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Roles of Information Technology in Supply Chain Management

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ROLES OF INFORMATION TECHNOLOGY IN SUPPLY CHAIN MANAGEMENT

by

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ABSTRACT

Supply Chain Information Technology (SCIT) is a key enabler of effective supply chain management (SCM) activities. In 2013, $300 billion was spent on SCIT by firms globally, an increase by 1.8% and 3.8% compared to 2012 and 2011, respectively. With such significant investments, firms face risks of eroded financial performance if SCIT does not perform as expected. In fact, there is a mix of evidence with some firms benefiting from SCIT while others failing to benefit from investing in SCIT. Despite substantial research relating to utilizing information technology in a SCM context, the impact of SCIT on firm performance remains unclear. In particular, the extant literature has reported contradictive results regarding relationships between SCIT and firm performance. Therefore, the purpose of this dissertation is to conduct a systematic investigation of roles of information technology in SCM and shed light on this extremely important research area.

In chapter 2, we investigate the direct impact of SCIT on firm performance by conducting a meta-analysis study. Specifically, we look at four types of SCIT characteristics (e.g. application integration, data compatibility, analytic ability, and evaluation and alertness ability) within three loci of utilization: upstream, downstream, and both upstream-downstream. We find that SCIT is not universally associated with improved firm performance. In particular, SCIT has multiple characteristics, and each characteristic is linked to different performance indicators.

In chapter 3, we investigate how SCIT can conditionally change the relationship between supply base complexity (SBC) or customer base complexity (CBC) and performance. Extant literature suggests that a complex supply or customer base can lead to suboptimal organizational performance. Using secondary data from the Bureau of Economic Analysis and the Annual Survey of Manufacturers, we are able to examine the impact of SBC and CBC on performance at the industry level of analysis. Further, we find that SCIT helps eliminate the negative impact of SBC and CBC on performance. By systematically investigating the direct and indirect impacts of SCIT on performance, this dissertation contributes to the understanding of the roles of information technology in supply chain management.

INDEX WORDS: Supply Chain Management, Supply Chain Information Technology, Interorganizational Information Systems, Operational Performance, Financial Performance, Market Performance, Supply Base Complexity, Customer Base Complexity

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DEDICATION

My dear and beautiful wife Hilda, this one is for you. Thank you for all your continuous love, support and prayers. I also dedicate this dissertation to my parents: Bapak and Ibu, to my in-laws: Papah and Mamah, and to my sons: Zee and Izzan.

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Chapter 1

Introduction

Over the past twenty years, academic research has highlighted two important issues: the importance of supply chain management and the roles of information technology (IT) in supply chain management (SCM). These two issues are complementary to each other. An effective SCM is impossible to achieve without information technology, while the development and use of IT became more pervasive in the SCM era (Gunasekaran & Ngai, 2004). Both anecdotal evidence and research show that effective supply chain management can yield significant operational and financial benefits. For example, Zara, a large clothing company based in Spain, consistently reevaluates its supply chain and collaborates with its customers and suppliers. As a result, Zara has enjoyed benefits such as innovative products, fast product lead times, efficient inventory, quick and reliable delivery, and enhanced profitability (Sawhney, et al., 2006). Zara's success story cannot be separated from its intensive use of IT. Zara has long been recognized as a strong user of IT in its supply chain operations. Pablo Isla, its CEO, announced the company's plan to gradually install radio frequency identification (RFID) tagging at item level in its all 2000 stores around the world (Smith, 2014). At the time of the announcement, Zara had installed RFID tagging at more than 700 of its stores and logistics centers. An RFID label encoding at item level enables Zara to immediately pinpoint which sizes and models need replenishing, and avoid any possible procurement and fulfillment mistakes with regards to quantity, model, size and color (Smith, 2014).

SCM literature particularly highlights the importance of supply chain information technology (SCIT). SCIT is a subset of information technology (IT) that is utilized within and across firm boundaries (Autry, et al., 2010). In other words, IT is SCIT when it is used in the context of SCM. SCIT has been viewed as a key enabler of effective supply chain management activities (Sanders & Premus, 2002). In particular, SCIT facilitates the flow of information and finances across firms with supply chain partners by enabling coordination, information sharing, and integration processes (Malone et al. 1987). In Zara's case, Zara stores utilize RFID, a form of SCIT, to better track their stocks, increase sales, and replenish their clothing racks more quickly (Bjork, 2014). Zara previously performed a storewide inventory check every six months, but since the implementation of RFID, an inventory check is done once every six weeks. This significant change provides Zara not only with a more accurate inventory level, but also with more accurate information of which products are selling well and which are not (Bjork, 2014). In addition, RFID has helped Zara increase sales by suggesting to customers what is available in the store, in a nearby Zara store, or online, when customers could not find a particular size or color in the model they desired. Furthermore, each time a product is sold, data from the RFID chip prompts an instant order to the stockroom to send out an identical item and simultaneously informs the distribution center about the change in inventory (Bjork, 2014; Smith, 2014).

SCIT has been viewed as a popular strategy to increase sales and profitability in many industries. Gartner reports that in 2013, $300 billion was spent on SCIT by firms globally. This investment spending has grown by 1.8 percent and 3.8 percent compared to spending in 2012 and 2011, respectively (Lovelock, et al., 2014). A study by Information Week reveals that majority of Fortune 500 companies expect an increase in their SCIT spending (Murphy 2013). SCIT spending accounts for at least 90% of total technology spending, and is predicted to grow by at least 3 percent in the next three years (Lovelock, et al., 2014). Similar anecdotal evidence occurs at the firm level. J.C. Penney spent $139 million on SCIT in 2009, while Kohl's Corp.

spent $100 million on its e-commerce system, a form of SCIT, in 2010, including addition of a new distribution center to support online sales (Dodes, 2010).

Whereas benefits and capabilities of SCIT are clear, the impact of SCIT on firm performance has been a long and ongoing debate in the literature. A study by Brynjolfsson in 1993 triggered a discussion of what has been called the “IT productivity paradox”, which questioned whether IT has a positive or negative impact on firm productivity. The study showed that, despite price declines in IT infrastructure investments and increases in IT computing capability, productivity of firms has been stagnant. Subsequent studies similarly questioned whether the use of IT in a supply chain context also has a positive impact on firm performance (Iyer, et al., 2009; Jeffers, et al., 2008; Johnston, et al., 2007).

The doubt concerning the impact of IT on firm performance is perhaps triggered by doubts among practitioners. For example, Hershey Foods Corp. implemented a new ERP system in 1999 that cost $112 million. However, this new system caused shipment delays and incomplete orders, ultimately resulting in a $150.5 million sales decline (Koch, 2002). Many large manufacturing companies were also dissatisfied with SCIT. Although they have spent millions of dollars on SCIT, these companies rarely use SCIT because it does not meet the line-of-business needs for supply chain optimization and visualization (Cecere, 2014). SCIT is not only highly priced, but also very costly to maintain, which may eventually erode a firm’s performance (Cecere, 2014). In Zara’s example, Zara still has to pay for at the 10-cent range for each RFID chip even after having sales volumes of hundreds of millions of items each year (Holste & Nystrom, 2014). With such significant investments, firms have to face risks of eroded financial performance if SCIT did not meet expectations. Wal-Mart had this bitter experience ten years ago. Wal-Mart pushed its suppliers to put RFID chips on cases of items, rather than on individual items. Due to the high cost of technology, it had to postpone and scale down the project (Bjork, 2014). It is not surprising to hear Heather Sheehan, VP of Indirect Sourcing and Logistics at Danaher Corp. and Chair of Council of Supply Chain Management Professional Board of Directors, saying, *"Companies struggle to understand and identify the real value and ROI on (Supply Chain) information technology"* (Sheehan, 2014).

The extant literature has also reported contradictive results regarding relationships between SCIT and firm performance. That is, SCIT has been shown to be positively correlated, uncorrelated, or even negatively correlated with firm performance (Bharadwaj, 2000; Jeffers, et al., 2008). For example, SCIT is positively associated with financial and operational performance in some studies (Rai, et al., 2006; Ranganathan, et al., 2011), but negatively associated with operational performance in other studies (Jeffers, et al., 2008). In contrast, another study finds that SCIT is not correlated with operational performance (Apigian, et al., 2006). Several studies have tried to reconcile these disparate findings through resolving potential methodological problems (Santhanam & Hartono, 2003), including lagged effects of SCIT on performance (Hendricks, et al., 2007) and addressing theoretical limitations (Iyer, et al., 2009). However, consistent relationships between SCIT and firm performance have yet to emerge (Vickery, et al., 2003; Zhang, et al., 2011).

This dissertation seeks to further evaluate roles of IT in SCM and its impact on firm performance. Inconclusive results from previous studies suggest that this research domain has not yet reached maturity. A research stream is best characterized as matured when a substantial number of empirical studies have been conducted, these studies have generated reasonably consistent and interpretable findings, and the research has led to a general consensus concerning the nature of key relationships (Palich, et al., 2000, p. 155). Although the first criterion may have been satisfied, the literature clearly fails to meet the last two criteria. In addition, investigating firm performance implications of SCIT is important because both academic and industry professionals are in need of such knowledge (Sheehan, 2014). In particular, this dissertation attempts to further explicate the extent to which IT is able to provide benefits to a firm in the context of supply chain management and also the extent to which IT can facilitate firms in managing their supply chain effectively and efficiently.

To answer these questions, this dissertation conducts two independent but related studies. Chapter 2 evaluates the impact of supply chain information technology (SCIT) on firm performance. In this first essay, a meta-analysis of a correlation method will be employed. There are three reasons why meta-analysis is the best approach to evaluate this issue. First, discussion of SCIT is scattered and fragmented across many domains with different conceptualizations. For example, one study refers to SCIT as a very specific tool (e.g. RFID, GEOps) while another study refers to SCIT as a general system (Subramani, 2004; Chengalur-Smith, et al., 2012). Second, as discussed previously, the relationship between SCIT and firm performance has been a long-standing area of inquiry. However, there is a lack of agreement with respect to the impact of SCIT on firm performance and whether SCIT is positively associated with firm performance. Third, across all previous studies discussing the SCIT-performance link, different performance measures have been utilized (e.g. operational, market, and financial). In this essay, following Saeed and colleagues (2011), we disaggregate SCIT into four characteristics (e.g. application integration, data compatibility, analytic ability, and evaluation and alertness ability) to investigate the relationships between each characteristic and firm performance. Such approach enables us to see and understand the difference among all characteristics with respect to their performance implications. Therefore, the main purpose of this essay is to identify any generalizable relationships that exist between SCIT characteristics and firm performance. Furthermore, this study will seek to identify if any of the SCIT-firm performance relationships are subject to unknown moderating factors. Finally, this essay will identify areas that have been under-studied and have significant potential for future research.

Chapter 3 evaluates how IT can conditionally change the relationship between supply base complexity (SBC) or customer base complexity (CBC) and a manufacturer's performance. S*upply (customer) base complexity is defined as the degree of complexity as reflected both in the number of a focal manufacturer's suppliers (customers) and in the degree dispersion in a focal manufacturer's supply base or customer base* (Choi & Krause, 2006; Hofer & Knemeyer, 2009). In other words, a large and highly dispersed supply base or customer base is much more complex than a small and concentrated one. Literature suggests that a complex supply base or customer base can lead to suboptimal performance (Gottinger, 1983; Choi & Krause, 2006; Bozarth, et al., 2009). This study is particularly relevant and important today with the potential trend increase of supply base and customer base complexity (Choi & Krause, 2006). There are several potential drivers that may motivate a focal manufacturer to increase its supply base and customer base complexity, such as globalization, sustainability, customization, innovation, and flexibility (Manuj & Sahin, 2011; Serdarasan, 2013). For example, Apple Inc. added more critical suppliers to bring new features into its iPad and iPhone and to compete with rivals while simultaneously establishing new relationships with major carriers and retailers (Arce, 2015). Although these motives are mainly positive, SBC and CBC complexity inherently creates additional challenge to firms, with respect to coordination costs and transaction risk. As a result, there is potential negative impact of SBC and CBC on performance. Firms that are unable to manage SBC and CBC in an effective manner may see suboptimal performance compared to their competitors.

Choi and Krause (2006) suggest that supply base complexity, and presumably customer base complexity, are also reflected at the aggregate industry level. Hence, investigating supply chain complexity at industry level can be justified.

The purpose of this second essay is two-fold. First, the purpose of this essay is to study the association between SBC and CBC and manufacturers' performance at industry level. In particular, this essay employs a measure of SBC and CBC that considers size and degree of dispersion of a focal manufacturer's supply or customer base. Previous studies on SBC and CBC have been inconclusive, with some studies unable to find the link between SBC and CBC and performance. Second, using industry-level data from the Bureau of Economic Analysis (BEA) and the U.S. Census Annual Survey of Manufacturers (ASM), this essay investigates the role of IT to mitigate the negative impact SCB complexity. .

Transaction cost economics (TCE) will be used in this study as a theoretical lens to develop the hypotheses because components of supply base and customer base complexity fit with components of transaction costs. In general, transaction costs are composed of coordination cost and transaction risk (Grover & Malhotra, 2003). In this study, the size of supply base or customer base that a focal manufacturer has is relevant to the size of coordination costs. Degree of dispersion is also relevant to transaction risk. An increase in degree of dispersion suggests an increase in uncertainty in the supply or customer base (Choi & Krause, 2006), which results in a higher transaction risk. TCE is also useful to use as a theoretical lens to develop hypotheses with regards to information technology (IT). IT has coordination and information sharing capabilities to minimize coordination costs (Rosenzweig, 2009). In addition, IT also has collaboration and monitoring capabilities to reduce transaction risk (Saldanha, et al., 2013).

SCIT has increasingly received scrutiny in recent years (Cecere, 2014; Carr, 2003). Because of many reasons, such as complexity of implementation, common standards of IT infrastructure, or high cost of maintenance, several academics and practitioners are skeptical on values of SCIT. Specifically, the question addressed is: What is the impact of SCIT on performance? This dissertation provides answer to this question. Essay 1 suggests that SCIT can directly impact firm performance with respect to operational, market, and financial performance. Essay 2 suggests that SCIT indirectly impacts manufacturer's performance by moderating potential negative impacts of supply base and customer base complexity. SBC and CBC are important aspects of SCM that should be managed carefully. Collectively, the two essays study roles of IT in SCM by investigating the performance implications of SCIT directly (essay 1) and indirectly (essay 2). Despite the theoretical interest in SCIT and its impact on performance, there is no empirical study that has simultaneously considered both direct and indirect effects with respect to performance.

There are four chapters in this dissertation. The next two chapters contain the two essays discussed previously. Finally, concluding remarks, future research, and contributions of this dissertation to academia and practitioners are discussed in chapter 4.

Chapter 2

Does Supply Chain Information Technology Improve Firm Performance? A Meta-Analytic Evaluation

INTRODUCTION

Increasing competitive pressures have forced firms to rely upon supply chain information technology (SCIT) to satisfy customer demands. Glenn Murphy, Chairman and CEO of GAP Inc., recently said that GAP is expanding its industry-leading omni-channel capability by leveraging information technology (Murphy, 2014). Levels of integration and coordination necessary to execute omni-channel distribution rely on effective SCIT. However, there are doubts concerning return on investments (ROI) in SCIT existing among practitioners. For example, Heather Sheehan, VP of Indirect Sourcing and Logistics at Danaher Corp. and Chair of CSCMP BOD, said, *"Companies struggle to understand and identify the real value and ROI on technology. Academics can help with research for quantifying the value in terms of benefits to shareholders"* (Sheehan, 2014).

Supply chain management (SCM) and SCIT are two concepts that are often closely linked. In seminal SCM articles, SCIT is recognized as a key factor by enabling coordination and integration across firm boundaries (Thomas & Griffin, 1996; Mentzer, et al., 2001; Cooper, et al., 1997). For example, SCIT enables firms to share information seamlessly and inexpensively with their chain partners, which is an important aspect of modern supply chain management (Cachon & Fisher, 2000). This view is further supported by Prajogo and Olhager (2012), who found that information sharing through the use of SCIT increases interorganizational (IO) integration.

Despite anecdotal evidence of improvements via SCIT usage, extant literature has not arrived at a consensus regarding relationships between SCIT and firm performance. That is, SCIT and firm performance have been shown to be positively correlated, uncorrelated, or even negatively correlated (Bharadwaj, 2000; Jeffers, et al., 2008; Mithas, et al., 2012). Several studies have tried to reconcile these disparate findings via methodological problems (Santhanam & Hartono, 2003), lag effects of SCIT impacts on performance (Hendricks, et al., 2007), and theoretical limitations (Iyer, et al., 2009). However, consistent relationships between SCIT and firm performance have yet to emerge (Vickery, et al., 2003; Zhang, et al., 2011).

To date, research studies with respect to SCIT and firm performance are fragmented. This fragmentation exists in several forms. First, researchers often utilize different performance measures. For example, although operational, market, and financial performance are the most common measures used in the literature, researchers often only examine a single performance measure rather than multiple measures. The way measures are conceptualized also differs across studies. For example, operational performance is conceptualized as using a single dimension in one study but is conceptualized as using multiple dimensions (e.g. cost, quality, delivery, and flexibility) in another study. As a result, it is difficult to triangulate research outcomes.

Secondly, the domains of SCIT researched are fragmented (Subramani, 2004). Due to its scope, SCIT is discussed across many areas of academic inquiry, such as in information systems (IS), operations management, supply chain management, logistics, and marketing. Conceptualizations, such as types of IT, are often different across these domains. For example, SCIT is often referred to as an Inter-Organizational System (IOS) in IS literature, which excludes technology devices such as radio-frequency identification (RFID) or global positioning system (GPS) that are discussed in logistics literature. Another complication to generalizing relationships between SCIT and firm performance is the speed with which proliferation and capabilities of SCIT have occurred over time. Currently, there are at least 25 examples of SCIT used by firms (Autry, et al., 2010). Research is further challenged to study and synthesize new forms of SCIT.

All these issues collectively suggest that a meta-analysis may be helpful to further theory building in this domain. Meta-analysis is a statistical technique that has an ability to integrate and examine research findings across individual studies (Mackelprang & Nair, 2010). This approach suits the purposes of this study in three ways. First, this study attempts to statistically identify which relationships between SCIT types and firm performance are generalizable. Finding generalizable results is also of great importance for practitioners. A recent study shows that $300 billion was spent by firms globally in 2013. This investment has grown 1.8 percent and 3.8 percent compared to those in 2012 and 2011, respectively, and will continue to grow significantly in the future (Lovelock, et al., 2014). Blind investments in SCIT only escalate the importance of this study, considering that firm's resources could be better invested in other areas. Secondly, this study identifies which SCIT-performance relationships are subject to unknown moderating factors that significantly influence the magnitude of the SCIT-performance relationship. Finally, this study will identify areas that are under-studied and thus, identify potentially fruitful avenues for future research.

The remainder of the paper is as follows. We first examine SCIT as it is discussed in the extant literature. Particularly, we consider categorization of SCIT. We then deliberate the findings from the review of the literature and how categories of SCIT are linked to firm performance. We then explain the method, meta-analysis of correlations used in this study, followed by a discussion of findings. Finally, we conclude with implications for academics and practitioners, as well as future research opportunities.

LITERATURE REVIEW

Supply Chain Information Technology

In information system literature, researchers often refer SCIT to supply chain information systems (SCIS), supply chain systems (SCS), or interorganizational systems (IOS). In this essay, these different terms will be used interchangeably only if necessary, for example when referring to certain researchers' definition of SCIT.

Research on SCIT, information technology that spans firm boundaries, emerged during the 1980s (Johnston and Vitale 1988). At first, SCIT was aimed at the automation of manual processes, such as ordering and settling accounts, and as a substitution of repetitive processes. Over time, SCIT developed a range of new features, such as information sharing communication, coordination, and collaboration, which connected a firm with its supply chain partners. These features allow a firm to reap benefits such as reduced operating costs, improved customer service, and sustained competitive advantages (Ray, et al., 2005). Hence, some of these features motivate the adoption of SCIT. For example, Wal-Mart has invested significantly in SCIT to better coordinate and collaborate with its suppliers. As a result, Wal-Mart is able to minimize the cost and pass the savings to its customers. However, not all companies benefit from SCIT. Prior studies show mixed results when evaluating the performance impact of SCIT.

A previous study suggests that the difference of outcomes can be subjected to how SCIT is used (Subramani, 2004). In this regard, the concept of appropriation provides useful insights. Differing appropriations can lead to diverse outcomes, even when the context of use and underlying technologies are similar (DeSanctis & Poole, 1994). For example, firms can easily buy package SCIT, such as enterprise resource planning systems or supply chain management systems. Such systems offer many features for a firm to use. However, a firm may not use all available features for some reasons such as limited resource and capability. In such circumstances, appropriation becomes more relevant than the SCIT itself.

In contrast, SCIT can be very specific, which as a result offers specific features and functions. For example, a barcode system is meant to standardize information for consistency reasons. Although standardized data is an important feature to facilitate automation and information flow, it cannot be used for other purposes such as evaluation or analysis.

Table 2.1. Range of SCIT

Element	Range	
Cost	Low-cost	High-cost
Development	Off-shelf	Custom-built
	Examples: SAP, Oracle, JDA Software	Examples: Wal-Mart SCIT, SPIN (Chrysler)
Connectivity	Direct link	Internet
	Example: EDI	Example: GeOPS, e-commerce
Function	Simple	Complex
	Example: Bar-code, RFID	Examples: Warehouse Management Systems, TMS
Hosting	Decentralized	Centralized
	Example: client-server	Example: cloud, SaaS
Code	Open Source	Protected
User	Supply or customer side	Fully integrated

Table 2.1. shows how SCIT has developed very quickly and examples of SCIT are abundance. With respect to cost, SCIT can be relatively cheap or extremely expensive. For example, barcode systems are relatively cheaper than RFID systems or complete module of supply chain management systems. Such wide-range of example requires categorization that can be meaningful for both practical and academic purposes (Saeed, et al., 2011).

To this end, this paper draws from an extant theory in the literature to evaluate performance implications of SCIT. There are two important issues here. First, diverse outcomes that a firm reaps from using SCIT are associated with how SCIT is used (Subramani, 2004). Second, how SCIT is used is also a function of characteristics of the SCIT itself. Because SCIT can be very broad or very specific, a discussion to identify SCIT characteristics will be important.

SCIT Categorization

Previous studies considered SCIT as a dimension within a broader theoretical domain or as a broad concept (Prajogo & Olhager, 2012; Ray, et al., 2005). A downside of this view is that authors consider SCIT broadly. SCIT, however, serves different purposes that are specific in functionality and characteristics. Due to the breadth of SCIT, categorizations of types of SCIT are critical for better delineating which type of SCIT fits with a firm's objectives (Saeed, et al., 2011). For example, Johnson and Vitale (1988) classify SCIT based on business purpose, relationship between sponsoring firm and its supply chain partner, and information function in the system. Other scholars categorize SCIT based on the degree of interdependence between partners in a supply chain and suggest three types of SCIT: pooled information resource, value/ supply chain IOS, and networked IOS (Kumar & Van Dissel, 1996). Bensaou and Venkatraman

(1995) use information processing theory as a theoretical lens and propose five types of SCIT: remote relationships, electronic control, electronic interdependence, structural relationships, and mutual adjustment.

Table 2.2. SCIT Categorization

Reference	SCIT Categorization			
	Application Integration	Data Compatibiltiy	Analytic Ability	Evaluation and Alertness Ability
(Rai, et al., 2006)	X	X		
(Subramani, 2004)			X	X
(Malhotra, et al., 2005)		X	X	X
(Malone, et al., 1987)	X	X		
(Johnston & Vitale, 1988)	X		X	X
(Mukhopadhyay & Kekre, 2002)		X		
(Saeed, et al., 2011)	X	X	X	X
(Christiaanse & Venkatraman, 2002)			X	X
(Kraemer & Dedrick, 2002)		X	X	X
(Choudhury, 1997)	X	X		X
(Byrd & Turner, 2000)	X	X		
(Kumar & Van Dissel, 1996)		X		
(Masetti & Zmud, 1996)	X	X		
(Clemons, et al., 1993)	X		X	X

(*adapted from Saeed et al,. 2011*)

A more recent study categorized SCIT based on its characteristics: application integration (AI), data compatibility (DC), analytic ability (AA), alertness, and evaluation ability (AE) (Saeed, et al., 2011). Application integration is defined as the extent to which SCIT is seamlessly assimilated in the supply chain. This characteristic emphasizes a firm's ability to connect its SCIT with its partners in real time with respect to planning applications, execution applications, and internal firm processes (Rai, et al., 2006). AI focuses on connectivity between a firm and partners' SCIT. Such applications facilitate real-time information sharing in a supply chain, improving coordination of business processes across functional areas and firms (Rai, et al., 2006).

Data compatibility refers to the extent to which the SCIT used by the firm and its supply chain partners consists of the same data formats, conventions, or metrics (Saeed, et al., 2011). Data compatibility in supply chains should enable faster information flow and consistent interpretation of information, minimizing errors. Data compatibility concerns the use of data in a supply chain. There are two dimensions of DC: data consistency and automated data capturing (Rai, et al., 2006). Data consistency is a major issue, especially in a supply chain where common data definitions are lacking. Common data definitions allow a firm to immediately access and use data without having to interpret the meaning (Saraf, et al., 2007). Common data definitions require integration between databases not only at the syntactic level, but also at the semantic level (Saraf, et al., 2007). When such integration exists, SCIT can be used to collaborate with partners to improve forecasts, production throughput, and flexible operations (Saraf, et al., 2007) Consistent data is also important to mitigate the bullwhip effect (Angeles, 2009). When tier-3 suppliers in the upstream can access and use data from customers in the downstream, they can better forecast and mitigate variability. In contrast, when data is not consistent, it needs to be cleaned, scrubbed, transformed, combined, and formatted before it is loaded into a data warehouse. These activities are the most expensive and time-consuming operations (Angeles, 2009). Inconsistent data may exist from legacy systems used by a firm. It may also be a result of using different SCIT by firms in the supply chain. Often, inconsistent data is not usable for initiating supply chain wide activities such as vendor managed inventories (VMI) or collaborative planning, forecasting, and replenishment (CPFR) (Angeles, 2009).

DC is also enabled by the use of automated systems which capture data accurately across supply chains (Rai, et al., 2006). Note that although both AI and DC concern automation, AI focuses more on the connectivity while DC focuses more on the data. An example of DC is a barcode system. When different barcode system codes are used by firms in a supply chain, the information that one firm has may be different from that of another. Automated data capture systems reduce costs by eliminating duplicate tasks in the supply chain. A firm does not need to reenter data as it is automatically captured and synchronized in the system. In addition, automated data capture systems reduce errors and therefore, increase quality of information shared with partners in a supply chain which in turn reduces the cost of transactions between buyers and sellers (Malhotra, et al., 2005).

