THE IMPACT OF INFORMATION TECHNOLOGY ON SUPPLY CHAIN PERFORMANCE: A KNOWLEDGE MANAGEMENT PERSPECTIVE

by

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ABSTRACT

YUAN NIU. The impact of information technology on supply chain performance: a knowledge management perspective (Under direction of DR. CHANDRASEKAR SUBRAMANIAM AND DR. ANTONIS STYLIANOU)

Supply chain management has become an increasingly important management tool to help organizations improve their business operations. Although information and communication technologies have been used extensively in supply chains, there is a lack of systematic evidence regarding the mechanisms through which IT creates value. Furthermore, as supply chain objectives are going beyond operational efficiency towards pursuing higher-order goals, such as understanding the market dynamics and discovering new partnering arrangements to provide greater customer value, the capabilities that are needed for supply chains to sustain their competitive advantages need to be well understood by researchers and practitioners. To fill this gap, this research investigates the effects of the supply chain's collective knowledge management capability on the supply chain performance. Drawing from the resource-based view of the firm and the relational view of firm's competitive advantage, this dissertation proposes a framework of supply chain IT capability as facilitating/inhibiting the supply chain's knowledge management capability. First, an empirical study using survey-based data collection was conducted. Second, a simulation model was built to investigate the mechanisms through which IT-enabled knowledge management activities affect firms' long-term knowledge outcome.

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CHAPTER 1: INTRODUCTION

1.1 Background

Supply chain management (SCM) has been noted as an increasingly important management field to help enterprises improve supply chain operations (Markus 2000). SCM involves the flows of material, information, and finance in a network consisting of suppliers, manufacturers, distributors, and customers. In the past decade, we have witnessed a shift in interorganizational relationships away from traditional market-based arm's-length relationships to strategic partnership-like relationships (Bensaou 1997; Scott 2000). In fact, both the academic literature and the practitioner literature have noted that business competitions in a number of industries are no longer between individual firms, but rather between supply chains (e.g., Lambert and Cooper 2000; Oh and Rhee 2008; Straub et al. 2004). One of the fundamental reasons that cause the paradigm shift in supply chain (SC) relationships is the advent of a knowledge-intensive economy. The value of most products and services in a knowledge-intensive economy depends primarily on the development of knowledge-based intangibles, like technological know-how, product design, marketing, preferences of customers, and understanding of value-added networks. As new product development becomes more complex and market environments become more dynamic and competitive, it is likely that the knowledge and information needed to deliver value to the end customers are no longer confined in a single firm (Hult et al. 2004; Inkpen and Dinur 1998; Lincoln et al. 1998). Firms that develop the competency of managing knowledge resources transcending organizational borders will be rewarded with higher economic benefits (Van de Ven 2005). For example, Motorola effectively reduced the stock-out rate of its inventory of mobile phone handsets by collaborating with its retailers to share and utilize the knowledge on product plans, exceptions, and forecasts (Cederlund et al. 2007).

Researchers who study the strategic impacts of knowledge management have noted the criticality of knowledge and knowledge management in building an effective supply chain relationship and in achieving positive supply chain performance. For instance, Jarvenpaa and Tanriverdi (2003) propose that knowledge creation is a key to a firm's survival and to its value chain's competitiveness. Hult et al. (2004) conclude that the knowledge development process in a strategic supply chain, which consists of knowledge acquisition activities, knowledge distribution activities, and formation of shared meaning, is an important predecessor to supply chain efficiency as measured by cycle time. Despite the emphasis on the role of knowledge in supply chains, there has been a lack of systematic understanding of what constitutes a supply chain's knowledge management capability and how to build knowledge management capability in supply chains (Gunasekaran and Ngai 2007).

Developing supply chain knowledge management capability that is difficult to imitate by other supply chain partnerships requires supply chain firms to take a relationship-oriented view toward their supply chain operations, such as aligning goals and activities involved in the supply chain (Im and Rai 2008). However, due to the amalgamation of skills and interests of multiple enterprises in a supply chain, combining and exchanging knowledge can be difficult and politically demanding for the supply chain companies involved (Van de Ven 2005). One of the difficulties in managing knowledge in supply chains can be ascribed to the competing, and sometimes conflicting, goals of firms. Firms forming knowledge-based networks can be heterogeneous in terms of size, industry, and organizational structures. These differences lead to discrepancies in the results that partnering firms expect from the supply chain. For example, a small supplier whose primary focus is operational excellence may be more likely to improve its order-interface related knowledge and may not be interested in accumulating product knowledge or customer knowledge. Therefore, it is essential for the supply chain partners to create effective underlying organizational and technological infrastructures to support the exploitation of the knowledge management capability of the supply chain.

In supply chains, the use of information and communication technologies has been shown to exert great impact on SC operational efficiency (Lee 2000) and to sustain the network of relationships (Saraf et al. 2007). Information technologies (IT) used for SCM, including supply chain management systems (SCMS), Internet/Web, electronic data interchange (EDI), ratio frequency identification (RFID), and mobile technologies, allow firms to exchange timely information, carry out plans precisely and perform various SC functions and activities efficiently. For example, EDI technologies, which have been used in supply chain management for many decades, automate transactions between two trading partners. Nonetheless, the theoretical and empirical research regarding the role of supply chain IT in facilitating/inhibiting a supply chain's ability to manage knowledge is scarce (Malhotra et al. 2005). As supply chain relationships are going beyond price-focused, arm's-length relationships and becoming knowledge-driven, collaborative relationships (Van de Ven 2005), it is important to understand how supply chains can harness IT in building the capabilities of managing knowledge resources.

To this end, this dissertation attempts to understand the role of supply chain IT infrastructure in bringing supply chain firms together and facilitating the creation of the knowledge management capability of the supply chain.

1.2 Research Objectives and Research Questions

A central objective of this dissertation is to understand the impact of supply chain knowledge management capability facilitated by supply chain IT on the supply chain's performance. The resource-based view and its extension – the relational view, which addresses competitive advantages of firms in interorganizational relationships, were drawn upon as the theoretical foundation. Specifically, the first objective of the dissertation is to understand the role of supply chain IT infrastructure in facilitating/inhibiting the knowledge management capability of supply chains, and in turn its impact on the supply chain performance. An empirical research method was used to investigate the research questions raised to fulfill this objective. The second research objective focuses on understanding a particular type of IT used in supply chains – the IT for knowledge management activities and its impact on long-term knowledge outcome of firms in a supply chain. A computer simulation approach was used to model KM IT and to investigate the mechanisms through which KM IT affect firms' average employee knowledge level. Achieving this objective allows a nuanced understanding of the use of KM IT in supply chains to develop by taking into account the complexity in the real world.

The overarching research question posed by this dissertation concerns the impact of the knowledge management capability enabled by IT used in supply chains. Specific research questions include:

1) What does the KM capability of a supply chain constitute and how does the KM capability of the supply chain impact the supply chain's performance?

2) How does the SC IT infrastructure capability affect the knowledge management capability of the supply chain?

3) What roles do KM ITs play in affecting the knowledge performance of firms in the supply chain?

1.3 Contributions

This dissertation study is expected to make several contributions to both research and practice. On the theoretical front, the first contribution of the dissertation is the development of a theoretical construct for SC KM capability. Previous research studying the relationship between KM and organizational performance has focused on the KM capability of a single organization (Gold et al. 2001; Tanriverdi 2005). In a supply chain where the supply chain partners are not all from the same organization, knowledge can be an important source of coordination (Hansen 2002), and thus be central to supply chain functioning. Understanding how supply chain firms can harness knowledge resources across organizational boundaries will help build theory that explains the role of KM in supply chain value creation.

The second contribution of the dissertation to the IS research is that the dissertation will advance our understanding of the linkage between IT capability and supply chain performance. The relationship between the use of IT and organizational performance has always been a subject that researchers in the IT value research stream are trying to explain. By investigating the relationship between IT capability of a supply chain and the supply chain's performance through the lens of a knowledge management perspective, the dissertation hopes to shed new light on the IT business value research.

The third theoretical contribution of the dissertation is that the computational simulation study will lay a foundation for theory building in IT-enabled inter-organizational KM. It is believed that the use of IT for KM in supply chain management is a highly relevant but under-researched area in IS (Scott 2000). Using a simulation approach to model KM IT use in supply chains, the dissertation extends research studying IT-enabled KM in a single organization (Kane and Alavi 2007) to inter-organizational contexts.

The findings of this dissertation will also be of significance and relevance to supply chain management professionals. First, in today's fast-changing business environment, firms in a supply chain cannot afford to operate as separate entities with little understanding of the customers, technologies and business processes subsumed in the competitive environment. This research will help firms develop supply chain strategies that maximize knowledge-based synergies between the firms and their business partners. Second, developing and leveraging knowledge resources allows supply chains to be more responsive to market requirements. This dissertation will help to improve practitioners' understandings of how knowledge management capabilities can be leveraged to derive supply chain performance in terms of operational and strategic benefits. Finally, the exploitation of IT capabilities provides supply chain firms with a foundation to create knowledge management initiatives. Understanding how IT supports knowledge activities in supply chains will allow supply chain professionals to effectively use and manage the portfolio of IT resources in firms.

1.4 Organization of the Dissertation

This dissertation consists of two components – an empirical study investigating the relationship between supply chains' IT capability and supply chains' KM capability, and a computational simulation study exploring the mechanisms by which knowledge management enabled by KM ITs in supply chains impact firms' long-term knowledge outcome.

The organization of the dissertation is as follows. Chapter 2 is a literature review covering the research streams that shed light on both studies. Chapter 3 and Chapter 4 present the empirical study and the simulation study, respectively. For each study, its research background, research model, methodology, results and future research are described. Chapter 5 summarizes the findings of the two studies and offers a conclusion to the dissertation.

1.5 Dissemination Plan

The completed dissertation will result in three journal publications. The empirical research in this dissertation can be divided into two studies, each forming an individual journal article. The first empirical paper will focus on presenting the impacts of supply chain IT capability on the supply chain's KM capability. The main research question that will be addressed in this paper is how supply chain IT facilitates or inhibits the supply chain's knowledge management capability. The working title of the first paper is "An Empirical Investigation of Information Technology Impact on Supply Chain Knowledge Management Capability." Because the theoretical constructs examined by the first study are of high relevance and value to the IS research community, we plan to target the first publication at the IS journals such as MIS Quarterly, Information Systems Research, the Journal of Management Information Systems, and Decision Sciences. The second empirical paper will be positioned with a research focus on the relationship between supply chain's KM capability and the supply chain's performance. This paper will address research questions including "How should supply chain firms manage knowledge needed in the supply chain as an inter-organizational resource?", and "What impact does the knowledge management capability of a supply chain have on the supply chain's performance?" The working title of the second paper is "Understanding Supply Chain Knowledge Management Capabilities and their Impact on Supply Chain Performance". This paper will help researchers understand the knowledge management factors that are important to supply chain performance. Further, this paper will benefit practitioners by identifying appropriate knowledge management capability in their supply chains in order to improve the supply chain performance. This paper will be of particular interest to audiences in the management science and operations management research community. Appropriate venues for publishing the second study include journals such as Management Science, the Journal of Operations Management, and the Journal of Supply Chain Management. Finally, the simulation study aims to understand the role of KM ITs in affecting firms' knowledge outcomes when firms learn from their supply chain partners. This paper will target IS journals, such as ISR and JMIS, or journals in organizational sciences, which are accepting of the use of simulation as a research method. The working title of the third publication is "Bridging Gaps in Organizational Knowledge - The Role of IT-Facilitated Organizational Learning in Supply Chain Partnerships." TABLE 1-1 summarizes the publication plan for the dissertation.

TABLE 1-1. Publication Plan

Working Titles of Publications	**Research Questions**	**Planned Publication Venues**
An Empirical Investigation of Information Technology Impact on Supply Chain Knowledge Management Capability	How does supply chain IT facilitate or inhibit the supply chain's knowledge management capability?	• MISQ • ISR • JMIS • Decision Sciences
Understanding Supply Chain Knowledge Management Capabilities and their Impact on Supply Chain Performance	How do supply chain firms manage knowledge needed in the supply chain as an inter-organizational resource? What impact does the knowledge management capability of a supply chain have on the supply chain's performance?	• Management Science • Journal of Operations Management • Journal of Supply Chain Management
Bridging Gaps in Organizational Knowledge - The Role of IT-Facilitated Organizational Learning in Supply Chain Partnerships	How does the use of KM ITs in a supply chain affect the performance of partnering firms?	• ISR • JMIS • Organizational Sciences

CHAPTER 2: LITERATURE REVIEW

IT has been shown as an effective means to manage organizational knowledge. As knowledge management becomes increasingly important to supply chains, the role of IT in building supply chains' knowledge management capabilities deserves research attention. To understand the complex phenomenon of using IT to manage knowledge in supply chains, this dissertation based its theoretical advancement on three distinct, but increasingly converging, streams of literature. First, the IT business value literature provides foundations for the conceptualization of IT capabilities and how business value can be derived from those capabilities. Next, the IOS and SCM literature offer insights about the factors influencing the IT implementation in SC and how IT has improved the efficiency of supply chains. Third, the knowledge management literature is a confluent of research from IS, management, organizational learning, and strategic management. It contributes to our understanding of the use of IT in improving knowledge management processes in organizational as well as interorganizational contexts.

2.1 IT Business Value

IT business value research examines the organizational performance impacts of IT (Melville et al. 2004). IS researchers formulate performance in terms of efficiency and effectiveness (Melville et al. 2004). Efficiency emphasizes the internal perspectives employing metrics such as cost reduction and productivity improvement, or "doing better at what they do" (Barua et al. 1995). Effectiveness, on the other hand, focuses on the achievement of organizational objectives in relation to a firm's external environment, or the attainment of competitive advantage (Barney 1991).

2.1.1 Three Research Streams

With the rapid growth of IT investments in organizations, researchers as well as practitioners feel the urge to understand the contribution of IT to organizational performance. Different streams of IT business value research have different views toward IT artifacts. Specifically, IT is treated as embodiment of particular functions, such as monetary investments (e.g., Hitt and Brynjolfsson 1996; Weill 1992), as strategic information systems (e.g., Banker and Kauffman 1991; Clemons and Weber 1990; Wade and Hulland 2004), or as organizational capabilities (e.g., Bharadwaj 2000; Sambamurthy et al. 2003).

IS researchers studying the relationship between IT investments and firm performance have adopted various microeconomic theoretical perspectives, including production theory (Brynjolfsson and Hitt 1995; Melville et al. 2004), consumer theory (Hitt and Brynjolfsson, 1996) and option-pricing models (Benaroch and Kauffman 1999; Melville et al. 2004). In this stream of research, IT investments have been shown to exhibit positive, negative, or no impact on firm performance (Barua et al. 1995; Hitt and Brynjolfsson 1996; Kohli and Devaraj 2003). The discrepancies in research results encouraged researchers to ponder the way in which this stream of research has been conducted. Some researchers suggest that to better trace the economic benefits of IT, scientific investigations should be made at the place where IT is used. For example, Barua et al. (1995) adopt a process-oriented methodology in measuring IT impacts and find that IT contributes significantly at the intermediate level (strategic business units).

Kohli and Devaraj (2003) conduct a meta-analysis to reconcile the mixed results in establishing a relationship between IT investment and firm performance. They discover that the factors that are likely to cause conflicting views of IT value include the sample size, the industry studied, whether the study is cross-sectional or longitudinal, and the choice of dependent variables. Findings from the economic value of IT research stream contribute to the general IT value research by identifying the intermediate business processes through which IT affects an organization's economic performance.

Research of strategic information systems focuses on the ability of strategic IT to reduce costs or differentiate firms' products or services. For example, American Airline's computer reservation system SABRE and American Hospital Supply's ASAP generated increased business volume and above average profits, thus becoming direct contributors of competitive advantage (Copeland and McKenney 1988; Short and Venkatraman 1992; Wade and Hulland 2004). Critics of this stream of research claim that it focuses only on the systems themselves while overlooking the socially complex organizational environment where the systems are embedded (Barney 1991; Mata et al. 1995). Overemphasis on specific information systems alone however, is insufficient to obtain sustained competitive advantage due to ease of imitation by other firms. After all, the technologies can usually be purchased from the market. So it is unlikely that technology itself can be a source of sustained competitive advantage (Barney 2001).

