of the loadings is an important criterion." In the case of this study, the items in question all maintain practical significance to their respective latent variables as well as the overall phenomenon under study. The items in question included, a measure of:

- workforce flexibility as a dimension of lean practices (producing a loading of 0.66);
- electronic auction use with key customers as a dimension of e-commerce use (producing a loading of 0.66);

Construct	Mean	SD	1	2	3	4	5
Lean practices	3.20	0.782	1				
E-commerce use	2.76	1.01	0.190*	1			
			0.000				
E-procurement use	2.66	0.850	0.221*	0.549*	1		
			0.000	0.000			
ERP use	3.52	0.967	0.307*	0.208*	0.196*	1	
			0.000	0.000	0.000		
MC performance	2.88	0.640	0.246*	0.227*	0.208*	0.136*	1
			0.000	0.000	0.000	0.000	

Note: Significant at: $^{*}p < 0.01$

Table II.
Correlations and descriptive statistics

- electronic auction use with key suppliers as a dimension of e-procurement use (producing a loading of 0.56); and
- product mix flexibility as a dimension of MC performance (producing a loading of 0.59).

Each of these items captures a practical dimension of their correlated latent variable and as such were retained in the study (Hair *et al.*, 2006). Evidence of discriminant validity was provided as none of the loadings exceeded 0.4 on more than one factor (Hair *et al.*, 2006). Content validity was confirmed by the literature review and theory development as discussed in Sections 2.0 and 3.0. Cronbach's alpha was employed as a test of reliability. All of the factors scored acceptably, well over the generally accepted standard of 0.7 suggested by Hair *et al.* (2006) (Table III).

Correlations among the variables and descriptive statistics are provided in Table II. It should be noted that correlations exist among the variables at a $p < 0.01$ level. Not surprisingly, the highest correlation (0.549) exists between e-commerce and e-procurement. This is likely due to the similarity in wording of the questions as well as the theoretical construction of the variables both dealing with internet use (see Table III for the operational definitions/items). Lower correlations exist among other variables, but all are well below the 0.90 cutoff as a measure of collinearity suggested by Hair *et al.* (2006). Multicollinearity tests such as tolerance and variance inflation factor were all within acceptable ranges (Hair *et al.*, 2006).

4.3 Model evaluation

Hierarchical regression was employed to analyze the hypothesized relationships. This approach allows the researcher to analyze each independent variable separately (Pedhazur and Schmelkin, 1991). This is an appropriate methodological selection when analyzing independent variables that are correlated to some degree (Cagliano *et al.*, 2006).

In testing the hypotheses, the independent variables were regressed onto the dependent variable, supply chain MC performance, one by one in models 1, 2, 3, and 4, as well as in aggregate in model 5. This allowed for the individual assessment of standardized betas (β), F-statistics, and changes in R^2 following each variable's entry into the model (Pedhazur and Schmelkin, 1991). The entry order of the independent variables into the model was based on their potential to explain the phenomenon under study (Hair *et al.*, 2006; Neter *et al.*, 1996). As such, entry order was supported statistically by the correlations between each of the independent variables and the dependent variable displayed in Table II earlier. Specifically, the variables were entered from the highest correlation to the lowest (Neter *et al.*, 1996).

4.3.1 Testing product and service focused firm hypotheses. The testing of *H5* and *H6* required bifurcating the sample into two groups. At this point, it is germane to recognize that "services play an increasingly important role in manufacturing firms" (Araujo and Spring, 2006, p. 797). More and more, increasing demands from customers, global competition, and technological advancements are leading many historically manufacturing-centric firms to market "*solutions*" to their customers:

> This claim [of selling "*solutions*"] is essentially offering services as a part of the value proposition, where the "*solution*" includes services intended to add value to customer's use of the tangible product (Hill *et al.*, 2002, p. 195).