Analytic ability is the extent to which SCIT provides analytical tools to support decision making regarding supply chain functions (Saeed, et al., 2011). Analytic ability emphasizes decision making functions such as creating a scenario analysis with goals to discover novel ways of creating value (Subramani, 2004). Analytic ability also facilitates partners to collaborate and create joint knowledge and/or functional fit of intraorganizational and interorganizational processes that can result in increased strategic, long-term performance (Subramani, 2004).

Evaluation and alertness ability is defined as the extent to which the IOS provides tools that support the performance evaluation of members in the supply chain and that are capable of detecting and reporting exceptions to users. Evaluation and alertness ability focuses on the elaboration of current practices and costs which is a class of actions oriented towards improvements in operational efficiencies (Subramani, 2004). SCIT can also be used to evaluate partners' performance and behavior which can provide insights on areas that need improvement (Saeed, et al., 2011).

In addition to that previous categorization, we also consider the location where the SCIT is employed. For loci of use, SCIT can be categorized as upstream, downstream, or both upstream and downstream (Craighead, et al., 2006). Upstream SCIT links a firm to its partners to manage procurement and relationships with suppliers in order to secure delivery of raw materials and components required for in-house production. In contrast, downstream SCIT links a firm to its partners to build relationships with customers and plan a future marketing strategy (Bayraktar, et al., 2009). Previous studies show that loci of use also explain diverse outcomes when evaluating SCIT and firm performance (Frohlich, 2002).

From our analysis, categorizations used by previous studies as discussed above can be mapped into the categorization offered by Saeed and colleagues (2011), which is also employed in this paper. The table 2.2 above shows how SCIT categorization employed in this paper is related to other SCIT characteristics suggested in the literature (Saeed, et al., 2011). For example, application integration and data consistency in Rai et al. (2006) have similar characteristics to application integration and data compatibility in Saeed et al. (2011).

Firm Performance

The connections between SCIT and firm performance are a long-standing area of inquiry (Cachon & Fisher, 2000). However, researchers rarely use common measures that can be generalized. With respect to firm performance, early studies in the literature mainly focus on short-term performance (e.g. operational performance), while in more recent studies, researchers take a longer-term performance perspective (e.g. financial and market performance). Researchers also use different performance measures due to context. For example, in a transportation industry when third-party logistics companies are examined, performance may be measured by on-time delivery and delivery speed, which are primary concerns for this type of industry. (Kent & Mentzer, 2003). In a more general context, operational performance such as cost, quality, delivery, and flexibility can be more appropriate performance measures (Devaraj, et al., 2007; Frohlich, 2002). Other performance criteria are also utilized in the literature. Among them is innovation, new product development, customer service, or coordination (Subramani, 2004; Hartono, et al., 2010; Fawcett, et al., 2011). Another related issue is measure of performance. Some scholars utilize unidimensional performance measures for operational, financial, or market performance (see Rai et al., 2006, Iyer et al., 2009), while others employ multidimensional performance measures in their study (see Frohlich & Westbrook, 2002).

Theoretically, SCIT positively impacts firm performance. However empirically, there have been inconsistent links between SCIT and firm performance as shown in the literature. For example, a previous study shows that SCIT has a positive impact on operational performance, as indicated in improvements in costs, delivery, and inventory turnover (Frohlich & Westbrook, 2002). Unfortunately, although the impact of SCIT on firm performance has been an area of interest for business scholars for many years, there is no major study that is influential enough being followed by subsequent research. As a result, researches that specifically observe categorization employed in this study are very limited. Observing the relationship between SCIT and firm performance in finer detail is important as it will provide academic and practitioners more meaningful knowledge. The literature also calls for greater granularity examination of SCIT, whether upstream, downstream, or upstream-downstream SCIT will differentially impact firm performance (Bharadwaj, et al., 2007, p. 449).

In the next section we will review findings in the literature. As discussed, the relationship between specific SCIT category and firm performance has not been formally studied. In many studies, unidimensional measures of SCIT are used, as opposed to multidimensional measures that correspond to our category of SCIT. Due to this lack of information in the literature, we observe the relationships using correlations of items. For example, positive correlation between an item that corresponds to application integration and operational performance suggests positive impact of application integration on operational performance.

Application Integration and Firm Performance

The link between application integration and firm performance varies based on the type of performance measures observed. With respect to operational performance, some studies find that application integration is directly and positively associated with operational performance (Rai, et al., 2006; Ranganathan, et al., 2011), while others fail to support this relationship (Li, et al., 2009; Barua, et al., 2004). Other researchers find that a positive, but indirect, relationship between application integration and operational performance exists (Angeles, 2009) (Saraf, et al., 2007; Hsu, et al., 2008). Similarly, positive association is also found between application integration and market and financial performance (Jeffers, et al., 2008). In contrast, literature also provides conflicting results. One study indicates that there is no significant impact of application integration on operational performance (Apigian, et al., 2006). In another study, application integration has a negative impact on operational performance with respect to quality and delivery (Jeffers, et al., 2008). Furthermore, application integration also has a negative impact on market and financial performance (Iyer, et al., 2009).

Data compatibility and Firm Performance

The empirical evidence about data compatibility and its association with firm performance is also not consistent in the literature. Data compatibility is shown to be directly and positively associated with operational performance, market performance, (Rai, et al., 2006; Chengalur-Smith, et al., 2012; Saeed, 2004; Hartono, et al., 2010; Singh, 2006), and financial performance (Kim et al. 2011). In another study, however, data compatibility is shown to be indirectly associated with operational and market performance (Angeles, 2009). In contrast, there is another study that indicates that data compatibility is negatively associated with firm performance (Byrd & Davidson, 2003).

Analytic ability and Firm Performance

For the analytic ability category of SCIT, literature shows that this category is positively associated with operational performance, market performance, and financial performance (Jeffers, et al., 2008; Im & Rai, 2008; Saeed, 2004). However, another study indicates that analytic ability is negatively associated with operational performance (McKone-Sweet & Lee, 2009).

Evaluation and Alertness Ability and Firm Performance

With respect to evaluation and alertness, a number of studies have found positive relationships between evaluation and alertness and firm performance. Particularly, evaluation and alertness is positively associated with operational performance (Iyer et al., 2009, Singh, 2006, Saeed, 2004, Wiengarten et al., 2011, Vijayasarathy, 2010), market performance, (Iyer et al., 2009, Jeffers et al., 2008, Tan et al., 2010), and financial performance (Liu et al., 2013, Tan et al., 2010, Iyer et al., 2009). However, an insignificant finding is also reported in the literature (Subramani, 2004). Finally, another study indicates that evaluation and alertness ability is negatively associated with operational performance (McKone-Sweet and Lee, 2009).

SCIT loci and firm performance

The empirical evidence about the link between SCIT loci (e.g. upstream, downstream, or both) and firm performance is not rarely studied in the literature. Some researchers implicitly discuss the loci by explaining the context of their studies (e.g. SCIT for procurement or sales) or explaining it in the survey (e.g. customers, suppliers). In general, SCIT that is used both upstream and downstream has strong positive impact on operational performance (Frohlich, 2002). However, using SCIT on just one side of the supply chain, either the upstream or downstream side, only provides marginal benefits (Frohlich and Westbrook, 2002). In contrast, another study shows that while downstream SCIT has positive impact on performance, upstream SCIT impact on performance is negligible (Barua et al., 2004, Angeles, 2009). In different studies, the downstream SCIT link to firm performance is also not found (Devaraj et al., 2007, Jeffers et al., 2008).

Table 2.3. Meta-analytic methodological procedures

	Step	Formula
1	Attenuation factor (A)	$A = \sqrt{\alpha_{xx}} \text{ x } \sqrt{\alpha_{yy}}$
2	Corrected correlations (r')	$r' = \frac{r}{A}$
3	Individual study weights (W_i)	$W_i = N \text{ x } A^2$
4	Weighted sample mean correlations ($\bar{r}$)	$\bar{r} = \frac{\sum W_i r}{\sum W_i}$
5	Corrected study sampling error (e_i)	$e_i = \frac{(1 - \bar{r}^2)^2}{(N-1)A^2}$
6	Weighted mean sampling error variance ($\bar{e}$)	$\bar{e} = \frac{\sum W_i e_i}{\sum W_i}$
7	Weighted mean corrected correlations ($\bar{r}'$)	$\bar{r}' = \frac{\sum W_i r'}{\sum W_i}$
8	Variance of the corrected correlations ($\sigma^2 r'$)	$\sigma^2 r' = \frac{\sum W_i (r' - \bar{r}')^2}{\sum W_i}$
9	Estimated population standard deviation (S_ρ)	$S_\rho = \sqrt{[(\sigma^2 r') - (\bar{e})}$
10	Calculate RATIO 1	$\text{RATIO 1} = \frac{\bar{r}'}{S_\rho}$
11	Calculate RATIO 2	$\text{RATIO 2} = \frac{\bar{e}}{\sigma^2 r'}$
12	Credibility interval (CI)	$CI = \bar{r}' \pm Z\, S_\rho$

METHODOLOGY

To investigate the relationships between SCIT and firm performance, we will perform a meta-analysis of correlations as instructed by Hunter and Schmidt (2004). Meta-analysis of correlations has recently gained interest among many scholars, especially in the supply chain management domain (Mackelprang & Nair, 2010; Mackelprang, et al., 2014; Wowak, et al., 2013; Leuschner, et al., 2013; Golicic & Smith, 2013). A meta-analysis of correlations goes beyond conducting a systematic literature review; it also provides insight of a phenomenon by finding the actual correlations between variables of interests (Hunter & Schmidt, 2004). Meta-analysis of correlations can correct statistical artifacts, such as sampling and measurement errors, and thus obtain better estimates of the population correlation between independent and dependent variables (Hunter & Schmidt, 2004).

Procedures

As discussed, researchers use various items, definitions, and constructs when measuring SCIT and firm performance. These measures may include multi items and multi-dimensional construct and there are certain variations between conceptualizations across studies. However, studies often provide readers with detail of items used in the measures. The item can then be used to examine relationships between independent and dependent variables of interest. Meta-analysis methodology allows this approach (Hunter & Schmidt, 2004). This idea is referred to as multiple operationalism (Webb, et al., 1981) and analogous to triangulation of measures (Mackelprang & Nair, 2010) which basically suggests that the same concept can be gauged by multiple measures that may have some imperfections and irrelevancies to them. At a higher level of abstraction, these measures can still reveal associational patterns between variables and because of the multiple realizations, the uncertainties regarding the relationships are greatly reduced (Webb, et al., 1981).

Table 2.3 shows the steps to calculate the two heuristics used in this study. As an initial step, we collected important information from the authors to know the relationships between independent and dependent variables of interest, and to give weights to those relationships. The information are item correlations, reliability of construct (alpha or rho), and sample size.

Conceptualizations

The approach in this paper is different from previous meta-analysis studies (e.g. Mackelprang and Nair 2010; Mackelprang et al. 2014). Typically, previous meta-analysis studies follow one or several seminal articles that have been around quite some time and have significant influence to theory. Scholars would then follow the approach used in those seminal articles in attempt to refine and revise, as well as to triangulate the theory. Such practice creates massive subsequent studies not only discussing certain particular focuses, but also using the same construct, definition, and also scales, as evidenced in a meta-analysis study on JIT and a meta-analysis study on supply chain integration. In contrast, although the discussion of SCIT emerged more than 25 years ago, there is no single study discussing types of SCIT that is followed by a majority of subsequent research.

As discussed, the inconsistent SCIT concept has been found and used in different academic literatures (Saeed, et al., 2011). While differences in conceptualization may capture the breadth of SCIT, they are not converged in meaning. The lack of consensus of a SCIT definition can, in turn, hinder the process to generalize findings from previous studies. Therefore, in order to better understand the impact of SCIT, it is very important to first discuss the concept of SCIT from previous studies prior to defining SCIT.

Early research on SCIT emerged during the 1980s (Cash & Konsynski, 1985). In a seminal article, SCIT is referred to as interorganizational systems (IOS), which is defined as information systems that link a firm to its suppliers, distributors, or customers (Johnston & Vitale, 1988). This view suggests that SCITs are mainly IT applications, software modules, or system components that enable a firm to share information across firm boundaries (Saeed, et al., 2011). Examples of IOS are electronic data interchange (EDI) systems, supply chain management systems, procurement systems, or electronic trading systems. Following this view, previous studies use different terms but with the same meaning such as interorganizational information systems (IOIS) (Kim, et al., 2011) or electronic information systems (EIS) (Ko, et al., 2009). In a later study, SCIT is also referred to as an integrated IT infrastructure (Rai, et al., 2006). An integrated IT infrastructure enables consistent and real-time transfer of information across partners in a supply chain (Rai, et al., 2006). Whereas an IOS focuses only on software, integrated IT infrastructure encompasses both software and databases. As technology excelled quickly over time, SCIT became more sophisticated and advanced. A recent SCIT definition adopted a more general approach by including network and devices, such as RFID or GPS, in addition to software and databases (Autry, et al., 2010).

In contrast to general approaches, the literature acknowledges studies that observe specific SCIT such as EDI (Tan et al., 2010) or RFID (Zelbst, et al., 2010a; Zelbst, et al., 2010b). Some studies go even more specific by observing a particular SCIT product such as GEOPS, which is a web-based supply chain application to run vendor managed inventory (VMI) offered by General Electric (Chengalur-Smith, et al., 2012), or a vertical information system (VIS) from

RosettaNet, which is an XML-based, open standards software that facilitates inter-organizational business activities (Xu, et al., 2014).

Johnson and Vitale emphasize that SCIT differs from internal IT by allowing information to be sent across organizational boundaries (1988, p. 154). Context is particularly important because the way SCIT is used determines the impact on firm performance (Cagliano, et al., 2006). For example, enterprise resource planning (ERP) may provide greater benefits to a firm when linked with that of suppliers, customers, or both, than if used as internal IT only.

In this study, SCIT is defined as the tools and/or techniques that may be implemented in order to effectuate integrated supply chain management within and across organizational boundaries (Autry, et al., 2010). This definition provides solid ground for our study for three reasons. First, the definition captures the time dimension of SCIT, to include both old and recent SCIT. Secondly, it captures the breadth of SCIT, such as IT infrastructure, application, information system, device, etc. Finally, the definition considers both intra-organizational and inter-organizational IT, as opposed to just considering either intra-organizational or inter-organizational contexts individually.

In an effort to be comprehensive, this paper utilizes a portfolio of firm performance metrics. Similar to delineating SCITs, detailed performance measures should be more meaningful to both academics and practitioners. Therefore, performance is conceptualized in terms of: cost, quality, delivery, flexibility, customer service, financial, and market performance.

Search protocol and sample

One of the most critical processes in a meta-analysis study is to collect data and select a sample. There are multiple ways of determining a sample frame for a meta-analysis study. The first step is to focus on a set of journals pertinent to the study (Mackelprang & Nair, 2010; Wowak, et al., 2013). One of the considerations includes selecting relevant journals. The other consideration is to include well-respected journals in that relevant domain. The benefit of this approach is that well-respected journals tend to have a rigorous process during review to ensure quality. However, such approach may neglect possible relevant studies published in journals not known to the authors (Mackelprang, et al., 2014). Therefore, to ensure comprehensiveness in searching for studies to include in our research, we followed a modified version of the widely utilized David and Han (2004) method (Mackelprang, et al., 2014).

Following Mackelprang et al. (2014), we restrict the sample through the initial three steps. First, we use relevant keywords when searching through ABI/Inform, EBSCO, Science Direct, Emerald, Wiley databases, and Google Scholar. The general keywords are supply chain information systems, supply chain information technology, interorganizational systems, and supply chain technology. In addition, we also use specific SCIT words, such as EDI, RFID, e-procurement, or e-sales as key words to search for studies. Step 2 is to restrict the sample to articles that evaluate firm performance using keywords such as performance, operations, market, finance, logistics, supplier, or customer. Third, we restrict our sample to articles that are empirical and, thus, eliminating qualitative and conceptual articles. During this step, we also exclude empirical studies that utilize secondary data sources.

Heuristics

Two heuristics are used in this meta-analytic study: RATIO1 and RATIO2. These two heuristics were developed by Hunter and Schmidt (2004) and have been used in many meta-analytic studies (Mackelprang & Nair, 2010; Mackelprang, et al., 2014). RATIO1 is used to detect if the population correlation is significantly different than zero. The formula to obtain value of RATIO1 can be seen in Table 2.3. RATIO1 is calculated as the mean corrected correlation divided by its standard deviation. Accordingly, a value of RATIO1 ≥ 2 indicates that the mean correlation is 2 standard deviation above 0. Further, the probability that a correlation is equal to zero would be less than 5 percent, given that the population correlation was normally distributed. RATIO1 can also be used to calculate a credibility interval which is analogous to a confidence interval.

RATIO2 is the heuristics to detect potential moderation effects in a meta-analysis of correlation studies. It reports the amount of observed variance that is due to artifacts. Orlitzky et al. (2003) suggest that a value of RATIO2 ≥.75 means that 75 percent or more of the variance of correlations is due to artifacts (e.g. sampling errors, measurement errors, transcriptional errors, etc). In other words, when the value of RATIO2 is greater than .75, it is likely that the population correlation is only one and moderators do not cause real variation. Conversely, when RATIO2 value is lower than .75, then unknown factors may play a moderating role in the relationship.

Figure 2.1. Search Protocol

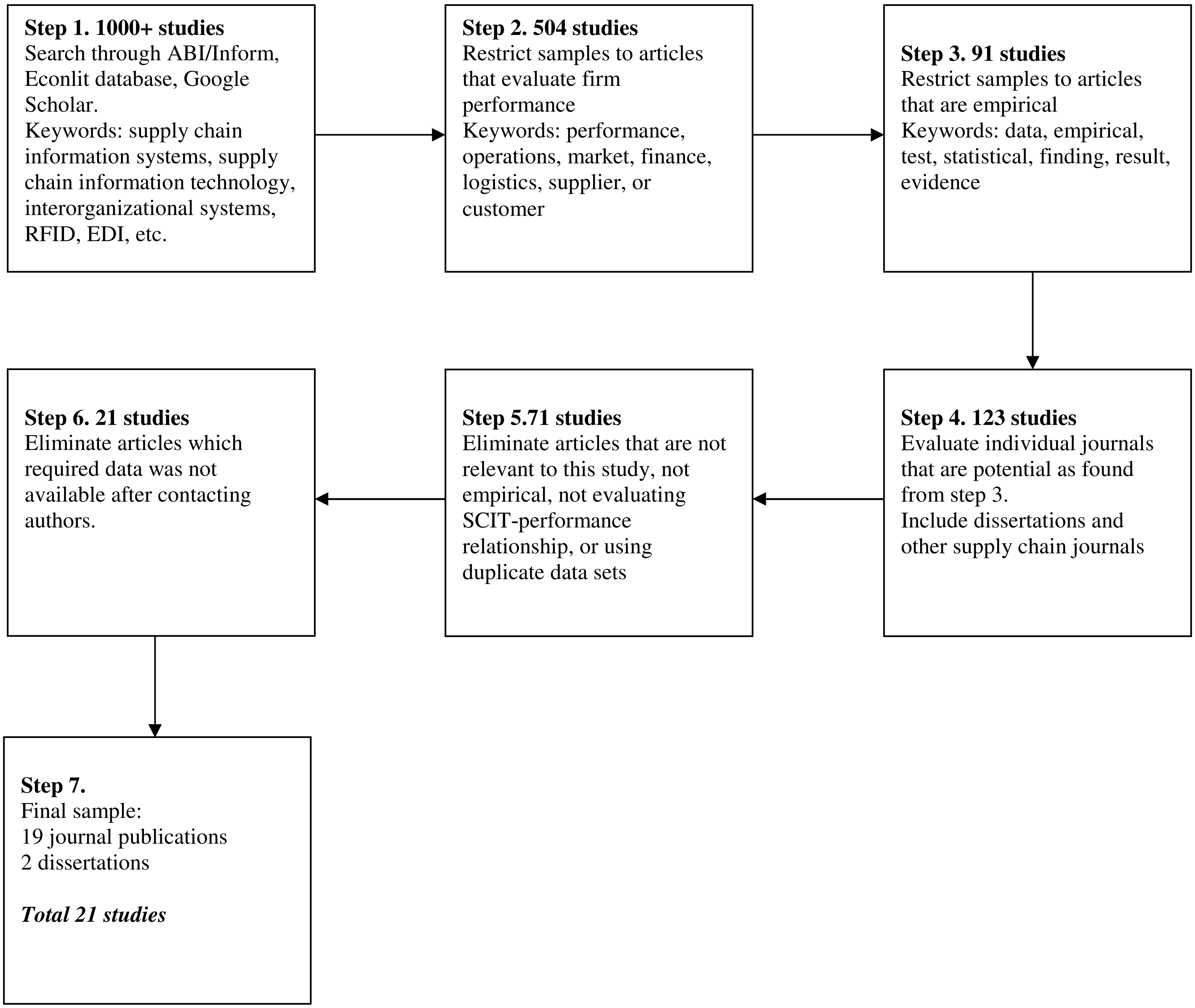


Table 2.3. Research included in the meta-analysis

Citation	Journal
(Iyer, et al., 2009)	Information and Management
(Saeed, 2004)	Dissertation
(Wong, et al., 2009)	International Journal of Production Economics
(Chengalur-Smith, et al., 2012)	Information and Management
(Hartono, et al., 2010)	International Journal of Information Management
(Singh, 2006)	Dissertation
(McKone-Sweet & Lee, 2009)	Journal of Supply Chain Management
(Zelbst, et al., 2010a)	Journal of Business & Industrial Marketing
(Zelbst, et al., 2010b)	Management Research Review
(Im & Rai, 2008)	Management Science
(Hsu, et al., 2008)	International Journal of Physical Distribution and Logistics Management
(Wiengarten, et al., 2011)	Supply Chain Management: An International Journal
(Jeffers, et al., 2008)	Decision Sciences
(Jayaram & Tan, 2010)	International Journal of Production Economics
(Vickery, et al., 2003)	Journal of Operations Management
(Vijayasarathy, 2010)	Information and Management
(Liu, et al., 2013)	Decision Support Systems
(Tan, et al., 2010)	International Journal of Physical Distribution and Logistics Management
(Barua, et al., 2004)	MIS Quarterly
(Kim, et al., 2011)	Omega
(Seggie, et al., 2006)	Journal of Business Research

Table 2.4. Inventory Performance

Study	Corrected correlation (r')	Study sample size (N)	Attenuation factor (A)	SCIT-performance correlation (r)	Study weight (W)
Application integration- upstream					
Iyer et al. 2009	0.268	152	0.788	0.211	94.377
Saeed 2004	0.004	50	0.789	0.003	31.150
Wong et al. 2009	0.203	188	0.788	0.160	116.729
Application integration- downstream					
Iyer et al. 2009	0.346	152	0.771	0.267	117.247
Application integration- both					
Chengalur-Smith et al. 2012	0.311	89	0.784	0.244	54.637
Hartono et al. 2010	0.424	227	0.784	0.332	139.355
Iyer et al. 2009	0.317	152	0.784	0.249	93.313
Singh 2006	0.378	167	0.784	0.296	102.521
Data Compatibility- upstream					
Chengalur-Smith et al. 2012	0.225	89	0.787	0.177	55.136
Saeed 2004	0.136	50	0.789	0.107	31.150
Data Compatibility- downstream					
No data available					
Data Compatibility- both					
Hartono et al. 2010	0.348	227	0.762	0.265	131.887
Singh 2006	0.262	167	0.762	0.200	97.027
Analytic Ability- upstream					
Mckone-Sweet and Lee 2009	-0.030	212	0.700	-0.021	103.880
Saeed 2004	0.244	50	0.811	0.198	32.900
Analytic Ability- downstream					
Mckone-Sweet and Lee 2009	-0.077	212	0.700	-0.054	148.400
Analytic Ability- both					
Mckone-Sweet and Lee 2009	-0.054	212	0.700	-0.038	148.400
Evaluation and Alertness Ability- upstream					
Mckone-Sweet and Lee 2009	-0.074	212	0.734	-0.054	114.268
Saeed 2004	0.232	50	0.802	0.186	32.200
Zelbst et al. 2010a	0.163	155	0.769	0.125	91.683
Zelbst et al. 2010b	0.565	122	0.769	0.435	72.163
Evaluation and Alertness Ability- downstream					
Mckone-Sweet and Lee 2010	-0.214	212	0.758	-0.162	121.688
Iyer et al. 2009	0.333	152	0.758	0.252	87.248
Zelbst et al. 2010a	0.263	155	0.758	0.199	88.970
Zelbst et al. 2010b	0.632	122	0.758	0.479	70.028

Evaluation and Alertness Ability- both					
Mckone-Sweet and Lee 2009	-0.147	212	0.734	-0.108	114.268
Iyer et al. 2009	0.303	152	0.783	0.237	93.100
Singh 2006	0.363	167	0.783	0.284	102.288
Zelbst et al. 2010a	0.183	155	0.829	0.152	106.547
Zelbst et al. 2010b	0.532	122	0.831	0.442	84.204

Table 2.5. Operational Cost Performance

Study	Corrected correlation (r')	Study sample size (N)	Attenuation factor (A)	SCIT-performance correlation (r)	Study weight (W)
Application integration- upstream					
No data available					
Application integration- downstream					
No data available					
Application integration- both					
Hartono et al. 2010	0.368	227	0.788	0.290	178.870
Data Compatibility- upstream					
No data available					
Data Compatibility- downstream					
No data available					
Data Compatibility- both					
Hartono et al. 2010	0.455	227	0.762	0.347	131.887
Im and Rai 2008	0.236	238	0.762	0.180	138.278
Analytic Ability- upstream					
Mckone-Sweet and Lee 2009	-0.054	212	0.758	-0.041	160.617
Analytic Ability- downstream					
Mckone-Sweet and Lee 2009	-0.099	212	0.700	-0.069	148.400
Analytic Ability- both					
Im and Rai 2008	0.386	238	0.700	0.270	116.620
Mckone-Sweet and Lee 2009	-0.079	212	0.700	-0.055	103.880
Evaluation and Alertness Ability- upstream					
Mckone-Sweet and Lee 2009	-0.114	212	0.734	-0.084	114.268
Zelbst et al. 2010a	0.308	155	0.769	0.237	91.683
Zelbst et al. 2010b	0.508	122	0.769	0.391	72.163
Evaluation and Alertness Ability- downstream					
Mckone-Sweet and Lee 2009	-0.133	212	0.758	-0.101	121.688
Zelbst et al. 2010a	0.343	155	0.758	0.260	88.970
Zelbst et al. 2010b	0.586	122	0.758	0.444	70.028
Evaluation and Alertness Ability- both					
Mckone-Sweet and Lee 2009	-0.127	212	0.734	-0.093	114.268
Zelbst et al. 2010a	0.285	155	0.829	0.236	106.547
Zelbst et al. 2010b	0.494	122	0.831	0.410	84.204