Increasingly, IS researchers treat the central construct of IT as an organizational capability (Mata et al. 1995; Bharadwaj 2000; Wade and Hulland 2004; Barua et al. 2004; Rai et al. 2006; Sambamurthy et al. 2003; Ravichandran and Lertowngsatien 2005). This view of IT suggests that various IT-related resources can be combined to form organizational IT capabilities that are valuable, rare, nonimitable and nonsubstitutable. Unlike many of the strategic systems in their early years, the modern modular and interoperable design of IT makes it difficult for firms to establish entry barriers that are based solely on proprietary technologies. Therefore, the capability view of IT argues that, instead of the specific information systems, it is the capabilities afforded by the information systems that generate sustained competitive advantages for the firms. The theoretical foundation for the capability view of IT is the resource-based view of the firm (RBV). The RBV emphasizes the importance of building unique, inimitable and heterogeneously distributed capabilities as sources of competitive advantage. Grounded in RBV, researchers studying IT value are able to establish positive links between IT and firm performance (e.g., Bharadwaj 2000). This dissertation adopts the capability view of IT to study the impact of interorganizational IT on supply chain performance.

2.1.2 The Resource-based View of the Firm and Its Application in the IT Value Research

The resource-based view of the firm (Barney 1991) has been widely adopted by organizational researchers to examine the efficiency and competitive advantage implications of firm resources. It argues that resources are heterogeneously distributed across firms, a subset of these resources enables firms to achieve competitive advantage and a further subset leads to superior long-term performance (Barney 1991; Amit and Schoemaker 1993). Barney (1991) describes four attributes required of a resource to generate a competitive advantage. The four attributes are value, rareness, inimitability and non-substitutability. First of all, the resource has to be valuable in order for the firm to gain benefits. Moreover, if the valuable resource is rare, a temporary competitive advantage will be generated so long as the competitors of the firm do not have the resource. Only if the valuable and rare resource is imperfectly imitable and there are no readily available substitutes can the firm obtain a sustained competitive advantage.

One of the key tasks of RBV theorists is to define what is meant by a resource. The RBV research has proliferated with different definitions and classifications of the key terminology (Wade and Hulland 2004). The differentiations between assets, resources and capabilities especially are often blurred in the literature (Amit and Schoemaker 1993; Grant 1991; Subramani 2004; Wade and Hulland 2004). Barney (1991) defined firm resources as all assets, capabilities, organizational processes, information and knowledge, that enabled the firm to generate competitive advantage. Although it was among the first definitions of firm resources in the RBV, Barney's definition did not shed much light on the differences among assets, resources, and capabilities. To further clarify and highlight the unique attributes inherent in the three concepts, this dissertation draws on the interpretations delineated in Wade and Hulland (2004). Wade and Hulland (2004) provide a review of the IS research grounded in the theoretical lens of RBV. They define *resources* as "assets and capabilities that are available and useful in detecting and responding to market opportunities or threats" (p. 108). *Assets* are further defined as "anything tangible or intangible that the firm can use in its processes for creating, producing, and/or offering its products (goods or services) to a market" (p. 109). Tangible assets can include information systems hardware and software, and intangible assets can include knowledge and IT-business relationships. *Capabilities*, in contrast, refer to "the repeatable patterns of actions in the use of assets to create, produce, and/or offer products to a market" (p. 109). Capabilities can include skills, such as technical or managerial ability, or processes, such as systems development or integration (Wade and Hulland, 2004). According to Wade and Hulland, assets and capabilities together constitute the set of resources in the firm. While assets are static, serving as inputs or outputs of a process, capabilities in the forms of skills and processes, actively transform the inputs to outputs of greater benefits.

IT capability can be understood as a firm's repeatable patterns of actions in the use of IT-related resources. RBV provides a robust framework for analyzing whether and how IT may be associated with competitive advantage and performance. Researchers have systematically applied RBV to the theoretical and empirical examination of the competitive advantage implications of information technology (Mata et al. 1995; Bharadwaj 2000; Ross et al. 1996; Santhanam and Hartono 2005). For example, when examining the association between IT capability and firm performance, Bharadwaj (2000) finds that firms with high IT capability tend to outperform other firms on a variety of profit and cost-based performance measures.

An examination of the IT value research based on RBV indicates two trends: studies focusing on the complementary role of IT capability and studies focusing on the mediating role of higher-order capability, in value creation. First, not only should firms customize, deploy, and maintain technological systems, firms must also manage non-IT resources that together can generate greater value than using IT resources alone (Melville et al. 2004; Wade and Hulland 2004). In other words, IT resources act in conjunction with other organizational resources to confer organization performance. For example, Powell and Dent-Micallef (1997) conclude that the complementary use of IT and human resources lead to superior firm performance. Non-IT resources can include internal resources, such as organizational practices and organizational structures that complement the varied functions of information systems (Clemons and Row 1991; Piccoli and Ives 2005; Wade and Hulland 2004). External resources can include the firms' relationships with trading partners (Barua et al. 2004; Melville et al. 2004; Saraf et al. 2007). IT business value research has been calling for studies to find out which resources are most synergistic with which types of information technology in a specific organizational context.

Second, in line with the process-oriented view prevalent in the economic modeling of IT business value, IS researchers realize that IT resources can indirectly contribute to performance and sustained competitive advantage via a complex chain of assets and capabilities (Wade and Hulland 2004). Extending RBV, researchers have proposed higher-order organizational capabilities as the critical passageway between IT capabilities and firm performance (Barua et al. 2004; Sambamurthy et al. 2003; Rai et al. 2006). Sambamurthy et al. (2003) argue that IT capabilities influence firm performance through three significant organizational capabilities - agility, digital options and entrepreneurial alertness. The notion of building higher order capabilities to derive firm performance does not only exist in the IS literature, but is also widely used by strategic management researchers as well (Grant 1996b; Teece et al. 1997). Grant (1996b), for instance, put forward a knowledge-based theory to underscore the role of firms in integrating individual's knowledge to form higher-order organizational capabilities.

As computing paradigms shift to a network era, the conceptualization of IT business value needs to evolve so that suppliers, customers, and business partners can be brought into the value circle (Barua et al. 2004; Melville et al. 2004). However, many IT value research studies have taken an organization-centric view, which treats firms as single entities. This view has lent itself to a number of limitations because it only takes into account a firm's internal business processes, organizational structures and workplace practices (Bharadwaj 2000; Mata et al. 1995) while overlooking the other stakeholders in IT-driven value creation. By extending RBV to the supply chain context, this dissertation attempts to respond to the new challenges facing IT business value research. Specifically, this dissertation addresses how IT capabilities transform transaction-based supply chain relationships to knowledge-driven partnerships.

2.2 Supply Chain Management and Interorganizational Information Systems

Supply chain management has emerged as a management discipline in the past couple of decades and has attracted attention from both practitioners and academics. The development of global markets forces businesses to seek management approaches that can meet global demand efficiently and effectively by working with partners worldwide. The global competition has brought customers an unprecedented number of products and services and also set new expectation standards for firms to meet market requirements. Information technologies have increased information availability and, manufacturing flexibility, but doing so has increased management complexity (Mabert and Venkataramanan 1998). Facing these challenges, managers and researchers have realized that the collection of functional activities through which raw materials are converted into finished products for sale to customers should be systematically managed as a supply chain.

However, the concept of supply chains is not consistently interpreted by all. Some have held a restricted definition of supply chains which refers to the relationship between a firm and its first-tier suppliers, while others take a broader view by including all upstream and downstream partners to a firm as part of the supply chain. The latter view is consistent with the “value chain” approach in which all activities required to bring a product to the marketplace, including supply/purchase, manufacturing, and distribution function, are considered essential functions in the supply chain (Ho et al. 2002; Mabert and Venkataramanan 1998). This research adopts the value chain view in defining the term supply chain. Therefore, according to Mabert and Venkataramanan (1998), *supply chains* are the “the network of facilities and activities that perform the functions of product development, procurement of material from vendors, the movement of materials between facilities, the manufacturing of products, the distribution of finished goods to customers, and after-market support for sustainment.” Furthermore, s*upply chain management* is defined as the systematic and strategic management of key business processes among a network of interdependent suppliers, manufacturers, distribution centers, and retailers in order to improve the flow of goods, services, and information from original suppliers to final customers, for the purpose of improving the long-term performance of the individual firms and the supply chain as a whole (Cheng and Grimm 2006).

As inter-organizational interactions become strategically indispensable to organizations but meanwhile grow increasingly complex, organizational researchers view supply chains as fruitful ground for studying strategic inter-organizational issues (Chen and Paulraj 2004a). Subsequently, SCM draws attention from researchers in disciplines such as management information systems, marketing, organizational behavior, and strategic management. Empirical research methods, such as surveys and case studies, have been adopted by a sizable number of research papers with an organizational focus.

A number of empirical studies of SCM try to link myriad supply chain practices with performance outcomes, both at the firm level as well as at the supply chain level. For example, Monczka et al. (1998) investigate the success factors in supply chain alliances. Tan et al. (1999) study the association between manufacturers' supply chain practices, such as total quality management and customer relationship management, with manufacturers' performance. Despite the interesting findings resulted from this group of research, the empirical studies in SCM have been criticized as primarily descriptive, lacking theoretical foundations and contributions (Croom et al. 2000; Ho et al. 2002). This makes theory building in SCM a difficult, yet necessary, effort. Because different firms engage in different strategies and tactics in their implementation of SCM practices, research with an excessive focus on concrete SCM practices is difficult to generalize and therefore, has less predictive power. Consequently, recent recommendations encourage researchers to focus on the interorganizational capabilities that integrate a firm with its network of suppliers and customers (Rai et al. 2006; Straub and Watson 2001).

2.2.1 IT and Supply Chain Management

Research classifies supply chain relationships into three levels – operational, tactical, and strategic (Shah et al. 2002). These three levels of relationships are largely characterized by the information sharing behaviors of the supply chain firms (Rai et al. 2006). The operational level supply chain relationships focus on exchanging transaction-based information between partners using interorganizational information sharing technologies such as EDI or extended ERP, as well as transaction-cost reduction programs such as Vendor Managed Inventory (VMI). At the tactical level, information sharing does not occur only between single departments across firms, but involves multiple divisions or functional departments within a firm or across firms. Information sharing goes beyond transactional efficiency to achieve further productivity and profitability goals. Examples of SCM initiatives at the tactical level include Collaborative Planning, Forecasting, and Replenishment (CPFR), Continuous Replenishment (CRP), or sharing of Point-of-Sale (POS) demand information. The supply chain relationships at the strategic level involve gathering and sharing competitive intelligence and necessitate the decision support functionality of IT applications (Akkermans et al. 2003). Despite various focuses of information sharing, the SC relationships can be highly collaborative or can involve one party dominating the information sharing processes with another party (Malhotra et al. 2005).

The research on IT impacts in the context of SCM has primarily examined the role of specific technologies and innovations, such as EDI, CRP, and RFID in improving SC processes and firm performance. Srinivasan et al. (1994) find that suppliers who use EDI to support manufacturing in a Just-in-Time (JIT) context have better delivery performance in terms of the level of shipment discrepancies. Raghunathan and Yeh (2001) show that continuous replenishment facilitated by CRP benefits both manufacturers and participating retailers. Lee et al. (2008) propose that a firm can use RFID to change its basis of competition from an efficiency-oriented strategy to strengthening of customer loyalty by increasing customers’ value perceptions. In essence, supply chain IT can improve supply chain efficiencies by reducing uncertainties associated with information unavailability, incompletion and distortion.

2.2.2 Research on Interorganizational Information Systems

SCM initiatives can be supported by a group of IT applications known as *inter-organizational information systems* (IOS). IOS are the information and communication technology-based systems that transcend legal enterprise boundaries (Shah et al., 2002). This section examines the literature on IOS to better understand how firms can derive value from the information technology deployed at the interface with other firms. IOS are planned and managed to support collaboration and strategic alliances between otherwise independent actors (Kumar and van Dissel 1996). They are components of IT artifacts deployed by firms and used primarily for interactions with other business entities. It is possible that a particular IT artifact may be deployed partly to manage internal operations and partly to interface with outside entities. For instance, an ERP system may include functions of internal operations as well as interorganizational transactions (Akkermans et al. 2003). These systems are designed with the objectives of improving information visibility (Lee 2000), reducing supply chain uncertainty and transaction costs (Clemons et al. 1992; Kumar and Crook 1999), and diffusing product and services into new markets (Kumar and van Dissel 1996).

The early IOS literature focuses on IOS-enabled inter-organization governance issues and subsequent firm performance (Clemons et al. 1992; Malone et al. 1987; Choudhury 1997; Bensaou and Venkatraman 1995; Kumar and Van Dissel 1996). Researchers propose various governance mechanisms and configuration modes for inter-organizational relationships. This stream of research is usually grounded in transaction cost economics (TCE) (Williamson 1985). The theory suggests that the boundary of firms and inter-organizational relationships are governed by 1) bounded rationality and opportunity costs 2) market inefficiency due to transaction costs, and 3) the firms' efforts to reduce the transaction costs. Drawing from TCE, Malone et al. (1987) predict that market-based relationships would replace hierarchy-based relationships between buyers and suppliers with the advancement of IOS, because the coordination costs are dramatically reduced in the IT-enabled transactions. In contrast, Clemons et al. (1992), also using TCE, propose a 'move-to-the-middle' thesis suggesting that implementing IOS would lead firms to establish more long-term supplier-buyer relationships with a small number of suppliers. According to their analysis, IT reduces coordination costs but does not cause transaction risks to go up, inducing a closer relationship between a firm and its small number of suppliers. Bensaou and Venkatraman (1995) combine the theories of TCE, political economy, and organizational information processing as a basis for explaining inter-firm relationships. They propose a configuration of inter-firm relationships based on the concept of fit between supply chains' information processing needs and information processing capabilities. Kumar and Van Dissel (1996) depict IOS as a rendering of cooperation between firms. They classify IOS into three categories based on the nature of interdependence between firms. They also identify the source of risks inherent in each of the IOS-based relationships. Choudhury et al. (1997) develop a typology of IOS (electronic monopolies, electronic dyads, multilateral IOS).

Another stream of IOS research studies the adoption and use of IOS, such as electronic data interchange (EDI) in inter-organizational relationships. Researchers suggest various determinants of adoption and use of IOS, such as trust, buyer and supplier power, transaction-specific investments, information processing needs, institutional pressures, network externalities, technology readiness, and perceived benefits (Chwelos et al. 2001; Premkumar et al. 1994; Hart and Saunders 1998; Premkumar and Saunders 2005; Zhu et al. 2006; Teo et al. 2003; Grover and Saeed 2007).

The third stream of IOS research focuses on the consequences of IOS use. Many researchers focus on EDI and study the operational efficiency (e.g., improved inventory turnover, reduced purchasing costs, and lowered operating error rates) and strategic aspects (e.g., gains in business volumes) of the system (Srinivansan et al. 1994; Raghunathan and Yeh 2000; Mukhopadhyay et al. 1995; Mukhopadhyay and Keker 2002; Bensaou 1997). For example, Srinivasan et al. (1994) investigate the degree to which increasing vertical information integration using EDI enhances shipment performance of suppliers in a JIT environment. They find that the use of EDI facilitates coordination in JIT, leading to fewer discrepancies in shipments. While EDI is viewed as having a positive impact on operational efficiency and strategic value by some, others argue that EDI value should be contingent upon the way the system is used (Chatfield and Yetton 2000; Truman 2000; Massetti and Zmud 1996; Subramani 2004). In order for firms to reap the benefits inherent in EDI, technical and organizational changes, such as integration with internal systems, joint strategic actions, and explorative or exploitative orientation in using the system, should be given attention along with EDI itself. The impact of EDI implementation on buyer-seller relationships is also mixed. Bensaou (1997) reports that EDI use is positively related to improved inter-firm cooperation in Japanese buyer-supplier relationships whereas there is little impact of EDI use on the U.S. counterparts.

This dissertation focuses on the performance impact of IT in supply chains, and thus, falls into the third stream of IOS literature. To better help understand the value of

IOS to supply chain firms, it is important to first understand the nature of supply chain firm relationships. The advent of the knowledge-intensive economy has generated paradigm shifts in the relationships between supply chain firms – from arm's length relationships to more cooperative relationships. These shifts are more dramatic in some industries than others (Tan et al. 1999). For example, manufacturers are increasingly tapping into suppliers' technologies and expertise in product design and development. The resulting pattern of relationships is characterized by high interdependence and knowledge-intensive interactions (El Sawy et al. 1999). This dissertation argues that a relational view of interorganizational competitive advantage is more relevant and appropriate for studying interorganizational competitive advantage. The relational view also allows the use of a knowledge-based logic to explore the business value of IT in organizational networks (Malhotra et al. 2005).