Table III. Operational definitions and factor analysis

Items	Factor structure				
	Lean practices	E-commerce use	E-procurement use	ERP use	MC performance
Cronbach's alpha	$\alpha = 0.73$	$\alpha = 0.88$	$\alpha = 0.79$	$\alpha = 0.87$	$\alpha = 0.73$
Indicate the degree to which your firm has…					
Implemented the lean organizational model by, e.g. reducing the number of levels and broadening the span of control during the last three years	0.76				
Implemented continuous improvement programs through systematic initiatives (e.g. kaizen, improvement teams, etc.) during the last three years	0.74				
Implemented action programs to increase the level of delegation and knowledge of your workforce (e.g. empowerment, training, autonomous teams, etc.) during the last three years	0.73				
Increased the level of workforce flexibility following your business unit's competitive strategy (e.g. temporary workers, part time, job sharing, variable working hours, etc.)	0.66				
Indicate to what extent do your key/strategic customers use electronic tools (*internet or EDI based*) *with you for the following*					
Content and knowledge management		0.83			
Order management and tracking		0.82			
RFx (request for quotation, proposal, and information)		0.81			
Access to catalogues		0.79			
Auctions		0.66			
Indicate to what extent do you use electronic tools (*Internet or EDI based*) *with your key/strategic suppliers for the following*					
RFx (request for quotation, proposal, and information)			0.75		
Content and knowledge management			0.72		
Access to catalogues			0.71		

(*continued*)

Table III.

Items	Lean practices	E-commerce use	Factor structure E-procurement use	ERP use	MC performance
Cronbach's alpha	$\alpha = 0.73$	$\alpha = 0.88$	$\alpha = 0.79$	$\alpha = 0.87$	$\alpha = 0.73$
Order management and tracking			0.70		
Auctions			0.56		
To what extent are the following management areas supported through the use of enterprise resource planning systems?					
Purchasing and supply management				0.87	
Material management				0.85	
Production planning and control				0.82	
Sales management				0.72	
Distribution management				0.72	
How does your current performance compare with main competitors?					
Manufacturing lead time					0.81
Delivery speed					0.78
Unit manufacturing cost					0.73
Mix flexibility					0.59

Note: Extraction method: principal component analysis, rotation: varimax

While increasing in popularity, the notion of manufacturing and using products as resources for delivering services is not nascent. Consider the view of Penrose (1959, p. 25) who suggested that:

> [. . .] the important distinction between resources [products] and services is not their relative durability: rather it lies in the fact that resources [products] consist of a bundle of potential services.

Recently, many industrial firms are considered to be service and/or product-based (Araujo and Spring, 2006). A specific example is IBM, historically well known for its product offerings, now generates one third of its revenue from services in some countries (Peters and Saidin, 2000).

As such, manufacturing firms can demonstrate greater or lesser degrees of service orientation. While this study does not intend, nor is capable of examining characteristics of "pure service firms," as defined by conventional attributes such as intangibility, heterogeneity, inseparability, and perishability (Fisk *et al.*, 1993; Kotler, 2003; Bowen and Ford, 2002; Araujo and Spring, 2006) the sample is representative of manufacturers who demonstrate greater or lesser service orientation as described previously and illustrated by IBM. Identifying and measuring this orientation was accomplished by dividing the sample at the mean score (3.8) of a five-point likert scale item which asked respondents to "describe the external environment" using anchors of "1" for focused on "physical attributes" of products or "5" for having a "service emphasis." This bifurcation method produced two subsamples; the first comprised of service focused firms ($\mu > 3.8$, $n = 465$), and the second comprised on product focused firms ($\mu < 3.8$, $n = 246$). The same hierarchical regression procedure described earlier was performed to analyze models 6 through 10 for the bifurcated sample of service focused firms, and models 11 through 15 for the product focused sample.

4.4 Model results and discussion

The results of the hierarchical regression for MC performance, testing the aggregate sample (service and product focused firms) are displayed in Table IV, model 1 suggests a significant relationship between lean practices and MC performance ($\beta = 0.246$, $p < 0.00$). This relationship holds through models 2 through 5 as the other independent variables are entered, suggesting strong evidence in support of *H1*. Models 2 and 5 provide evidence of a relationship between e-commerce use and MC performance ($\beta = 0.187$, $p < 0.00$, and $\beta = 0.138$, $p < 0.00$), lending support for *H2*. *H3*, the posited relationship between e-procurement use and MC performance, is tested in models 3 and 5. Model 3 suggests a relationship ($\beta = 0.162$, $p < 0.00$) as does model 5 ($\beta = 0.084$, $p < 0.05$). These findings lend reasonable support to *H3*. Models 4 and 5 examine *H4*, the posited relationship between ERP use and MC performance. Model 4 provides weak evidence of a relationship ($\beta = 0.067$, $p < 0.1$), while model 5 is not significant. Considering these results collectively, *H4* is not supported. An evaluation of the *F*-statistics and changes in R^2 suggests that in general, the use of these supply chain technologies (particularly e-commerce and e-procurement) does significantly improve the explanation provided by the regression models.