Table 2.6. Quality Performance

Study	Corrected correlation (r')	Study sample size (N)	Attenuation factor (A)	SCIT-performance correlation (r)	Study weight (W)
Application integration- upstream					
Hsu et al. 2008	0.136	625	0.788	0.107	388.063
Iyer et al. 2009	0.228	152	0.788	0.180	94.377
Saeed 2004	0.099	50	0.789	0.078	31.150
Wiengarten et al. 2011	0.038	152	0.788	0.030	94.377
Application integration- downstream					
Hsu et al. 2008	0.006	625	0.771	0.005	371.875
Iyer et al. 2009	0.145	152	0.771	0.112	90.440
Jeffers et al. 2008	-0.179	64	0.771	-0.138	38.080
Wiengarten et al. 2011	0.004	152	0.771	0.003	90.440
Application integration- both					
Hartono et al. 2010	0.265	227	0.784	0.208	139.355
Hsu et al. 2008	0.091	625	0.784	0.072	383.688
Iyer et al. 2009	0.316	152	0.784	0.248	93.313
Jayaram and Tan 2010	0.257	411	0.784	0.201	252.313
Wiengarten et al. 2011	0.021	152	0.784	0.017	93.313
Data Compatibility- upstream					
Hsu et al. 2008	0.230	625	0.787	0.181	387.188
Saeed 2004	0.241	50	0.789	0.190	31.150
Wiengarten et al. 2011	0.032	152	0.787	0.025	94.164
Data Compatibility- downstream					
Wiengarten et al. 2011	0.066	152	0.700	0.046	74.480
Jeffers et al. 2008	0.010	64	0.700	0.007	31.360
Data Compatibility- both					
Hartono et al. 2010	0.192	227	0.762	0.146	131.887
Hsu et al. 2008	0.197	625	0.762	0.150	363.125
Im and Rai 2008	0.289	238	0.762	0.220	138.278
Wiengarten et al. 2011	0.047	152	0.762	0.036	88.312
Analytic Ability- upstream					
Mckone-Sweet and Lee 2009	-0.039	212	0.700	-0.027	103.880
Saeed 2004	0.105	50	0.811	0.085	32.900
Analytic Ability- downstream					
Mckone-Sweet and Lee 2009	-0.109	212	0.700	-0.076	103.880
Jeffers et al. 2008	0.026	64	0.700	0.018	31.360
Analytic Ability- both					
Im and Rai 2008	0.443	238	0.700	0.310	116.620
Mckone-Sweet and Lee 2009	-0.074	212	0.700	-0.052	103.880

Evaluation and Alertness Ability- upstream					
Mckone-Sweet and Lee 2009	-0.132	212	0.734	-0.097	114.268
Saeed 2004	0.045	50	0.802	0.036	32.200
Wiengarten et al. 2011	0.075	152	0.769	0.057	89.908
Zelbst et al. 2010a	0.183	155	0.769	0.141	91.683
Evaluation and Alertness Ability- downstream					
Jeffers et al. 2008	0.096	64	0.758	0.073	36.736
Iyer et al. 2009	0.244	152	0.758	0.185	87.248
Mckone-Sweet and Lee 2009	-0.103	212	0.758	-0.078	121.688
Zelbst et al. 2010a	0.201	155	0.758	0.153	88.970
Evaluation and Alertness Ability- both					
Iyer et al. 2009	0.231	152	0.783	0.181	93.100
Mckone-Sweet and Lee 2009	-0.119	212	0.734	-0.087	114.268
Tan et al. 2010	0.137	625	0.783	0.107	382.813
Zelbst et al. 2010a	0.180	155	0.829	0.149	106.547

Table 2.7. On-time Delivery Performance

Study	Corrected correlation (r')	Study sample size (N)	Attenuation factor (A)	SCIT-performance correlation (r)	Study weight (W)
Application integration- upstream					
Iyer et al. 2009	0.164	152	0.788	0.129	94.377
Saeed 2004	0.442	50	0.789	0.349	31.150
Application integration- downstream					
Iyer et al. 2009	0.252	152	0.771	0.194	90.440
Jeffers et al. 2008	-0.359	64	0.771	-0.277	38.080
Application integration- both					
Chengalur-Smith et al. 2012	0.226	89	0.784	0.177	54.637
Hartono et al. 2010	0.414	227	0.784	0.324	139.355
Iyer et al. 2009	0.303	152	0.784	0.238	93.313
Vickery et al. 2003	0.482	57	0.784	0.378	34.992
Vijayasarathy 2010	0.101	276	0.784	0.079	169.436
Data Compatibility- upstream					
Chengalur-Smith et al. 2012	0.180	89	0.787	0.142	55.136
Saeed 2004	0.039	50	0.789	0.031	31.150
Data Compatibility- downstream					
Jeffers et al. 2008	0.003	64	0.700	0.002	44.800
Data Compatibility- both					
Hartono et al. 2010	0.348	227	0.762	0.265	131.887
Vickery et al. 2003	0.475	57	0.762	0.362	33.117
Vijayasarathy 2010	0.075	276	0.762	0.057	160.356
Analytic Ability- upstream					
Mckone-Sweet and Lee 2009	0.029	212	0.700	0.020	103.880
Saeed 2004	0.163	50	0.811	0.133	32.900
Analytic Ability- downstream					
Jeffers et al. 2008	-0.148	64	0.700	-0.104	31.360
Mckone-Sweet and Lee 2009	-0.069	212	0.700	-0.048	103.880
Analytic Ability- both					
Mckone-Sweet and Lee 2009	-0.020	212	0.700	-0.014	103.880
Vijayasarathy 2010	-0.013	276	0.700	-0.009	135.240
Evaluation and Alertness Ability- upstream					
Mckone-Sweet and Lee 2009	-0.095	212	0.734	-0.070	114.268
Saeed 2004	0.233	50	0.802	0.187	32.200
Zelbst et al. 2010a	0.146	155	0.769	0.113	91.683

Evaluation and Alertness Ability- downstream					
Iyer et al. 2009	0.242	152	0.758	0.183	87.248
Jeffers et al. 2008	-0.077	64	0.758	-0.059	36.736
Mckone-Sweet and Lee 2009	-0.030	212	0.758	-0.023	121.688
Zelbst et al. 2010a	0.204	155	0.758	0.155	88.970
Evaluation and Alertness Ability- both					
Iyer et al. 2009	0.270	152	0.783	0.211	93.100
Mckone-Sweet and Lee 2009	-0.064	212	0.734	-0.047	114.268
Vijayasarathy 2010	0.101	276	0.783	0.079	169.050
Zelbst et al. 2010a	0.151	155	0.829	0.125	106.547

Table 2.8. Delivery Speed Performance

Study	Corrected correlation (r')	Study sample size (N)	Attenuation factor (A)	SCIT-performance correlation (r)	Study weight (W)
Application integration- upstream					
Saeed 2004	0.503	50	0.789	0.397	31.150
Wiengarten et al. 2011	0.071	152	0.788	0.056	94.377
Application integration- downstream					
Wiengarten et al. 2011	0.146	152	0.771	0.113	117.247
Application integration- both					
Liu et al. 2013	0.177	286	0.784	0.139	175.575
Wiengarten et al. 2011	0.108	152	0.784	0.085	93.313
Vijayasarathy 2010	0.081	276	0.784	0.064	169.436
Data Compatibility- upstream					
Saeed 2004	0.533	50	0.789	0.421	31.150
Wiengarten et al. 2011	0.147	152	0.787	0.116	94.164
Data Compatibility- downstream					
Wiengarten et al. 2011	0.141	152	0.700	0.099	106.400
Data Compatibility- both					
Im and Rai 2008	0.249	238	0.762	0.190	138.278
Liu et al. 2013	0.268	286	0.762	0.205	166.166
Vickery et al. 2003	0.164	57	0.762	0.125	33.117
Wiengarten et al. 2011	0.141	152	0.762	0.108	88.312
Vijayasarathy 2010	0.120	276	0.762	0.092	160.356
Analytic Ability- upstream					
Mckone-Sweet and Lee 2009	0.050	212	0.700	0.035	103.880
Saeed 2004	0.472	50	0.811	0.383	32.900
Analytic Ability- downstream					
Mckone-Sweet and Lee 2009	-0.036	212	0.700	-0.025	148.400
Analytic Ability- both					
Im and Rai 2008	0.343	238	0.700	0.240	116.620
Mckone-Sweet and Lee 2009	0.007	212	0.700	0.005	103.880
Vijayasarathy 2010	0.081	276	0.700	0.057	135.240
Evaluation and Alertness Ability- upstream					
Liu et al. 2013	0.364	286	0.769	0.280	169.169
Mckone-Sweet and Lee 2009	-0.051	212	0.734	-0.038	114.268
Saeed 2004	0.210	50	0.802	0.169	32.200
Wiengarten et al. 2011	0.072	152	0.769	0.056	89.908
Zelbst et al.2010b	0.533	122	0.769	0.410	72.163

Evaluation and Alertness Ability- downstream					
Liu et al. 2013	0.385	286	0.758	0.292	164.164
Mckone-Sweet and Lee 2009	-0.094	212	0.758	-0.071	121.688
Zelbst et al.2010b	0.568	122	0.758	0.430	70.028
Evaluation and Alertness Ability- both					
Liu et al. 2013	0.365	286	0.783	0.286	175.175
Mckone-Sweet and Lee 2009	-0.074	212	0.734	-0.054	114.268
Vijayasarathy 2010	0.013	276	0.783	0.010	169.050
Zelbst et al.2010b	0.469	122	0.831	0.390	84.204

Table 2.9. Volume Flexibility Performance

Study	Corrected correlation (r')	Study sample size (N)	Attenuation factor (A)	SCIT-performance correlation (r)	Study weight (W)
Application integration- upstream					
Iyer et al. 2009	0.235	152	0.788	0.185	94.377
Saeed 2004	0.241	50	0.789	0.191	31.150
Application integration- downstream					
Iyer et al. 2009	0.259	152	0.771	0.200	117.247
Application integration- both					
Iyer et al. 2009	0.338	152	0.784	0.265	93.313
Vijayasarathy 2010	0.094	276	0.784	0.074	169.436
Data Compatibility- upstream					
Saeed 2004	-0.294	50	0.789	-0.232	39.465
Data Compatibility- downstream					
No data available					
Data Compatibility- both					
Vijayasarathy 2010	0.016	276	0.762	0.012	210.376
Analytic Ability- upstream					
Mckone-Sweet and Lee 2009	0.000	212	0.700	0.000	103.880
Saeed 2004	0.114	50	0.811	0.092	32.900
Analytic Ability- downstream					
Mckone-Sweet and Lee 2009	-0.020	212	0.700	-0.014	148.400
Analytic Ability- both					
Mckone-Sweet and Lee 2009	-0.010	212	0.700	-0.007	103.880
Vijayasarathy 2010	-0.051	276	0.700	-0.036	135.240
Evaluation and Alertness Ability- upstream					
Mckone-Sweet and Lee 2009	-0.151	212	0.734	-0.111	114.268
Saeed 2004	0.228	50	0.802	0.183	32.200
Zelbst et al. 2010a	0.165	155	0.769	0.127	91.683
Evaluation and Alertness Ability- downstream					
Iyer et al. 2009	0.301	152	0.758	0.228	87.248
Mckone-Sweet and Lee 2009	-0.016	212	0.758	-0.012	121.688
Zelbst et al. 2010a	0.228	155	0.758	0.173	88.970
Evaluation and Alertness Ability- both					
Iyer et al. 2009	0.290	152	0.783	0.227	93.100
Mckone-Sweet and Lee 2009	-0.084	212	0.734	-0.062	114.268
Vijayasarathy 2010	0.046	276	0.783	0.036	169.050
Zelbst et al. 2010a	0.179	155	0.829	0.148	106.547

Table 2.10. Customer Service Performance

Study	Corrected correlation (r')	Study sample size (N)	Attenuation factor (A)	SCIT-performance correlation (r)	Study weight (W)
Application integration- upstream					
Hsu et al. 2008	0.246	625	0.789	0.194	493.315
Application integration- downstream					
Hsu et al. 2008	0.111	625	0.771	0.086	371.875
Jeffers et al. 2008	-0.157	64	0.771	-0.121	38.080
Application integration- both					
Hsu et al. 2008	0.144	625	0.784	0.113	383.688
Jayaram and Tan 2010	0.105	411	0.784	0.082	252.313
Liu et al. 2013	0.282	286	0.784	0.221	175.575
Vickery et al. 2003	0.127	57	0.784	0.100	34.992
Data Compatibility- upstream					
Hsu et al. 2008	0.229	625	0.789	0.181	493.315
Data Compatibility- downstream					
Jeffers et al. 2008	0.084	64	0.700	0.059	44.800
Data Compatibility- both					
Hsu et al. 2008	0.194	625	0.762	0.148	363.125
Liu et al. 2013	0.428	286	0.762	0.327	166.166
Vickery et al. 2003	0.207	57	0.762	0.158	33.117
Analytic Ability- upstream					
No data available					
Analytic Ability- downstream					
Jeffers et al. 2008	0.094	64	0.700	0.066	44.800
Analytic Ability- both					
No data available					
Evaluation and Alertness Ability- upstream					
Liu et al. 2013	0.293	286	0.769	0.225	169.169
Zelbst et al. 2010a	0.209	155	0.769	0.161	91.683
Evaluation and Alertness Ability- downstream					
Jeffers et al. 2008	-0.024	64	0.758	-0.018	36.736
Liu et al. 2013	0.297	286	0.758	0.225	164.164
Zelbst et al. 2010a	0.276	155	0.758	0.209	88.970
Evaluation and Alertness Ability- both					
Liu et al. 2013	0.287	286	0.783	0.225	175.175
Tan et al. 2010	0.264	625	0.783	0.207	382.813
Zelbst et al. 2010a	0.232	155	0.829	0.192	106.547

Table 2.11. Financial Performance

Study	Corrected correlation (r')	Study sample size (N)	Attenuation factor (A)	SCIT-performance correlation (r)	Study weight (W)
Application integration- upstream					
Barua et al. 2004	0.352	1076	0.884	0.311	840.571
Hsu et al. 2008	0.053	625	0.903	0.048	510.025
Iyer et al. 2009	0.040	152	0.903	0.036	124.038
Kim et al. 2011	0.157	51	0.924	0.145	43.542
Application integration- downstream					
Barua et al. 2004	0.149	1076	0.838	0.125	756.428
Hsu et al. 2008	0.047	625	0.887	0.042	491.406
Iyer et al. 2009	0.195	152	0.887	0.173	119.510
Jeffers et al. 2008	0.332	64	0.887	0.295	50.320
Kim et al. 2011	0.425	51	0.931	0.396	44.199
Application integration- both					
Barua et al. 2004	0.253	1076	0.863	0.218	800.544
Hartono et al. 2010	0.458	227	0.898	0.411	183.153
Hsu et al. 2008	0.058	625	0.898	0.052	504.275
Iyer et al. 2009	0.164	152	0.898	0.148	122.640
Jayaram and Tan 2010	0.166	411	0.898	0.149	331.611
Kim et al. 2011	0.292	51	0.927	0.271	43.870
Liu et al. 2013	0.288	286	0.898	0.259	230.756
Seggie et al 2006	0.451	184	0.910	0.410	152.352
Vickery et al. 2003	0.107	57	0.898	0.096	45.990
Data Compatibility- upstream					
Hsu et al. 2008	0.149	625	0.905	0.135	565.487
Data Compatibility- downstream					
Jeffers et al. 2008	0.500	64	0.805	0.402	51.499
Data Compatibility- both					
Barua et al. 2004	0.107	1076	0.879	0.094	830.564
Hartono et al. 2010	0.468	227	0.874	0.409	173.337
Hsu et al. 2008	0.142	625	0.874	0.125	477.250
Kim et al. 2011	0.336	51	0.915	0.307	42.697
Liu et al. 2013	0.242	286	0.874	0.211	218.390
Seggie et al 2006	0.470	184	0.915	0.430	154.045
Vickery et al. 2003	-0.169	57	0.874	-0.148	43.525
Analytic Ability- upstream					
No data available					
Analytic Ability- downstream					
Jeffers et al. 2008	0.454	64	0.805	0.366	51.499

Analytic Ability- both					
No data available					
Evaluation and Alertness Ability- upstream					
Liu et al. 2013	0.262	286	0.884	0.232	252.851
Evaluation and Alertness Ability- downstream					
Iyer et al. 2009	0.240	152	0.871	0.209	115.292
Jeffers et al. 2008	0.440	64	0.871	0.383	48.544
Liu et al. 2013	0.317	286	0.871	0.277	216.931
Evaluation and Alertness Ability- both					
Iyer et al. 2009	0.236	152	0.900	0.212	123.025
Liu et al. 2013	0.282	286	0.900	0.254	231.481
Tan et al. 2010	0.177	625	0.900	0.159	505.859

Table 2.12. Market Performance

Study	Corrected correlation (r')	Study sample size (N)	Attenuation factor (A)	SCIT-performance correlation (r)	Study weight (W)
Application integration- upstream					
Hsu et al. 2008	0.035	625	0.883	0.031	487.850
Iyer et al. 2009	-0.004	152	0.883	-0.004	118.645
Application integration- downstream					
Hsu et al. 2008	-0.013	625	0.865	-0.011	467.500
Iyer et al. 2009	-0.009	152	0.865	-0.008	113.696
Jeffers et al. 2008	0.363	64	0.865	0.314	47.872
Application integration- both					
Hsu et al. 2008	-0.005	625	0.878	-0.005	482.350
Iyer et al. 2009	-0.005	152	0.878	-0.004	117.308
Jayaram and Tan 2010	0.213	411	0.878	0.188	317.193
Seggie et al 2006	0.438	184	0.890	0.390	145.728
Data Compatibility- upstream					
No data available					
Data Compatibility- downstream					
Jeffers et al. 2008	0.394	64	0.785	0.309	50.231
Data Compatibility- both					
Hsu et al. 2008	0.149	625	0.855	0.127	456.500
Im and Rai 2008	0.328	238	0.855	0.280	173.835
Seggie et al 2006	0.449	184	0.890	0.400	145.728
Analytic Ability- upstream					
No data available					
Analytic Ability- downstream					
Jeffers et al. 2008	0.447	64	0.785	0.351	50.231
Analytic Ability- both					
Im and Rai 2008	0.471	238	0.785	0.370	186.796
Evaluation and Alertness Ability- upstream					
No data available					
Evaluation and Alertness Ability- downstream					
Iyer et al. 2009	0.012	152	0.849	0.011	109.683
Jeffers et al. 2008	0.357	64	0.849	0.303	46.182
Evaluation and Alertness Ability- both					
Iyer et al. 2009	0.046	152	0.877	0.040	117.040
Tan et al. 2010	0.207	625	0.877	0.182	481.250

From the results, we were able to list journals that are potentially relevant to our study. Because using keywords could potentially eliminate usable studies, we further searched to identify potential articles by performing an in-depth search in those potential journals we listed previously. We examined the text of each article for identified keywords. In addition, to eliminate file drawer bias in research, we also included dissertations in our search. From the results, we went through several processes to screen the articles, making sure that the articles are applicable to this study. The processes that we went through are illustrated in Figure 2.1 below.

RESULTS

Table 2.3 provides a list of studies included in this meta-analysis. As discussed, the studies come from journal publications and dissertation manuscripts. Tables 2.4 to 2.12 provide the data evaluated in this meta-analysis. These tables also provide more detail information of which studies are used to represent certain relationships of interest. In total, we are interested in to looking at 108 relationships as a product of 4 x 3 x 9 matrix for SCIT characteristics, loci of SCIT, and firm performance, respectively. However, due to data availability, we can only interpret 70 relationships out of those 108 possible relationships. As discussed, we collected sample correlations (r), sample size (N), and Cronbach's alpha (α) or composite reliability (ρ) from each study. Using this data, we are able to calculate the compound attenuation factor (A) that is used to correct measurement error, and to calculate the weight of each study (W_i), which will later be used to calculate the overall results of this meta-analysis.

The overall results, as indicated in weighted mean corrected correlations ($\bar{r}'$), RATIO1 and RATIO2, are shown in table 2.13. Note that some correlation links do not have RATIO1 and

RATIO2 due to insufficient data for analysis. This study needs at least two studies for each correlation to be able to interpret the result.

The results of the meta-analysis show that SCIT characteristics are not always positively associated with firm performance. As shown in table 2.13, some links indicate significant and positive correlations while others indicate significant and negative correlations. In contrast, there are some others that show insignificant results as indicated from RATIO1 values that are less than 2. We will discuss these results in detail below, followed by a discussion with respect to the results from the RATIO2 calculation.

DISCUSSION

Main effects

Our goal in this study is to find generalities that may exist in the relationships between SCIT and firm performance. Since the beginning of the interorganizational system era, researchers have found contradictory evidence on the performance implication of SCIT (Mithas, et al., 2012). Indeed, our results also indicate that SCIT is not universally associated with improved performance. Unlike some previous studies, however, we are able to evaluate SCIT at a more granular level. Note that this meta-analysis study only indicates correlations, not causality. Extra care may need to be taken when making an interpretation as the direction of the correlation can go both ways. In other words, SCIT may lead to improved performance (e.g. when positive correlation occurs), or high-performing firms tend to adopt SCIT.

As shown in table 2.13, we find that almost one-half (31/70) of SCIT performance links are not significant. The proportion between significant and insignificant relationships is not surprising. For years, discussion in information systems and supply chain management literature centered in the performance paradox issue. Our findings show that there are wide variations surrounding corrected correlations in the SCIT performance links. In some cases, this variation can be explained by potential moderating factors, which will be examined later in the next section.

Across all SCIT characteristics, we find that evaluation and alertness ability yields to insignificant results when linked to operational performance (e.g. cost, quality, delivery, and flexibility). This finding is consistent with previous studies that also found similar results (Rosenzweig 2009, Subramani 2004). A firm may reap operational benefits from the ability to evaluate its supply chain partners. However, SCIT with an evaluation ability may also increase the likelihood of a firm to switch partners, which may negatively impact quality and reliability issues. Our finding also indicates that only customer service is positively associated with all SCIT characteristics at all supply chain loci. This suggests that in order to improve customer service, a firm may not need to adopt all the types of SCIT in both the upstream and downstream sides of a supply chain.

Table 2.13. Overall Meta-analysis of Correlation Results

SCIT characteristic	# of studies	Overall sample size (N)	Weighted mean corrected correlation (r □')	Mean error variance (e □)	Est. pop. standard deviation (S_ρ)	95% Credibility Interval r □'+ Z x Sρ	95% Credibility Interval r □'- Z x Sρ	Ratio 1	Ratio 2
Application Integration- Upstream									
Inventory performance	3	390	0.2026	0.0119	0	0.2026	0.2026	∞	**1.7628**
Operational cost	0			Insufficient data for analysis					
Quality	4	979	0.1331	0.0065	0	0.1331	0.1331	∞	**2.2558**
On-time delivery	2	202	0.2328	0.0151	0	0.2328	0.2328	∞	**1.0413**
Delivery speed	2	202	0.1782	0.0155	0.1387	0.4499	-0.094	1.2848	0.4466
Volume flexibility	2	202	0.2364	0.0150	0	0.2364	0.2364	∞	**1867.0503**
Customer service	1			Insufficient data for analysis					
Financial	4	1904	0.2204	0.0025	0.1389	0.4927	-0.052	1.5870	0.1129
Market	2	777	0.0274	0.0033	0	0.0274	0.0274	∞	13.7835
Application Integration- Downstream									
Inventory performance	1			Insufficient data for analysis					
Operational cost	0			Insufficient data for analysis					
Quality	4	993	0.0153	0.0068	0	0.0153	0.0153	∞	**1.3393**
On-time delivery	2	216	0.0705	0.0156	0.2493	0.5591	-0.418	0.2830	0.2011
Delivery speed	1			Insufficient data for analysis					
Volume flexibility	1			Insufficient data for analysis					
Customer service	2	689	0.0865	0.0049	0.0348	0.1547	0.0184	**2.4894**	**0.8015**
Financial	5	1968	0.1333	0.0034	0.0592	0.2494	0.0173	**2.2514**	0.4894
Market	3	841	0.0165	0.0048	0.0714	0.1564	-0.123	0.2314	0.4854
Application Integration- Both									
Inventory performance	4	635	0.3705	0.0087	0	0.3705	0.3705	∞	**3.9587**
Operational cost	1			Insufficient data for analysis					
Quality	5	1567	0.1749	0.0050	0.0702	0.3125	0.0372	**2.4895**	0.5047
On-time delivery	5	801	0.2689	0.0094	0.0998	0.4646	0.0732	**2.6934**	0.4845
Delivery speed	3	714	0.1253	0.0067	0	0.1253	0.1253	∞	**3.5318**
Volume flexibility	2	428	0.1804	0.0073	0.0791	0.3355	0.0253	**2.2797**	0.5399
Customer service	4	1379	0.1600	0.0046	0	0.1600	0.1600	∞	**1.1048**
Financial	9	3069	0.2249	0.0035	0.1066	0.4338	0.0161	**2.1108**	0.2335
Market	4	1372	0.1208	0.0028	0.1503	0.4154	-0.174	0.8042	0.1092
Data compatibility- Upstream									
Inventory performance	2	139	0.1928	0.0225	0	0.1928	0.1928	∞	**12.3165**
Operational cost	0			Insufficient data for analysis					
Quality	3	827	0.1942	0.0056	0.0176	0.2287	0.1597	**11.0300**	**0.9479**
On-time delivery	2	139	0.1294	0.0231	0	0.1294	0.1294	∞	**5.0006**
Delivery speed	2	202	0.2433	0.0150	0.1132	0.4651	0.0215	**2.1501**	0.5396
Volume flexibility	1			Insufficient data for analysis					
Customer service	1			Insufficient data for analysis					
Financial	1			Insufficient data for analysis					