2.2.3 The Relational View

The relational view (Dyer and Singh 1998) is an extension of RBV to study the source of strategic advantage in an inter-firm relationship. While RBV focuses on how individual firms generate competitive advantages by utilizing unique resources and capabilities housed within the firms, the relational view extends RBV into the context of organization networks. The relational view suggests that competitive advantages of a pair or network of firms stem from the idiosyncratic inter-firm linkages which fall into four categories: relation-specific assets, inter-firm knowledge sharing routines, complementary resources and effective governance mechanism, i.e. establishing goodwill and trust between partners (Dyer and Singh 1998). Researchers of the relational view believe that rents are generated jointly by partnering firms. The rise of the relational perspective of firms can be attributed to the fact that more and more firms have moved to the strategic alliance form of partnership instead of arm’s length market relationships. In the strategic alliance relationships, a firm’s critical resources may span firm boundaries. For example, computer manufactures purchase highly customized products from their suppliers. The relational view can help us understand why some supply chains are more successful than others in terms of their competitive advantages.

A relational view considers a dyad/network as the unit of analysis. It is consistent with IS researchers’ arguments that a pair or network of firms is an increasingly important unit of analysis and therefore deserves more attention (Straub and Watson 2001). IS researchers have adopted the relational view in studying supplier-buyer relationships (Subramani 2004; Patnayakuni et al. 2006). These studies suggest that operational and strategic gains in the value chain are possible when trading partners are willing to make relation-specific investments and combine resources in unique ways. Therefore, there is a great opportunity for IS research to study the IOS capabilities that are important for creating relational value in supply chains.

As mentioned in the previous section, TCE has been a widely used theory in understanding interorganizational relationships and has been effective in explaining phenomena such as outsourcing and vertical integration. However, its applications are not without criticism. Theorists have pointed out that the theory cynically assumes an opportunistic nature of firms rather than collaborative actions. Moreover, TCE tends to focus on single transactions rather than dynamically evolving relationships driven by the learning between partners (Lorenzoni and Lipparini 1999). TCE also analyzes transactions from a single firm’s perspective rather than focusing on multi-firm collaborative processes to develop collective capabilities. Therefore, this dissertation argues that TCE is not appropriate for studying the collective knowledge management processes in supply chains.

2.3 Knowledge Management

This section first provides a definition of knowledge and describes the different types of knowledge in organizations. Next, the section reviews and synthesizes firms' KM processes from the literature of IS, management, organizational learning, and strategic management. Finally, the section focuses on understanding the extant status of research on KM in SC.

2.3.1 Knowledge and Knowledge Management

Knowledge is viewed as the set of justified beliefs that enhance an entity's ability for effective action (Alavi and Leidner 2001; Nonaka 1994). The emphasis of this definition lies in the role of knowledge in guiding future actions of an individual, a group or an organization. Knowledge is considered distinct from, but also interrelated to, information and data. In fact, researchers, particularly in the IS field, have offered insights into the differences between knowledge, information and data. For example, Nissen (1999) presents a useful definition of these three constructs. He describes data to be elemental, descriptive, and not systematized for decision making. Information, on the other hand, is an aggregation of data that have been organized or given structure, placed in context, and therefore conferred with meaning. Knowledge, however, goes beyond the actual representation of what is happening and allows for the making of predictions, causal associations, or prescriptive decisions about what to do. Nissen (1991)'s interpretation of knowledge highlights the concept of knowledge as "actionable information." Davenport and Prusak (1998) define knowledge as "a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information" (Davenport and Prusak 1998, p. 5). While information is used to describe the present or the past, knowledge is more generalized and can be used to help shape the future.

Real-world examples can help us better discern the differences between the three constructs. In a supply chain setting, data may be in the form of numbers included in a purchase order placed by a manufacturer to a supplier. Information in a supply chain would be about any facet of the organization that deserves to be measured or reported on, such as sales volume of a product line for a certain time period, current and past inventory levels, and production levels. Knowledge is an interpretation of information based on experiences, insights, beliefs, and contexts. Knowledge can generate actionable decisions that go above and beyond actions defined from standard operational procedures (Meixell et al. 2008). For example, knowledge pertaining to market fluctuations faced by a retailer can result in the change of order quantities from upstream suppliers.

Knowledge can exist in individuals as well as in the collective (Nonaka 1994; Alavi and Leidner 2001). Individual knowledge is created by and stored in individuals. It is what Alavi and Leidner (2001) described as "personalized information". Collective knowledge is "created by and inherent in the collective actions of a group" (Alavi and Leidner 2001). Organizations are social collectives (Alavi and Leidner 2001). Organizations accumulate knowledge over time by learning from their members (March 1991). Organizational knowledge is stored in the organization's procedures, norms, rules and forms (March 1991).

The two interdependent and reinforcing dimensions of knowledge are tacit knowledge and explicit knowledge (Alavi and Leidner 2001; Nonaka 1994). Tacit knowledge is rooted in individuals' experiences, beliefs, and involvement in a specific context. It is a product of the interplay between two elements: the cognitive element and the technical element (Nonaka 1994). The cognitive element refers to a person's mental models that consist of mental maps, beliefs, paradigms, and viewpoints (Alavi and Leidner 2001). The technical element refers to concrete know-how, crafts and skills (Alavi and Leidner 2001). Tacit knowledge is difficult to articulate and is challenging to transfer (Nonaka 1994). The use of rich communication media, such as observation, is considered suitable at transferring tacit knowledge. Explicit knowledge can be articulated, codified, and communicated in written forms. Although explicit knowledge is codifiable, this is not to suggest that this form of knowledge equals information. The difference between explicit knowledge and information is their value in directing actions. Knowledge should be able to increase the recipients' ability to take actions. As Alavi and Leidner (1999) point out, knowledge is "information made actionable." Information technologies have been claimed as being valuable and effective in managing explicit knowledge due to their ability to search, store, and disseminate knowledge.

2.3.2 Knowledge Management Capability and Firm Performance

Knowledge management in organizations refers to identifying and leveraging collective knowledge in an organization to help the organization compete (Alavi and Leidner 2001). Most of the existing literature presents the definition of KM from a process perspective. Thus, it is important for us to first understand the distinct but interdependent processes of KM. Researchers have identified the key processes of organizational KM including knowledge creation (Alavi and Leidner 2001; Cui et al. 2005; Gold et al. 2001; Lee and Choi 2003; Nonaka 1994; Sabherwal and Becerra-Fernandez 2003; Sabherwal and Sabherwal 2005), knowledge transfer (Alavi and Leidner 2001; Tanriverdi 2005), knowledge storage (Alavi and Leidner 2001; Argote et al. 2003), knowledge application (Cui et al. 2005; Gold et al. 2001; Tanriverdi 2005), knowledge conversion (Cui et al. 2005; Gold et al. 2001), knowledge integration (Grant 1996b; Tanriverdi 2005), and knowledge protection (Gold et al. 2001). Alavi and Leidner (2001) develop a framework for understanding the potential role of information technologies in organizational knowledge management. The framework suggests four socially enacted and interconnected knowledge processes – knowledge creation, knowledge storage/retrieval, knowledge transfer, and knowledge application. Argote et al. (2003) suggest that knowledge management research should study organizations' knowledge activities as three outcomes: outcomes of knowledge creation, knowledge transfer and knowledge retention. Tanriverdi (2005) identifies four interrelated knowledge management processes useful for multi-unit firms to develop cross-unit synergies. Those four processes include creation of related knowledge, transfer of related knowledge, integration of related knowledge, and leverage of related knowledge. Cross-unit KM capability was defined in Tanriverdi (2005) as the firm's ability to create, transfer, integrate and leverage related knowledge across its business units.

With the rise of the resource based view (RBV) and the knowledge-based view (KBV), much attention has been paid to the knowledge management capabilities of organizations and the impact of the cultivation of those capabilities to organizations' performance. KM capabilities can be broadly understood as an organization's capability to effectively initiate and maintain knowledge management practices. According to KBV, firms are superior to markets in their ability to integrate knowledge across individuals, groups, and divisions. KBV suggests that the primary reason for the existence of the firm is its superior ability to integrate multiple knowledge streams, for the application of existing knowledge to tasks (Grant 1991; 1996a; 1996b).

The process view of KM can also help to define KM capability (Gold et al. 2001; Gunasekaran and Ngai 2007; Tanriverdi 2005). Tanriverdi (2005) defines KM capability as the firm's ability to create, transfer, integrate, and leverage related knowledge across its business units. Similarly, Gold et al. (2001) view KM process capabilities as the extent to which the organizations engage in knowledge acquisition, conversion, application and protection processes.

One stream of KM research concerns the impact of organizational KM capabilities on organizational performance. Gold et al. (2001) view knowledge management capability as consisting of the infrastructure dimension and the process dimension. The supporting information technologies, organizational structure and organizational culture are the three components in the infrastructure dimension. Knowledge process capability includes four dimensions - acquisition, conversion, application and protection. The study found that each of the two KM capabilities uniquely contributed to organizational effectiveness. Building on the findings of Gold et al. (2001), Lee and Choi (2003) propose a framework linking KM enablers, knowledge creation processes, and organizational performance. IT support, the technology dimension of KM enablers, is shown to have only significant impact on knowledge combination processes. In addition, this research empirically observes that knowledge creation processes are positively related to organizational creativity, which then leads to organizational performance. Tanriverdi (2005) considers KM capabilities as a critical mediator between IT and firm performance. In the context of multi-unit corporations, this study finds that knowledge management capabilities, reflected by corporations' abilities to create, transfer, integrate and leverage their product, customer and managerial knowledge across multiple units, are positively related to performance. Lee and Sukoco (2007) adopt Gold et al.'s (2001) framework for understanding KM capabilities. Their study shows entrepreneurial orientation and KM capabilities positively impact organizational innovation competence and organizational effectiveness, and furthermore, these positive relationships are moderated by social capital. Cui et al. (2005) focus on the influence of market conditions on KM capabilities of multinational companies and, in turn, the companies' performance. They discover that KM capabilities are driven by market volatilities and there is a positive relationship between multi-national firms' abilities to manage knowledge (acquire new knowledge, convert knowledge obtained to into a useful form, and utilize the knowledge) and performance. In summary, consistent with the strategic view of knowledge resources (Grant 1996a), these studies suggest that knowledge management capability is a critical enabler of superior organizational performance.

In the IS literature, researchers have theorized KM capability of firms as an intermediate construct through which IT can influence performance outcomes. Sambamurthy et al. (2003) suggest that the effects of IT competence on firm financial performance are realized through enhanced knowledge reach and richness. Despite the widely accepted theoretical argument regarding the relationship between IT and KM capabilities, little work has been done to empirically examine the relationship. In addition, there is scarce theoretical development of the conceptualization of IT capabilities that may be critical to KM. For instance, although Gold et al. (2001) propose a knowledge management infrastructure that consists of technology, organizational and cultural support, they overlook the possible impacts of the KM infrastructure components on KM process capabilities. Upon identifying the gap in the understanding of IT and KM capability, Lee and Choi (2003) propose a framework to link technological KM enablers and KM capabilities. Rather than examining KM capabilities, however, their work focuses on one aspect of KM, knowledge creation only. One exception to the literature gap is the work of Tanriverdi (2005). His study empirically establishes the relationships among IT, KM capability, and financial firm performance. IT is theorized as IT relatedness that indicates the extent to which a firm had related IT infrastructure, IT strategic making process, IT HR management process and IT vendor management process, across different business units. Tanriverdi (2005) finds that KM capability fully mediates the relationship between IT relatedness and firm performance.

2.3.3 Knowledge Management in Supply Chains

With the escalation of global competition and fast-changing market needs, organizations have realized that competing as a single unit in today’s business environment becomes increasingly difficult due to the limited tangible and intangible resources a firm can obtain and manage. Hence, many firms have resorted to focusing only on their core competences while outsourcing the rest of the business functions to other firms. By shifting to a disintegrated mode of governance, firms are confronted with a great need to manage the flow of talents and technologies across organizational boundaries. In the environment where organizational boundaries become permeated, studying a supply chain partnership as a unit of analysis seems appropriate and imperative.

Knowledge has been shown to be a strategic intangible asset in various interorganizational configurations, such as R&D networks (Powell et al. 1996), joint ventures (Inkpen and Dinur 1998), franchises (Eunni et al. 2006), and strategic partnerships (Lorenzoni and Lipparini 1999). Although supply chains are an important form of interorganizational configuration, because the focus of supply chain activities has primarily been about mundane operations and transactions, knowledge has not been viewed as an equally salient component in supply chains as in other interorganizational relationship types, such as R&D alliances, where knowledge is the main driver for forming the alliances.

Yet, the knowledge-based view of firms (KBV) has sparked research interest on the value of knowledge in supply chains. Research results have revealed that knowledge is an important asset in supply chain operations (Gunasekaran and Ngai 2007; Meixell et al. 2008). Cheng and Grimm (2006) review the empirical SCM research with a strategic management focus and report that one stream of studies is interested in the strategic role of KM in SC. Eunni et al. (2006) review KM processes in international business alliances that can include many forms of interorganizational relationships. Eunni et al. (2006) conclude that the literature on KM in international alliances emphasizes three distinct processes of inter-organizational learning: transfer of knowledge between the firms, creation of new knowledge through transformation of resources contributed by the firms, and application of the new knowledge to improve the existing partnership. Gunasekaran and Ngai (2007) suggest that it is important to examine the extent to which integrated information systems are used to facilitate innovation and knowledge diffusion along the supply chain for an ultimate improvement of manufacturing effectiveness. With a clear objective to understand the effects of using knowledge, not just information or data, in supply chain functions, Meixell et al. (2008) develop a simulation model to quantify the value of knowledge in the replenishment processes for a service parts supply chain. A review of the extant empirical research on managing knowledge across firm boundaries has shown that research has predominantly been done in the area of knowledge transfer and knowledge creation. For instance, Malhotra et al. (2005) discover five SC partnership configurations based on the partnership's potential for knowledge creation. Hult et al. (2004) report that memory of SC firms about the transaction with their partners was positively related to knowledge acquisition of the SC as a whole, which in turn had an impact on information distribution among the SC. Hult et al. also find that knowledge-related constructs including knowledge acquisition and shared meaning positively contribute to SC performance indicated by the SC's cycle time. In addition to the empirical studies, there are also a number of conceptual papers discussing the role of KM in SC (e.g., Dyer and Nobeoka 2000; Lincoln et al. 1998; Lorenzoli and Lipparini 1999).

Although there has been an increasing number of research papers focusing on the knowledge management issues in supply chains, research in this area is plagued with a couple of problems. First, as Cheng and Grimm (2006) point out in their literature review, research studying KM in supply chains has largely relied on single case studies with little attention to theoretical development. More empirical research founded in theoretical grounds is needed. Second, little is understood about the mechanisms by which knowledge can be utilized to contribute to supply chain effectiveness. In fact, there have been calls for a deeper understanding of how organizations should deploy organizational resources and design organizational processes so that knowledge can be mobilized between supply chain partners (Cheng and Grimm 2006; Gunasekaran and Ngai 2007). Therefore, this dissertation intends to fill the gap in the supply chain KM literature and to contribute to the advancement of the field.

CHAPTER 3: THE ROLE OF KNOWLEDGE MANAGEMENT IN THE RELATIONSHIP BETWEEN SUPPLY CHAIN IT CAPABILITY AND SUPPLY CHAIN PERFORMANCE

3.1 Background

The objective of the empirical study is to understand the IT-driven knowledge management processes and the value of knowledge management in supply chains. IT has been considered by practitioners and academicians alike as a strategically critical resource to confer benefits to firms. However, there is little knowledge of the mechanisms through which IT generates value to firms (Sambamurthy et al. 2003). Moreover, when extended enterprises arise as a new form of governing among firms, even scarcer understanding is readily available in the literature on the value creation process of IT deployed to form firm linkages (Barua et al. 2004). An important motivation for firms to collaborate in various configurations of extended enterprises is to access complementary knowledge and capabilities from partnering firms. In fact, a number of research studies rooted in the resource based view of the firms (RBV) have identified the strategic value of knowledge on firm performance (e.g., Grant 1996). This study argues that the better inter-organizational partnerships are at acquiring, sharing, and utilizing knowledge resources, the more benefits the partnering firms can get out of the relationship. Studying supply chains as a particular form of inter-organizational relationship configurations, this research intends to shed light on the facilitating/inhibiting role of IT in a supply chain partnership's knowledge management.