The results of the hierarchical regression for MC performance, testing the service focused sample are displayed in Table V. Again, models 6 through 10 all provide evidence of the relationship between lean practices and MC performance. *H5* emphasizes

Table IV. Hierarchical regression analysis for MC performance (aggregate sample)

Independent variables	Model 1	Sig.	Model 2	Sig.	Model 3	Sig.	Model 4	Sig.	Model 5	Sig.
(Constant)		0.00		0.00		0.00		0.00		0.00
Lean practices	0.246***	0.00	0.211***	0.00	0.211***	0.00	0.226***	0.00	0.192***	0.00
E-commerce use			0.187***	0.00					0.138***	0.00
E-procurement use					0.162***	0.00			0.084**	0.05
ERP use							0.067*	0.08	0.032	ns
R^2	0.061		0.094		0.086		0.065		0.100	
Adjusted R^2	0.059		0.092		0.083		0.062		0.095	
F	45.78		36.91		33.14		24.47		19.70	
d.f	1/709		2/708		2/708		2/708		4/706	
Sig.	0.00		0.00		0.00		0.00		0.00	
Change in R^2			0.034		0.025		0.004		0.040	
Change in F -value			26.41		19.318		3.04		10.40	
d.f			1/708		1/708		2/708		3/706	
Sig.			0.00		0.00		0.08		0.000	

Notes: Standardized coefficients are statistically significant at: $^{*}p < 0.1$, $^{**}p < 0.05$, and $^{***}p < 0.01$; changes in R^2 and F- values are calculated comparing models 2, 3, 4, and 5 to model 1

Table V. Hierarchical regression analysis for MC performance (service focused sample)

Independent variables	Model 6	Sig.	Model 7	Sig.	Model 8	Sig.	Model 9	Sig.	Model 10	Sig.
(Constant)		0.00		0.00		0.00		0.00		0.00
Lean practices	0.248***	0.00	0.214***	0.00	0.215***	0.00	0.241***	0.00	0.205***	0.00
E-commerce use			0.159***	0.00					0.126**	0.02
E-procurement use					0.130***	0.00			0.059	ns
ERP use							0.028	ns	0.004	ns
R^2	0.062		0.086		0.077		0.062		0.088	
Adjusted R^2	0.060		0.082		0.073		0.058		0.080	
F	30.39		21.67		19.39		15.36		11.09	
d.f	1/463		2/462		2/462		2/462		4/460	
Sig.	0.00		0.00		0.00		0.00		0.00	
Change in R^2			0.024		0.016		0.001		0.026	
Change in F -value			12.19		7.94		0.36		4.43	
d.f			1/462		1/462		1/462		3/460	
Sig.			0.00		0.01		ns		0.01	

Notes: Standardized coefficients are statistically significant at: $^{*}p < 0.1$, $^{**}p < 0.05$, and $^{***}p < 0.01$; changes in R^2 and F- values are calculated comparing models 7, 8, 9, and 10 to model 6

the primacy of e-commerce use in service focused firms over e-procurement and ERP technologies in influencing supply chain performance. Models 7 and 10 provide evidence of e-commerce use in service focused firms ($\beta = 0.159, p < 0.00$ and $\beta = .126, p < 0.05$). Models 8 and 10 explore the influence of e-procurement demonstrating evidence of a relationship in model 8 ($\beta = 0.130, p < 0.00$), however, the relationship is not significant in model 10. Models 9 and 10 examine ERP use, neither suggesting a relationship with MC performance. These findings suggest support for *H5*, in that e-commerce use is shown to be more positively related to MC performance than e-procurement use or ERP use in service focused firms.

The results of the hierarchical regression for supply chain performance, testing the product sample are displayed in Table VI. As with the previous regressions, evidence of the relationship between lean practices and MC performance is suggested in models 11 through 15. *H6* posited a balanced and equal relationship between the three supply chain technologies and MC performance. Models 12 and 15 provide evidence of the relationship between e-commerce use and MC performance ($\beta = 0.239$, $p < 0.00$ and $\beta = 0.167$, $p < 0.05$). Models 13 and 15 show support for the relationship between e-procurement use and MC performance ($\beta = 0.222$, $p < 0.00$ and $\beta = 0.131$, $p < 0.1$). Model 14 provides support for a relationship between ERP use and MC performance, however this relationship is not significant in model 15. Thus, in considering the models collectively, *H6* is not explicitly supported.