Market	1			Insufficient data for analysis					
Data compatibility- Downstream									
Inventory performance	0			Insufficient data for analysis					
Operational cost	0			Insufficient data for analysis					
Quality	2	216	0.0491	0.0191	0	0.0491	0.0491	∞	**29.0073**
On-time delivery	1			Insufficient data for analysis					
Delivery speed	1			Insufficient data for analysis					
Volume flexibility	1			Insufficient data for analysis					
Customer service	0			Insufficient data for analysis					
Financial	1			Insufficient data for analysis					
Market	1			Insufficient data for analysis					
Data compatibility- Both									
Inventory performance	2	394	0.3115	0.0078	0	0.3115	0.3115	∞	**4.4036**
Operational cost	2	465	0.3431	0.0065	0.0744	0.4890	0.1972	**4.6092**	0.5380
Quality	4	1242	0.1952	0.0053	0	0.1952	0.1952	∞	**1.2152**
On-time delivery	3	560	0.2261	0.0088	0.1217	0.4647	-0.013	1.8574	0.3714
Delivery speed	5	1009	0.1982	0.0082	0	0.1982	0.1982	∞	**1.9402**
Volume flexibility	1			Insufficient data for analysis					
Customer service	3	968	0.2643	0.0049	0.0796	0.4204	0.1082	**3.3185**	0.4382
Financial	7	2506	0.1908	0.0034	0.1299	0.4454	-0.064	1.4690	0.1690
Market	3	1047	0.2454	0.0024	0.1116	0.4641	0.0266	**2.1985**	0.1591
Analytic ability- Upstream									
Inventory performance	2	262	0.0360	0.0148	0	0.0360	0.0360	∞	**1.0747**
Operational cost	1			Insufficient data for analysis					
Quality	2	262	-0.0041	0.0148	0	-0.004	-0.004	∞	**3.9573**
On-time delivery	2	262	0.0420	0.0127	0.0739	0.1869	-0.103	0.5689	0.6992
Delivery speed	2	262	0.1516	0.0144	0.1349	0.4160	-0.112	1.1237	0.4415
Volume flexibility	2	262	0.0274	0.0148	0	0.0274	0.0274	∞	**6.2832**
Customer service	1			Insufficient data for analysis					
Financial	0			Insufficient data for analysis					
Market	0			Insufficient data for analysis					
Analytic ability- Downstream									
Inventory performance	1			Insufficient data for analysis					
Operational cost	1			Insufficient data for analysis					
Quality	2	276	-0.0774	0.0149	0	-0.077	-0.077	∞	**4.6049**
On-time delivery	2	276	-0.0870	0.0148	0	-0.087	-0.087	∞	**13.2454**
Delivery speed	1			Insufficient data for analysis					
Volume flexibility	1			Insufficient data for analysis					
Customer service	1			Insufficient data for analysis					
Financial	1			Insufficient data for analysis					
Market	1			Insufficient data for analysis					
Analytic ability- Both									
Inventory performance	1			Insufficient data for analysis					
Operational cost	2	450	0.1670	0.0089	0.2118	0.5821	-0.248	0.7885	0.1650
Quality	2	450	0.1992	0.0088	0.2406	0.6708	-0.272	0.8281	0.1315

On-time delivery	2	488	-0.0160	0.0084	0	-0.016	-0.016	∞	**669.8405**
Delivery speed	3	726	0.1454	0.0083	0.1078	0.3568	-0.066	1.3489	0.4164
Volume flexibility	2	488	-0.0334	0.0084	0	-0.033	-0.033	∞	**19.8952**
Customer service	0			Insufficient data for analysis					
Financial	0			Insufficient data for analysis					
Market	1			Insufficient data for analysis					
Evaluation and alertness ability- Upstream									
Inventory performance	4	539	0.1764	0.0125	0.2144	0.5965	-0.244	0.8227	0.2143
Operational cost	3	489	0.1865	0.0104	0.2420	0.6608	-0.288	0.7706	0.1509
Quality	4	569	0.0299	0.0123	0.0628	0.1529	-0.093	0.4759	**0.7572**
On-time delivery	3	417	0.0420	0.0127	0.0739	0.1869	-0.103	0.5689	0.6992
Delivery speed	4	700	0.2250	0.0099	0.1841	0.5858	-0.136	1.2224	0.2266
Volume flexibility	3	417	0.0219	0.0127	0.1237	0.2643	-0.221	0.1768	0.4539
Customer service	2	441	0.2633	0.0071	0	0.2633	0.2633	∞	**4.4896**
Financial	1			Insufficient data for analysis					
Market	0			Insufficient data for analysis					
Evaluation and alertness ability- Downstream									
Inventory performance	4	641	0.1919	0.0105	0.2944	0.7689	-0.385	0.6518	0.1079
Operational cost	3	489	0.1972	0.0103	0.2856	0.7569	-0.363	0.6905	0.1120
Quality	4	583	0.0903	0.0119	0.1053	0.2967	-0.116	0.8572	0.5184
On-time delivery	4	583	0.0977	0.0119	0.0761	0.2469	-0.052	1.2832	0.6729
Delivery speed	2	498	0.2574	0.0078	0.2466	0.7407	-0.226	1.0440	0.1143
Volume flexibility	3	519	0.1499	0.0099	0.0993	0.3446	-0.045	1.5085	0.5000
Customer service	3	505	0.2498	0.0097	0.0358	0.3200	0.1795	**6.9675**	**0.8831**
Financial	3	502	0.3096	0.0068	0	0.3096	0.3096	∞	**1.8596**
Market	2	216	0.1144	0.0127	0.1095	0.3290	-0.100	1.0447	0.5150
Evaluation and alertness ability- Both									
Inventory performance	5	808	0.2255	0.0094	0.2085	0.6342	-0.183	1.0814	0.1775
Operational cost	3	489	0.1882	0.0094	0.2382	0.6551	-0.278	0.7902	0.1421
Quality	4	1144	0.1141	0.0057	0.0773	0.2656	-0.037	1.4758	0.4870
On-time delivery	4	795	0.1054	0.0082	0.0651	0.2331	-0.022	1.6185	0.6592
Delivery speed	3	774	0.1793	0.0071	0.1981	0.5676	-0.209	0.9050	0.1532
Volume flexibility	4	795	0.0914	0.0082	0.0953	0.2782	-0.095	0.9591	0.4755
Customer service	3	1066	0.2653	0.0041	0	0.2653	0.2653	∞	**13.2565**
Financial	3	1063	0.2136	0.0032	0	0.2136	0.2136	∞	**1.5175**
Market	2	777	0.1758	0.0032	0.0304	0.2353	0.1162	**5.7886**	**0.7763**

Table 2.14. Impact analysis of individual SCIT characteristic on performance outcomes

SCIT characteristic	Inventory	Operational Cost	Quality	On-time Delivery	Delivery Speed	Volume Flexibility	Customer Service	Financial	Market	Breadth of impact	Depth of impact
Application Integration-Upstream	X*	n/a	X*	X*		X*	n/a		X*	71%	0.166
Application Integration-Downstream	n/a	n/a	X*		n/a	n/a	X*	X		60%	0.078
Application Integration-Both	X*	n/a	X	X	X*	X	X	X		88%	0.215
Data compatibility-Upstream	X*	n/a	X*	X*	X	n/a	n/a	n/a	n/a	100%	0.190
Data compatibility-Downstream	n/a	n/a	X*	n/a	n/a	n/a	n/a	n/a	n/a	100%	0.049
Data compatibility- Both	X*	X	X*		X*	n/a	X		X	75%	0.260
Analytic ability-Upstream	X*	n/a	X*			X*	n/a	n/a	n/a	60%	0.020
Analytic ability-Downstream	n/a	n/a	X*	X*	n/a	n/a	n/a	n/a	n/a	100%	-0.082
Analytic ability- Both	n/a			X*		X*	n/a	n/a	n/a	40%	-0.025
Evaluation and alertness ability- Upstream			*				X*	n/a	n/a	14%	0.263
Evaluation and alertness ability- Downstream							X*	X*		22%	0.280
Evaluation and alertness ability- Both							X*	X*	X*	33%	0.218

X = significant correlation, *= not subject to moderating factors, n/a= not analyzed due to insufficient data

Our results also indicate that upstream application integration has more unmoderated direct relationships, compared to other SCIT characteristics. This suggests that upstream application integration is positively associated with a wide range of performance measures, regardless of the context in which it is utilized. Our results also suggest that a full-scale use of SCIT at both upstream and downstream, as indicated in application integration and evaluation and alertness ability, yields to more positive outcomes, compared to only using SCIT either at upstream or downstream alone. This finding is consistent with previous studies which suggest that extending the use of SCIT can help a firm balance supply and demand better (Frohlich & Westbrook, 2002; Craighead et al., 2006). With respect to type of performance outcomes, there is no systematic difference between one-side facing (e.g. upstream or downstream) and full SCIT adoption. Performance outcomes can be generally grouped as aggregate (financial and market), firm centric (inventory, cost, and quality), or supply chain centric (delivery and flexibility) (Mackelprang et al., 2014). Our findings indicate that correlations between SCIT facing and type of performance are unique and not systematic. It is also important to note that SCIT is not always positively correlated with performance. Our results reveal that upstream analytic ability is negatively correlated with quality, downstream analytic ability is negatively correlated with quality and on-time delivery, and full analytic ability is negatively correlated with on-time delivery and volume flexibility. It is interesting to note that all negative correlations are associated only with analytic ability. Analytic ability concerns the ability to understand patterns of customer preferences and trends, to perform simulation, or to develop novel approaches to issues (Saeed et al., 2011; Subramani, 2004). Adopting SCIT with analytic ability at either upstream or downstream only will, therefore, have marginal value when associated with quality. A firm needs to understand customers' needs but simultaneously needs to balance resources from its suppliers. Analytic ability is also negatively correlated with on-time delivery and volume flexibility. A plausible explanation to this is that analytic ability can bring a novel solution to a problem that may not be aligned with current practices.

Unknown Moderating Factors

As shown in Table 2.13, about 57% (40/70) of the relationships evaluated in this meta-analytic study are subjected to unknown moderating factors. This finding indicates an important feature, as the magnitude or even the direction of the relationship can vary widely depending on the context. For example, application integration at both supplier and customer facing is positively associated with financial performance but has a distribution between .434 and 0.016 as indicated from the credibility interval. This suggests that one firm may have financial performance 27 times better than other firms when adopting application integration under certain conditions. The identification of these certain conditions becomes very important to build and refine the theory in both IS and SCM literatures. Results also show that 43% (30/70) of the insignificant relationships are due to moderating factors. This finding suggests that under certain factors, SCIT can have either a negative or a positive impact on performance. This circumstance is consistent with the literature. For example, evaluation and alertness ability that aims at gaining efficiency positively impacts firm performance. However, under demand volatility and uncertainty, the impact can become negative as it lacks the ability to adapt and restructure (Iyer et al., 2009; Saldanha et al., 2012).

An interesting feature is exhibited in the relationship between upstream evaluation and alertness ability and quality performance. As shown in table 2.13, the RATIO1 of this relationship is below 2, but the RATIO2 is above .75. This result suggests that there is no impact of upstream evaluation and alertness ability and quality performance regardless the context. As discussed, evaluation and alertness ability focuses on a structured process to gain efficiency. When a firm works with its suppliers to create a more efficient process (e.g. cost reduction), it is more likely happening as a trade-off with the quality of its output. Furthermore, alertness and tracking ability, which are also features of this type of SCIT, may have little relevance to quality performance.

ACADEMIC IMPLICATIONS

The primary goal of this meta-analytic study is to answer whether or not SCIT improves firm performance. Consistent with the long discussion in many information systems and supply chain management literature, our results indicate that SCIT may have positive, negative, or no correlations with firm performance. This finding does not necessarily indicate that SCIT has marginal value. Rather, we should view SCIT as a complex artifact with many characteristics. Each characteristic can be used for different purposes. Consequently, these differing purposes and uses can lead to diverse outcomes, even when the underlying technologies are similar (Subramani, 2004).

Our results indicate that more than 50 percent of the relationships evaluated in this study are due to unknown moderating factors. These potential moderating factors can change the magnitude as well as the direction of the impact. Some important implications from this finding are, therefore, to follow up and find those moderating factors. Given the wide-variability distribution of some results, future research should attempt to find the factors that can maximize the impact of SCIT. For example, under what conditions would full facing application integration have the greatest impact on quality, on-time delivery, volume flexibility, and financial performance? Conversely, our findings also indicate more certain relationships. For example, delivery speed and customer service are assured performance when adopting full-facing application integration.

As discussed, our study also provides directions for potential research at a more granular level. With respect to our insignificant findings, future research can try to uncover circumstances and factors which will reveal the directions of the relationships, whether positive or negative. Another possible direction is to study whether there is a trade off or complementary relationship among all these SCIT characteristics. For example, does increasing application integration mitigate or enhance analytic ability? Finally, as shown in Table 2.13, we identified some areas where there was not enough data to conduct an analysis. This suggests that there is still very limited research in those areas. For instance, research about the impact of analytic ability on performance is very limited. This issue is also highlighted in MISQ that calls for a paper about IT that can analyze big data. Consequently, research in this area is warranted, especially to inform how analytic ability impacts the broad types of performance.

MANAGERIAL IMPLICATIONS

This study also provides important insights for managers and practitioners. As discussed, we reveal that not all SCIT characteristics yield positive outcomes, with some yielding negative outcomes and others yielding no significant impact. In Table 2.13, we identify which SCIT brings such performance. Managers can weigh the potential trade-off when choosing one SCIT over another. Conversely, managers can combine characteristics of SCIT to reap more benefits and to improve performance. Furthermore, managers can align their firms' competitive priority with the potential benefits of a certain SCIT.

Table 2.14 presents two columns that highlight the breadth and depth of impact of each SCIT characteristic. As shown, data compatibility and application integration in general has the highest impact compared to other characteristics. This suggests that implementing data compatibility yields to a wide-array of improved performance. However, our findings do not necessarily undermine the value of other characteristics. For example, a recent call for papers in MISQ reveals that 90% of all IT data has been created in the past two years. However, little is known as how to analyze this data effectively. A firm may want to develop a proprietary system and become a pioneer in the industry. Such an approach has been empirically studied to have positive impact on profitability (Mithas, et al., 2012).

CONCLUSION

Our study proposes to consolidate and integrate studies of SCIT across fields of literature and is an answer to a call for an empirical meta-analysis with respect to SCIT (Zhang, et al., 2011). Second, we identify areas of study that are still underdeveloped. Finally, this study will provide empirical results of the impact of SCIT on performance. By doing so, this paper should contribute not only to the body of academic knowledge in this area, but it should also be relevant to supply chain and information technology practitioners.

Although significant effort has been made to ensure quality, we are aware that there arestill a few limitations in this study. First, we were not able to include all identified studies due to data availability. Such limitation may have led to the failure to detect a statistically significant relationship between SCIT and performance. Second, we substituted reliability measures of dependent variables and independent variables across all studies when the data was not available. Such approach is consistent with previous meta-analytic studies. In some cases, we replaced the value with the minimum alpha suggested by Nunnaly (1978) due to disaggregation of construct. In this regard, we double-checked and made sure that the efforts were appropriate. Finally, we understand that there are other factors that are not accounted for in this study. However, we account for correction of errors that relate to sampling and measurement of variables which are also important issues in a meta-analytic study.

Chapter 3

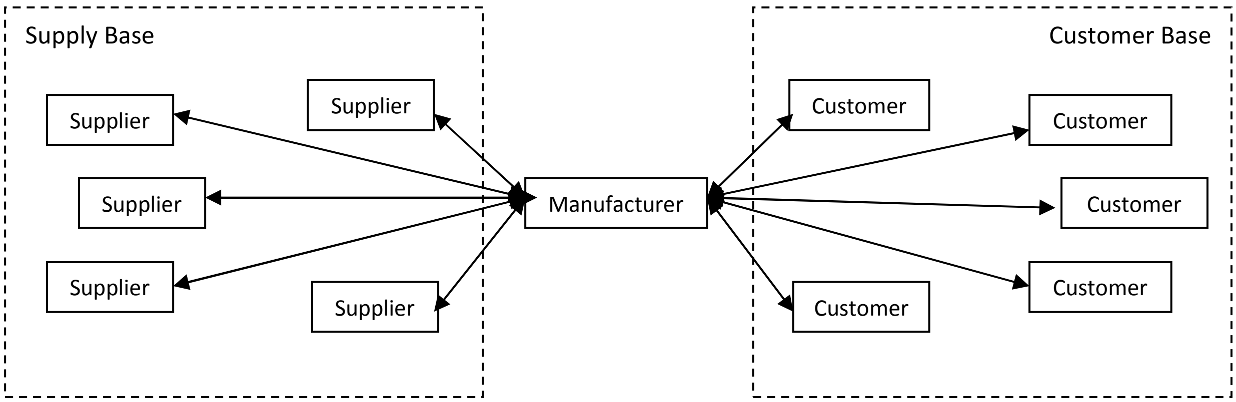
Do Supply Base and Customer Base Complexity Reduce Firm Performance?: The Moderating Role of Information Technology

INTRODUCTION

Information technology (IT) has long been viewed as a key enabler of effective supply chain management (SCM) activities (Sanders & Premus, 2002). Given its capabilities, businesses invest significant amounts in IT with the expectation of improvedperformance. Gartner (2014) reports that in 2013, $300 billion was spent on supply chain information technology (SCIT) by firms globally, an increase by 1.8% and 3.8% compared to 2012 and 2011, respectively. SCIT is a form of IT utilized specifically for managing supply chain activities. In addition, according to the U.S. Bureau of Economic Analysis, investments in IT account for more than 50% of capital expenditures in the United States (Yao & Zhu, 2012). One would expect that such considerable investments have brought significant benefits, yet research investigating benefits of IT in enabling effective SCM activities remains inconclusive (Vickery, et al., 2003; Zhang, et al., 2011). In this essay, we are interested in looking at the moderating role of IT in mitigating supply chain complexity in supply chain network.

A vast majority of research in supply chain management viewed buyer-supplier relationships as linear or dyadic structures (Kim, et al., 2011). However, a network view of multiple suppliers and customers should be a more appropriate approach because it provides a more realistic and a richer view of a supply chain (Bellamy, et al., 2014). In particular, all manufacturers engaged in value-adding activities purchase and sell goods and services from a group of suppliers and a group of customers, respectively (see Figure 3.1). This group of suppliers is referred to as supply base while the group of customers is referred to as customer base (Choi & Krause, 2006).

Figure 3.1. Supply Chain Network



Over the past ten years, the supply chain management literature has begun addressing complexity issues in supply chain network and how complexity can be detrimental to a manufacturer's performance (Choi, et al., 2001; Bozarth, et al., 2009). Literature suggests that supply bases and customer bases are among sources of complexity in the supply chain network (Choi & Krause, 2006; Bozarth, et al., 2009; Caridi, et al., 2010; Perona & Miragliotta, 2004). In general, the complexity emanates from the size of a supply base and a customer base and the dispersion of the relationship between focal firm and its supply chain partners (Choi & Krause, 2006). Simply put, a large and highly critical supply base or customer base is much more complex than a small and less critical one. Complex supply bases and customer bases have become the norm in many industries (Pathak, et al., 2007). For example, Apple Inc. added more critical suppliers to bring new features into its iPad and iPhone and to compete with rivals while at the same time, establishing new relationships with major carriers and retailers as its customers.

Literature suggests a manufacturer to have a less complex supply base, such as working with only a few and concentrated supply base (Porter, 1997; Talluri & Narasimhan, 2005; Ogden, 2006). Such approach is said to have more benefits to the manufacturers with regards to costs, innovation, time, and quality (Cooper & Ellram, 1993; Harland, 1996). However, there has been a trend of increasing levels of outsourcing which would basically increase the supply base complexity (Choi & Krause, 2006). In addition, having more critical suppliers provides a resource slack that enables a firm to respond quickly and more effectively to volatility and uncertainties (Swafford, et al., 2006). There are other motives behind adopting a more complex supply base including product variety, diversification, or entering new markets (Bozarth, et al., 2009). For example, when a manufacturer offers a number of product varieties, it needs to source specific and critical raw materials that were not initially available from current suppliers or it needs to increase its levels of outsourcing (Choi & Krause, 2006). Consequently, both size and dispersion of the supply base increases.

Having a complex customer base is sometimes unavoidable. . For example, by having more critical customers, a manufacturer can seek more information from customers and have a better understanding about its market (Ofek & Sarvary, 2001; Ganesh, et al., 2000). Moreover, competition may push a manufacturer to further increase the downstream market size (Bozarth, et al., 2009) by increasing its product variety, market diversification, and geographical diversification. From a marketing standpoint, there can be an endogenous effect of customer base complexity. A manufacturer with a large and critical customer base needs to keep its good reputation and quality of products, which in turn will further enhance its customer base complexity (Rob & Fishman, 2005).

With the potential trend increase, the issue of supply base and customer base complexity becomes more important to study. Furthermore, previous studies have linked complexity in supply bases and customer bases to suboptimal performance (Choi & Krause, 2006; Bozarth, et al., 2009). A seminal article by Choi and Krause (2006) definesand proposes supply base complexity and its impact on manufacturer's performance. Since this article, there have been very few studies that discuss supply base or customer base complexity, signaling gap in the literature. Moreover, although in theory supply base complexity is negatively associated with a manufacturer's performance, a previous study failed to find empirical evidence to support that argument (Bozarth, et al., 2009).

This study builds on the discussion of supply base complexity in the supply chain management literature and empirically addresses two research questions. First, *does supply base complexity reduce focal manufacturer's performance?* Specifically, this study examines performance using three measures: raw material inventory turnover, finished goods inventory turnover, and return on sales. In addition, this study extends the first question to also examine the impact of customer base complexity. As discussed, customer base complexity is gaining interest and may also have potential negative impact on firm performance. Furthermore, this study seeks to examine the interaction effect of supply base complexity and customer base complexity on performance.

Second, this study is also interested in finding a cure that mitigates the potential negative impact of supply base and customer base complexity on a manufacturer's performance. Therefore this study asks: *does information technology moderate the association between supply base and customer base complexity and a focal manufacturer's performance?* To empirically test the hypothesized relationships, industry-level data from two secondary data sources are collected. The data comes from the annual survey of manufacturers (ASM) and the Bureau of Economic Analysis (BEA). A previous study has attempted to examine complexity of supply and customer base but failed to find empirical evidence (Bozarth, et al., 2009) which would be a contribution of this essay. Choi and Krause (2006) suggest that supply base complexity, and presumably customer base complexity, are reflected at the industry level. In particular, working with a single industry should have less complexity than working with multiple industries for a given level of relationship dispersion.

This essay contributes to the literature on examining complexity in supply chains in the following ways. First, this study proposes a new and solid measure of supply base complexity based on the definition of complexity found in complexity literature. Supply base complexity is measured as a product of two factors: the number of suppliers and the degree of dispersion of a focal manufacturer's supply base. Previous studies mainly rely on the number of suppliers when it comes to measuring supply base complexity, although there are other factors of it (Bozarth, et al., 2009; Perona & Miragliotta, 2004; Caridi, et al., 2010). Second, this study extends to investigate the customer base and the interaction between supply base and customer base complexity. To our knowledge, there are a few studies in supply chain literature that have formally examined the link between customer base complexity and performance (Bozarth, et al., 2009). Third, in addition to addressing the potential negative effects of supply base, customer base, and the supply chain (e.g. interaction of supply and customer base) complexity, this study also examines the role of information technology. In particular, this study seeks to find empirical evidence of the moderating impact of IT in the relationship between complexity and performance.

The following sections are organized as follows. Section 2 discusses a review of the literature with regards to complexity, supply base, and customer base. Included in section 2 is a theoretical background that provides guidance to support the hypotheses. Section 3 discusses hypotheses development which details and formalizes all hypotheses proposed in this study. Section 4 outlines the research design and methodology with regards to the data collection process, the econometric model, analysis techniques, and hypothesis testing. Section 5 reports and summarizes the research findings which are followed by a discussion and interpretation of the results. Finally, Section 6 concludes this study by offering managerial and academic implications and contribution, recognizing research limitation and offering future research directions.

LITERATURE REVIEW AND THEORETICAL BACKGROUND

Supply Base and Customer Base in Supply Chain Network

As discussed, a supply chain is more appropriately portrayed as a network rather than as a linear relationship or a dyadic relationship (Bellamy, et al., 2014). A network perspective can provide a more realistic and richer view of a supply chain by taking into account multiple relationships that a focal manufacturer has with supplier industries and buyer industries. Furthermore, within a business relationship, there are transactions, communications, and information which are important components that create nuances in the relationship (Cooper & Ellram, 1993). For example, a focal manufacturer may have different communication and give different access of information to its two distinct supplier industries. Here, a supply chain network is an inter-linked network of industries consisting of a manufacturer, supplier industries, and customer industries that interact to execute supply chain activities with the manufacturer as the focal manufacturer (Bellamy, et al., 2014).

A supply chain network consists of two parts: a supply network and a customer network (Choi & Hong, 2002). A supply network is the network of industries that exist *upstream* to the focal manufacturer (Choi & Krause, 2006). In contrast, a customer network is the network of industries that exist *downstream* to the focal manufacturer. Note that both supply networks and customer networks include all industries that directly and indirectly relate to the focal manufacturer. In other words, third-tier supplier and customer industries are part of the supply chain network (Choi & Krause, 2006).

As shown in Figure 1, in a supply chain network, a focal manufacturer has a group of supplier industries and a group of customer industries that supply and buy its products, respectively (see Figure 1). This group of supplier industries is referred to as a supply base while the group of customer industries is referred to as a customer base (Choi & Krause, 2006). In this study, the terms focal manufacturer and manufacturer are used interchangeably. Note that a supply base is a portion of the supply network of the focal manufacturer consisting of all supplier industries that are directly linked to the focal manufacturer (Choi & Krause, 2006). Using the same token, a customer base is defined as a portion of the customer network of the focal manufacturer consisting of all customer industries that are directly linked to the focal manufacturer.

Complexity in Supply Chains

First, it is important to review complexity in a supply chain before defining supply base complexity and customer base complexity. Complexity arises from a large number of components of a system and interactions of those components (Simon, 1962). The number of components of a system is a major factor in defining complexity. Complexity literature suggests that the greater the number of inputs associated with a system, the higher the system complexity is (Manuj & Sahin, 2011). Interactions of the components are also critical, as they add a layer of uncertainty into the system (Serdarasan, 2013). Complexity in a system must be managed or otherwise can lead to sub-optimization (Gottinger, 1983). In a supply chain context, a system is composed of firms and the flow of products, services, information, and finances (Mentzer, et al., 2001). At the industry level, a system is composed of industries, instead of firms. Failure in managing these components may lead to subpar focal manufacturer's performance (Vachon & Klassen, 2002; Bozarth, et al., 2009).