Because this research is interested in the supply chain performance implications of IT, it lends itself to the cumulative tradition in the IT business value research. As explained in the literature review, there have been three streams of research examining IT business value. This study draws on the RBV and conceptualizes IT as capabilities, rather than as specific technology features. Particularly, it focuses on the capabilities of the IT infrastructure deployed in the supply chain. IS researchers suggest that the link from IT to performance is tenuous, so important intermediate organizational capabilities that mediate the relationship between IT and firm performance should be further explored (Barua et al. 2004; Sambamurthy et al. 2003; Wade and Hulland 2004). There have been calls for research on the higher level organizational capabilities as a source of performance (Barua et al. 2004; Rai et al. 2006; Sambamurthy et al. 2003; Tanriverdi 2005). To study the impact of supply chain IT infrastructure capability on supply chain relationship performance, knowledge management is identified as an important capability of a supply chain that should channel the effects of IT on performance. This research is also a response to the research call that suggests IS research based on RBV should not only study how IT capabilities help mobilize firms' internal resources but also the external resources embedded in the relationships with suppliers, customers, and competitors (Melville et al. 2004).

Capabilities are defined as "the repeatable patterns of actions in the use of assets to create, produce, and/or offer products to a market" (Wade and Hulland 2004; p. 109). According to Wade and Hulland, capabilities can include skills such as software development expertise, and processes such as information system integration. This definition of capabilities also echoes the capability construct proposed in the capability maturity model (Paulk et al. 1993). The capability maturity model (CMM) was first developed to evaluate software engineering processes and has been extended to areas such as risk management, human resource management, and IT management. Although the framework of CMM focuses on business processes and not on human skills, it can shed light on the general understanding of organizational capabilities. According to the CMM, process capabilities are established when the processes are repeatable and can generate stable results. The definition of capabilities that this study adopts emphasizes the *use* of organizational assets to achieve desirable goals. An information system, if not used, is an IT asset, not an IT capability. Adopting a system-view of the organization, IT assets are either the inputs or the outputs. Research suggests that IT assets are the easiest resources for competitors to imitate and, therefore, they are the most vulnerable source of sustainable competitive advantage for a firm (Teece et al. 1997). On the other hand, capabilities take an extended period of time to develop and it is likely that capabilities are idiosyncratic to the firm's culture, human resources, and processes. As a result it is difficult for competitors to disentangle the causal linkages between capabilities and performance.

3.2 Research Model and Hypotheses

Combining the RBV, knowledge-based view of the firm and the relational view of the firm, this study proposes a research model that evaluates the impact of supply chain IT infrastructure capability on supply chain performance through knowledge management capability, a higher order capability construct. The research model is presented in FIGURE 3-1.

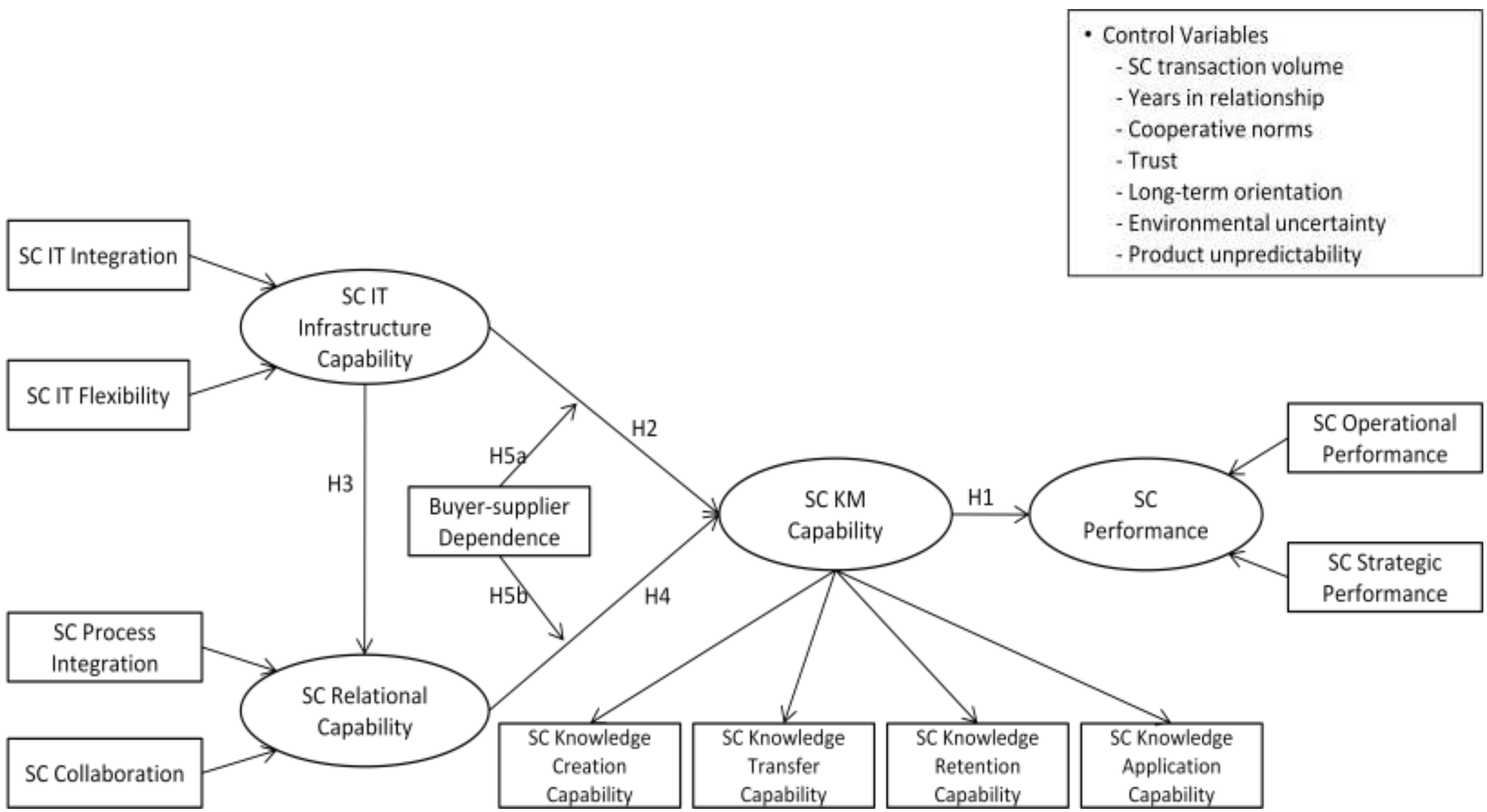

FIGURE 3-1. Research Model

3.2.1 Supply Chain Knowledge Management Capability and Its Impacts on Supply Chain Performance

3.2.1.1 SC knowledge management capability

Knowledge Management Processes

Knowledge management in organizations refers to identifying and leveraging the collective knowledge in an organization to help the organization compete (Alavi and Leidner 2001). KM can be viewed as interrelated processes, such as the knowledge creation processes, knowledge transfer processes, knowledge retention processes, and knowledge application processes (Alavi and Leidner 2001; Argote et al. 2003). KM processes should not be treated as discrete and monolithic phenomena (Alavi and Leidner 2001); rather, they should be viewed as a combination of the intertwined activities that complement each other to maximize KM effects. TABLE 3-1 describes the four KM processes and enumerates other terms that have been used to name the four processes. This study also draws from the IS literature focusing on supply chain relationships to identify the constructs related to the KM processes in the SC context. TABLE 3-2 presents those constructs that have been empirically evaluated.

TABLE 3-1. KM Processes in Firms

KM Process	Equivalent Concepts Appeared in the Literature and References	Description
Knowledge creation	• Knowledge creation (Alavi and Leidner 2001; Argote et al. 2003; Tanriverdi 2005; Sabherwal and Sabherwal 2005) • Knowledge acquisition (Gold et al. 2001; Cui et al. 2005) • Knowledge conversion (Gold et al. 2001; Cui et al. 2005) • Socialization, externalization, combination, internalization (Becerra-Fernandez and Sabherwal 2001; Lee and Choi 2003) • Knowledge integration (Grant 1996b; Tanriverdi 2005)	• Knowledge creation involves developing new content or replacing existing content within the organization’s tacit and explicit knowledge. • There are four modes of knowledge creation based on Nonaka’s theory of knowledge creation – internalization, externalization, socialization, and combination.
Knowledge transfer	• Knowledge transfer (Alavi and Leidner 2001; Argote et al. 2003; Tanriverdi 2005) • Knowledge sharing (Sabherwal and Sabherwal 2005)	• Knowledge transfer refers to the flow of knowledge between components in a knowledge system and across various levels. • The various components in a knowledge system include human and data storage for explicit knowledge. The various levels of knowledge refer to individuals, groups, and organizations. Knowledge flows between individuals, from individuals to data sources, from individuals to groups, between groups, across groups, and from the group to the organization.

TABLE 3-1 (Continued)

Knowledge retention	• Knowledge retention (Argote et al. 2003) • Knowledge storage (Alavi and Leidner 2001)	• This concept is also referred to as organizational memory and is an important aspect of effective organizational KM. Organizational memory (OM) defined as “the means by which knowledge from the past, experience, and events influence present organizational capabilities” (Alavi and Leidner, 2001). • OM includes knowledge residing in various forms, such as written documentation, structured information stored in databases, codified human knowledge stored in expert systems, documented work procedures and standards, organizational culture, and tacit knowledge belonged to individuals and groups of individuals.
Knowledge application	• Knowledge application (Alavi and Leidner 2001; Gold et al. 2001; Cui et al. 2005) • Knowledge leverage (Tanriverdi 2005) • Knowledge utilization (Sabherwal and Sabherwal 2005)	• Knowledge application is referred to as applying existing knowledge to organizational practices. • Existing knowledge can be a result of knowledge creation, or can be received from others or can be knowledge retrieved from knowledge storage.

TABLE 3-2. Constructs Related to KM Processes in SC Contexts (Empirically Tested)

KM Constructs	References	Definitions	Measures
Knowledge creation	Partner-enabled market knowledge creation (Malhotra et al. 2005)	Extent to which working with a supply chain partner allows an enterprise to develop a better understanding of and respond to the market and competitive environment.	Working with partners helps the focal firm: • Understand the market segment served • Understand the needs of customers • Understand intentions and capabilities of competitors • Understand new markets • Understand better ways of distributing/selling • Improve service for customers • Develop strategies to compete
	Knowledge acquisition activities (Hult et al. 2004)	Activities that SC partners engage in aiming to seek out more knowledge about the SC.	Regarding the order fulfillment process of the firm's SC involving end users, corporate buyers and external suppliers: • Meet regularly to find out what products are needed in the future • Do much in-house research on products that may be needed • Poll participants once a year to assess the quality of supply chain services • Periodically review the likely effect of changes in the supply chain environment • Form routines to uncover faulty assumptions about the supply chain.
Knowledge sharing	Knowledge sharing with partners (Saraf et al. 2007)	The extent to which an enterprise shares insights and know-how about its business context with its partners.	• Frequently share knowledge about business environment • Share knowledge about all partners, competitors • Share business insights

TABLE 3-2 (Continued)

	Information distribution activities (Hult et al. 2004)		Regarding the order fulfillment process of the firm's SC involving end users, corporate buyers and external suppliers: • Frequently have interdepartmental meetings to discuss trends in our supply chain. • Spend time discussing future supply chain needs. • Share data on participant satisfaction in the supply chain on a regular basis. • Alert participants when something important happens in the supply chain.
Knowledge retention	Organizational memory of past exchange episodes (Gosain et al. 2004)	The ability to remember past experiences that are relevant to understanding and dealing with a given change situation	Ability to • Derive inferences from past events (process exceptions, patterns of demand shifts, effects of different company responses) • Retain experiences through people's memory, IS, organization routines about SC events
	Achieved memory (Hult et al. 2004)	The amount of knowledge experience, and familiarity with the SC process.	• We have a great deal of knowledge about the SC • We have a great deal of experience with the SC • We have a great deal of familiarity with the SC
	Interfirm relationship knowledge store (Johnson et al. 2004)	The level of which IR knowledge retained in the firm's memory.	Level of interactional knowledge retained: 1. about negotiating with suppliers, 2. about planning and management of partnering activities 3. about using computers to network and communicate with suppliers 4. about managing conflicts with suppliers 5. about initiating and implementing cooperative programs

TABLE 3-2 (Continued)

	Interfirm relationship knowledge store (Johnson et al. 2004)	The level of which IR knowledge retained in the firm's memory.	Level of functional knowledge retained: 1. about cost reduction 2. about product development 3. about delivery time 4. about quality management 5. about inventory management 6. about production efficiency of suppliers Level of environmental knowledge retained: 1. about laws and regulations relevant to supplier relationships 2. about market conditions affecting buying 3. about labor conditions in supplier firms 4. about competitors' purchasing behaviors

Conceptualizing SC Knowledge Management Capability

This dissertation uses the process view of knowledge management to conceptualize SC knowledge management capability. By integrating the literature on knowledge management in firms and the literature on knowledge management in interorganizational relationships, four distinct but interrelated processes are identified that are required for SC firms to manage knowledge of markets, processes, and products. The four processes are knowledge creation, knowledge transfer, knowledge retention, and knowledge application. The knowledge management processes presented in TABLE 3-1 can be considered equivalent to those in TABLE 3-2. For example, the knowledge conversion process proposed by Gold et al. (2001), the constructs of socialization, externalization, combination, internalization in Lee and Choi (2001), and knowledge integration in Tanriverdi (2005) are sub-processes of knowledge creation. Knowledge acquisition can also be viewed as equivalent to knowledge creation. An equivalent notion of knowledge transfer is knowledge sharing. An equivalent notion of knowledge retention is knowledge storage, and equivalent notions for knowledge application include knowledge leverage and knowledge utilization.

The knowledge creation process generates new insights and know-how about the SC. The knowledge transfer process occurs when knowledge flows among employees, across business units and firms as needed. Organizational memory literature suggests that organizations not only learn but also forget. Once the knowledge previously acquired gets lost, organizations suffer from stagnant growth due to their inability to innovate (Bogner and Bansal 2007). Supply chain firms that can manage to retain the knowledge created and transferred to them by other firms will be able to utilize the existing knowledge as a foundation for performance improvement. The four knowledge management processes are interrelated because one process may build on the others. For example, firms can create knowledge about the SC by drawing inferences from past knowledge and experiences retained in the SC. In this case, knowledge retention is an indispensable process preceding knowledge creation. The study also argues that the four processes are distinct because each emphasizes a distinct aspect of knowledge management across firm boundaries that cannot be accomplished entirely by the other processes.

In summary, *SC KM capability* is defined as the ability of firms in a SC to share and collectively create, store and apply SC knowledge related to products, markets and processes. Therefore, the study conceptualizes SC KM capability as a reflective multi-dimensional second-order construct that is reflected by four dimensions - SC knowledge creation capability, SC knowledge transfer capability, SC knowledge retention capability, and SC application capability. The four KM dimensions are correlated. In addition, the definition of SC KM capability emphasizes the *collective* capability of SC firms to engage in KM processes, not only the ability of single firms to manage knowledge.

3.2.1.2 SC performance

Empirical research examining the impact of innovations applied to supply chain processes has conceptualized the constructs pertaining to capabilities and performance at the firm level (Straub et al. 2004). Because the notion of SC implies a collective effort from multiple firms, there have been calls to broaden the context in SCM research and to examine the performance of a supply chain relationship, rather than just the performance of individual firms in the relationship (Beamon 1999; Chen and Paulraj 2004b; Kleijnen and Smits 2003; Straub et al. 2004; Klein et al. 2007). My study argues that improved collective knowledge management capability of a supply chain should have an impact on the performance of the supply chain as whole, not just on the performance of one or more firms involved in the supply chain. Thus, the construct of supply chain performance in my research is conceptualized at the supply chain network level.

Empirical researchers in the SCM field commonly evaluate firm performance on the dimensions of financial, operational and strategic performance (Chen and Paulraj 2004b; Sengupta et al. 2006). Financial performance indicators include ROI, earnings per share, and profitability, and are usually calculated for and more appropriate to gauge a single firm's performance. *Operational performance* is related to the improvements in specific supply chain processes. Examples include efficient inventory management, shortened delivery cycles, lower operating costs, and greater percentage of products or services meeting specifications. *Strategic performance* has long-term impacts and is a result of firms taking advantage of the opportunities inherent in the inter-organizational relationships (Mukhopadhyay and Kekre 2002; Subramani 2004). Different aspects of strategic performance include the increase of business volume between SC partners, strengthening of partnerships, and the ability of the partnership in working together to respond to customer needs. Better strategic performance positions supply chains more advantageously than their competitors.