4.5 Benchmarking "best practices"

This study provides useful insights into the use of lean practices and IT for MC by identifying key relationships among variables established in scholarly literature and of interest to practitioners. However, further analysis is required to address an important question on the minds of many practitioners – *RQ3*. This is an important question given that success for global firms, such as those reported on herein, requires that they emulate the practices of other successful organizations (Yusuff, 2004). As such, firms benchmark or look for best practices which can be linked to superior performance (Camp, 1989). It follows that superior operational performance, such as MC, can be linked to the superior performance of the business and higher levels of competitiveness (Voss *et al.*, 1995; Davies and Kochhar, 2002).

With this understanding and interest in exploring best practices, the aggregate sample was bifurcated for a second time into two subsamples:

(1) high MC performers; and

(2) low MC performers.

The mean for the endogenous variable, MC performance, is 2.88, thus high MC performers are specified as those firms with a mean value > 2.88 ($n = 330$), while low MC performers are specified as those firms with a mean value < 2.88 ($n = 381$). Next, *t*-tests were employed to examine mean differences among each of the exogenous four variables. The results are displayed in Table VII.

The results of the *t*-tests reveal that all of the *t*-values measuring difference between the means are statistically significant at $p < 0.01$. In other words, high MC performers have higher levels of lean practices, e-commerce use, e-procurement use, and ERP use than do low MC performers. The greatest difference exists with regard to lean practices, where high MC performers featuring a mean score of 3.39, compared to low MC

Table VI. Hierarchical regression analysis for MC performance (product focused sample)

Independent variables	Model 11	Sig.	Model 12	Sig.	Model 13	Sig.	Model 14	Sig.	Model 15	Sig.
(Constant)		0.00		0.00		0.00		0.00		0.00
Lean practices	0.222***	0.00	0.191***	0.00	0.182***	0.00	0.186***	0.01	0.161***	0.01
E-commerce use			0.239***	0.00					0.167**	0.02
E-procurement use					0.222***	0.00			0.131*	0.07
ERP use							0.117*	0.07	0.052	ns
R^2	0.049		0.106		0.097		0.062		0.122	
Adjusted R^2	0.045		0.098		0.090		0.054		0.108	
F	12.66		14.34		13.05		8.00		8.38	
d.f	1/244		2/243		2/243		2/243		4/241	
Sig.	0.00		0.00		0.00		0.00		0.00	
Change in R^2			0.056		0.048		0.012		0.073	
Change in F- value			15.28		12.82		3.23		6.67	
d.f			1/243		1/243		1/243		3/241	
Sig.			0.00		0.00		0.07		0.00	

Notes: Standardized coefficients are statistically significant at: $^{*}p < 0.1$, $^{**}p < 0.05$, and $^{***}p < 0.01$; changes in R^2 and F- values are calculated comparing models 12, 13, 14, and 15 to model 11

performers with a mean of 3.04 (t-value of 6.03, $p < 0.01$). E-procurement use represents the next greatest difference between high and low MC performers. In this category high MC performers have a mean of 2.85, while low MC performers produce a mean of 2.49 (t-value of 5.82, $p < 0.01$). The analysis of e-commerce use provides the third greatest difference between high and low MC performers. For e-commerce use, high MC performers have a mean of 2.97, while low MC performers produce a mean of 2.58 (t-value of 5.30, $p < 0.01$). While still statistically significant, the smallest difference exists with regard to ERP use, where high MC performers featuring a mean score of 3.65, compared to low MC performers with a mean of 3.41 (t-value of 3.44, $p < 0.01$).

5. Conclusion and implications

This international study achieved its intended purposes in testing the relationships between different types of supply chain IT on MC performance when using lean practices. In this context, the study also explored hypothesized differences in the way service and product focused firms use supply chain technologies to improve performance, informing two important research questions (*RQ1* and *RQ2*) Finally, further analysis suggested some potential "best practices" of high MC performers. This final analysis addressed an important practical question (*RQ3*). A summary of the results is provided in Table VIII.

These findings provide convincing support of a positive relationship between lean practices and MC performance. This is a valuable contribution to scholars and practitioners alike as they struggle to sort through the myriad of operational improvement programs (i.e. total quality management, JIT, design for manufacturing, quality function deployment, and Six Sigma) often only to realize disappointing results (Hayes *et al.*, 2005). Additionally, these findings support the use of e-commerce and

Table VII.
T-tests of mean differences between high and low MC performing firms

Variables and means	Lean practices	E-commerce use	E-procurement use	ERP use
High MC performers ($\mu > 2.88$, $n = 330$)	3.39	2.97	2.85	3.65
Low MC performers ($\mu < 2.88$, $n = 381$)	3.04	2.58	2.49	3.41
t-value	6.03*	5.30*	5.82*	3.44*