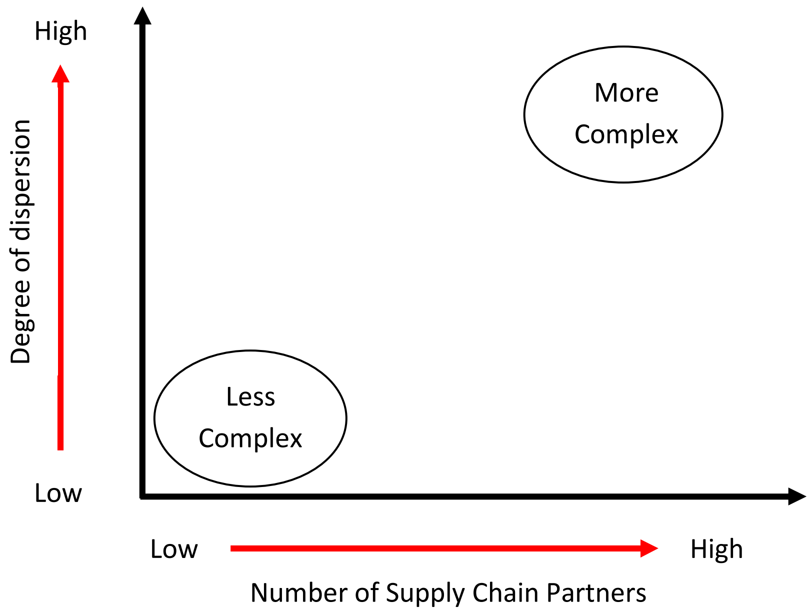
Supply chain complexity has been discussed in many literatures (e.g. operations management, engineering, information technology) for over 20 years, creating a variety of definitions (Wilding, 1998; Choi, et al., 2001; Rao & Young, 1994). For example, supply chain complexity is used to illustrate increased uncertainties in a system due to deterministic chaos, parallel interactions, and demand amplification (Wilding, 1998). Wilding (1998) suggests that interactions of these three factors cause dynamic behavior in the supply chain. Other scholars define supply chain complexity as the level of detail complexity and dynamic complexity exhibited by the products, processes, and relationships that make up a supply chain (Bozarth et al., 2009). Detail complexity arises from the number of supply chain components while dynamic complexity arises from interactions among those supply chain components. In another study, supply chain complexity is broadly defined as the structure, type, volume of interdependent activities, transactions, and processes in the supply chain that also includes constraints and uncertainties under which these activities, transactions, and processes take place (Manuj &

Sahin, 2011). In a more recent article, supply chain complexity encompasses three dimensions: static, dynamic, and decision making (Serdarasan 2013). Static is described by the structure of the supply chain, the variety of its components, and the strength of the interactions among those components. The dynamic aspect is represented by uncertainty in the supply chain and involves the aspect of time and randomness. Decision making is associated with the volume and nature of the information that should be considered when making supply chain related decisions. Collectively, these studies suggest that supply chain complexity is a broad concept that encompasses many aspects, including structure, firms, products, processes, information, and interactions among all those components that make up a supply chain (Bozarth et al., 2009; Serdarasan, 2013).

Complexity in Supply and Customer Base

As in the supply chain, there is an inherent complexity in a supply base and a customer base. In contrast to supply chain complexity which broadly covers all components of a supply chain such as products, processes, or tools, the scope of supply and customer base complexity is limited to the supplier and customer industries directly linked to the focal manufacturer (Choi and Krause, 2006). In other words, supply base and customer base complexity is a portion of supply chain complexity. An important feature of reducing the scope of the perspective from supply chain to supply base and customer base is because it enables this study to focus on the issue of orchestrating (e.g. coordinating and controlling) activities with supplier industries and customer industries in the supply and customer base (Agrawal & Nahmias, 1997; Choi & Krause, 2006). Furthermore, managing a supply chain as a whole would be beyond a focal manufacturer's reach. In contrast, a supply base or a customer base is within a focal manufacturer's reach. Focusing on part of a complex system allows an understanding behavior of that system and thus understanding the complexity of the whole system (Choi, et al., 2001).

Figure 3.2. Dimensions of Complexity



Sources of Complexity in Supply Base and Customer Base

As discussed, complexity emanates from the number of components in a system and the interaction of those components in the system (Simon, 1962). From the perspective of a focal manufacturer, the number of components in a supply chain includes the number of supplier industries and customer industries that make up a supply base and a customer base, respectively. An increase in the number of supplier industries in a focal manufacturer's supply base translates as an increase in the interface, communication, and transaction that a focal manufacturer must conduct with all of its supplier industries. In addition, the breadth of the supply base also increases. In such a situation, managing, coordinating, and monitoring the supply base becomes more complicated for a focal manufacturer (Cooper & Ellram, 1993). Therefore, some studies suggest a supply base reduction to minimize such complexity (Harland, 1996; Ogden, 2006). For example, SCM literature shows the challenge that a firm must face when dealing with numerous suppliers. As a result, firms such as GE, Toyota, or Xerox have worked hard to reduce the number of suppliers in their supply base (Talluri & Narasimhan, 2005).

An increase in the number of supplier industries also causes an increase of information flowing between a focal manufacturer and its supplier industries. Information is an important component in supply chain management (Mentzer, et al., 2001). Particularly for a manufacturer, information can be used to better schedule production, plan capacity, forecast, and manage inventory (Cachon & Fisher, 2000; Lee, et al., 2004; Cachon & Terwiesch, 2005). However, complexity in managing information, especially with regards to the ability to store, retrieve, sort, filter, and analyze information also increases when the information flow increases (Shapiro & Varian, 1999).

A similar situation happens with a customer base. As a customer base increases, the complexity of managing customer industries, with regards to transaction, communication and information, also increases. Simply put, a customer base with only one customer is less complex than a customer base with ten customers.

In addition the number of supply chain partners and the interactions between a manufacturer and its suppliers or customers also adds another layer of complexity to a focal manufacturer's supply base and customer base. The level of interactions between a focal manufacturer and its supply chain partners depends on the degree of dispersion of supply chain partners in the supply or customer base (Cooper & Ellram, 1993; Hofer & Knemeyer, 2009). Dispersion is defined as the degree to which a focal manufacturer's views its supply chain partners (e.g. suppliers or customers) in its supply or customer base as equally critical to the success of the venture (Spekman, et al., 1998). If the supply or customer base is highly dispersed, communication and focus are scattered to all SC partners. In addition, the level of information shared by both parties would also be high. In contrast, if the relationship is concentrated, communication is more focused and information exchanged is also more focused (Cooper & Ellram, 1993). Literature suggests that a criticality of relationship does not need to be necessarily the same with every partner in a supply chain (Spekman, et al., 1998). Simply put, supplier industries or customer industries that bring major contribution to focal industries are the ones that are critical. There are several potential drivers that may motivate a focal manufacturer to increase its supply base and customer base complexity, such as globalization, sustainability, customization, innovation, and flexibility (Manuj & Sahin, 2011, Serdarasan, 2013). Globalization increases complexity in a focal manufacturer's supply and customer base. First, globalization can increase customer base complexity, as the number of critical customer increases during the global expansion. Second, serving foreign markets may motivate a firm to operate close to the market. As an impact, supply base complexity for the firm can also increase. For example, Lego, a Denmark toy company, decided to shut its packaging operations in Denmark in 2015 and will focus operations in Mexico as one of the plants which mostly supplies North America markets. Lego realizes that serving a market from a far away location is inefficient, as toys will be on the seas for weeks (Hansegard, 2013). Sustainability can also increase complexity. For example, industry standards change or government regulations may impact how a supply base is selected or changed. As a result, new critical suppliers will be added to a manufacturer's supply base. Innovation, with respect to product proliferation, can also drive supply base and customer base complexity. Firms are under pressure to introduce new products more frequently (Milgate, 2001; Salvador, et al., 2002). A common response to product proliferation is for a firm to expand its supply base, in order to source parts that may not be available from current suppliers (Choi and Krause, 2006). Furthermore, a firm may also expand its customer base, in response to product proliferation, to offset investments that were made for developing the new product and to ensure profitability of the firm.

In this study, we define:

supply base complexity as the degree of complexity as reflected both in the number of a focal manufacturer's suppliers and in the degree of dispersion of a focal manufacturer's suppliers in its supply base.

This definition is consistent with the definition used in the literature (see Choi and Krause, 2006, Bozarth et al., 2009). Similarly,

customer base complexity is defined as the degree of complexity as reflected both in the number of a focal manufacturer's customers and in the degree of the dispersion of a focal manufacturer's customers in its customer base.

Customer base complexity increases as the number of customers increases and as the degree of dispersion increases. Craighead et al. (2007) suggest that customer base complexity is determined by the concentration/ dispersion of customer base, in addition to size of customer base. As in supply base complexity, the degree of interaction between a focal manufacturer and its customer industries plays an important role and therefore, should be considered together.

It is important to discuss why both dimensions of complexity (e.g.number of components and interaction of components) are essentially important by distinguishing the definition between complicatedness and complexity. Cilliers (2000) suggests that something that is complicated can be intricate, but the relationship between the components is fixed and well-defined. In contrast, a complex system is characterized in terms of the nonlinear dynamic interactions of the individual components (Pathak, et al., 2007, p. 559). The important properties of complex systems are due to interactions between components that cannot be explained individually or as a sum of the components. As discussed, the two factors of supply base or customer base complexity are the number of supplier industries or customer industries and the degree of dispersion. Therefore, to be able to evaluate completely, both factors must be addressed together. Figure 3.2 illustrates this definition of supply base and customer base complexity. As shown in Figure 3.2, the supply base or the customer base is less complex when the number of supplier industries or customer industries is low and the degree of dispersion is also low. In contrast, a supply base or a customer base is more complex when supply or customer base is high and the degree of dispersion is also high.

Literature also supports this interaction approach. Theoretically, the number of suppliers makes up a firm's supply base. As the number of supply base increases, the complexity also increases (Simon 1962, Casti 1979), which may result in costly, time consuming, and inefficient interaction between a firm and its suppliers. Accordingly, supply base reduction has become a trend in the U.S (Lemke, et al., 2000). For example, Asmus and Griffin (1993) report that manufacturers in the automotive industry have reduced their supplier base by 50% and have moved to single-sourcing. Another study also shows that Motorola and Xerox have reduced their supplier base by 44% and 90%, respectively (Sheth & Sharma, 1997). Similar practice is also found in the U.K, where four industries (e.g. process, engineering, electronics and household) are shown for having reduced their suppliers by around 35% in between 1991 and 1995 (Goffin, et al., 1997).

However, the link between supply base reduction and firm performance has been mixed. For example, using the Global Manufacturing Research Group (GRMG) dataset covering 18 countries, Milgate (2001) found that the number of suppliers has no significant impact on delivery performance. Vachon and Klassen (2002) used the same dataset with 19 countries being covered. They found that the number of supply bases has a significant impact on delivery reliability but not delivery speed. Perona and Miragliotta (2004) conducted a study in three Italian industries: household appliances, fashion, and book publishing. They found that the number of suppliers negatively impacts operating profits. More recently, Bozarth et al. (2009) used a High Performance Manufacturing (HPM) dataset which surveyed manufacturing plants in seven countries. They found no significant evidence linking the number of suppliers to plant performance as measured by schedule attainment, manufacturing costs, customer satisfaction, and competitive performance.

This study also argues that supplier base complexity and customer base complexity may have an interaction effect. That is, when both complexities exist, a focal manufacturer may face a much more complex situation that cannot be explained by the sum of supply base and customer base complexity. As discussed, a supply base and a customer base are the portion of upstream and downstream network that is directly linked with a focal manufacturer (Choi and Krause, 2006). When both upstream and downstream networks are considered together, the number of nodes (e.g. customer industries and supplier industries) and interactions of those with a focal manufacturer increase; which will naturally increase complexity (Craighead et al., 2007). The intensity of the interaction will also increase, as each relationship will no longer be dyadic between buyer industry and focal manufacturer or supplier industry and focal manufacturer, but triadic, with a focal firm as a mediator between its supplier industry and customer industry.

Furthermore, interaction with one side of complexity may amplify complexity on the other side. For example, intense interaction with a customer may inspire a new product innovation that requires a firm to search for new sources and in turn, increase supply base complexity.

In summary, we suggest that supply chain base complexity is determined by the number of partners in a focal firm's network within its managerial control and the degree of dispersion between a focal manufacturer and its supply chain partners. This view is consistent with the network complexity theory which suggests that the source of complexity comes from the number of components and nonsimple interaction (Simon, 1962, Amaral and Uzzi, 2007). This study extends this view, capturing the degree of the interaction effect.

This study combines the idea of evaluating the potential negative impacts of supply chain base complexity on firm performance with the idea that information technology (IT) may be at play to mitigate the adverse effect. The next section will elaborate how supply chain base complexity affects firm performance with respect to Return on Sales and inventory turnover. Literature suggests that SCB complexity impacts operational and financial performance. This essay uses the raw material inventory turnover and finished goods inventory turnover to measure operational performance and Return on Sales (ROS) to measure financial performance. These measures are chosen due to the direct impact that supply base and customer base complexity may have on focal manufacturer performance. In addition, those measures have been used in supply chain management literature (Yao and Zhang 2012). This study will then discuss how IT plays as a mechanism to moderate the relationship between supply chain base complexity and firm performance.

Transaction Cost Economics

In general, transaction costs are equal to the sum of coordination costs and transaction risk costs (Grover & Malhotra, 2003). Transaction costs economics (TCE) argue that there are difficulties and challenges in an exchange process with suppliers and customers in a supply chain (Williamson, 1975).These challenges increase transaction costs, with respect to negotiation, monitoring, and enforcement activity due to increase coordination costs and transaction risk. Some factors that are said to affect these costs are bounded rationality, opportunism, uncertainty and complexity, small numbers, asset specificity, and information asymmetry (Jones & Hill, 1988). The existence of one or more factors combined causes specific transaction challenges which in turn, will increase transaction costs. Costs are incurred for developing, maintaining, and monitoring transactions and relationships, and guarding against opportunistic behaviors (Choi & Krause, 2006).

TCE is particularly useful to investigate the supply base and customer base complexity phenomenon because TCE captures transactions happening between a focal manufacturer and its supplier industries or customer industries. In addition, components of supply base and customer base complexity fit with components of transactions cost. In particular, the size of the supply base or customer base that a focal manufacturer has is relevant to the size of coordination costs. Degree of dispersion is also relevant to transaction risk. An increase in degree of dispersion suggests path dependency between a focal manufacturer and its supply chain partner (Spekman, et al., 1998), which results in a higher transaction risk. In such a circumstance, monitoring cost may also increase.

Furthermore, characteristics of supply base complexity and customer base complexity resemble those transactions assumed in TCE. For example, supply base or customer base complexity increases when a focal manufacturer closely relies on critical suppliers or customers. Such a condition may resemble a small numbers factor which may increase the risks of opportunistic behaviors. In such situations, a monitoring activity is required. This is also more likely to happen if an investment in specialized assets is involved or information asymmetry exists between transacting partners (Jones & Hill, 1988). Complexity also increases when the number of supplier industries or customer industries increases in a focal firm supply or customer base (Choi & Krause, 2006). Such conditions increase complexity to develop, maintain, and monitor the exchange relationship. For example, due to an increase in the supply or customer base, intensity of the negotiation and communication channel also increase. In addition, uncertainty also increases, as a focal manufacturer needs to divide its focus on managing a wide array of supplies (i.e. raw materials)or a wide array of customers' demand (i.e. finished products). A complex supply base and customer base also has an impact with difficulties arising in order placing and problem tracing (Choi & Krause, 2006).

TCE is also useful as a theoretical lens to guide hypotheses with regards to information technology (IT). IT has a coordination and information sharing capability to minimize coordination costs (Rosenzweig, 2009). In addition, IT also has collaboration and monitoring capabilities to reduce transaction risks (Saldanha, et al., 2013).

HYPOTHESES DEVELOPMENT

Supply Base Complexity (SBC) and Performance

As discussed, a complex supply base may result in higher transaction costs, with regards to coordination costs and transaction risks. An effective supplier management plays a vital role in helping manufacturers achieve superior performance. If the supply base consists of a large number of critical supplier industries, coordination and interaction become very costly, time consuming, and inefficient. In many industries, management of suppliers can account for as much as 60% of manufacturing costs (Asmus and Griffin 1993). Furthermore, there is an additional cost incurred at a focal firm to guard from opportunistic behavior of those critical suppliers. Additionally, a non-reliable critical supplier can result in more detrimental effect on performance than a non-reliable less critical supplier. For example, risks of errors in procurement process, scheduling, and lead time will be more detrimental in such situations. As a result, a focal manufacturer may suffer from increased monitoring costs to ensure that everything goes as planned. From a logistics standpoint, a complex supply base translates as diseconomies of scale, which can result in higher transportation, order placement, preparation, and receiving costs because a focal manufacturer needs to spread out risk or increase coordination cost (Ellram, 1993). Moreover, a complex supply base also results in a high level of information sharing, which requires more resources to store, retrieve, sort, filter, analyze, and distribute that information (Shapiro & Varian, 1999). In sum, supply base complexity increases costs which in turn, decrease profits and return on sales.

Supply base complexity may also have a negative impact on inventory turnover. In particular, inventory turnover may decrease as a result of increased inventory level with regards to increased cycle stock inventory and safety stock inventory. A complex supply base implies a larger supply base which may result in more variety of cycle stock inventories held by the focal manufacturer due to the unique characteristics of inventory that can only be sourced from certain critical suppliers. In addition, a complex supply base may result in an increased level of safety stock to buffer from uncertainties. The safety stock is even larger not only because of the size of supply base, but also because of the dispersion factor. As discussed, degree of dispersion increases the uncertainty which is related to risk. Accordingly, a focal manufacturer needs to ensure availability of inventory to maintain long production operations. In general, supply base complexity tends to directly increase raw material inventory levels and thus, decrease raw material inventory turnover. Note that finished goods inventory is a product of raw material inventory (e.g. new product development as a result of new raw material sourcing) and therefore, may also be indirectly affected by the increased supply base complexity.

Hence:

H1a. Supplier base complexity is negatively associated with performance as measured by Raw Material Inventory (RMI) turnover

H1b. Supplier base complexity is negatively associated with performance as measured by Finished Goods Inventory (FGI) turnover

H1c. Supplier base complexity is negatively associated with performance as measured by Return on Sales (ROS)

Customer Base Complexity (CBC) and Performance

Customer base complexity has a negative impact on performance. As transaction cost economics suggests, the increasing level of customer base complexity can increase the cost of controlling the firm and the transaction risk (Narasimhan & Kim, 2002). As discussed earlier, there are many additional costs accompanying customer-management related tasks. Costs such as identification, monitoring, coordinating, contracting, and enforcement also apply when maintaining a customer base (Dyer 1996). At first blush, an increasing number of customers may positively influence performance, with respect to manufacturing costs, due to economies of scale and scope. However, such benefit only applies in a homogeneous market. A wide array of critical relationships in the customer base is unlikely to be homogeneous. It is likely in a complex customer base that each customer industry works closely with a focal manufacturer by joining assets, capability, and knowledge to come up with idiosyncratic outcomes (Dyer and Singh 1998). A plausible reason for such action is because it is too costly to lose customers for an industry with a complex customer base. In such circumstances, an outcome for one customer may be unrelated to that for another customer, resulting in smaller batches of production. As a result, the cost of manufacturing a product will be higher (Narasimhan and Kim 2002). From a logistics perspective, having many different sales channels may also result in high transportation costs (Perona and Miragliotta 2004). Furthermore, there are also transaction risks associated with a complex customer base. Stockout risk and fulfillment error risk can be more detrimental in such circumstances, which may lead to losing critical customers. Moreover, the high level of information available from the demand side is very costly to manage. In sum, customer base complexity tends to increase costs and decrease profits.

Customer base complexity may also have a negative impact of inventory performance. Again, both cycle stock and safety stock inventory level may increase as a result of more complex customer base. In particular, the cycle stock inventory level may increase as a result of carrying more of a variety of products to satisfy a complex customer base. As a consequence, the safety stock inventory for each variety of products may also increase. Further, a manufacturer may choose to increase its service level to satisfy the complex customers which will resulted in an increase of safety stock inventory. In addition, when dealing with complex customer base, a manufacturer may be overwhelmed with all the information (Villena, et al., 2011). In such a circumstance, buffer stock can be a good solution. This view is also consistent with the literature. Perona and Miragliotta (2004) find that customer base complexity is negatively associated with inventory turnover. In general, customer base complexity tends to directly increase the finished goods inventory level and therefore, decrease FGI inventory turnover. Note that finished goods inventory is a product of raw material inventory and therefore, there can be a ripple effect of customer base complexity that affects RMI turnover. Further, the costs to holding FGI are much more expensive than that to holding RMI. It is logical to a manufacturer to spread the buffer out to both FGI and RMI, than to just holding all FGI. This approach is also widely known as form postponement in operations management textbook. A manufacturer will wait until it receives actual demand from customers before begin the production.

Hence:

H2a. Customer base complexity is negatively associated with performance as measured by RMI turnover

H2b. Customer base complexity is negatively associated with performance as measured by FGI turnover

H2c. Customer base complexity is negatively associated with performance as measured by Return on Sales

Interaction of SBC and CBC

As discussed earlier, we expect to see an amplification of complexity when both supplier base and customer base complexity interact. Literature suggests that to find a compatible partner is not only a challenge, but also costly (Dyer 1996). When both complexity directions are considered, a firm needs to maintain both suppliers and customer simultaneously. Incompatible triadic relationships produce little synergy. As a result, additional costs can be expected to maintain triadic relationships that consist of supplier-firm-customer. Given the potential negative impact of supply base complexity and customer base complexity alone, the interaction of SBC and CBC may cause a greater impact that cannot be explained by the sum of each complexity. For example, there can be an endogenous effect of SBC on CBC and vice versa which makes CBC larger when SBC is larger. A new product development initiated by customer industries in a complex customer base can illustrate this situation. As a result of new product development demand, a focal manufacturer needs to find suppliers with certain capabilities which basically increase SBC.

There can also be a joint negative impact of both supplier base and customer base complexity on inventory performance. When both directions have a high level of complexity, a firm must have more buffer inventory to ensure smooth production as well as a satisfactory service level. Using the new product development example, both finished goods and raw material inventory levels are affected due to not only a variety of inventory, but also the safety stock inventory to buffer against uncertain situations. In addition, high levels of information across the triadic relationship may cause confusion that leads to inaccurate decision making with regards to procurement and forecast.

Hence:

H3a. Supply base complexity is more negatively associated with RMI turnover in the presence of customer base complexity.

H3b. Supply base complexity is more negatively associated with FGI turnover in the presence of customer base complexity.

H3c. Supply base complexity is more negatively associated with Return on Sales in the presence of customer base complexity.

Information Technology Intensity as a moderator

This study argues that benefits of IT encompass the two performance measures: Return on Sales and inventory turnover. IT has coordination and information sharing capabilities relevant to reducing transaction costs (Narasimhan and Kim 2002). As the literature suggests, the use of IT can help a firm reduce transaction costs. In an interorganizational setting, IT targets the automation of routine processes and substitutes repetitive human effort which reduces operational cost (Srinivasan, et al., 1994). IT allows more information to be communicated atthe same time which reduces the cost of communications (Malone, et al., 1987). IT can connect many buyers and suppliers and provide information relevant to those suppliers and customers which reduces transaction costs (Malone et al. 1987). IT allows a firm to integrate with its chain partners which reduces coordination costs. With respect to supply base complexity, IT can help a firm managing relationship. Costs of transactions can be reduced, as IT enables a firm to communicate and integrate with suppliers at lower costs (Saldanha, et al., 2013). Inter-organizational processes can also be improved. A firm can eliminate duplicate tasks or automate repetitive tasks such as the order process. IT can also facilitate the searching process which can significantly reduce searching costs (Zhu & Kraemer, 2005). IT can also reduce risk

The use of IT can also contribute to inventory performance. IT can facilitate information sharing between a firm and its suppliers in an efficient and effective manner. Information sharing at real time can lead to lower inventory costs due to improved forecasts and visibility. As a result, the level of safety stock to minimize uncertainties can also be reduced. IT can also help a focal manufacturer against the bullwhip effect (Lee, et al., 2004), which results in less inventory. IT can also be used for collaborative activities with suppliers. Such activities can result in better manufacturing and procurement decisions such as in JIT or CPFR.

Hence:

H4a. IT negates the negative association between supplier base complexity and performance as measured by RMI turnover

H4b. IT negates the negative association between supplier base complexity and performance as measured by FGI turnover

H4c. IT negates the negative association between supplier base complexity and performance as measured by Return on Sales

IT can also mitigate the negative impact of customer base complexity on performance with respect to Return on Sales. Communication and interaction with customers can be done in a more efficient manner which reduce costs. IT can also facilitate market expansion, by connecting customers through internet sales. At the same time, such activity can reduce marketing costs significantly, by eliminating the needs for having outlets or showrooms. For example, Xiaomi Inc., a Chinese smartphone maker, has successfully expanded to Hong Kong, Taiwan, Singapore, and Malaysia. It recently entered India and gained success by selling out 55,000 phones in four days from only internet sales. Xiaomi phones are 40 percent cheaper than comparable phones in India, which was the main attraction for customers in India (Min, 2014).

IT can also help the inventory performance of a firm. IT facilitates communication between a firm and its customers. As a result, a firm can improve forecast and production decisions which then, can result in less total inventory. Collaborative activities such as CPFR can also be greatly enhanced by using IT. For example, inventory at Sears has been reduced by 25% as a result from the use of IT in its collaboration with Michelin (Sanders, 2008). IT can also facilitate information sharing at real time which in turn, results in improved forecasts and visibility. As a result, the level of safety stock to minimize uncertainties can also be reduced. IT can also help a focal manufacturer against the bullwhip effect (Lee, et al., 2004), which results in a lower inventory level.

Hence:

H5a. IT negates the negative association between customer base complexity and performance as measured by RMI turnover

H5b. IT negates the negative association between customer base complexity and performance as measured by FGI turnover

H5c. IT negates the negative association between supplier base complexity and performance as measured by Return on Sales

As discussed, a higher complexity exists when both supplier base and customer base complexity interact than if complexity comes either from supplier base or customer base complexity alone. IT can facilitate integration in this triadic relationship at low cost. In general, the use of IT can reduce transaction costs with regards to coordination costs and transaction risk. Information sharing can be done seamlessly in an efficient manner. Furthermore, IT can facilitate inter-organizational processes, resulting in better performance with respect to flexibility (Saldanha et al. 2013). As discussed, IT can significantly improve forecasts by expanding visibility to both upstream and downstream sides in a supply chain. As a result, inventory performance can be enhanced.

Hence:

H6a. IT negates the negative the impact of interaction between supplier base and customer base complexity on performance as measured by RMI turnover

H6b. IT negates the negative the impact of interaction between supplier base and customer base complexity on performance as measured by FGI turnover

H6c. IT negates the negative the impact of interaction between supplier base and customer base complexity on performance as measured by Return on Sales

METHODOLOGY

Data Sources

Data used for this research will be gathered from the Bureau of Economic Analysis (BEA) and the Annual Survey of Manufacturers (ASM). From BEA, we use an input-output account table, which shows how much a manufacturing industry's output was used as an input of another industry. Specifically, the table shows how manufacturing industries provide inputs and use outputs from each other to produce gross domestic product. By using this table, we will be able to determine supplying industries to a focal manufacturer and industries that are supplied from a focal manufacturer. As a result, we are able to create a map of the supply base and customer base for any given industry. In addition, we will use ASM data which provides knowledge of investments in IT infrastructure, including investments in computers and peripheral equipment and software and communication equipment. ASM also provides data on costs, inventories, total cost of materials, total value of shipments, value added, and production wages.