Although financial performance indicators have been widely used in empirical research, they are not reliable indicators of performance. Financial measures are criticized for blurring the true performance effects of the variables because those measures tend to have indirect and tenuous relationship with the independent variables. Furthermore, when it is the SC as a whole that becomes the unit of analysis, meaningful financial indicators are not readily available. Hence, this study conceptualizes supply chain performance as composed of two constructs –operational supply chain performance and strategic supply chain performance.

3.2.1.3 SC knowledge management capability and SC performance

The knowledge management capability has been shown to positively influence firm performance (Gold et al. 2001; Lee and Choi 2003; Tanriverdi 2005). In an interorganizational context, a number of studies have recognized the implications on network performance of the ability of a network of firms to manage knowledge (Dyer and Nobeoka 2000; El Sawy et al. 1999; Lorenzoni and Lipparini 1999). However, little has been done to empirically test the relationship between knowledge management capability of interorganizational configurations such as supply chains and their performance. This research proposes that the knowledge management capability of a supply chain will be positively related to the supply chain's performance.

The knowledge creation capability of a SC refers to the collective ability of supply chain firms to generate new insights and know-how about the supply chain in which they are operating. In the fast changing business environment, the constant growth of new knowledge will keep supply chains efficient and responsive to changes. New knowledge about SC processes enables supply chain firms to adopt new ways to coordinate, improving operational efficiency and customer satisfaction. New product knowledge created in the collaborative effort improves the product innovation rate and shrinks time to market. New understandings of the market and customer preferences help supply chain firms adjust their resources to meet market demand. Therefore, the supply chain's knowledge creation capability is positively related to the supply chain's operational and strategic performance.

The knowledge transfer capability of a SC refers to the ability of supply chain firms to share insights and know-how about the supply chain in which they are operating. The organizational impacts of knowledge transfer across firm boundaries have been observed. For example, Saraf et al. (2007) find that a business unit's knowledge sharing with its distribution channel partners can improve the business unit's performance. Similarly, the ability to transfer knowledge on Toyota's supply network significantly differentiates Toyota from its competitors on operational efficiency and innovation (Dyer and Nobeoka 2000).

The transfer of knowledge between supply chain partners allows them to realize and utilize the complementarities of each others' resources and capabilities. The transfer of technical know-how signals potential improvements in each others' production technologies. With the knowledge of market forecasting transferred from manufactures to suppliers, the suppliers can improve their own capability to devise production plans so that the probability of backorders is reduced, benefiting the supply chain as a whole. Finally, the transfer of process knowledge between supply chain partners provides an effective feedback loop that allows the chain partners to constantly refine their supply chain processes to accommodate each others' needs and to remove efficiency bottlenecks.

The knowledge retention capability of a SC refers to the ability of the firms in a SC as a whole to keep the knowledge and experiences stemming from past interactions with each other that are relevant to understanding current SC operations. Alavi and Leidner (2001) use the term "knowledge storage" to describe the knowledge retention process. Organizational memory literature is relevant in explaining knowledge retention. Stein and Zwass (1995) define organizational memory as a means by which knowledge from the past is brought to bear on present organizational activities. Organizational memory of a SC can include knowledge retained in various forms, such as explicit knowledge stored in SC information systems, explicit knowledge embedded in documented operating procedures, and tacit knowledge residing in the minds of individual employees. Knowledge retention is an important dimension of the SC knowledge management capability because knowledge obtained in the past can help SC firms to avoid replicating previous work and making similar mistakes. Operational efficiency of the SC can be improved because of the accumulated experiences of interacting. Knowledge stored in both human minds and technology artifacts can also allow firms to draw inferences from current business operations. The new insights obtained allow the SC firms to benefit strategically. For example, business volume between a supplier and a customer can increase if the supplier offers discount orders in a certain stage of the product life cycle, based on the suppliers' familiarity with previous SC transactions with the customer. Consequently, past knowledge about SC products, processes and market environments serve as buffers to allow SCs to weather business changes and survive competition in the long-run.

The knowledge application capability of a SC is defined as the ability of firms in a SC to collectively utilize the knowledge retained, created, and shared in changing the SC operations. Knowledge application capability can help convert knowledge potential into actual performance results. In the light of the discussions above, the following hypothesis is proposed:

Hypothesis 1: A supply chain's knowledge management capability will positively impact the supply chain's performance.

3.2.2 SC IT Infrastructure Capability

IOS is a general term referring to any information system implemented to enable inter-organizational information processing. Because the focus of this research is on the context of supply chains, SC IT is used to refer to the IOS artifacts used in supply chains for the management of business transactions and communications between SC partners.

The theoretical basis for defining the business value of a supply chain has primarily been from a transaction cost economics viewpoint. TCE suggests that a major benefit of IOS is reducing transaction and coordination costs. However, the benefits obtained from IOS may go beyond simple efficiency in order to achieve performance goals (Straub and Watson 2001). The broadened view of IOS goes beyond TCE and calls for a new way of theorizing IOS values. In fact, there was recently a call for research studying IOS using empirical methods in the post-EDI era (Robey et al. 2008). Robey et al. (2008) argue that although many empirical studies on IOS adoption and the consequences of IOS provide descriptions of the features and functions of IOS, those papers did not engage with IOS artifacts on theoretical grounds. Their suggestion implies that, instead of treating IOS as a monolithic black-box with specific functions hidden from view, researchers should focus on the characteristics of IOS that are conferred by specific IOS functions.

To this end, one theoretically grounded approach to study the role of SC IT infrastructure on supply chain performance is to conceptualize SC IT as capabilities that confer business and technological functionalities to supply chains. The resource-based view of the firm (RBV) is an important theoretical framework to study the impact of IT capabilities on firms. RBV provides us with the foundation to conceptualize IOS as specific capabilities (Rai et al. 2006; Saraf et al. 2007). *Capabilities* refer to "the repeatable patterns of actions in the use of assets to create, produce, and/or offer products to a market" (Wade and Hulland 2004, p.109). *IT capability* thus can be understood as a firm's repeatable patterns of actions in the use of IT-related resources. In a supply chain that involves at least a dyadic relationship, *SC IT infrastructure capability* is defined as the ability of SC firms to collectively mobilize and deploy IT infrastructure implemented in the supply chain.

This study focuses on the capability of SC IT infrastructure, rather than on the specific technological functions of SC IT. Because functional attributes of SC IT are idiosyncratic to the systems, studying the capability inherent in SC IT infrastructure allows researchers to generalize the findings of this research to all types of firms. Moreover, given the same SC IT functions, different SC relationships can use those functions differently, thus causing different business outcomes to the collective entity. Hence, studying SC IT infrastructure capability can contribute to the cumulative tradition in the IT value research that is grounded in the resource-based view. Based on prior research on IOS capability, SC IT infrastructure capability is conceptualized as a formative multidimensional construct that is made of two dimensions – SC IT integration and SC IT flexibility. TABLE 3-3 summarizes the constructs of SC IT infrastructure capabilities that have been studied in the literature and how those constructs are mapped to the dimensions of SC IT infrastructure capability proposed in this study.

TABLE 3-3. SC IT Infrastructure Capability Studied by Prior IS Research

SC IT infrastructure capability	Constructs from the literature	References	Description
SC IT integration	EDI integration	Truman 2000	Two facets of integration in EDI environment: integration between EDI and internal systems and integration among internal systems.
	EDI embeddedness	Chatfield 2000	Measured by joint strategic actions and EDI integration with internal systems.
	System integration	Barua et al., 2004	Information visibility throughout the chain
	IT infrastructure integration	Rai et al., 2006	Consistent and high velocity transfer of SC information
	IS integration	Saraf et al, 2007	IS applications working as a functional whole
SC IT flexibility	IS flexibility	Saraf et al, 2007	IS applications adapting to changes

3.2.2.1 SC IT integration capability

SC IT integration capability indicates the extent to which information systems deployed in a supply chain have achieved consistent and real-time transfer of supply chain related information within and across individual firm boundaries (Rai et al., 2006). Integrated SC IT infrastructure allows the transfer of consistent data and the integration of functional applications between supply chain firms (Markus 2000; Rai et al. 2006; Saraf et al. 2007; Barua et al. 2004).

Data consistency is ensured by an integrated SC IT because data can be entered into the system only once and retrieved by others. The higher the data consistency, the lower the discrepancies of the data exchanged and the more commonality of the data shared by the partners. For example, in a supply chain with high data standardization, suppliers and buyers use the same product codes and their definitions of the codes are consistent. A change of data in one part of the supply chain application can be automatically reflected in the associated parts in an integrated environment. For example, changes in a buyer's order can automatically trigger changes in the suppliers' billing, order management and production systems.

In summary, IT integration reduces data inconsistency in disparate and fragmented systems across supply chains and enables the various functions in the supply chain across multiple platforms to share the common data. Moreover, IT integration enhances the communication among software applications such as SCM, ERP or CRM with other applications in the firm or across firm boundaries.

3.2.2.2 SC IT flexibility

Flexible IT infrastructure has been viewed as a source of competitive advantage to organizations (Byrd and Turner 2000; Ray et al. 2005; Ross et al. 1996; Weill 1992; Duncan 1995). The development of a flexible and responsive IT infrastructure is frequently identified as a key IT management priority. Flexible IT infrastructure can support a wide variety of business applications and various types of information. The ease of adding, adapting and removing software applications that process diverse information objects facilitates technology-dependent business process changes and innovations. Firms that are equipped with a flexible IT infrastructure can take quick actions in response to competitors' moves.

A number of IS scholars have contributed to IT flexibility research by focusing on the conceptualization and measurement of IT infrastructure flexibility. Duncan (1995) proposes a framework for evaluating IT infrastructure flexibility. Her study suggests that the technical IT flexibility refers to the degree to which the IT infrastructure components are sharable and reusable. In her work, Duncan empirically demonstrates that IT infrastructure flexibility is manifested through the qualities of connectivity, compatibility, and modularity. Byrd and Turner (2000) further identify eight dimensions of IT infrastructure flexibility - data transparency, compatibility, application functionality, connectivity, technical skills, boundary skills, and technology management. Their analysis shows that the eight dimensions can be grouped into three factors: modularity, integration and IT personnel flexibility, with the first two concerned with technical components and the last concerned with human component of IT infrastructure. They define IT infrastructure flexibility as the ability to easily and readily diffuse or support a wide variety of hardware, software, communications technologies, data, and core applications within the technological base of the existing IT infrastructure.

Drawing on the previous papers on IT flexibility, my study defines *SC IT flexibility* as the extent to which a supply chain's IT infrastructure and software applications can be modified or updated to adapt to the changing supply chain requirements (Langdon 2006; Duncan 1995; Byrd and Turner 2000; Nelson and Ghods 1998). This definition echoes Longdon's definition of IS flexibility as "the ready capability of an information systems to be adapted to new, different, or changing business requirements." One important aspect that this definition of IT flexibility highlights is that the value of flexibility depends on the business requirements (Kumar 2004; Gosain et al.

2004). SC IT should be designed to support changes in the existing relationship, such as changes involving products or changes in transaction volumes (Crowe 1992).

Distinctions between IT flexibility and IT integration

Integration and flexibility are two important aspects of IT infrastructure. Both constructs include multiple dimensions, reflecting the intricate nature of organizational IT artifacts. However, the relationship between the two constructs has been a topic of discussion in IS research and the results are not conclusive. One group of researchers suggests that, IT infrastructure flexibility can be considered as a multi-dimensional construct and that IT infrastructure integration is one dimension of IT infrastructure flexibility (Byrd and Turner 2000; Byrd and Davidson 2003). For example, Byrd and Turner (2000) report that IT managers perceive that a well-integrated IT platform contributes to the flexibility of the IT infrastructure. Their research suggests that the measures of the connectivity and compatibility of IT infrastructure reflect the degree of infrastructure integration. Connectivity is the “ability of any technology component to attach to any of the other components inside and outside the organization” and compatibility refers to the “ability to share any type of information across any technology component” (Byrd and Turner 2000).

Other researchers have recognized the distinction, and sometimes reverse relationship between the two constructs. Allen and Boyton (1991), in their early work in analyzing the pros and cons of the centralized and decentralized IT environments, suggest that an integrated environment is ideal for achieving efficiency and a decentralized architecture is ideal for building flexibility. Duncan (1995) records the concerns of some IS executives about the negative impacts of IT infrastructure integration on the IT function's responsiveness to business requirements. As Duncan points out, some organizations achieve system integration through uniquely designed and implemented system components. In such a tightly integrated environment, a large number of system and business processes could be embedded in the centralized system so that any change to one process might affect all others. This potentially conflicting nature of integration and flexibility is also acknowledged by Crowe (1992). He reminds the firms not to pursue integration of manufacturing systems by sacrificing the system's responsiveness to product changes. Crowe (1992) uses the term "hard integration" to describe the dilemma manufacturing units might face when they use rigid information interfaces to achieve integration. In organizations, the integration of application systems through interfaces, data warehousing or integrated application packages (such as ERP, CRM) incurs high maintenance costs and causes inflexibility in response to changes (Markus 2000). The trade-offs between the two constructs are more conspicuous in interorganizational systems. Academic studies and anecdotal evidence have shown that two firms interconnected through EDI, characterized by the proprietary technological platform and hard-coded business processes, may run into a serious inability to adapt to changing business environments. EDI transactions are supported by pre-defined transaction sets. The structures, contents and sequences of the transaction sets are determined based on the agreements between the participating businesses. The transaction sets are uniquely designed to support the specific business scenarios between the pair of transaction partners. The close linkages with trading partners enabled by EDI can improve the responsiveness of the supply chain. But business changes such as the phasing out of older products, the introduction of new products, the expansion into new geographic markets, a growth in demand, or a change in customer preferences require specific parameters in EDI transaction sets to be rapidly altered or abandoned. However, because of the interdependencies among the sets, changes cannot be easily implemented without replacing the entire transaction sets.

With the increased use of standards, a rising number of studies have called for reconciliation between the two aspects of IT infrastructure (Dietrich et al. 2007; Langdon 2006; Saraf et al. 2007; White et al. 2005). This group of researchers acknowledges the distinctiveness of integration and flexibility, but they also propose that the relationship between integration and flexibility should no longer be an inverse relationship. For example, Saraf et al. (2007) find that flexibility of IS implemented between two firms is positively related to IS integration. Similarly, after observing the supply chain management practices in the integrated supply chain division of IBM, White (2005) concludes that supply chain firms can integrate their information systems while at the same time keep the interconnected system flexible in terms of meeting new market conditions. A number of new information systems and technologies have emerged over recent years, such as web services, electronic trading hubs, business process management systems, and automatic data capture, allowing firms to integrate technological functions while keeping resiliency in the technological platform.

Whether integration and flexibility share the same technological properties and deserve the same conceptualization largely depend on the underlying assumptions of how integration is achieved. My research argues that integration can be achieved either by utilizing modular and standard technology components or by interweaving unique components, such as in the case of early EDI. The former method will grant greater IT flexibility than the latter. Hence, integration and flexibility should be treated as two distinctive aspects of SC IT and one cannot be substituted for the other. Although the focus of this study is not on disentangling the relationships between the two constructs, it is necessary for us to understand different views and the root of divergence of opinions. The purpose of the discussion is to clarify the understanding of the two IT infrastructure properties so that the rest of the study can focus on their distinctive contributions to supply chain performance.

3.2.2.4 Relationships between SC IT infrastructure capability and SC KM capability

Putting in place an integrated IT infrastructure in a supply chain requires supply chain firms to focus on understanding inter-firm processes and translating that knowledge into an appropriate IS configuration for better inter-firm relationships. For example, integration of IT infrastructures requires the trading partners to get involved in collaborative planning activities, such as understanding each other's business processes, mapping data elements, and investing in shared resources. These interactions form a bond between the two firms (Malhotra et al., 2007), which increases the relational embeddedness of the two firms. *Relational embeddedness* (Granovetter 1973) is a concept developed in sociology and used by organizational researchers to study inter-organizational relationships. Relational embeddedness indicates the degree of reciprocity and closeness among actors. A high degree of relational embeddedness displays high levels of cooperation between firms and promotes a knowledge-oriented working environment between them (Rindfleisch and Moorman 2001; Uzzi 1997).