Notes: *Significant at: $p < 0.01$; scale anchors: 1 = none/no use, 5 = high/high use

Table VIII.
Summary of results

Hypotheses	Results
H1. Lean practices are positively related to MC performance	Supported
H2. E-commerce use is positively related to MC performance when using lean practices	Supported
H3. E-procurement use is positively related to MC performance when using lean practices	Supported
H4. ERP use is positively related to MC performance when using lean practices	Not supported
H5. E-commerce use is more positively related to MC performance in service focused firms using lean practices than are e-procurement use or ERP use	Supported
H6. E-commerce use, e-procurement use, and ERP use are all positively and equally related to MC performance in product focused firms using lean practices	Not supported

e-procurement for MC performance when firms use lean practices. This study thus builds upon the complimentary work of previous scholars discussed in Section 2.0 who have tested the use of these technologies in isolation and/or different contexts. In doing so, this study illuminates insights into the contributions IT can make on a key measure of supply chain performance, that of MC. These findings suggest that practitioners should focus primarily on technologies that can enhance customer transaction experiences (e-commerce use) when making IT investments. Conversely, investments in supply chain visibility technology such as ERP may not provide the flexibility necessary to achieve higher levels of supply chain performance, complimenting and extending the work of Akkermans *et al.* (2003) and Rabinovich *et al.* (2003).

Differences in how service and product focused manufacturing firms use supply chain technologies were also identified. Extending the work of Peters and Saidin (2000, p. 107), these findings suggest that by using e-commerce technologies, service focused firms can emphasize and enhance the "characteristics of service offerings," enabling more favorable MC outcomes for customers. While the corresponding hypothesis (*H6*) was not fully support, these findings provide partial evidence that product focused manufacturing firms should take a more balanced approach to IT investment to support the supply chain than service focused firms. While this does not extend to ERP technologies, these findings suggest that product focused manufacturing firms can benefit from investment in e-procurement to integrate the upstream supply chain as well as e-commerce for downstream integration with customers.

This study provides additional insights into the "best practices" of high MC performers. In reviewing the operational definitions of the variables understudy, the results suggest that high MC performers implement lean organizational models (e.g. reducing the levels of management) and continuous improvement programs (e.g. kaizen) to a greater extent than do low MC performers. They place more emphasis on delegation and developing a knowable workforce, and work to increase work force flexibility (e.g. job sharing and variable working hours) than do low MC performers. Considering e-procurement use, high MC performers use electronic tools such as the internet or electronic data interchange (EDI) to communicate with key suppliers for RFQs, content and knowledge management, access to catalogues, order management and tracking, and auctions to a greater extent than do low MC performers. In regard to e-commerce use, high MC performers use electronic tools such as the internet or EDI to communicate with key customers for content and knowledge management, order management and tracking, RFQs, access to catalogues, and auctions to a greater extent than do low MC performers. Finally, this study finds that high MC performers use ERP to manage purchasing and supply management (purchasing), materials management, production planning and control (manufacturing management), sales management (customers orders), and distribution (and other supply chain activities) to a greater extent than do low MC performers. While these results reveal the smallest difference in best practice adoption among high and low MC performers exists for ERP use, it is worth noting that the mean scores for ERP use are the highest among all of the variables under study. This infers that regardless of MC performance, firms today are adopting ERP and which is particularly interesting given that ERP is not found to be a significant driver of MC performance.

Specifically, for scholars, the study provides evidence of the applicability of value co-creation theory when studying MC performance. This supports the work of previous

scholars such as Piller *et al.* (2004). More interesting and valuable however, is the contribution it makes in suggesting how value co-creation can be applied in service and product focused environments differently to provide rich explanation of the MC phenomenon.

While making a scholarly and practical contribution, this study is subject to some limitations and opportunities for future research. First, limitations consistent with survey research (i.e. challenges related to respondent bias and measurement of perceptions) are possible due to the data collection method employed by this study. Second, the focus of this study was the impact of IT on MC performance. As such, other factors may influence supply chain performance that were not included in this study, and warrant future investigation. Third, while the measures employed herein met reasonable standards for statistical sufficiency, repetition of this study may be valuable in further validating the results in other samples. Finally, while important insights are provided into the differences between product focused and service focused firms, this represents but a small fraction of the potential learnings. The hope of the authors is for future research to further explore these differences and identify the other factors that contribute to the supply chain performance of both product and service focused firms.

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