The I/O table is released every 5 years with the newest one being from 2007 (BEA 2013). In this study we will create a complexity index using the I/O table from the year of 2007. Due to different NAISC codes between ASM and BEA, the BEA format is used and thus, aggregates some industries' observations in the ASM data to match with BEA data.

Table 3.1. Variables and Measurements

Type	Variable/ Proxy of	Measures	Source
Independent	HHIxSupCount/ Supply base complexity	$SBC = \left(1 - \sum_{j=1}^{n}\left(\frac{x_{ij}}{\sum_j x_{ij}}\right)^2\right) SupRatioCount$	BEA
Independent	HHIxCustCount/ Customer base complexity	$CBC = \left(1 - \sum_{j=1}^{n}\left(\frac{y_{ij}}{\sum_j y_{ij}}\right)^2\right) CusRatioCount$	BEA
Dependent	Gross margin/ profitability	(Value added- production wages)/ total value of shipment	ASM
Dependent	Inventory turns/ Inventory performance	RMI= raw mat inv/ total shipment FGI= fin. goods inv/ total shipment Total= Σ(RMI, WIP, FGI)/ total shipment	ASM
Moderating	IT expenses/ IT infrastructure	IT= Σ (expensed computer hardware and equipment, purchases of software and data processing, other purchased computer services)	ASM
Control	Adv. Intensity, Industry size, durable/ non durable		ASM, BEA

Variables

Independent Variables

Supply base complexity is calculated using the formula below:

$$SBC = \left(1 - \sum_{j=1}^{n}\left(\frac{x_{ij}}{\sum_j x_{ij}}\right)^2\right) SupRatioCount$$

This formula captures the two characteristics of SCB complexity. First, it captures the degree of dispersionbetween an industry and its supplier industries as measured by the reversed Herfindahl Index (HI). The original HI shows if an industry is concentrated or widely dispersed.

When reversed, the index will be scaled from 0 to 1 with 0 indicating a concentrated supply base and 1 indicating a dispersed and competitive supply base. In the first component, *i* denotes the focal manufacturer, *j* denotes the supplier industries, x_{ij} denotes the total value of supplies from industry *j* to industry *i*. Second, it captures the number of suppliers that an industry interacts with. To be consistent with the first component, we divided by the total available industries in the list, thus creating a ratio. Furthermore, the index will also be easily interpreted, with a low index indicating low complexity while a high index shows high complexity. Note that by combining the two components, the scale remains from 0 to 1. Using the input-output table, we are able to identify all of the supplier industries and their shares of input for a focal manufacturer (x_{ij}). In this study, we restrict the supplier industries to only those that supply raw materials. This study argues that raw materials that focal industries use as input make up the value of outputs produced by manufacturing industries. SBC is log-transformed before estimation.

Customer base complexity is calculated using the formula below:

$$CBC = \left(1 - \sum_{j=1}^{n} \left(\frac{y_{ij}}{\sum_j y_{ij}}\right)^2\right) CustRatioCount$$

The formula for customer base complexity is calculated the same was as that for supply base complexity. The only difference is that instead of looking across columns in an input-output table, we look across rows to identify all of the industries that a focal manufacturer supplies, with the addition of end consumer expense, government expense, government investment, and net exports that make up GDP (y_{ij}). For calculating the customer base, we include all industries and other GDP measures as those are all customer industries to a focal manufacturer. CBC is log-transformed before estimation.

IT is calculated as the sum of the capital expenditures of computer hardware and equipment, purchases of software, and data processing and other purchased computer services (Yao and Zhu 2012). The data for calculating IT is provided in the Annual Survey of Manufacturers (ASM).

Dependent Variables

There are two types of performance measures that we use here. First is Return on Sales (ROS) as a measure of financial performance. ROS is calculated as (value added-SG&A)/ total value of shipment. According to a U.S. Census, value added measures the difference between sales and total costs of materials. Removing labor costs and selling, general, and administrative expenses from the value added yields to operating income. This calculation is consistent with those in the literature (Cachon et al. 2007, Yao and Zhu 2012). Second, we calculated inventory performance using raw materials inventory (RMI), and finished goods inventory (FGI). RMI is calculated as raw materials inventory divided by total value of shipments. Finally, FGI is calculated as finished goods inventory divided by divided by total value of shipments. All these measures are consistent with the literature (Saldanha et al. 2013). All dependent variables are log-transformed, except return on sales.

Control Variables

There are three control variables used in this study. The first is Advertising Intensity (AdsIn) calculated as advertising expenses over value of product shipments. The level of advertising intensity should correlate with the inventory level and sales and thus, an appropriate control variable for this study. The second variable is durable goods industry which is measured using a dummy variable. The annual survey of manufacturers groups industries into two categories: durable goods and non-durable goods industry. Literature suggests that the impacts of durable goods vs. nondurable goods industries on margin and inventory level are significantly different (Yao and Zhu 2012). In particular, nondurable goods industries tend to have a higher margin than the durable goods industries. Finally, this study also controls industry size which is calculated as log natural of value of product shipments.

Model Specification

The dependent variables in the model are Return on Sales (ROS), raw material inventory turnover (RMI_turn), and finished goods inventory turnover (FGI_turn). The main explanatory variables are supply base complexity (SBC), customer base complexity (CBC), and interaction of SBC and CBC (SBCxCBC). Control variables are industry size, advertising intensity, and durable goods industry. The first set of models (equations 1-3) estimates the impact of supply base complexity and customer base complexity on performance. The second set of models (equations 4-6) estimates the interaction effect between SBC and CBC and its impact on performance. The moderating effect of IT is estimated using the second model (equations 4-6) and a median split approach. Note that our dependent variables may be correlated to one another; that is, finished goods are product of raw material goods, and they both affect ROS particularly with regards to inventory cost. Accordingly, the errors of the three equation models in each set may be correlated to one another.

The main effect model has the following form:

$$ROS = \beta_1 + \beta_2 SBC + \beta_3 CBC + \beta_{4\text{-}6} Control\_Vars + \varepsilon \quad (1)$$

$$RMI\_turn = \beta_{11} + \beta_{12} SBC + \beta_{13} CBC + \beta_{14\text{-}16} Control\_Vars + \varepsilon \quad (2)$$

$$FGI\_turn = \beta_{21} + \beta_{22}SBC + \beta_{23}CBC + \beta_{24\text{-}26}Control\_Vars + \varepsilon \quad (3)$$

The interaction and moderation effect model has the following form:

$$ROS = \beta_{1} + \beta_{2}SBC + \beta_{3}CBC + \beta_{4}SBCxCBC + \beta_{5\text{-}7}Control\_Vars + \varepsilon \quad (4)$$

$$RMI\_turn = \beta_{11} + \beta_{12}SBC + \beta_{13}CBC + \beta_{14}SBCxCBC + \beta_{15\text{-}17}Control\_Vars + \varepsilon \quad (5)$$

$$FGI\_turn = \beta_{21} + \beta_{22}SBC + \beta_{23}CBC + \beta_{24}SBCxCBC + \beta_{25\text{-}27}Control\_Vars + \varepsilon \quad (6)$$

Data

Table 3.2 presents industry characteristics and distributions of industry by industry sector (three-digit NAICS). As seen in the data, machinery, transportation equipment, and food sectors have the highest number of observations, representing one-third of the total sample. In contrast, apparel and leather sectors have only one observation each in the data. Average of the industry sector sales are about $25 billion with a wide range across industry sectors. The petroleum and coal sector has the highest average sales with $147.81 billion while leather and electrical equipment sectors have the lowest average sales with $5 billion and $7.14 billion, respectively.

In terms of supply base complexity, industries in transportation equipment, furniture, and machinery sectors have the highest while textile products and petroleum and coal sectors have the lowest complexity. In terms of customer base complexity, industries in plastic and rubber, machinery, and primary metal sectors are the most complex while industries grouped in wood, textile products, and petroleum and coal sectors are the least complex. In general, the machinery sector has a relatively more complex supply and customer base compared to other industry sectors. In contrast, industries in textile products and petroleum and coal sectors are less complex in terms of both supply and customer base compared to other sectors. In terms of IT intensity, printing, miscellaneous, and leather sectors have the highest, while textile mills, food, and petroleum and coal sectors have the lowest.

Table 3.2. Sample Characteristics

NAICS	Industry Description	No. of Obs.	Avg. Industry Sales ($B)	Average Supply Base Complexity	Average Cust. Base Complexity	Average IT Intensity	Avg. RMI Turn	Avg. FGI Turn	Avg. ROS
311	Food	24	23.49	0.168	0.089	6.79E-04	28.17	21.53	0.219
312	Beverage and Tobacco	5	24.46	0.162	0.083	7.18E-04	24.74	35.04	0.404
313	Textile Mills	3	11.68	0.160	0.064	7.09E-04	20.15	16.10	0.099
314	Textile Product Mills	3	8.79	0.135	0.053	1.32E-03	14.62	12.34	0.069
315	Apparel	1	16.88	0.161	0.089	1.59E-03	18.34	8.40	-0.235
316	Leather	1	5.00	0.173	0.085	2.96E-03	10.84	6.98	-0.002
321	Wood	4	24.25	0.229	0.054	1.26E-03	15.74	16.07	0.011
322	Paper	8	21.38	0.189	0.062	1.27E-03	14.89	17.32	0.159
323	Printing	2	48.81	0.221	0.063	4.24E-03	22.84	25.36	0.073
324	Petroleum and Coal	4	147.81	0.118	0.033	4.51E-04	30.63	19.70	0.172
325	Chemical	19	34.96	0.195	0.285	1.37E-03	18.60	11.86	0.226
326	Plastic and Rubber	10	20.07	0.192	0.391	1.23E-03	16.84	14.44	0.104
327	Nonmetallic Mineral	12	10.20	0.224	0.128	9.15E-04	15.73	14.76	0.168
331	Primary Metals	10	22.60	0.167	0.322	7.68E-04	27.03	24.19	0.116
332	Fabricated Metal	20	15.95	0.223	0.269	1.58E-03	12.84	16.07	0.082
333	Machinery	30	10.74	0.256	0.368	1.86E-03	11.10	13.97	0.055
334	Computer and Electronics	20	17.93	0.239	0.170	2.87E-03	10.97	22.17	0.106
335	Electrical Equipments	17	7.14	0.206	0.297	1.18E-03	16.54	19.32	0.113
336	Transportation Equipment	25	28.94	0.272	0.171	9.14E-04	26.14	72.14	0.081
337	Furniture	8	9.86	0.258	0.157	1.81E-03	13.49	20.90	0.052
339	Miscellaneous	11	12.32	0.235	0.200	3.19E-03	11.935	8.145	0.104
	Total	237							

In terms of performance, petroleum and coal, food, and primary metal are among sectors that have a high RMI turnover while machinery, computer and electronics, and leather are among sectors with a low RMI turnover. In terms of FGI turnover, the transportation equipment sector has the highest with 72.14 turns per year, which is more than double the average of the FGI turnover in the manufacturing industry in the U.S. In contrast, industries in apparel, miscellaneous, and leather sectors have, on average, the lowest FGI turnover. In terms of ROS, beverage and tobacco, chemical, and food sectors have the highest ROS while leather and apparel sectors have, on average, not only the lowest, but also a negative ROS.

The average RMI turnover and FGI turnover for all industries in the sample is 17.92 and 23.15, respectively. The average ROS for this sample is 11.8% with a median ROS of 9.8%. The mean of SBC is 0.22 while the mean of CBC is 0.21. Other statistics and the correlation matrix of variables used in this study are as indicated in table 3.3.

As discussed, a median split approach was performed to distinguish the IT intensity level of industry in the sample. In particular, industries with a value of IT intensity lower than the median value are grouped in a Low IT subsample while industries with value of IT intensity higher than the median value are grouped in a High IT subsample. The median split yielded equal sample sizes with 118 observations in each subsample. Statistics of variables in each subsample are provided in table 3.4.

To avoid a multicollinearity issue as well as to avoid losing observations during the log transform, the interaction term between SBC and CBC are shifted up by the mean value of the respected variable (Modi & Mishra, 2011). In particular, 0.22 and 0.21 were added to every value of SBC and CBC, respectively. This action, which has a similar purpose to mean centering, shifts the scale over to mitigate any potential multicollinearity issue but retains the units for the regression purpose. Furthermore, adding the mean to every value, instead of subtracting the mean from every value in mean centering, provides all positive values for SBC and CBC variables for the log transformation purpose. Variance inflation factors (VIF) test for multicollinearity were then run for all variables. The test shows that VIF scores for all variables are low to moderate, with the highest score being 4.88, lower than the commonly maximum acceptable level of 10 (Lunt, 2003), suggesting multicollinearity is not an issue in this study.

Table 3.3. Descriptive Statistics and Correlation Matrix Used in the Regressions

Variable	Mean	Std.Dev.	lnRM_Turn	lnFG_Turn	ROS	lnsbc	lncbc	ln_sbcxcbc	AdvInt
lnRM_Turn	2.71	0.55	1						
lnFG_Turn	2.76	0.72	0.53*	1					
ROS	0.12	0.13	0.06	0.001	1				
lnsbc	-1.60	0.40	-0.21*	0.02	-0.17*	1			
lncbc	-2.34	1.52	-0.23*	-0.12	-0.07	0.11	1		
ln_sbcxcbc	-1.83	0.52	-0.19*	-0.06	-0.12	0.39*	0.84*	1	
AdvInt (x 10^{-3})	4.50	6.58	-0.23*	-0.36*	-0.20*	0.14*	-0.08	-0.02	1
lnSize	16.35	0.91	0.34*	0.28*	0.16*	0.14*	-0.07	-0.03	-0.23*

* Significant correlations, with *p*-value < 0.05

Table 3.4. Descriptive Statistics of Median Split Subsamples

	High IT Intensity Industries	
Variable	**Mean**	**Std. Dev.**
lnRM_Turn	2.46	0.38
lnFG_Turn	2.59	0.57
ROS	0.08	0.13
lnsbc	-1.50	0.31
lncbc	-2.10	1.35
ln_sbcxcbc	-1.72	0.54
AdvInt (x 10^{-3})	6.81	8.22
lnSize	16.17	0.86

	Low IT Intensity Industries	
Variable	**Mean**	**Std. Dev.**
lnRM_Turn	2.96	0.58
lnFG_Turn	2.94	0.80
ROS	0.15	0.13
lnsbc	-1.69	0.46
lncbc	-2.58	1.65
ln_sbcxcbc	-1.93	0.49
AdvInt (x 10^{-3})	2.23	3.01
lnSize	16.51	0.92

RESULTS

Estimation Models and Regression Results

In this study, there are three separate regression models to test for industry performance with respect to raw material inventory turnover, finished goods inventory turnover, and return on sales. Although the three models seem to be independent of each other, the error terms of the models are expected to be correlated. Therefore, seemingly unrelated regression (SUR) is performed to estimate the regression equations. The Breusch-Pagan test of independence confirms that residuals are indeed correlated with Chi-squared of 64.592, justifying the use of Seemingly Unrelated Regression estimation technique.

To control for Type II error, a statistical power analysis is conducted by following Cohen (1992). Having enough statistical power should provide confidence to reject H_0, when H_0 is false. Cohen (1992) suggests that a minimum power of 0.80 is required to minimize the risk of making a Type II error. Statistical power can be determined for given α, sample size, and effect size. As Cohen suggests, effect sizes (ES) for multiple regression analysis can be small (ES < 0.02), medium (ES < 0.15), or large (ES < 0.35) (Cohen, 1992). Given $\alpha = 0.05$, Power = 0.80, 6 independent variables, and sample size of 237 for the full sample, this study is able to detect small ES. This study can also still detect small to medium ES for the IT intensity median split sample with 118 observations (Cohen, 1992).

Regression results for all models and all explanatory variables are presented in Table 3.5-Table 3.8. Overall; all models have significant Wald Chi-squared statistics. For models with a full sample, the lowest Wald Chi-squared statistic is 41.59 and highly significant ($p < 0.001$). For models with an IT intensity median split sample, the lowest Wald Chi-squared statistic is 14.66 ($p < 0.05$).

Table 3.5. Main Effect Estimation Result

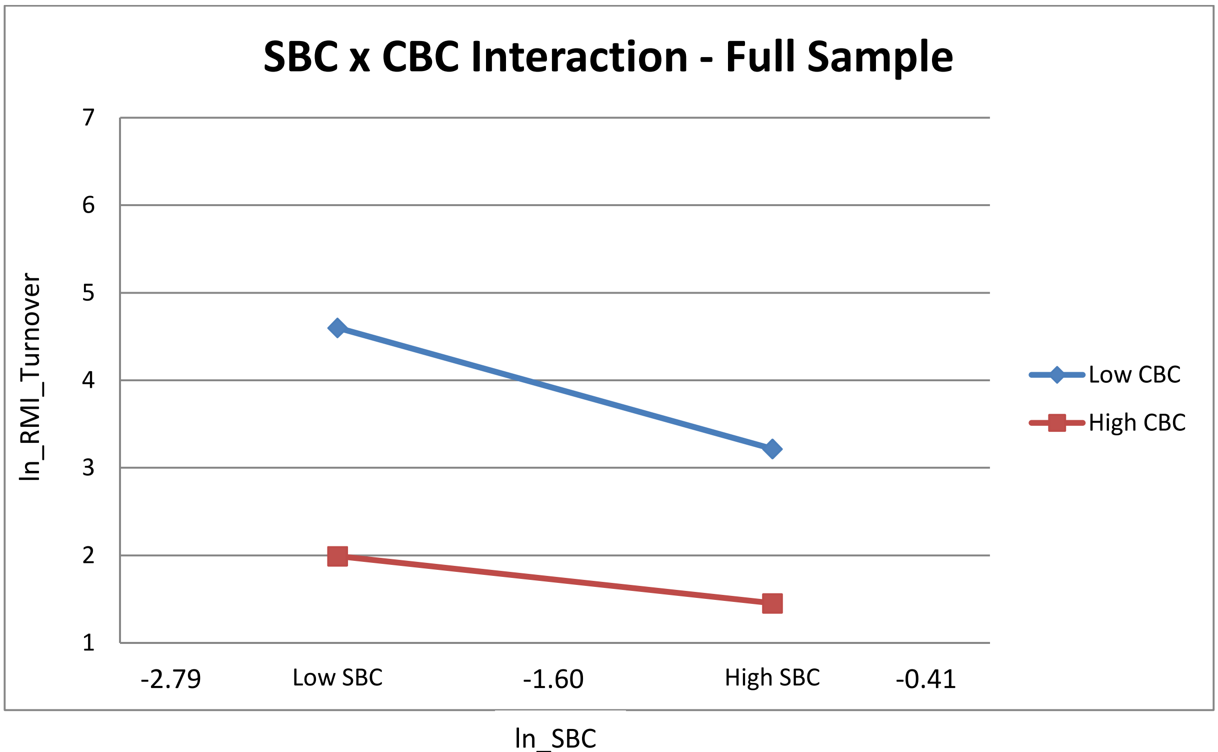
	lnRM_Turn		lnFG_Turn		ROS	
Variables	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value
lnsbc	**-0.237**	**0.009**	-0.075	0.522	-0.012	0.601
lncbc	**-0.067**	**0.002**	**-0.078**	**0.004**	-0.002	0.738
ln_sbcxcbc						
AdvInt	**-11.608**	**0.021**	**-37.038**	**0.000**	**-2.867**	**0.026**
lnSize	**0.179**	**0.000**	**0.199**	**0.000**	0.008	0.398
Durable	-0.115	0.135	**0.372**	**0.000**	**-0.084**	**0.000**
_cons	-0.621	0.380	-0.868	0.345	0.029	0.874
N	237		237		237	
Chi-Squared	74.57		71.64		41.59	
R-sq	0.239		0.232		0.150	

Table 3.6. Interaction Effect Estimation Result

	lnRM_Turn		lnFG_Turn		ROS	
Variables	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value
lnsbc	**-0.372**	**0.000**	-0.145	0.277	-0.009	0.724
lncbc	**-0.166**	**0.000**	**-0.130**	**0.018**	0.000	0.985
ln_sbcxcbc	**0.358**	**0.006**	0.186	0.280	-0.007	0.831
AdvInt	**-11.399**	**0.021**	**-36.930**	**0.000**	**-2.872**	**0.025**
lnSize	**0.179**	**0.000**	**0.199**	**0.000**	0.008	0.398
Durable	*-0.135*	*0.077*	**0.362**	**0.000**	**-0.084**	**0.000**
_cons	-0.404	0.564	-0.756	0.564	0.024	0.894
N	237		237		237	
Chi-Squared	84.46		73.16		41.64	
R-sq	0.262		0.236		0.150	

For the main effect model, the coefficient for SBC is negative and significant (β= -0.237, $p < 0.01$), indicating that supply base complexity reduces raw material inventory turnover. The coefficient for CBC is also negative and significant (β = -0.067, $p < 0.01$), indicating that CBC also reduces raw material inventory turnover. The regression result on the FGI turn for CBC is also consistent with that on the RMI turn. CBC tends to decrease finished goods inventory turnover (β = -0.078, $p < 0.01$). Note that the negative effect of the complexity from supply base is larger than that from the customer base. The Wald test is significant and thus, confirms the significant different effect size between SBC and CBC. In general, hypothesis 1 and hypothesis 2 are supported for the RMI turnover model, partially supported for the FGI turnover model, and not supported for the ROS model.

Figure 3.3. Interaction between SBC and CBC using Full Sample



A results summary for the interaction effect model is shown in Table 3.6. Here, the interaction effect is introduced while controlling for main effects. The coefficient for the interaction term of SBC and CBC is positive and significant (β = 0.358, $p < 0.01$). Because the sign of the interaction coefficient is opposite to that of SBC and CBC, the result indicates that the presence of CBC is weakening the negative impact of SBC on raw material inventory turnover. Note that the total effect of SBC and CBC can be calculated as -0.372xSBC – 0.166xCBC + 0.358 xSBC*CBC. Given the imbalance coefficient between SBC and CBC, with SBC having a larger coefficient, the size of the total effect is contingent upon SBC. That is, when supply base complexity is high, the total effect tends to be high. In general, our interaction hypotheses are not supported for all performance measures; tests show inconclusive results for the FGI turnover and the ROS as a performance indicator and a counter result for RMI turnover.

The coefficients for the control variables are generally significant. The relationships between advertising intensity and all performance measures are surprisingly negative and significant, indicating that large advertising costs are detrimental to inventory turnover and ROS. This situation is possible because intense advertising often requires more inventory stock for speculative reasons. In addition, having high advertising costs can negatively impact net income. The coefficients for industry size are positive and significant on inventory turnover measures possibly because firm size effects are carried over at the aggregate industry level. Large firms often have better inventory performance due to economies of scale, better resources, and stronger bargaining power over suppliers and customers. The coefficients for durable are mixed, with positive and significant on FG inventory performance but negative and significant on ROS. This result suggests that non-durable goods industries have faster finished goods inventory turnover but lower ROS. This is possible because the non-durable goods industry includes perishable goods which sell fast, moving products at low margin.

Table 3.7. Low IT Intensity Estimation Result

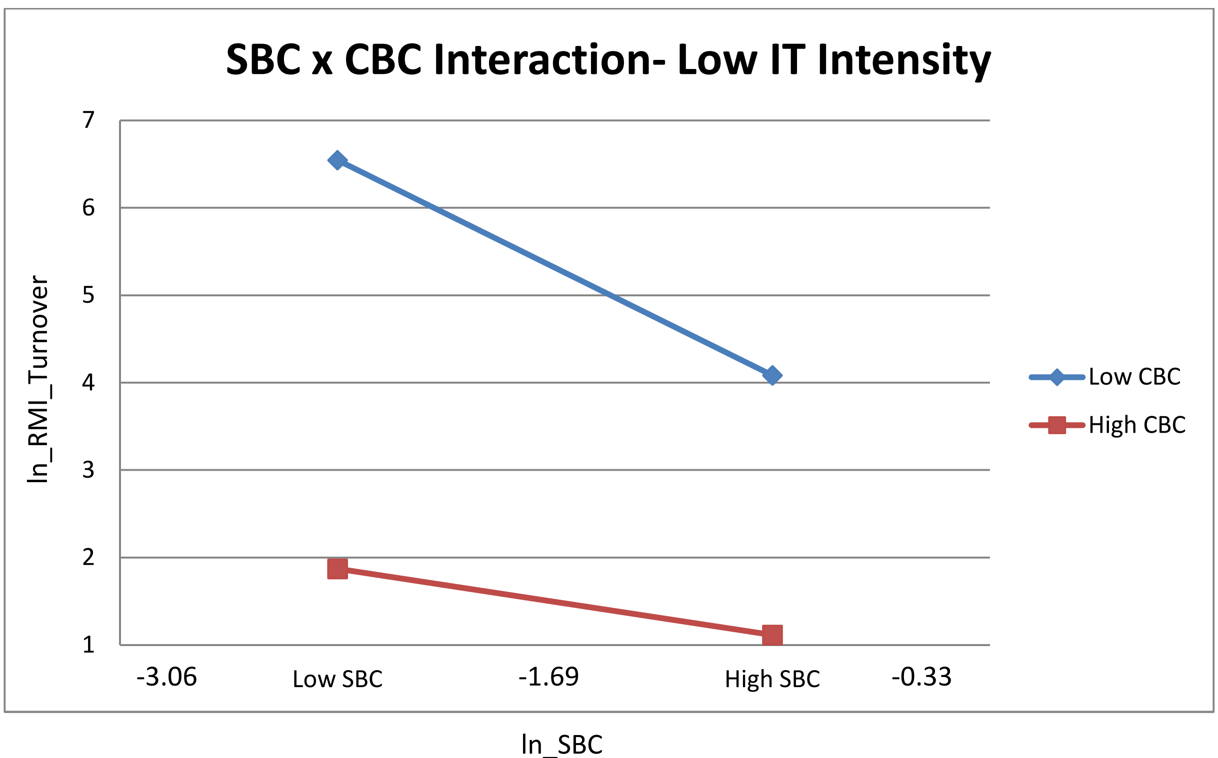
	lnRM_Turn		lnFG_Turn		ROS	
Variables	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value
lnsbc	**-0.302**	**0.022**	-0.043	0.805	0.020	0.528
lncbc	**-0.197**	**0.000**	**-0.158**	**0.022**	0.004	0.746
ln_sbcxcbc	**0.568**	**0.004**	0.377	0.150	0.011	0.825
AdvInt	-10.201	0.534	**-82.056**	**0.000**	-2.367	0.554
lnSize	**0.225**	**0.000**	**0.265**	**0.000**	-0.020	0.130
Durable	-0.078	0.471	**0.404**	**0.005**	**-0.113**	**0.000**
_cons	-0.608	0.543	-1.226	0.353	**0.613**	**0.012**
N	118		118		118	
Chi-Squared	39.85		53.71		20.28	
R-sq	0.253		0.313		0.147	

Table 3.8. High IT Intensity Estimation Result

	lnRM_Turn		lnFG_Turn		ROS	
Variables	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value
lnsbc	-0.238	0.134	0.034	0.879	-0.093	0.124
lncbc	-0.032	0.640	-0.021	0.834	-0.030	0.161
ln_sbcxcbc	0.031	0.862	-0.131	0.607	0.060	0.285
AdvInt	-1.835	0.669	**-26.500**	**0.000**	-2.032	0.131
lnSize	*0.078*	*0.096*	0.054	0.417	**0.056**	**0.000**
Durable	*-0.156*	*0.099*	0.191	0.156	-0.017	0.574
_cons	0.957	0.294	1.520	0.244	**-0.967**	**0.001**
N	118		118		118	
Chi-Squared	14.66		24.89		31.22	
R-sq	0.111		0.174		0.209	

Model 2 was run on two subsamples to test impacts of complexity on performance under two IT intensity levels: low and high. In the low IT intensity group, variables that affect raw material inventory are SBC (β= -0.302, p< 0.05), CBC (β= -0.197, p< 0.001), and interaction between SBC and CBC (β= 0.568, p< 0.01). These results suggest that SBC and CBC negatively impact raw material inventory turnover and finished goods inventory turnover in industries with a low IT intensity. In particular, SBC or CBC reduces raw material inventory turnover. In contrast, when SBC and CBC coexist, the negative effect of complexity is dampened. Again, the total effect of SBC and CBC can be calculated as -0.302xSBC – 0.197xCBC + 0.568 xSBC*CBC. Similar to a full sample interaction result, SBC plays a bigger role in the total effect due to larger coefficient size. With FGI turnover as a dependent variable, CBC relationship is negative and significant (β= -0.158, $p< 0.05$), indicating that under a low IT intensity situation, CBC reduces FGI turnover. That is, a one percent increase of customer base complexity results in a 0.158 percent decrease of finished goods inventory turnover.