IT infrastructure integration also increases the information processing capabilities of the supply chain by enabling rich and real-time information transfer (Barua et al. 2004;

Rai et al. 2006; Malhotra et al. 2007; Premkumar 2000). The improved information processing capabilities of a supply chain allow the supply chain's participants to exploit and explore information available to them so that their knowledge management capabilities are cultivated. This occurs because information flows are automated between two trading partners in the integrated information systems environment, so there is less need for supply chain personnel to decipher or translate the exchanged information. This frees the human capital from mundane operational issues and lets them focus on the tacit and more valuable information (Malhotra et al. 2007). Further, the design and deployment process that precedes the integrated transactions enables the information exchanged to be customized to both parties' needs (Malhotra et al. 2005). The customized information flow can eliminate information overload on the firms, enhancing the firms' absorptive capacity in assimilating useful information. Last, consistent and real-time information flows channel the information scattered in disparate information systems. Supply chain trading partners do not have to search for the information needed. Dyer and Singh (1998) point out that an obstacle in knowledge transfer between firms is the difficulty in searching.

The literature on boundary spanning can offer another perspective to understand the role of IS integration in enabling the processes of knowledge management. Carlile (2004) identifies three types of boundaries across which knowledge may be transferred: syntactic, semantic and pragmatic boundaries. The syntactic boundary is characterized by well understood knowledge differences, knowledge dependence and an environment of low novelty. A common language is sufficient for knowledge transfer across syntactic boundaries. The knowledge transfer capability needed under the syntactic-boundary context relies on information processing capabilities, such as information repository and retrieval. As the novelty requirements increase, meanings of communication become ambiguous. The same measures, outcomes, and words may be interpreted differently. Common language is not enough for effective knowledge exchange. Under such circumstances, cross-functional teams or individuals are needed as translators to develop shared meanings. This practice echoes Nonaka's externalization stage in the knowledge creation process (making tacit knowledge explicit). Pragmatic boundaries rise when actors in different knowledge domains have conflicting interests. Establishing common interests, not only meanings, becomes important. In the inter-organizational context, knowledge transfer is likely to occur across those three types of boundaries. Integrated IS serves as a boundary spanning object to ensure that knowledge sharing is possible across the different types of boundaries. First, IS integration facilitates knowledge sharing across syntactic boundaries by improving the speed and accuracy of information exchanged. Second, IS integration enables knowledge sharing between semantic boundaries by imposing common meanings to the information components. Third, the collaborative design and deployment that precede IS integration help identify common interests of different constituents, and therefore, support knowledge sharing across pragmatic boundaries. Increasing amounts of organizational knowledge are being embedded in software, or related computer-based media. The centralized data repositories enabled by the integrated IT infrastructure can store knowledge and activities from different domains that become critical facets of the supply chain businesses, such as engineering, manufacturing, and customer service (D'Adderlo 2003).

The impact of flexible SC IT on a supply chain's knowledge creation capability can be understood through the theoretical lens of absorptive capacity (Zahra and George 2002). Absorptive capacity is defined as "a set of organizational routines and processes by which firms acquire, assimilate, transform, and exploit knowledge to produce a dynamic organizational capability" (Zahra and George 2002, p.186). Changing market demands make it increasingly difficult for supply chain partners to understand the complex environment in which they are operating, posing a serious threat to the supply chain's ability to assimilate new knowledge coming from outside. Flexible IT grants the SC firms the ability to configure their information systems to quickly adapt to the changing environment. When information systems are configured to respond to the new aspects of business, new information will be infused into the relationship, providing fresh perspectives to the SC. Opportunities for creating new knowledge are increased in these circumstances with a flexible IT.

Flexible SC IT can ensure a continuous flow of knowledge between supply chain partners even during times of disruption caused by unstable or new market conditions. Organizations in the supply chain can quickly configure IT infrastructure and application components to meet the informational needs of the new market, allowing supply chain partners to exchange explicit knowledge that is a product of the flexible information systems. So, supply chain partners adopting flexible designs for IT infrastructure and applications have a better ability to support the flow of explicit knowledge than do partners adopting inflexible IT. Flexible SC IT can also support tacit knowledge exchange between SC partners. Flexible SC IT frees supply chain personnel from onerous re-configuration of existing electronic linkages so that they will have more time and resources to exchange value-added tacit knowledge related to the supply chain. Previous research has found that the deployment of flexible IT in the form of standard business interfaces between SC partners reduces the partners' concerns of lock-in, and therefore, encourages them to share rich and valuable information without worrying about their partners using the proprietary information against them (Malhotra et al. 2007).

Knowledge manifested in organizational routines and organizational culture is embedded in IT. If IT does not change, there is a risk of over-exploiting the existing knowledge, diminishing the effectiveness of knowledge application. Flexible IT infrastructure makes it easier for an organization to update their IT so that new knowledge can be applied (Alavi and Leidner 2001).

In summary, this study proposes that there is a positive impact of SC IT infrastructure capability on SC KM capability. SC IT integration implies the degree to which SC IT is integrated into a functional whole so that data are represented consistently across firms. Fragmented SC IT causes isolated data, limiting the firms' ability to transfer knowledge and extract event patterns. SC IT integration can contribute positively to SC KM capability by generating relational embeddedness between the two SC partners, improving the SC's information processing capabilities, and bridging gaps between different knowledge domains. Furthermore, employees are the conduits in the process of building SC KM capability. By creating a seamless information exchange platform for connecting employees and opportunities for employees working in various functions to interact with each other, SC IT integration can facilitate KM processes. SC IT flexibility is concerned with the degree of ease for a SC partnership to change IT infrastructure and applications in responding to changes in the business environment. Flexible IT entails SC partnerships to keep up with the information needs required by the changing business environment. The flexibility inherent in SC IT will be a catalyst for assimilation of new knowledge by the SC partnership. In addition, flexible design of IT infrastructure and software applications can free SC personnel from repetitive re-configuration of existing electronic linkages so that they can engage in value-added knowledge-based activities. Therefore, the following hypothesis is proposed regarding the relationship between the SC IT infrastructure capability and the SC KM capability:

Hypothesis 2: A supply chain's IT infrastructure capability will positively impact the supply chain's knowledge management capability.

3.2.3 SC Relational Capability

Supply chain firms are embedded in economically, socially, and technologically complex relationships (Lincoln et al. 1998; Lorenzoni and Lipparini 1996; Uzzi, 1997). According to the relational view of the firm, when supply chain firms are able to combine resources in the supply chain in unique ways, the buyer-seller relationship will generate relational rents that, in turn, will provide the participating firms a source of competitive advantage over those who are not willing to or are not able to mobilize their inter-firm resources (Dyer and Singh 1998). *Relational rent* can be understood as the benefits stemming from the synergies created through interactions between firms. The relational view of firms defines relational rent as "a supernormal profit generated in an exchange relationship that cannot be generated by either firm in isolation and can only be created through the joint idiosyncratic contributions of the specific alliance partners." Dyer and Singh (1998) emphasize the capabilities of firms to recognize the potential value of inter-firm linkages and configure the resources allocated to the linkages in concert with their partners.

Drawing on the relational view, my study defines *a supply chain's relational capability* as the ability of supply chain firms to collectively mobilize, deploy and combine complementary relation-specific resources that each firm brings to bear. The relation-specific resources contributed by each firm may include human expertise, operational processes, organizational routines and information. IS research has shown that SC IT can positively influence the information processing capability of supply chains (Bensaou and Venkatraman 1995; Premkumar and Saunders 2000). Improved information visibility and information availability in the supply chain are expected to positively impact the supply chain's abilities to deploy operational processes and mobilize human resources in individual firms (Cederlund et al. 2007). The relational capabilities that can be greatly improved by the use of IT are referred to as *IT-enabled relational capabilities*. Investments in relation specific assets, such as physical sites, processes, and human expertise, are the resources on which relational rent can be created (Dyer and Singh 1998). Among the different types of strategic assets, however, site assets are not relevant in the IT-enabled supply chain context because a supply chain can span different geographical locations with the help of modern communication information technologies. So, this study focuses on the building of relation-specific processes by SC process integration and combining complementary knowledge expertise through SC collaboration as the two dimensions that form the second-order multi-dimensional construct of supply chain relational capabilities.

3.2.3.1 SC process integration

SC process integration refers to the degree to which a supply chain's key processes are designed to accommodate the idiosyncrasies in the business processes of the supply chain partners (Saraf et al. 2007). It is driven by the relational focus of supply chain partners (Dyer and Singh 1998). Process integration implies the ability of supply chain firms to coordinate individual activities to meet each other's needs in order to achieve a set of collective goals. The supply chain processes can be carried out by automated information systems or by human agents. Each firm in the supply chain has a set of rules and sequences to execute the processes. In an integrated supply chain environment, the decision outcomes resulting from one step can directly feed into the next step so that the supply chain activities are connected as a seamless whole without interruption or intervention. The capability is manifested by the coordinated inter-firm activities, in which joint actions and quick assistance with exception handling are the norms (Robicheaux and Coleman 1994). The tightly integrated processes can reduce transaction costs in the supply chain (Goldhar and Lei 1991).

The SC IT integration capability can enhance the supply chain's ability to achieve tightly integrated business processes. Common data definitions for key data fields provide a seamless semantic platform to support the coordination between firms. Integrated applications allow the data to be entered into a system only once to be populated in other system functions. This can reduce information silos and improve the cross-functional, cross-firm information visibility, enhancing firms' abilities to coordinate. Development of a global optimization becomes possible in integrated SC IT environments (Rai et al. 2006). The integration of supply chain applications with ERP, CRM and other internal applications can facilitate the coordination of the external processes with internal firm processes (Rai et al. 2006).

Flexible SC IT enhances the ability of supply chain firms to configure their information systems to adapt to the idiosyncrasies of business partners' processes, increasing the ability to interconnect processes across the chain. Finally, the electronic connectivity afforded by SC IT allows many employees working on related functions to be involved in interconnected supply chain processes. Therefore, it is expected that higher SC IT capability is associated with higher SC process integration.

3.2.3.2 SC collaboration capability

Relational capabilities can be created by combining complementary resources (Dyer and Singh 1998). Inter-firm collaboration provides supply chain firms an opportunity to explore and utilize complementary resources across firm boundaries. The term 'collaboration' is loosely used in research. Some researchers use the term to mean working together (Scott 2000) while other researchers refer to specific collaborative programs such as Collaborative Planning, Forecasting, and Replenishment (CPFR). While some researchers view the term as having a neutral connotation, others suggest that a collaborative relationship should be cooperative rather than adversarial (Lamming et al. 2000; Mclaren 2004). In supply chains, many relationships are not truly cooperative due to the imbalance of power (Bensaou 1997). So my study adopts a broader view of collaboration and defines *supply chain collaboration* as the degree to which activities related to a supply chain relationship are carried out jointly (Bensaou 1997). My study does not distinguish between the different environments (e.g., cooperative vs. adversarial) in which joint activities are accomplished. Supply chain collaboration can occur at the operational decision-making level, such as business forecasting (Shah et al. 2003), the tactic decision-making level, such as process engineering (Bensaou 1997), and the strategic decision-making level, such as product design and development (Shah et al., 2003; Holmqvist 2004).

IT capabilities are critical for collaborative practices in supply chains (Sheu et al. 2006). Previous literature suggested that interorganizational collaboration can be fostered by the use of EDI (Bensaou 1997), and the information systems built to support the monitoring, modeling, and collaborative activities between supply chain partners (Scott 2000). Supply chain IT integration is expected be positively associated with supply chain collaboration capability. One of the difficulties for firms to identify potential collaborative opportunities is to acquire information about their partners (Dyer and Singh 1998). Improved exchange of information as a result of IT integration provides opportunities for firms to identify the potential resources or capabilities in their partner firms that may have potential for collaboration. Moreover, electronically integrated documents, such as prototype designs and product specifications, can facilitate collaboration among firms (Scott 2000).

Collaboration teams across a supply chain are emerging to deal with new challenges in fast-changing marketplaces. Collaborative efforts require the adaptation of current information to new business needs or the obtaining of new information. Therefore, it can be expected that flexible IT in a supply chain is positively associated with collaborative efforts among firms.

Because SC IT infrastructure capability is shown to have a positive impact on the two dimensions of SC relational capability - SC process integration and SC collaboration, the following hypothesis is proposed:

Hypothesis 3: A supply chain's IT infrastructure capability will positively impact the supply chain's relational capability.

3.2.3.3 SC IT-enabled relational capability and SC knowledge management capability

SC process integration contributes to the SC's ability to create new knowledge and apply that knowledge to SC practice by facilitating the accumulation of employees' tacit knowledge and by shifting employees' focus from routine work to value-added knowledge work. SC process integration improves the visibility of supply chain processes. The improved visibility can help employees working in the supply chain to easily understand and become familiar with the activities involved in the execution of supply chain activities. When employees' tacit knowledge about the supply chain in the form of experience and familiarity with the supply chain accumulates, it is easier for the employees to identify problems within the processes (Hult et al. 2004). In other words, the familiarity with the supply chain can help the supply chain employees to seek out more knowledge that have impacts on the supply chain operations and strategic improvements. In addition, employees can take further informative actions in correcting problems and make improvements to the existing practices. The integrated supply chain processes reflect an efficient execution of supply chain activities with a minimal level of discontinuation. Transaction costs in terms of coordination efforts can be reduced and the decision inputs and outputs are unlikely to be duplicated. In such an environment, employees are no longer occupied by the routines for keeping the processes moving; their focus can be shifted to resolving knowledge-intensive problems and uncovering new ways of doing business.

In order for effective knowledge sharing to occur, knowledge has to transcend syntactic, semantic, and pragmatic boundaries (Carlile 2004). Some researchers have suggested that structural, cognitive, behavioral and political barriers may stifle knowledge sharing (Zahra and George 2002; Nahapiet and Ghoshal, 1998; Grant 1996b). The supply chain firms who are able to marshal governance resources to fill various types of barriers between the firms will be able to build a common ground for exchanged meanings and will be better at fostering knowledge sharing. In supply chains where there is a lack of many formal and informal governance mechanisms, such as hierarchy, values, traditions and beliefs (Hult et al. 2004), that guide decision flows as in established firms, process-oriented integration mechanisms play a vital role in facilitating free flow of knowledge. With the integrated supply chain processes, employees working in different functions are aware of the roles of the others and of the causal relationships between the discrete functions. The shared understanding in the supply chain will, in turn, impose the same meaning on the supply chain activities. In other words, there is a common ground for interpreting supply chain activities in terms of the goals of the supply chain, the execution of information flows, and the expected outcomes for given information inputs. The overarching meanings and interests will provide a nurturing platform for free transfer of knowledge (Zahra and George 2002).

The collaboration between two supply chain firms allows access to complementary resources and specialized knowledge from each other. Interfirm collaboration can enhance interfirm learning by introducing new knowledge and a diversity of ideas into the relationship. Prior literature indicates that supply chain partners who engage in collaborative activities, such as new product development, inventory management, and demand forecasts, will have tighter supply chain relationship and create specific knowledge (Lorenzoni and Lipparini 1999; Scott 2000). Nonaka's knowledge creation theory (1994) highlights the importance of human interactions and collaboration that provide a promising arena for firms to exchange ideas and thus learn from each other.

In summary, improved relational capabilities as a result of IT infrastructure capability should enhance the supply chain's knowledge management capability. Knowledge can be effectively managed when firms have the opportunities and abilities to practice knowledge management initiatives (Arogote et al. 2003; Nahapiet and Ghoshal 1998). In the process of configuring supply chain processes and resources to meet market demands, partnering firms have opportunities to learn from each other. The values of knowledge management can become increasingly crystallized when the supply chain firms work together to achieve a common goal. Maintaining synergies in the relationship becomes an important motivational factor that encourages supply chain firms to share knowledge with each other and to actively contribute to the accumulation of new knowledge. Therefore, the hypothesis regarding the linkage between the IT-enabled SC relational capability and SC KM capability is the following:

Hypothesis 4: A supply chain's relational capability will positively impact the supply chain's knowledge management capability.

3.2.4 Moderating Effects of Buyer-supplier Dependence

The impact of SC IT capabilities and IT-enabled SC relational capabilities on the supply chain's knowledge management capability may be contingent upon factors pertaining to the relationship characteristics of the supply chain.