Figure 3.4. Interaction between SBC and CBC using Low IT Intensity Sample



In addition to a statistical power analysis, other robustness checks were performed. First, to justify for the median split, a Wald test between the two subsamples was performed in a similar fashion of moderator testing suggested by Baron and Kenny (1986). The results are significant for all three dependent variables: the RMI turnover (F= 5.43, $p < 0.001$), the FGI turnover (F =2.92, $p < 0.01$), and ROS (F= 3.23, $p < 0.01$).

DISCUSSION

Table 3.9. Summary of Results

Hypothesis	Summary of hypothesis	Result
H1a	SBC is negatively associated with RMI turnover	**Supported**
H1b	SBC is negatively associated with FGI turnover	Not Supported
H1c	SBC is negatively associated with ROS	Not Supported
H2a	CBC is negatively associated with RMI turnover	**Supported**
H2b	CBC is negatively associated with FGI turnover	**Supported**
H2c	CBC is negatively associated with ROS	Not Supported
H3a	SBCxCBC is negatively associated with RMI turnover	***Not Supported****
H3b	SBCxCBC is negatively associated with FGI turnover	Not Supported
H3c	SBCxCBC is negatively associated with ROS	Not Supported
H4a	IT intensity mitigates negative relationship between SBC and RMI turnover	**Supported**
H4b	IT intensity mitigates negative relationship between SBC and FGI turnover	Not Supported
H4c	IT intensity mitigates negative relationship between CBC and ROS	Not Supported
H5a	IT intensity mitigates negative relationship between CBC and RMI turnover	**Supported**
H5b	IT intensity mitigates negative relationship between CBC and FGI turnover	**Supported**
H5c	IT intensity mitigates negative relationship between CBC and ROS	Not Supported
H6a	IT intensity mitigates negative relationship between SBCxCBC and RMI turnover	**Supported**
H6b	IT intensity mitigates negative relationship between SBCxCBC and FGI turnover	Not Supported
H6c	IT intensity mitigates negative relationship between SBCxCBC and ROS	Not Supported

* Results show significant finding counter to hypothesis

Practitioners are starting to realize complexity issues coming from their supply chain partners may harm their firm performance (Deloitte and Touche, 2003). However, empirically finding the source of complexity and the impact of complexity has been proven difficult. Researchers suggest that the number of supply chain partners (i.e. suppliers or customers) is the main source of complexity in a supply chain (Choi & Krause, 2006; Bozarth, et al., 2009), but no relationship was found between that and firm performance. This study proposed an alternative way to measure complexity in a supply chain, not only by considering the number of supply chain partners, but also by the level of dispersion of a focal manufacturer's supply chain network. Furthermore, the roles of IT in mitigating the negative impact of supply and customer base complexity are also evaluated and tested in this study. Industry level data from multiple secondary sources is used in this study to evaluate three conceptual models. A total of 237 observations provide significant evidence and important insights about complexity and IT.

A summary of the results is presented in table 3.9. Literature suggests that complexity in the supply chain comes from both upstream and downstream, that is, supply base and customer base complexity. We find that not only both sources of complexity exist, but both SBC and CBC also negatively affect performance. First, SBC is negatively associated with raw material inventory turnover. As discussed, the hypothesized negative effect may originate from two sources. First, a complex supply base for a focal manufacturer may have been the result of the need of new or different components that were not sourced previously. Some motivations that require sourcing new components include new product development, a manufacturing process change, or a diversification strategy (Choi & Krause, 2006; Lee, 2002). As a result, that industry holds more variety of components which in total, increases the raw material inventory level.

Second, a more complex base implies a high number of critical suppliers for a focal manufacturer. Given that safety stock inventory is needed for each supplier to buffer from lead time variability, a focal manufacturer with a large supply base would end up having a high raw material inventory as an aggregation of those safety stock inventories for all suppliers it has. The importance of this necessity increases when a focal manufacturer has a high dependence on particular industries. Because the results could not find support for the finished goods inventory turnover and return on sales, the first hypothesis is only supported partially.

The results also show CBC is negatively associated with raw material inventory turnover and finished goods inventory turnover. The results however, could not find support for the relationship between customer base complexity and return on sales. Therefore, findings only partially support the second hypothesis. As discussed, a complex customer base tends to increase inventory levels in several ways. First, a focal manufacturer may increase its service level to reduce the risk of losing customers. Second, a complex customer base may increase the inventory level due to product variety to satisfy the various customer industries in a customer base. A higher product variety makes it harder to precisely forecast demand and maintain continuous supply, resulting in mismatches between product supply and demand (Wan, et al., 2012). Under such circumstances, it is reasonable to carry more safety stock as a buffer for both raw materials and finished goods inventory. Third, a more complex customer base also implies a high number of critical customers to serve which have higher variability in demand. In sum, these two factors may result in higher inventory levels which in turn, results in a lower inventory turnover for both RMI and FGI. Our results confirm that this is indeed the case. It is also important to note the effect size of CBC on inventory turnover compared to that of SBC on inventory turnover. The negative effect size of CBC on RMI turnover is relatively small according to Cohen's (1992) scale while that of SBC on RMI turnover is medium. Clearly, SBC has a more detrimental effect on RMI turnover than CBC does, although CBC's negative impact affect both RMI and FGI turnover and not RMI turnover alone.

Furthermore, to better understand the negative impact of complexity on performance, the interaction effect between SBC and CBC is also examined. As previously discussed, a significant result is only found in the interaction-RMI turnover relationship. Figure 3 provides a plot of the interaction effect on RMI turnover. A key finding is that the fastest RMI turnover is achieved under a low supply base and a low customer base complexity situation, which justifies the danger of complexity. This finding also suggests that complexity needs to be avoided, and to achieve the best inventory performance, one should choose to have complexity in both supply and customer bases. The results also show that as complexity increases in either SBC or CBC, RMI turnover decreases.

To better understand the effect, the interaction effect between SBC and CBC is also examined. Interestingly, the results also show that instead of amplifying the negative impact of complexity on RMI turnover, the interaction effect is attenuating it. This finding is a counter to hypothesis 3. A possible explanation to this finding is the level of safety stock. As discussed, due to variability in demand, a safety stock is needed. However, when SBC and CBC are combined, there is a risk-pooling effect across the two complexities. Even though the level of complexity may be double, the safety stock to buffer the variability in raw material inventory does not necessarily need to be double (Chopra & Sodhi, 2004). Hence, the positive sign of the interaction effect. In addition, the slope of the model is less steep under high CBC than that under low CBC. As discussed, because of the opposing sign between the main and interaction effect and because of the imbalance effect sizes of SBC and CBC, the results suggest that CBC plays a more important role than SBC with respect to the attenuating impact. In other words, holding the SBC constant, a change in the CBC will have more total effect change on RMI turnover than a change in SBC, holding CBC constant. It is also important to note that the graph represents the actual condition of industry in the U.S. So, although the significant drop of RMI turnover happens in a low CBC and high SBC situation, the worst RMI turnover exists in a high CBC and high SBC situation.

In the low IT intensity subsample, all significant relationships from the interaction model remain significant. In particular, SBC and CBC variables are negatively associated with the RMI turnover while the interaction effect of SBC and CBC on RMI turnover is positive. In contrast, all significant relationships from the interaction model become insignificant in the high IT intensity subsample. Comparing both subsamples, the results suggest that the intensity of IT has a positive effect, which nullifies the negative impact of complexity on RMI turnover. In addition, supply base and customer base complexities tend to reduce RMI turnover when IT intensity is low. This finding is consistent with a recent study on IT which suggests that the level of IT intensity determines the level of variation between inventory levels and actual demand (Yao & Zhu, 2012). In particular, their results found an excessive inventory level in industries with a low level of IT intensity (Yao & Zhu, 2012). A review of statistical power also justifies this conclusion. That is, with 118 observations for each subsample, small to medium effect sizes can be detected, if any (Cohen, 1992). Among the three dependent variables of interest, one dependent variable is significant and therefore, hypothesis 4 is partially supported.

CONCLUSION

The objective of this study is to examine whether complexity in the supply base and customer base of an industry results in reduced performance as indicated in the raw material inventory turnover, finished goods inventory turnover, and return on sales. In addition, this study also examines whether IT intensity can mitigate the potential negative impact of complexity on those performance indicators. To achieve those objectives, several hypotheses are proposed and tested by constructing an econometric model based on a data set of U.S. manufacturing supply chains from the Annual Survey of Manufacturers and the Bureau of Economic Analysis. In sum, the results suggest that supply base complexity and customer base complexity have a negative impact on industry performance. Specifically, supply base complexity has a negative impact on raw material inventory turnover, while customer base complexity has a negative impact on raw material as well as finished goods inventory turnover. These findings are consistent with theory and literature.

Another important finding is that IT mitigates negative relationships between complexities and inventory turnover. As previously discussed, IT nullifies the negative impact of SBC on RMI turnover. Furthermore, IT also neutralizes the negative impact of CBC on RMI turnover and FGI turnover. These findings are also consistent with the literature which suggests that IT has the coordination, information sharing, and monitoring capabilities pertinent to complexity effect reduction.

Counter-hypothesis but interesting results are found in this study. Results show that the interaction of SBC and CBC is positively associated with RMI turnover. In other words, the presence of both complexities tends to reduce the RMI turnover at a slower rate, instead of multiplying the RMI turnover reduction. As previously discussed, this result suggests a pooling effect risk, where combination of supply base and customer base complexities do not necessarily need double safety stock inventory as a buffer.

Academic Contributions

Academic contributions of this study are twofold. First, with regards to complexity literature, this study has found sources of complexity in supply chain. In particular, supply base and customer base complexities are composed number suppliers and customers, respectively. Previous studies have proposed the idea of a number of partners in supply chain that may increase complexity due to an increased amount of transactions (Choi & Krause, 2006; Bozarth, et al., 2009). However, they could not find evidence linking the number of suppliers or customers to decreased performance. Furthermore, this study establishes a dependency exists between suppliers or customers and a focal manufacturer which contributes to increased complexity in the supply base and customer base. In sum, not only does this study find that the number of partners in a supply chain and dependency are key components of complexity in supply base and customer base, this study also finds a negative correlation between complexity and performance.

Second, with regards to IT literature, this study has found justification on how IT can help mitigate complexity issues. Although benefits of IT in a supply chain context have received much attention in Operations Management, IT, and SCM literature, studies at the nexus of IT and supply or customer base complexity are very limited. Findings in this study suggest that IT has indeed strong contributions to neutralize the potential negative impacts of complexity on industries' operational performance. However, there may be some IT examples that may not be compatible with certain conditions of supply base complexity as discussed previously.

Managerial Implications

Increased complexity in supply base and/or customer base is sometimes unavoidable in a highly competitive business environment. For example, Apple Inc. expanded its supply base to introduce more features in their new iPhone and iPad. At the same time, it expanded its customer base to increase its market by working with new cellular providers. This study illuminates the issue of complexity in this evolving business environment. Specifically, this study contributes by finding the potential negative impact of complexity on performance.

This study suggests that operational performance is directly affected by complexity. In particular, increased supply base complexity can reduce raw material inventory turnover. In addition, increased customer base complexity can reduce finished goods and raw material inventory turnover. Managers need to be aware of this particular impact because the extant literature exhibits examples how reduced operational performance relates to reduced financial performance. It is important to note also that combined complexity does not equal to double reduction in inventory turnover. This study shows that combined complexity tends to reduce inventory turnover but at a lower rate than each complexity individually.

Finally, this study suggests the use of IT to mitigate the potential negative impact of complexity. Specifically, IT can help neutralize the negative impact of complexity on inventory turnover. IT helps managers coordinate, monitor, and share information with their supply chain partners. However, managers need to be aware also that there may be certain type of IT examples that are not compatible with practices related to supply base complexity. Instead of reducing, IT may increase the negative effect of complexity on financial performance

Limitations and Future Research

This study has several limitations. First, although industry-level data has been proved useful by prior studies, such aggregate data falls short of providing a certain level of details needed to investigate complexities in supply base and customer base. Specifically, it would be useful to investigate complexities at firm level to understand a more realistic situation in a certain type of industry. Although data availability is a concern of this study, a following study can further investigate this issue to check if the same results hold.

Second, measures of IT are very general and broad. Because of data limitation, IT intensity is measured by capital expenditure of IT over sales. Such measure considers IT as a general variable and blends together different characteristics of IT into one variable. Literature suggests distinctions of IT based on purposes or based on characteristics. For example, IT can be used for transaction or collaboration (Rosenzweig, 2009; Saldanha, et al., 2013). IT can be also differentiated based on characteristics and capability such as application integration, data compatibility, analytic ability, and evaluation and alertness ability (Saeed, et al., 2011). Future result should decompose IT based on these characteristics and see whether the negative impact of IT on performance is indeed associated with a certain type of IT characteristic.

To summarize, this study attempts to find empirical evidence of complexities in a supply chain and their impact on performance. In addition, the role of IT to mitigate this issue is also examined. It is the hope of this study that the results and findings will stimulate more research in this important area and will be beneficial for practitioners.

Chapter 4

Conclusions

This dissertation contains two independent but related empirical studies; each of which explores roles of information technology in supply chain management. As discussed, SCIT is regarded as a key enabler of effective supply chain management activities. Businesses have seen a significant amount of investments in SCIT in the past. In 2013, $300 billion was spent on SCIT, and the trend is expected to increase (Gartner 2014). However, there has been a mix of evidence with some firms benefitting from SCIT while some others did not. In addition, there is no consensus in the literature with regards to firm performance implications of SCIT. Therefore, further investigating the roles of SCIT in supply chain management is particularly important. The objective of this dissertation is, therefore, to conduct a systemic investigation by examining the direct effect and indirect effect of SCIT on performance.

Table 4.1. Summary of Findings

Essay	Findings
Essay 1	• SCIT impact on firm performance is not a clear cut. • SCIT has multiple dimensions and each dimension has different impact on different performance outcomes.
Essay 2	• SCIT mitigates the negative impact of supply base and customer base complexity on RMI turnover and FGI turnover.

In Chapter 2, the first essay performs a meta-analysis study examining the direct impact of SCIT on firm performance, with regards to operational, market, and financial performance. In this study, SCIT is categorized into four major groups: application integration, data compatibility, analytic ability, and evaluation and alertness ability. Within each group, SCIT is differentiated into three sub-groups based on loci of use: upstream, downstream, and both upstream-downstream. Results show that SCIT is not universally associated with improved performance. For example, the evaluation and alertness ability type of SCIT is not associated with operational performance (e.g. cost, quality, delivery, and flexibility). In contrast, application integration is shown to have an association with a wide range of performance indicators regardless the context in which it is used.

In Chapter 3,the second essay in this dissertation investigates the indirect impact of SCIT on performance at the industry level. In this study, SCIT moderates the association between supply base complexity (SBC) and customer base complexity (CBC), and performance, with regards to raw material inventory turnover, finished goods inventory turnover, and return on sales. Results show that SBC and CBC are negatively associated with inventory turnover. The major finding in this study suggests that complexity is at the lowest when size of supply or customer base and the degree of dispersion are both low and thus, support the danger of complexity. Interestingly, when SBC and CBC co-exist, the negative impact on inventory turnover is not more detrimental than if SBC and CBC exist individually. This result shows the effect of risk pooling in inventory management. Results also suggest that SCIT positively impacts operational performance as measured by inventory turnover. In particular, SCIT neutralizes the negative impact of supply base and customer base complexity on inventory turnover.

Collectively, the two essays shed some light on the roles of information technology in supply chain management. SCIT positively impacts performance directly and indirectly through neutralizing the negative impact of supply base complexity and customer base complexity. Results also show that SCIT has multiple dimensions and characteristics. Each characteristic may have a different impact on different performance indicators. Consequently, when aggregated, the impact of SCIT may or may not be apparent.

THEORETICAL IMPLICATIONS

Findings from both essays in this dissertation provide several important implications to academia, which lead to multiple future research directions. First, the meta-analysis study from essay one provides a road map of underdeveloped research areas with regards to supply chain information technology. In addition, essay one also provides guidance of research areas in which moderating factors can be a mechanism that will conditionally change the relationship between SCIT and firm performance. Consequently, establishing this road map and highlighting the potential research areas serves as a catalyst for scholars to further contribute to literature, particularly in the area of supply chain management.

One example of a future research opportunity could be to investigate further of the analytic ability type of SCIT. Previous studies in SCM literature put too much attention to the integrative capability of SCIT and overlook the analytic ability. Nowadays, big data plays an important role in the business environment and will become even more important in the future (Waller & Fawcett, 2013). Over the last few years, the volume of data has exploded. In 15 of the U.S. economy's sectors, companies with more than 1,000 employees store, on average, over 235 terabytes of data, which is more data than is contained in the U.S. Library of Congress (Brown, et al., 2011). Anecdotal evidence shows how a sizeable U.S. firm's massive investment in its ability to collect, integrate, analyze data from customers had given it the ability to surpass the market leader (Brown, et al., 2011). This is a future research area that could be particularly fruitful to explore given the underdeveloped nature of the area.

Essay two also provides a foundation for future research opportunities. In particular, it provides an important contribution to scholars by offering a new and solid measure of supply base and customer base complexity. This area of research is particularly important given the increasing trend of firms having a more complex supply base and customer base. As discussed, this area of research is new and yet underdeveloped with a lack of empirical support from the literature. Literature suggests that in addition to cost, SBC, and CBC are also associated with risks, innovation, and supplier responsiveness (Choi & Krause, 2006). Findings from this study could be particularly interesting and valuable because of potential positive impacts of SBC and CBC.

Collectively, both essay one and two also provide future research opportunity. In essay two, we could not find support that SCIT significantly impacts financial performance by reducing or eliminating the negative impact of SBC and CBC. As discussed, SBC and CBC mainly hinder coordination and information sharing activities in the supply chain. Essay one provides us guidance to expect that application integration type of SCIT would be more suitable to manage these complexities. One possible future research opportunity is therefore to investigate if application integration can indeed help firms solve their complexity problems and help their financial performance.

MANAGERIAL IMPLICATIONS

Findings from this dissertation also provide important and valuable insight into the roles of information technology from a managerial perspective. In particular, essay one provides guidance on where firms should allocate its investments in order to achieve their intended objectives. As discussed, each characteristic of SCIT is linked to different performance indicators. In other words, SCIT is not a medicine for all diseases. Therefore, managers need to contemplate which performance measure they want to pursue, with regards to their competitive priority and competitive capability. For example, an investment in an analytic ability type of SCIT may be a good way to understand customer expectation. However, it may also lead to constant changes in operations which in turn, may harm operational performance. Our findings support that this scenario is true. Managers also need to be aware of the payback of their investment in SCIT. For example, our results show that evaluation and alertness ability is not related to operational performance but is related to market and financial performance. This finding suggests that SCIT with an evaluation and alertness ability has a long-term payback. Therefore, managers should not expect to see significant impact soon after the investment.

We have also shown that in general, SCIT with characteristics of application integration and data compatibility provides more benefits than other characteristics. This finding suggests managers adopt these types of SCIT if they would like to target multiple performance improvements in their operations. Our study also finds that extending the use to both upstream and downstream sides of the supply chain can better improve firm performance than utilizing to one side only. This finding is consistent with the previous study by Frohlich and Westbrook (2002).

We have also demonstrated in essay 2 that complexity in the supply base and the customer base can be detrimental to inventory performance. In particular, our results suggest that the inventory level increases to buffer from uncertainties due to an increasing complexity in the supply base and customer base. Since inventory costs are a major portion of operating expenses, having unnecessary and excessive inventory would be undesirable. The key finding in this study is that thelowest negative impact on inventory turnover is achieved under a low SBC and low CBC situation. However, our findings also provide a solution if complexity in the supply base or the customer base is unavoidable. In particular, the use of information technology should negate the negative impact of complexity on inventory turnover. Managers should use IT to share information with suppliers and customers about their plan to balance supply and demand. Such coordination activity should reduce uncertainty which would reduce the level of safety stock inventory. Moreover, essay one suggests that managers may want to consider application integration at both upstream and downstream sides of the supply chain to improve inventory performance.

LIMITATIONS

In sum, findings from this dissertation provide insight into future SCIT research, but certain limitations do exist. First, although we identify more than 70 potential researches that could be included in our meta-analysis, we only included 21 studies. As discussed, we were not able to collect the data necessary to compute correlations for the meta-analysis. A low response rate from researchers however, is a limitation in many meta-analyses of correlation studies (Mackelprang & Nair, 2010; Mackelprang, et al., 2014), and therefore, not a unique limitation of this dissertation. To increase the response rate, we have sent a wave of reminders using multiple modes (e.g. e-mail and telephone) to the researchers to participate in our study. In addition, we have also sought help from our network to connect with these researchers. And lastly, we attended conferences with the hope to be able to meet with them in person.

Second, we conducted essay two at the industry level of analysis, knowing that the firm-level analysis would be more desirable and would perhaps, provide more granularity into the results. However, there is no data currently available at the firm level to investigate the issue of supply base and customer base complexity in supply chain management. In addition, literature suggests that the complexity effect would also be reflected at the industry level (Choi & Krause, 2006). This limitation opens a future research opportunity that can be addressed.

FUTURE RESEARCH

There are many research opportunities open beyond the future research directions that we have delineated previously. In the beginning, we discussed that practitioners are skeptical about the value of SCIT. Investigating the value of SCIT will therefore be particularly important. One possible research opportunity includes investigating the product diversification strategy. The product diversification strategy has been discussed considerably in strategic management literature. A key finding in the discussion is that the product diversification strategy would provide suboptimal performance to firms when it is too low or too high. A potential research opportunity would be to investigate if SCIT could help firms with these trade-offs if firms want to expand their businesses.