Dependence has been studied as a critical determinant of partners' attitudes, such as trust, commitment, conflict, and long-term orientation, in interorganizatonal relationships (Ganesan 1994; Kumar et al. 1995). Dependence of the firm on the supply chain partner reflects the extent to which the firm relies on the partnering firm for resources and services. A supplier is dependent on a customer if the customer is responsible for a large portion of the supplier's sales volume and profitability. On the other hand, a customer is dependent on a supplier if the supplier provides unique products or has invested in specialized assets that other suppliers do not possess. An interorganizational relationship's dependence structure encompasses two important facets: total interdependence and asymmetry of dependence. Total interdependence is the sum of both firm's dependence, whereas dependence asymmetry is the difference between the firm's dependence on its partner and the partner's dependence on the firm (Kumar et al. 1995). Both the degree of total interdependence and the asymmetry of dependence can affect sentiments in interorganizational relationships, such as trust and commitment, on both sides of the relationship (Kumar et al. 1995).

When total interdependence is low, the commitment between firms is low (Kumar et al. 1995; Palmatier et al. 2007) and the interfirm relationship tends to lack long-term orientation (Ganesan 1994). The business relationship between firms with low interdependence tends to focus on transactional exchanges, rather than higher-order collaborative partnership building, such as creating knowledge management capabilities in the supply chain. The main goal of using SC IT in such relationships is to facilitate day-to-day business transactions. Therefore, it can be expected that when supply chain partners have little dependence on each other, the relationship between SC IT capability and SC KM capability is weak.

Dependence asymmetry can create a power imbalance (Hart and Saunders 1998; Kumar et al. 1995). Power is "the firm's capability to influence change in another firm that is dependent on the resources of the "focal firm" (Hart and Saunders 1998, p. 90). Power can influence the development approach of IOS (Choudhury 1997). Research on EDI adoption suggests that supplier dependence, and thus customer power, can positively affect the customer's ability to influence the supplier to adopt EDI, and can negatively affect the diversity of EDI use (Hart and Saunders 1998; Son et al. 2005).

Recent research calls for more studies focusing on how differences in power would influence knowledge management outcomes in organizations (e.g., Argote et al. 2003). In a supply chain relationship with an unbalanced dependence structure, the more powerful supply chain partners consider their smaller partners as participants in their relationships, rather than as contributors. The powerful partner tends to ignore the information needs of their less powerful counterparts and to enforce information rules on the smaller supply chain partners (Malhotra et al. 2005). In the presence of dependence asymmetry, collaboration may not be intended to improve the welfare of all participants, but rather to serve specific interests of the more powerful partners (Hardy and Phillips 1998; Rokkan and Haugland 2002). The less power a firm possesses, the more difficult it is for the firm to convince other firms in the supply chain to contribute to an innovation

(Harland et al. 2001). In a supply chain relationship with unbalanced dependence structure, the use of information systems is likely to be confined to activities that are required by the more powerful partner (Hart and Saunders 1998). Consequently, although IT infrastructure capabilities and IT-enabled relational capabilities of a SC can be high, those capabilities may be exploited by the powerful players for their own advantages, instead of being used to nurture the knowledge management capabilities that need collective efforts from both sides of the relationship.

In summary, my study proposes that knowledge management capability is most likely to be cultivated by using IT and IT-enabled relational resources in symmetric and highly interdependent relationships than in asymmetric relationships or relationships with little interdependence. The hypotheses are stated as follows:

Hypothesis 5a: Dependence will moderate the relationship between the supply chain's IT infrastructure capability and the supply chain's knowledge management capability. The relationship between IT infrastructure capability and knowledge management capability will be the strongest when dependence between firms is both high and symmetric.

Hypothesis 5b: Dependence will moderate the relationship between the supply chain's relational capability and the supply chain's knowledge management capability. The relationship between relational capability and knowledge management capability will be the strongest when dependence between firms is both high and symmetric.

TABLE 3-4 summarizes the hypotheses proposed in the research model.

TABLE 3-4. Summary of Hypotheses

Hypothesis 1	A supply chain's knowledge management capability will positively impact the supply chain's performance.
Hypothesis 2	A supply chain's IT infrastructure capability will positively impact the supply chain's knowledge management capability.
Hypothesis 3	A supply chain's IT infrastructure capability will positively impact the supply chain's relational capability.
Hypothesis 4	A supply chain's relational capability will positively impact the supply chain's knowledge management capability.
Hypothesis 5a	Dependence will moderate the relationship between the supply chain's IT infrastructure capability and the supply chain's knowledge management capability. The relationship between IT infrastructure capability and knowledge management capability will be the strongest when dependence between firms is both high and symmetric.
Hypothesis 5b	Dependence will moderate the relationship between the supply chain's relational capability and the supply chain's knowledge management capability. The relationship between relational capability and knowledge management capability will be the strongest when dependence between firms is both high and symmetric.

3.2.5 Control Variables

The following variables are proposed to have an impact on SC performance and, therefore, are controlled for.

Volume of transactions. The volume of transactions between firms is likely to influence the performance of buyer-seller relationships (Sheth and Shah 2003). The greater the transaction volume between two firms, the larger the size of the supply chain between the two firms. Larger supply chains may be in a better position than smaller supply chains to achieve performance gains because synergies across firms can be leveraged more efficiently by taking advantage of the economies of scale.

Years in Relationship. Relationship time has been considered an important indicator of the evolution of the focus of partnerships (Malhotra et al. 2007). Early stage partnerships usually feature discrete and arm-length transactions. With the passage of time, the supply chain may be able to achieve higher performance due to better alignment of supply chain functions with their goals.

*Cooperative Norms***.** Performance of a SC is likely to be affected by the development of cooperative norms between interacting partners. Cooperative norms reflect expectations that two exchanging parties have about working together to achieve mutual and individual goals jointly (Malhotra et al. 2007). Cooperative norms provide an amiable environment for SC firms to form collective capabilities for transferring, renewing, retaining, and using knowledge in the supply chain, thus positively affecting supply chain performance.

Trust. Trust implies the willingness of a firm to rely on the business partner in whom it has confidence (Ganesan 1994). When trust is present, opportunistic behaviors in business relationships can be mitigated or removed, thus allowing for future exchanges and increased risk-taking in the relationship. Hence, trust can have a positive effect on the supply chain performance (Selnes and Sallis 2003).

Long-term orientation. Long-term orientation in supply chain relationships is shown to positively impact firms' investments in relationship specific assets and their willingness to exchange information and knowledge with partners (Patnayakuni et al. 2006). It is expected that supply chain relationships with long-term goals can have more positive supply chain performance.

Environmental Uncertainty. Supply chain relationships occur within an external environment, and the uncertainty inherent in the environment can affect relationship norms (Noordewier et al. 1990), relationship learning (Selnes and Sallis 2003) and relationship performance (Palmatier et al. 2007). The environment external to a dyadic supply chain relationship should be understood as the output environment of the dyad that is composed of the end users of the supply chain's outputs (Achrol and Stern 1988). Because it is ultimately the market behavior and the choices of the end users that drive the supply chain exchange relationship, the output environment constitutes the backdrop against which the supply chain relationship operates. Environmental uncertainty refers to the forces in the environment that are beyond the control of the firms in a supply chain relationship and that is difficult for the firms to anticipate (Selnes and Sallis 2003). It has been shown that environmental uncertainty affects relationship performance (e.g., Krishnan et al. 2006). Therefore, environmental uncertainty is used as a control variable for SC performance.

Product unpredictability. The characteristics of the products/services exchanged in the supply chain relationship can also affect supply chain performance. Complex product designs and constantly changing product specifications can contribute to the unpredictability of the products. Product unpredictability is likely to have a negative impact on supply chain performance (Rai et al. 2006).

3.3 Methodology

This study employs a survey methodology. The unit of analysis is a dyadic SC relationship between a supplier firm and a customer firm. The proposed constructs were measured at the SC dyad level from one of the supply chain partners' perspective. This approach of collecting SC level data has been adopted by a number of studies that focus on the impact of SC strategies or SC information systems on SC performance (Malhotra et al. 2005; Monczka et al. 1998; Narasimhan and Jayaram 1998; Tan et al. 1999). The sampling frame of the survey included those supply chain professionals who have direct responsibility for and knowledge about the SC function in their firms, and are involved in one of two professional organizations (ISM and APICS) in the supply chain industry. This section describes the methodology and the development of measures for the empirical study. Specifically, three key areas are discussed: instrument development, operationalization of the constructs, and sample.

3.3.1 Instrument Development

A survey instrument was developed based on the guidelines provided in the literature (Podsakoff et al. 2003; Rossi et al. 1983). To develop the questionnaire, existing measures were adapted whenever possible. New measures were developed when existing scale items were not available. To ensure content validity of the measures, the past literature was carefully reviewed and a comprehensive list of possible items for each construct was developed. In addition, two professors who have expertise in the area of survey design and in the subject areas of knowledge management and supply chain management reviewed the measures in several rounds, further improving content validity and face validity of the measures.

The informants were asked to think of a product line/service that they were most familiar with in a supply chain relationship between their firms and their partnering firms. Based on the role of the informant's firm –customer or supplier - in the identified supply chain relationship, the informant was directed to the survey developed for the customer's perspective or for the supplier's perspective. The Likert type of scale was used for the questions measuring the key variables. The informants were also provided with "Does Not Apply" and "Don't Know" options for each question in addition to the options on the Likert scale, to encourage more responses.

Two pilot tests were conducted in order to evaluate the clarity of instructions, appropriateness of terminology, item-wording, response format and scales of the questionnaire. The first pilot test was conducted in May 2009. Paper surveys were distributed to a group of 50 randomly selected supply chain professionals who attended an annual international supply chain management conference. The participants were asked to fill out the survey and mail it back in a pre-stamped mail-back envelope no later than May 30th. 11 out of the 50 participants returned their paper survey. The feedback from the 11 participants was carefully reviewed and was used to modify the questionnaire. The second pilot test was conducted in June 2009 with several PhD students at the researcher's department and several MBA students who were taking summer classes at the researcher's university. All the MBA participants have work experience in the area of supply chain management. Face-to-face interviews and email discussions were conducted and adjustments were made to the questionnaire based on the feedback.

3.3.2 Measures

The variables in the study were operationalized using multi-item reflective and formative measures. Formative indicators have the following characteristics: they form a latent construct with each indicator explaining a unique portion of variance in the latent construct, they do not necessarily covary, and they are not interchangeable (Petter et al. 2007). Reflective indicators, in contrast, are caused by a latent construct, necessarily covary, and are interchangeable. TABLE 3-5 presents the constructs studied, types of the constructs, abbreviated items in each scale, and origin of the items. The survey instrument is presented in Appendix B.

TABLE 3-5. Measure Development

Second-order Constructs (Type)	First-order Constructs	# of Items	Type	Adapted From
SC Knowledge Management Capability (Reflective)	SC Knowledge Creation Capability	4	Reflective	New measures
	SC Knowledge Transfer Capability	2	Reflective	New measures
	SC Knowledge Retention Capability	3	Reflective	New measures
	SC Knowledge Application Capability	4	Reflective	New measures
SC Performance (Formative)	Operational Performance	4	Formative	Malhotra et al. 2005; Palmatier et al. 2007; Robson et al. 2008; Ross et al. 2009; Selnes and Sallis 2003
	Strategic performance	5	Reflective	
SC IT infrastructure Capability (Formative)	SC IT Integration	4	Reflective	Saraf et al. 2007
	SC IT Flexibility	4	Reflective	Saraf et al. 2007; Byrd and Turner 2000
IT-enabled SC Relational Capability (Formative)	SC Process integration	5	Reflective	Rai et al. 2006; Saraf et al. 2007
	SC Collaboration	6	Formative	Bensaou and Venkatraman 1995; Rai et al. 2006; Kulp et al. 2004; Malhotra et al. 2005
Buyer-supplier dependence (Derived)	Dependence on the partner firm	5	Formative	Kumar et al. 1998; Heide and John 1988
	Perception of the partner firm's dependence	5	Formative	

TABLE 3-5 (Continued)

Volume of transactions		1) Dollar transaction volume 2) Percentage of transaction valve	Alternative measures	Sheth and Shah 2003
Cooperative norms		1		Malhotra et al. 2007
Long-term orientation		1		Patnayakuni et al. 2006
Trust		1		Ganesan 1994
Environmental uncertainty		3	Reflective	Selnes and Sallis 2003; Ganesan 1994
Product unpredictability		2	Formative	Subramani and Venkatraman 2003
Relationship time		1) Less than 1 year 2) 1-5 years 3) 6-10 years 4) 11-15 years 5) 16-20 years 6) 21 years or more		Klein and Rai 2009

SC KM Capability. SC KM capability is a second-order construct reflected by four first-order constructs: SC knowledge creation, SC knowledge transfer, SC knowledge retention, and SC knowledge application, each of which was measured using a multi-item scale developed for this research. Because no direct measures were found for the SC KM capability construct, new measurement items were developed. The measure development process first identified papers from the knowledge management literature and the IS literature that studied KM constructs in single-firm or multi-firm contexts. Then, the measures used by those papers were reviewed. The researcher found that the measures can be categorized into one of the following groups: measures for one of the four KM processes (creation, transfer, retention and application), technological support to KM, and organizational support to KM (see TABLE A-2 in Appendix A for a summary of the measures identified from the literature related to KM). *SC KM capability* is defined in my study as the ability of firms in a SC to share and collectively create, store and apply SC knowledge related to products, markets and processes. Because my research concerns the sharing, creation, retention and application processes of knowledge management, the "KM processes" group of the KM measures was the most relevant. Subsequently, a new set of measurement items were created by modifying the list of KM process measures identified from the literature. When selecting the measures, it was required that 1) the new measures were related, but not repeated, 2) the new measures were as inclusive as possible to cover all the aspects indicated in the existing KM process measures; 3) the new measures were appropriate to the inter-firm level; and 4) the new measures were at the same detail level. The informants were asked to choose the percentage of time when their company and their SC partner company collectively engaged in a particular knowledge management process (using a five-point Likert type scale ranging from "0% - 20% of the time" to "81% - 100% of the time" with its mid-point anchored as "41% - 60% of the time").

Supply Chain Performance. The performance construct that the research is interested in studying is the performance of the business-to-business exchange relationship between a buyer firm and a supplier firm, and not the firm performance of either side of the supply chain. SC performance was conceptualized as a composite construct consisting of operational performance and strategic performance of a supply chain. *Operational performance* refers to the performance measures that are process-based (Mukhopadhyay and Kekre 2002). It has been shown that operational measures are better than financial measures for SC performance because operational measures reflect the impact of SC activities more directly, more accurately and more timely (Chen and Paulraj 2004a; Chen and Paulraj 2004b). Operational measures can also change over time to reflect market needs. Moreover, operational measures can provide SC partners with opportunities for continuous improvement. *Strategic performance* is a result of firms taking advantage of the opportunities inherent in the inter-organizational relationships (Mukhopadhyay and Kekre 2002; Subramani 2004). The increase of business volume in the buyer-seller relationship is an example of strategic performance. Strategic measures concern performance outcomes at a higher and more aggregated level than the operational measures, and they are not tied to a specific process. Hence, strategic and operational measures are complementary.

The performance measures were developed based on the papers studying dyadic performance (Malhotra et al. 2005; Palmatier et al. 2007; Robson et al. 2008; Ross et al. 2009; Selnes and Sallis 2003). The researcher specified the operational performance as a formative first-order construct and the strategic performance as a reflective first-order construct. In developing the performance measures, a large pool of measurement items as indicators of operational performance and strategic performance were first identified based on an extensive literature review. In this step, the researcher made sure that the candidate items covered the entire scope of the two constructs. The measurement items were selected and purified according to a number of criteria. First, the measures should be relevant to the supplier-buyer relationship, not just to one firm. In other words, the measures should be appropriate to be used at the dyadic supply chain level. The second criterion was that either side of the supply chain relationship should be familiar with the measures so that the questionnaire items could be answered by firms on either side of a relationship. The third criterion was that the selected formative measures for operational performance should not overlap and should, in combination, cover all spectrums of operational performance that were identified. The last criterion followed the conventional guidelines in selecting measures from the literature, which relates to the evaluation of clarity, length, lack of ambiguity and avoidance of jargon (Diamantopoulos and Winklhofer 2001).

The indicator specification process resulted in a set of subjective measures for operational and strategic performance. Operational performance and one of the strategic performance aspects (business volume increase) were measured on a five-point Likert scale, comparing the supply chain's performance to the industry average. The scale ranged from "Significantly Worse Than Industry Average" to "Significantly Better Than Industry Average". The other strategic performance measures were measured on a five-point Likert scale, ranging from "Strongly Disagree" to "Strongly Agree" with a midpoint anchor of "Neutral."