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APPENDIX A

COMPLEXITY INDEX

			Supply Base Complexity Index			Customer Base Complexity Index		
No	Code	Commodity Description	Sup HHI	Count	SBC	Cust HHI	Count	CBC
1	321100	Sawmills and wood preservation	0.426	45	0.109	0.366	24	0.038
2	321200	Veneer, plywood, and engineered wood product manufacturing	0.150	54	0.194	0.127	40	0.088
3	321910	Millwork	0.132	68	0.249	0.525	32	0.038
4	3219A0	All other wood product manufacturing	0.097	96	0.366	0.293	30	0.053
5	327100	Clay product and refractory manufacturing	0.094	69	0.264	0.409	46	0.068
6	327200	Glass and glass product manufacturing	0.104	71	0.268	0.095	70	0.160
7	327310	Cement manufacturing	0.118	56	0.208	0.537	16	0.019
8	327320	Ready-mix concrete manufacturing	0.224	73	0.239	0.362	10	0.016
9	327330	Concrete pipe, brick, and block manufacturing	0.083	61	0.236	0.384	42	0.065
10	327390	Other concrete product manufacturing	0.068	64	0.252	0.453	27	0.037
11	327400	Lime and gypsum product manufacturing	0.119	53	0.197	0.175	44	0.091
12	327910	Abrasive product manufacturing	0.149	60	0.216	0.188	31	0.063
13	327991	Cut stone and stone product manufacturing	0.076	40	0.156	0.172	18	0.038
14	327992	Ground or treated mineral and earth manufacturing	0.111	38	0.143	0.547	250	0.285
15	327993	Mineral wool manufacturing	0.054	65	0.260	0.127	274	0.603
16	327999	Miscellaneous nonmetallic mineral products	0.113	68	0.254	0.171	44	0.092
17	331110	Iron and steel mills and ferroalloy manufacturing	0.167	73	0.257	0.122	77	0.170
18	331200	Steel product manufacturing from purchased steel	0.393	68	0.174	0.094	56	0.128
19	33131A	Alumina refining and primary aluminum production	0.162	56	0.198	0.085	93	0.214
21	33131B	Aluminum product manufacturing from purchased aluminum	0.397	48	0.122	1.000	1	0.000
22	331411	Primary smelting and refining of copper	0.390	31	0.080	0.715	13	0.009
23	331419	Primary smelting and refining of nonferrous metal (except copper and aluminum)	0.294	27	0.080	0.223	389	0.761
24	331420	Copper rolling, drawing, extruding and alloying	0.374	57	0.151	0.182	386	0.796
25	331490	Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying	0.213	55	0.183	0.312	386	0.669
26	331510	Ferrous metal foundries	0.145	63	0.227	0.061	117	0.277
27	331520	Nonferrous metal foundries	0.177	58	0.201	0.063	81	0.191
28	33211A	All other forging, stamping, and sintering	0.198	48	0.162	0.137	139	0.302
29	332114	Custom roll forming	0.709	46	0.056	0.086	226	0.520
30	33211B	Crown and closure manufacturing and metal stamping	0.194	74	0.252	0.062	109	0.258
31	332200	Cutlery and handtool manufacturing	0.152	72	0.257	0.048	213	0.511
32	332310	Plate work and fabricated structural product manufacturing	0.271	67	0.206	0.348	61	0.100
33	332320	Ornamental and architectural metal products manufacturing	0.192	77	0.262	0.102	76	0.172
34	332410	Power boiler and heat exchanger manufacturing	0.079	61	0.237	0.074	62	0.145
35	332420	Metal tank (heavy gauge) manufacturing	0.268	65	0.201	0.074	140	0.326
36	332430	Metal can, box, and other metal container (light gauge)	0.221	63	0.207	0.052	82	0.196

		manufacturing						
37	332500	Hardware manufacturing	0.081	71	0.275	0.046	223	0.536
38	332600	Spring and wire product manufacturing	0.186	61	0.209	0.240	32	0.061
39	332710	Machine shops	0.065	90	0.355	0.068	46	0.108
40	332720	Turned product and screw, nut, and bolt manufacturing	0.096	61	0.233	0.152	46	0.098
41	332800	Coating, engraving, heat treating and allied activities	0.135	67	0.244	0.082	56	0.129
42	33291A	Valve and fittings other than plumbing	0.074	66	0.258	0.036	280	0.680
43	332913	Plumbing fixture fitting and trim manufacturing	0.126	51	0.188	0.049	159	0.381
44	332991	Ball and roller bearing manufacturing	0.229	49	0.160	0.177	139	0.288
45	33299A	Ammunition, arms, ordnance, and accessories manufacturing	0.120	54	0.200	0.078	153	0.355
46	332996	Fabricated pipe and pipe fitting manufacturing	0.294	51	0.152	0.373	44	0.069
47	33299B	Other fabricated metal manufacturing	0.117	93	0.347	0.080	63	0.146
48	333111	Farm machinery and equipment manufacturing	0.061	72	0.285	0.093	118	0.270
49	333112	Lawn and garden equipment manufacturing	0.094	60	0.229	0.066	173	0.407
50	333120	Construction machinery manufacturing	0.066	71	0.280	0.041	141	0.341
51	333130	Mining and oil and gas field machinery manufacturing	0.104	70	0.265	0.076	156	0.363
52	33329A	Other industrial machinery manufacturing	0.047	82	0.330	0.028	177	0.433
53	333220	Plastics and rubber industry machinery manufacturing	0.049	66	0.265	0.099	154	0.349
54	333295	Semiconductor machinery manufacturing	0.089	74	0.284	0.033	204	0.497
55	33331A	Vending, commercial laundry, and other commercial and service industry machinery manufacturing	0.054	88	0.351	0.130	331	0.725
56	333313	Office machinery manufacturing	0.063	74	0.293	0.039	240	0.581
57	333314	Optical instrument and lens manufacturing	0.095	56	0.214	0.048	178	0.427
58	333315	Photographic and photocopying equipment manufacturing	0.058	61	0.242	0.172	70	0.146
59	33341A	Air purification and ventilation equipment manufacturing	0.092	71	0.272	0.197	56	0.113
60	333414	Heating equipment (except warm air furnaces) manufacturing	0.090	66	0.253	0.085	237	0.546
61	333415	Air conditioning, refrigeration, and warm air heating equipment manufacturing	0.099	84	0.319	0.036	197	0.478
62	333511	Industrial mold manufacturing	0.085	56	0.216	0.054	210	0.500
63	33351A	Metal cutting and forming machine tool manufacturing	0.069	64	0.252	0.013	358	0.890
64	333514	Special tool, die, jig, and fixture manufacturing	0.095	60	0.229	0.017	327	0.810
65	33351B	Cutting and machine tool accessory, rolling mill, and other metalworking machinery manufacturing	0.099	64	0.243	0.013	287	0.714
66	333611	Turbine and turbine generator set units manufacturing	0.078	57	0.222	0.045	232	0.558
67	333612	Speed changer, industrial high-speed drive, and gear manufacturing	0.122	49	0.181	0.088	52	0.119
68	333613	Mechanical power transmission equipment manufacturing	0.103	53	0.200	0.054	155	0.369
69	333618	Other engine equipment manufacturing	0.055	96	0.383	0.205	13	0.026
70	33391A	Pump and pumping equipment manufacturing	0.052	64	0.256	0.073	56	0.131
71	333912	Air and gas compressor manufacturing	0.061	68	0.270	0.045	390	0.938
72	333920	Material handling equipment manufacturing	0.064	69	0.272	0.446	29	0.040
73	333991	Power-driven handtool manufacturing	0.077	52	0.202	0.594	28	0.029
74	33399A	Other general purpose machinery manufacturing	0.045	74	0.298	0.369	38	0.060
75	333993	Packaging machinery manufacturing	0.067	58	0.228	0.333	19	0.032
76	333994	Industrial process furnace and oven manufacturing	0.135	46	0.168	0.381	78	0.122

77	33399B	Fluid power process machinery	0.108	50	0.188	0.539	16	0.019
78	334111	Electronic computer manufacturing	0.209	62	0.207	0.389	28	0.043
79	334112	Computer storage device manufacturing	0.298	54	0.160	0.405	171	0.256
80	33411A	Computer terminals and other computer peripheral equipment manufacturing	0.076	83	0.324	0.148	33	0.071
81	334210	Telephone apparatus manufacturing	0.133	72	0.263	0.307	32	0.056
82	334220	Broadcast and wireless communications equipment	0.352	71	0.194	0.298	22	0.039
83	334290	Other communications equipment manufacturing	0.059	58	0.230	0.209	47	0.094
84	334300	Audio and video equipment manufacturing	0.171	58	0.203	0.120	73	0.162
85	33441A	Other electronic component manufacturing	0.089	74	0.284	0.071	316	0.739
86	334413	Semiconductor and related device manufacturing	0.118	90	0.335	0.588	20	0.021
87	334418	Printed circuit assembly (electronic assembly) manufacturing	0.200	71	0.240	0.426	26	0.038
88	334510	Electromedical and electrotherapeutic apparatus manufacturing	0.047	59	0.237	0.636	34	0.031
89	334511	Search, detection, and navigation instruments manufacturing	0.069	87	0.342	0.117	286	0.636
90	334512	Automatic environmental control manufacturing	0.055	54	0.215	0.382	19	0.030
91	334513	Industrial process variable instruments manufacturing	0.043	60	0.242	0.070	58	0.136
92	334514	Totalizing fluid meter and counting device manufacturing	0.050	57	0.228	0.098	32	0.073
93	334515	Electricity and signal testing instruments manufacturing	0.146	58	0.209	0.104	90	0.203
94	334516	Analytical laboratory instrument manufacturing	0.048	61	0.245	0.302	49	0.086
95	334517	Irradiation apparatus manufacturing	0.079	47	0.183	0.338	48	0.080
96	33451A	Watch, clock, and other measuring and controlling device manufacturing	0.049	59	0.237	0.372	340	0.538
97	334610	Manufacturing and reproducing magnetic and optical media	0.117	54	0.201	0.293	41	0.073
98	335110	Electric lamp bulb and part manufacturing	0.138	36	0.131	0.311	352	0.611
99	335120	Lighting fixture manufacturing	0.051	59	0.236	0.460	8	0.011
100	335210	Small electrical appliance manufacturing	0.107	62	0.234	0.360	11	0.018
101	335221	Household cooking appliance manufacturing	0.082	62	0.240	0.061	69	0.163
102	335222	Household refrigerator and home freezer manufacturing	0.065	63	0.249	0.363	22	0.035
103	335224	Household laundry equipment manufacturing	0.103	49	0.186	0.168	66	0.138
104	335228	Other major household appliance manufacturing	0.077	61	0.237	0.123	261	0.576
105	335311	Power, distribution, and specialty transformer manufacturing	0.112	52	0.195	0.246	199	0.378
106	335312	Motor and generator manufacturing	0.060	72	0.286	0.204	196	0.393
107	335313	Switchgear and switchboard apparatus manufacturing	0.114	51	0.191	0.074	214	0.499
108	335314	Relay and industrial control manufacturing	0.081	59	0.229	0.398	76	0.115
109	335911	Storage battery manufacturing	0.364	59	0.158	0.082	330	0.763
110	335912	Primary battery manufacturing	0.158	50	0.178	0.174	261	0.543
111	335920	Communication and energy wire and cable manufacturing	0.314	65	0.188	0.081	262	0.607
112	335930	Wiring device manufacturing	0.079	57	0.221	0.509	27	0.033
113	335991	Carbon and graphite product manufacturing	0.229	35	0.114	0.235	25	0.048
114	335999	All other miscellaneous electrical equipment and component manufacturing	0.111	61	0.229	0.082	52	0.120
115	336111	Automobile manufacturing	0.095	90	0.344	0.288	109	0.195
116	336112	Light truck and utility vehicle manufacturing	0.090	90	0.345	0.168	85	0.178
117	336120	Heavy duty truck manufacturing	0.108	95	0.358	0.248	23	0.044

118	336211	Motor vehicle body manufacturing	0.088	68	0.262	0.415	31	0.046
119	336212	Truck trailer manufacturing	0.132	64	0.234	0.405	15	0.022
120	336213	Motor home manufacturing	0.163	71	0.251	0.214	84	0.166
121	336214	Travel trailer and camper manufacturing	0.064	71	0.280	0.061	127	0.300
122	336310	Motor vehicle gasoline engine and engine parts manufacturing	0.063	102	0.403	0.151	168	0.359
123	336320	Motor vehicle electrical and electronic equipment manufacturing	0.084	86	0.332	0.055	114	0.271
124	3363A0	Motor vehicle steering, suspension component (except spring), and brake systems manufacturing	0.060	105	0.417	0.604	46	0.046
125	336350	Motor vehicle transmission and power train parts manufacturing	0.068	103	0.405	0.443	13	0.018
126	336360	Motor vehicle seating and interior trim manufacturing	0.081	78	0.302	0.416	11	0.016
127	336370	Motor vehicle metal stamping	0.401	75	0.190	0.627	7	0.007
128	336390	Other motor vehicle parts manufacturing	0.065	119	0.469	0.137	21	0.046
129	336411	Aircraft manufacturing	0.150	73	0.262	0.411	181	0.269
130	336412	Aircraft engine and engine parts manufacturing	0.491	62	0.133	0.073	139	0.325
131	336413	Other aircraft parts and auxiliary equipment manufacturing	0.107	67	0.253	0.145	77	0.166
132	336414	Guided missile and space vehicle manufacturing	0.466	41	0.092	0.066	253	0.595
133	33641A	Propulsion units and parts for space vehicles and guided missiles	0.356	53	0.144	0.095	118	0.269
134	336500	Railroad rolling stock manufacturing	0.099	59	0.224	0.519	46	0.056
135	336611	Ship building and repairing	0.059	83	0.330	0.045	144	0.346
136	336612	Boat building	0.065	69	0.272	0.066	117	0.275
137	336991	Motorcycle, bicycle, and parts manufacturing	0.160	42	0.149	0.130	41	0.090
138	336992	Military armored vehicle, tank, and tank component manufacturing	0.329	49	0.139	0.315	96	0.166
139	336999	All other transportation equipment manufacturing	0.091	57	0.219	0.423	7	0.010
140	337110	Wood kitchen cabinet and countertop manufacturing	0.110	57	0.214	0.411	9	0.013
141	337121	Upholstered household furniture manufacturing	0.129	71	0.261	0.328	15	0.025
142	337122	Nonupholstered wood household furniture manufacturing	0.107	81	0.305	0.281	20	0.036
143	33712A	Other household nonupholstered furniture	0.077	67	0.261	0.768	6	0.004
144	337127	Institutional furniture manufacturing	0.053	65	0.260	0.780	3	0.002
145	33721A	Office furniture and custom architectural woodwork and millwork manufacturing	0.067	73	0.287	0.414	15	0.022
146	337215	Showcase, partition, shelving, and locker manufacturing	0.147	71	0.256	0.150	301	0.645
147	337900	Other furniture related product manufacturing	0.116	58	0.216	0.058	213	0.505
148	339112	Surgical and medical instrument manufacturing	0.106	73	0.275	0.083	274	0.633
149	339113	Surgical appliance and supplies manufacturing	0.042	91	0.368	0.205	314	0.629
150	339114	Dental equipment and supplies manufacturing	0.348	50	0.137	0.349	54	0.089
151	339115	Ophthalmic goods manufacturing	0.134	54	0.197	0.283	23	0.042
152	339116	Dental laboratories	0.361	43	0.116	0.115	305	0.680
153	339910	Jewelry and silverware manufacturing	0.380	54	0.141	0.292	14	0.025
154	339920	Sporting and athletic goods manufacturing	0.070	77	0.302	0.316	15	0.026
155	339930	Doll, toy, and game manufacturing	0.122	55	0.204	0.396	9	0.014
156	339940	Office supplies (except paper) manufacturing	0.090	61	0.234	0.211	8	0.016
157	339950	Sign manufacturing	0.051	68	0.272	0.199	7	0.014

158	339990	All other miscellaneous manufacturing	0.056	86	0.342	0.358	18	0.029
159	311111	Dog and cat food manufacturing	0.136	50	0.182	0.294	10	0.018
160	311119	Other animal food manufacturing	0.236	48	0.155	0.491	11	0.014
161	311210	Flour milling and malt manufacturing	0.742	27	0.029	0.507	13	0.016
162	311221	Wet corn milling	0.407	35	0.088	0.325	5	0.009
163	31122A	Soybean and other oilseed processing	0.665	42	0.059	0.373	45	0.071
164	311225	Fats and oils refining and blending	0.349	43	0.118	0.207	56	0.112
165	311230	Breakfast cereal manufacturing	0.127	53	0.195	0.807	14	0.007
166	311300	Sugar and confectionery product manufacturing	0.148	63	0.227	0.783	8	0.004
167	311410	Frozen food manufacturing	0.088	58	0.223	0.681	35	0.028
168	311420	Fruit and vegetable canning, pickling, and drying	0.075	70	0.273	0.568	39	0.042
169	31151A	Fluid milk and butter manufacturing	0.487	67	0.145	0.415	13	0.019
170	311513	Cheese manufacturing	0.458	59	0.135	0.265	81	0.150
171	311514	Dry, condensed, and evaporated dairy product manufacturing	0.292	53	0.158	0.736	25	0.017
172	311520	Ice cream and frozen dessert manufacturing	0.082	53	0.205	0.274	32	0.059
173	31161A	Animal (except poultry) slaughtering, rendering, and processing	0.348	48	0.132	0.115	96	0.214
174	311615	Poultry processing	0.459	50	0.114	0.304	10	0.018
175	311700	Seafood product preparation and packaging	0.432	45	0.108	0.789	44	0.023
176	311810	Bread and bakery product manufacturing	0.061	68	0.270	0.984	6	0.000
177	3118A0	Cookie, cracker, pasta, and tortilla manufacturing	0.109	64	0.241	0.523	80	0.096
178	311910	Snack food manufacturing	0.085	62	0.239	0.555	97	0.109
179	311920	Coffee and tea manufacturing	0.330	28	0.079	0.717	24	0.017
180	311930	Flavoring syrup and concentrate manufacturing	0.202	46	0.155	0.193	291	0.592
181	311940	Seasoning and dressing manufacturing	0.070	58	0.228	0.784	18	0.010
182	311990	All other food manufacturing	0.070	68	0.267	0.177	233	0.483
183	312110	Soft drink and ice manufacturing	0.177	59	0.205	0.841	11	0.004
184	312120	Breweries	0.151	56	0.201	0.242	28	0.053
185	312130	Wineries	0.164	39	0.138	0.119	41	0.091
186	312140	Distilleries	0.238	31	0.100	0.063	58	0.137
187	312200	Tobacco product manufacturing	0.254	53	0.167	0.102	58	0.131
188	313100	Fiber, yarn, and thread mills	0.385	40	0.104	0.142	49	0.106
189	313200	Fabric mills	0.133	62	0.227	0.781	19	0.010
190	313300	Textile and fabric finishing and fabric coating mills	0.135	41	0.150	0.412	51	0.076
191	314110	Carpet and rug mills	0.308	41	0.120	0.581	36	0.038
192	314120	Curtain and linen mills	0.221	35	0.115	0.409	42	0.062
193	314900	Other textile product mills	0.155	48	0.171	0.405	39	0.058
194	315000	Apparel manufacturing	0.239	50	0.161	0.194	44	0.089
195	316000	Leather and allied product manufacturing	0.165	49	0.173	0.236	44	0.085
196	322110	Pulp mills	0.116	45	0.168	0.161	30	0.063
197	322120	Paper mills	0.068	76	0.299	0.276	80	0.146
198	322130	Paperboard mills	0.086	67	0.258	0.355	35	0.057
199	322210	Paperboard container manufacturing	0.327	53	0.150	0.187	31	0.064

200	322220	Paper bag and coated and treated paper manufacturing	0.118	53	0.197	0.663	43	0.036
201	322230	Stationery product manufacturing	0.222	44	0.144	0.721	35	0.025
202	322291	Sanitary paper product manufacturing	0.109	37	0.139	0.638	42	0.038
203	322299	All other converted paper product manufacturing	0.135	42	0.153	0.325	40	0.068
204	323110	Printing	0.081	74	0.287	0.278	31	0.056
205	323120	Support activities for printing	0.056	39	0.155	0.374	44	0.069
206	324110	Petroleum refineries	0.891	71	0.033	0.471	47	0.063
207	324121	Asphalt paving mixture and block manufacturing	0.374	65	0.172	0.778	43	0.024
208	324122	Asphalt shingle and coating materials manufacturing	0.303	36	0.106	0.753	31	0.019
209	324190	Other petroleum and coal products manufacturing	0.174	46	0.160	0.580	26	0.028
210	325110	Petrochemical manufacturing	0.394	54	0.138	0.372	32	0.051
211	325120	Industrial gas manufacturing	0.138	66	0.240	0.759	5	0.003
212	325130	Synthetic dye and pigment manufacturing	0.158	55	0.195	0.141	31	0.067
213	325180	Other basic inorganic chemical manufacturing	0.096	62	0.237	0.076	95	0.221
214	325190	Other basic organic chemical manufacturing	0.239	82	0.263	0.050	82	0.196
215	325211	Plastics material and resin manufacturing	0.257	67	0.210	0.353	48	0.078
216	3252A0	Synthetic rubber and artificial and synthetic fibers and filaments manufacturing	0.157	49	0.174	0.521	36	0.043
217	325310	Fertilizer manufacturing	0.228	37	0.121	0.105	173	0.390
218	325320	Pesticide and other agricultural chemical manufacturing	0.313	52	0.151	0.807	78	0.038
219	325411	Medicinal and botanical manufacturing	0.280	56	0.170	0.733	54	0.036
220	325412	Pharmaceutical preparation manufacturing	0.200	60	0.202	0.274	12	0.022
221	325413	In-vitro diagnostic substance manufacturing	0.252	57	0.180	0.120	295	0.654
222	325414	Biological product (except diagnostic) manufacturing	0.439	49	0.116	0.170	365	0.763
223	325510	Paint and coating manufacturing	0.116	58	0.216	0.011	373	0.929
224	325520	Adhesive manufacturing	0.094	52	0.199	0.052	377	0.900
225	325610	Soap and cleaning compound manufacturing	0.182	61	0.210	0.262	130	0.242
226	325620	Toilet preparation manufacturing	0.074	65	0.254	0.298	41	0.073
227	325910	Printing ink manufacturing	0.207	32	0.107	0.063	92	0.217
228	3259A0	All other chemical product and preparation manufacturing	0.082	82	0.317	0.047	202	0.485
229	326110	Plastics packaging materials and unlaminated film and sheet manufacturing	0.368	57	0.152	0.155	40	0.085
230	326120	Plastics pipe, pipe fitting, and unlaminated profile shape manufacturing	0.552	45	0.085	0.134	389	0.848
231	326130	Laminated plastics plate, sheet (except packaging), and shape manufacturing	0.154	42	0.150	0.143	53	0.114
232	326140	Polystyrene foam product manufacturing	0.274	56	0.172	0.159	34	0.072
233	326150	Urethane and other foam product (except polystyrene) manufacturing	0.086	63	0.243	0.081	302	0.699
234	326160	Plastics bottle manufacturing	0.407	43	0.108	0.209	127	0.253
235	326190	Other plastics product manufacturing	0.239	106	0.341	0.049	160	0.383
236	326210	Tire manufacturing	0.119	63	0.234	0.115	116	0.259
237	326220	Rubber and plastics hoses and belting manufacturing	0.118	44	0.164	0.078	173	0.402
238	326290	Other rubber product manufacturing	0.075	69	0.269	0.104	353	0.797

APPENDIX B

ASM VARIABLES DEFINITION

Capital expenditures for new and used plant and equipment - Represents the total new and used capital expenditures reported by establishments in operation and any known plants under construction.

- Computers and peripheral data processing equipment. This item includes all purchases of computers and related equipment.

Cost of materials - This term refers to direct charges actually paid or payable for items consumed or put into production during the year, including freight charges and other direct charges incurred by the establishment in acquiring these materials. It includes the cost of materials or fuel consumed, whether purchased by the individual establishment from other companies, transferred to it from other establishments of the same company, or withdrawn from inventory during the year. Included in total cost of materials are:

1. Cost of parts, components, containers, etc. Includes all raw materials, semifinished goods, parts, containers, scrap, and supplies put into production or used as operating supplies and for repair and maintenance during the year.
2. Cost of products bought and sold in the same condition.
3. Cost of fuels consumed for heat and power. Includes the cost of materials or fuel consumed, whether purchased by the individual establishment from other companies, transferred to it from other establishments of the same company, or withdrawn from inventory during the year.
4. Cost of purchased electricity. The cost of purchased electric energy represents the amount actually used during the year for heat and power. In addition, information was collected on the quantity of electric energy generated by the establishment and the quantity of electric energy sold or transferred to other plants of the same company.
5. Cost of contract work. This term applies to work done by others on materials furnished by the manufacturing establishment. The actual cost of the material is to be reported on the cost of materials, parts, and containers line of this item. The term "Contract Work" refers to the fee a company pays to another company to perform a service.

Duplication in cost of materials and value of shipments - The aggregate of the cost of materials and value of shipments figures for industry groups and for all manufacturing industries includes large amounts of duplication, since the products of some industries are used as materials by others. This duplication results, in part, from the addition of related industries representing successive stages in the production of a finished manufactured product. Examples are the addition of flour mills to bakeries in the food group and the addition of pulp mills to the paper manufacturing group of industries. Estimates of the overall extent of this duplication indicate that the value of manufactured products exclusive of such duplication (the value of finished manufactures) tends to approximate twothirds of the total value of products reported in the annual survey. Duplication of products within individual industries is significant within a number of industry groups, e.g., machinery and transportation industries. These industries frequently include complete machinery and their parts. In this case, the parts made for original equipment are materials consumed for assembly plants in the same industry. Even when no significant amount of duplication is involved, value of shipments figures are deficient as measures of the relative economic importance of individual manufacturing industries or geographic areas because of the wide variation in ratio of materials, labor, and other processing costs of value of shipments, both among industries and within the same industry.

Number of Employees - This item includes all full-time and part-time employees on the payrolls of operating manufacturing establishments during any part of the pay period that included the 12th of March, June, September, and December. Included are employees on paid sick leave, paid holidays, and paid vacations; not included are proprietors and partners of unincorporated businesses. The ‘‘all employees’’ number is the average number of production workers plus the number of other employees in mid-March.

Payroll - This item includes the gross earnings of all employees on the payrolls of operating manufacturing establishments paid in the calendar year. Respondents are told they could follow the definition of payrolls used for calculating the federal withholding tax. It includes all forms of compensation, such as salaries, wages, commissions, dismissal pay, bonuses, vacation and sick leave pay, and compensation in kind, prior to such deductions as employees’ social security contributions, withholding taxes, group insurance, union dues, and savings bonds. The total includes salaries of officers of corporations; it excludes payments to proprietors or partners of unincorporated concerns. Also excluded are payments to members of Armed Forces and pensioners carried on the active payrolls of manufacturing establishments. The census definition of payrolls is identical to that recommended to all federal statistical agencies by the Office of Management and Budget. It should be noted that this definition does not include employers’ social security contributions or other nonpayroll labor costs, such as employees’ pension plans, group insurance premiums, and workers’ compensation. The Annual Survey of Manufactures (ASM) provides estimates of employers’ total supplemental labor costs (those required by federal and state laws and those incurred voluntarily or as part of collective bargaining agreements).

Total beginning and end of year inventories - - These items are comprised of:

1. Finished goods
2. Work-in-process
3. Materials, supplies, fuels, etc.

Materials inventories refer to goods that are raw inputs to the manufacturing process, and that will be substantially altered to produce an establishment's output. Work-in-process inventories refer to goods that have been substantially transformed in the manufacturing process, but that are not yet the final output of the establishment. Finished goods are goods that represent the final output of the establishment, but that are still within ownership of the establishment.

Total Fringe Benefits - This item is the employer's costs for social security tax, unemployment tax, workmen's compensation insurance, state disability insurance pension plans, stock purchase plans, union-negotiated benefits, life insurance premiums, and insurance premiums on hospital and medical plans for employees. Fringe benefits are divided into legally required expenditures and payments for voluntary programs. The legally required portion consists primarily of federal old age and survivors' insurance, unemployment compensation, and workers' compensation. Payments for voluntary programs include all programs not specifically required by legislation, whether they are employer initiated or the result of collective bargaining. They include the employer portion of such plans as insurance premiums, premiums for supplemental accident and sickness insurance, pension plans, supplemental unemployment compensation, welfare plans, stock purchase plans on which the employer payment is not subject to withholding tax, and deferred profit-sharing plans. They exclude such items as company-operated cafeterias, in-plant medical services, free parking lots, discounts on employee purchases, and uniforms and work clothing for employees.

Value added - This measure of manufacturing activity is derived by subtracting the cost of materials, supplies, containers, fuel, purchased electricity, and contract work from the value of shipments (products manufactured plus receipts for services rendered). The result of this calculation is adjusted by the addition of value added by merchandising operations (i.e., the difference between the sales value and the cost of merchandise sold without further manufacture, processing, or assembly) plus the net change in finished goods and work-in-process between the beginning- and end-of-year inventories. For those industries where value of production is collected instead of value of shipments, value added is adjusted only for the change in work-in-process inventories between the beginning and end of year. For those industries where value of work done is collected, the value added does not include an adjustment for the change in finished goods or work-in-process inventories. "Value added" avoids the duplication in the figure for value of shipments that results from the use of products of some establishments as materials by others. Value added is considered to be the best value measure available for comparing the relative economic importance of manufacturing among industries and geographic areas.

Value of product shipments - Includes the total value of all products produced and shipped by all producers, not just those with values of $100,000 or more. However, for selected products, this can represent value of receipts, value of production, or value of work done.