SC IT Capability. SC IT was operationalized as the SC applications used between the informants' companies and their SC partnering companies for business transactions and managerial activities. SC IT capability is a second-order construct consisting of two first-order constructs - SC IT integration and SC IT flexibility. Each of the first-order constructs was measured using a multi-item scale adapted from the literature. SC IT integration measures reflected the extent to which SC applications can be treated as a functional whole. Four measurement items measuring SC IT integration were adapted from Saraf et al. (2007). Because covariance among the four items is assumed, the four indicators of SC IT integration are reflective indicators. SC IT flexibility was measured using four reflective measurement items adapted from Saraf et al. (2007) and Byrd and Turner (2000). The items for SC IT flexibility measured the extent to which SC applications can be changed to accommodate business and technological changes. A five-point Likert- type scale, ranging from “0% - 20% of the time” to “81% - 100% of the time” with its mid-point anchored as “41% - 60% of the time” was used to measure the extent to which the described IT was used in the identified supply chain relationship.

SC Relational Capability. IT-enabled SC relational capability is a second-order construct including two first-order dimensions, SC process integration and SC collaboration. SC process integration was measured using five reflective indicators adapted from Saraf et al. (2007) and Yang and Papazoglou (2000). SC collaboration was measured using six formative indicators developed based on previous research on SC relationships (Bensaou and Venkatraman 1995; Subramani and Venkatraman 2003; Sheu et al. 2006). A five-point Likert-type scale, ranging from “0% - 20% of the time” to “81% - 100% of the time” with its mid-point anchored as “41% - 60% of the time,” was used to measure the extent to which each supply chain activity from a list of activities was carried out.

Buyer-supplier Dependence. Measures of firm dependence on a supply chain relationship were adapted from Kumar et al. (1998) and Heide and John (1988). Firm’s dependence on the supply chain partner is determined by the value of the supply chain partner to the firm and the replaceability of the supply chain partner (Heide and John 1988). The value of the supply chain partner is indicated by the importance of the partner to the firm's sales and profits and the firm's achievement of its performance goals. The replaceability of the supply chain partner is indicated by the ease of replacing the supply chain partner with other firms.

This study measured the firm's dependence on the supply chain partner and the firm's perceived dependence of the partner on the firm. To a supplier, the five indicators of its dependence on a customer included 1) the degree to which the customer is a key customer for the supplier's product or service, 2) the degree to which the supplier's relationship with the customer is important to the supplier's performance goals, 3) the degree to which other customers are available, 4) the switching cost in replacing the customer with a different customer, and 5) the loss of sales and profits incurred by the supplier if the customer is replaced. From the supplier's perspective, the customer's dependence on the supplier was determined by 1) the supplier's perception of its role in serving the customer's needs for the product or service, 2) the supplier's perception of the importance of the supplier-customer relationship to the customer's performance goals, 3) the supplier's perception of the ease with which the customer can find alternative suppliers for the same product/service, 4) the customer's switching costs in replacing the supplier, and 5) the supplier's perception of the degree of the customer's loss of profits if the customer switches the supplier.

To a customer, the five indicators of its dependence on a supplier included 1) the degree to which the supplier is a key vendor of the product/service, 2) the degree to which the customer's relationship with the supplier is important to achieve the customer's performance goals, 3) the availability of alternative sources of supply of comparable product/service, 4) the switching costs in replacing the supplier, and 5) the loss of profits and sales occurred on the customer's side in replacing the supplier. The customer's perception of the supplier's dependence was measured by 1) the customer's perception of its importance in the supplier's sales, 2) the customer's perception of the importance of the supplier-customer relationship to the supplier's performance goals, 3) the customer's perception of the availability of alternative customers for the supplier, 4) the customer's perception about supplier's switching costs in replacing the customer with a different customer, and 5) the customer's perception of the degree to which the supplier can replace the customer without significant loss to profits. The dependence measures were evaluated on a five-point scale, ranging from "Strongly Disagree" to "Strongly Agree" with the midpoint being "Neutral."

Consistent with Kumar et al. (1998), dependence was conceptualized as a composite index. Each of the five items measuring dependence represented a dimension of it and the dependence construct was defined by the total of the scores across all items. The constructs studied by the research are Total Interdependence of supply chain partners and Dependence Asymmetry. Total Interdependence was calculated as the sum of the firm's dependence on the partner and the partner's dependence on the firm. Dependence Asymmetry was calculated as the absolute difference between the firm's dependence on the partner and the partner's dependence on the firm.

Control Variables

Transaction volume. Two alternative measures were used to measure transaction volume between the supply chain partners. The first was an absolute measure that used the dollar value of transactions in the supply chain relationship from the previous year. The second measure was a relative measure that indicated the percentage of the transaction volume between the supply chain partners in the firm’s total business volume. Specifically, this measure was the percentage of the firm’s total sales revenue that was accounted for by the buyer’s firm from a supplier’s perspective or the percentage of the firm’s total purchasing value that was accounted for by the supplier’s product/service from the buyer’s perspective.

Relationship time. Relationship time was measured by a six-item option scale, ranging from “Less than 1 year” to “21 years or more” with the other four options spanning five years each.

Cooperative norms. Cooperative norms have been shown to play an important role in shaping a relationship atmosphere conducive to performance gains (Malhotra et al. 2007). A single-item measure was used to measure cooperative norms.

Long-term orientation. A single-item measure inquiring whether a supply chain relationship has long-term relationship goals was used to measure long-term orientation between the supply chain partners.

Trust. The research used a single-item measure for trust, which asked the informants if the relationship with their partner firms was built on trust.

Environmental Uncertainty. Environmental uncertainty is reflected by market volatility and market diversity (Achrol and Stern 1988; Ganesan 2004; Palmatier et al. 2007). Market volatility is the frequency of changes in market forces and market diversity is the degree of heterogeneity in the needs and preferences of end users. The measures of environmental uncertainty were adapted from Selnes and Sallis (2003) and Ganesan (1994). The respondents were asked to indicate their agreement with three items describing the environment of the end market for the product(s)/service exchanged in the supply chain relationship. A five-point Likert scale ranging from “Strongly Disagree” to “Strongly Agree” was used.

Product unpredictability. Product unpredictability may adversely impact supply chain performance. Product complexity and unstable product specifications contribute to product unpredictability. Thus, product unpredictability was captured by two items, each measuring one of the dimensions of the construct. A five-point Likert scale ranging from “Strongly Disagree” to “Strongly Agree” was used.

3.3.3 Sample

Data were collected using an online survey over a five-month period. The survey was distributed to supply chain professionals with the assistance of two supply chain professional associations – the Association for Operations Management (APICS) and the Institute for Supply Management (ISM). As an incentive for participating in the survey, respondents who completed the survey were offered an opportunity to win one of five $50 Amazon gift certifications.

The researcher first collected data from a random list of 2,480 members of APICS. The targeted informants were middle or senior managers with direct responsibilities for the supply chain management function in their organizations. For privacy reasons, APICS did not disclose the e-mails of the selected members. However, it agreed to send an email on behalf of the researcher to those members inviting their participation. To encourage responses, the researcher offered to provide an executive summary of the findings to APICS and interested members. The survey invitation email was sent in two rounds in mid-July, with the second round being a reminder after one week of the first round. A total of 83 responses were received. The response rate was 3%. Of the 83 responses, 7 were discarded due to excessive missing information, which resulted in 76 usable responses. The number of responses from customers was 46 and the number of responses from suppliers was 30.

Second, the researcher contacted via e-mail the board of directors and officers of 145 ISM affiliates to ask for their participation in the survey. In addition, they were asked to forward the hyperlink of the survey to other ISM members who might be interested in the research subject. Finally, the Executive Officers of each affiliate were contacted via e-mails and telephone calls to ask for their support in distributing the survey to the members of their affiliates. To encourage participation, the researcher offered to provide an executive report of the study's findings to ISM affiliates and their interested members. 14 affiliates allowed the researcher to share the survey. A total of 97 responses were received from the ISM population. Of the 97 responses, 9 were deleted due to excessive missing information, leaving the size of usable responses to 88. The number of responses from customers was 80 and the number of responses from suppliers was 8.

The APICS sample and the ISM sample were compared with respect to the supply chain characteristics, including time of the supply chain relationship, the annual dollar transaction value in the supply chain and the percentage of the responding firm's overall transaction value accounted for by the supply chain. Analysis of variance (ANOVA) was used to conduct the comparison. The results showed that the supply chain data collected from the two supply chain associations did not differ significantly on those supply chain characteristics. In addition, the respondents' number of years working in the supply chain management area was compared across the APICS sample and the ISM sample using ANOVA. There was no statistically significant difference between the two samples regarding the respondent's experience in supply chain management. Therefore, sample bias was not an issue in the data and the APICS sample and ISM sample can be combined for further analysis. TABLE 3-6 shows the results of the ANOVA tests.

TABLE 3-6. ANOVA Tests Comparing Responses From APICS Sample and ISM Sample

Factor	**Source**	**Sum of Squares**	**Mean Square**	**F**	**Sig.**
Relationship time	Between Within Total	1.12 324.50 325.62	1.12 2.00	0.56	0.46
Transaction volume ($)	Between Within Total	1.48E+16 2.98E+19 2.98E+19	1.48E+16 2.11E+17	0.07	0.79
Relative transaction volume (%)	Between Within Total	0.03 7.47 8.41	0.03 0.05	0.57	0.45
Respondent's years of experience in SCM	Between Within Total	12.39 683.43 695.85	12.39 4.41	2.81	0.10

Nonresponse bias can be assessed by comparing data collected from early and late survey respondents (Armstrong and Overton 1977). However, the survey service website that the researcher used to collect data did not record the time when each questionnaire was completed. Hence, the researcher could not differentiate the responses collected before and after the reminder message, making the assessment of nonresponse bias difficult. Nonetheless, as the ISM sample responded to the survey chronologically later than the APICS sample, the absence of statistically significant differences between the two samples regarding the supply chain characteristics and the respondents' characteristic provided partial evidence that nonresponse bias was not likely to be a problem in the data.

The supplier sample and buyer sample were also compared with respect to the supply chain characteristics and the respondent characteristic using ANOVA. TABLE 3-

7 shows the ANOVA results. The results did not show significant differences between the responses from the two sides regarding those characteristics. Hence, it can be inferred that the supply chain relationships were not different between the two groups and the data provided by the two sides can be analyzed as a whole.

TABLE 3-7. ANOVA Tests Comparing the Supplier Responses and Customer Responses

Factor	Source	Sum of Squares	Mean Square	F	Sig.
Relationship time	Between Within Total	3.63 323.91 327.68	3.63 2.00	1.82	0.18
Transaction volume ($)	Between Within Total	4.11E+16 2.90E+19 2.90E+19	4.11E+16 2.06E+17	0.20	0.66
Relative transaction volume (%)	Between Within Total	0.00 5.31 5.31	0.00 0.06	0.01	0.95
Respondent’s years of experience in SCM	Between Within Total	4.86 697.50 702.42	4.86 4.50	1.08	0.33

In the combined sample, the total number of responses was 164, among which 126 were from customers and 38 from suppliers. The average annual transaction value in the supply chains was $86,504,539 and the average percentage of the responding firm’s overall transaction value accounted for by the identified supply chain relationship was 19%. The supply chain’s relationship time and the respondent’s SCM experience are shown in TABLE 3-8.

TABLE 3-8. Frequencies of Relationship Time and Respondent's Years of SCM Experience

Characteristics	Categories	% in the sample
Relationship Time	1) Less than 1 year	0.9
	2) 1 – 5 years	19.8
	3) 6 – 10 years	31.1
	4) 11 – 15 years	17.9
	5) 16 – 20 years	11.3
	6) 21 years or more	18.9
Respondent's years of SCM experience	1) Less than 1 year	2.9
	2) 1 – 4 years	7.6
	3) 5 – 8 years	16.2
	4) 9 – 12 years	16.2
	5) 13 – 16 years	10.5
	6) 17 – 20 years	9.5
	7) 21 – 24 years	18.1
	8) 25 years or more	19.0

To evaluate common method bias in the data, Harman's post hoc one-factor test was used (Podsakoff et al. 2003). Principal components factor analysis extracted 14 factors that had Eigen values greater than 1. The first factor explained 27% of the variance in the data, indicating that a single factor does not account for most of the variance. Consequently, it can be concluded that common method bias was not a problem with the data.

3.4 Data Analysis and Results

3.4.1 Measurement Model

Because the model includes both reflective and formative measures, appropriate validation procedures were followed for the two types of measures. The reflective constructs include SC IT integration (ITINT), SC IT flexibility (ITFLEX), SC process integration (PROINT), SC knowledge creation capability (CREAT), SC knowledge transfer capability (TRANS), SC knowledge retention capability (RETEN), SC knowledge application capability (APPL), SC strategic performance (STRAT), and environment uncertainty (ENV). The formative constructs include SC collaboration (COL), SC operational performance (OPER), product unpredictability (UNPRED), dependence on SC partner firm (DEPONP), and dependence of SC partner firm (DEPOFP). The guidelines for examining internal consistency, convergent validity and discriminant validity were followed to check the measurement validity of reflective constructs (Gefen and Straub 2005). Discriminant validity and multicollinearity were tested for formative measures.

SPSS was used as the first step to check the internal consistency of the reflective measures. Cronbach's alphas were produced for each reflective first-order construct. Other than STRAT (Cronbach's alpha = 0.52), all constructs had a Cronbach's alpha value greater than 0.6, the recommended value for exploratory research (Nunnally and Bernstein 1994). After conducting a principle component analysis on the five measures of STRAT, strat1 and strat3 loaded on two different factors separated from the other three STRAT measures. Therefore, strat1 and strat3 were removed from the scale to ensure the internal consistency of the construct. After the removal of strat1 and strat3, the Cronbach's alpha of STRAT became 0.62. TABLE 3-9 displays the Cronbach's alpha values for all the reflective constructs.

TABLE 3-9. Test of Measurement Reliability

Construct	**Cronbach's Alpha**
STRAT	0.62
ITINT	0.83
ITFLEX	0.87
CREAT	0.91
TRANSF	0.94
RENT	0.88
APPL	0.90
PROCINT	0.92
ENV	0.74

Exploratory factor analysis was used to evaluate the discriminant validity of the reflective measures. TABLE 3-10 shows the factor structure that emerged from the data. The factor analysis results indicated that there was one dimension for the KM capability measures and one dimension for the IT capability measures. The measurement model was refined to reflect the findings from the factor analysis. After the refinement, the construct of SC IT capability (ITCAP) became a first-order construct measured by 8 reflective indicators, and the construct of SC KM capability (KMCAP) became a first-order construct measured by 13 reflective indicators.

TABLE 3-10. Factor Analysis Results

	Components			
	1	2	3	4
STRAT2				0.40
STRAT4				0.75
STRAT5				0.64
ITINT1		0.67		
ITINT2		0.73		
ITINT3		0.79		
ITINT4		0.73		
ITFLEX1		0.73		
ITFLEX2		0.64		
ITFLEX3		0.73		
ITFLEX4		0.73		
CREAT1	0.74			
CREAT2	0.77			
CREAT3	0.75			
CREAT4	0.85			
TRANSF1	0.89			
TRANSF2	0.88			
RETEN1	0.80			
RETEN2	0.79			
RETEN3	0.75			
APPL1	0.78			
APPL2	0.80			
APPL3	0.76			
APPL4	0.76			
PROINT1			0.70	
PROINT2			0.78	
PROINT3			0.70	
PROINT4			0.61	
PROINT5			0.56	

Notes: Principal components method was used for extracting the components and Varimax was the rotation method. All factor loadings below 0.40 were suppressed.

Confirmatory factor analysis in SmartPLS (Ringle et al. 2005) was used to validate the purified measurement model. Because the model contained two second-order constructs – SC relational capability (RELCAP) and SC performance (SCPERF), a repeated indicator model, or multi-hierarchy model was created. Seven control variables were also included in the model for the confirmatory factor analysis test. The control variables were percentage of SC transaction in the firm's overall transaction volume (PERCT), years in relationship (TIME), cooperative norms (NORM), trust (TRUST), long-term orientation (LONGTERM), environmental uncertainty (ENV), and product unpredictability (UNPRED).

TABLE 3-11 presents the descriptive statistics and correlations among the constructs. Convergent validity, discriminant validity and internal consistency of the reflective measures were also examined. Average variance extracted (AVE) of the reflective measures exceeded the recommended minimum of 0.5 (Gefen and Straub 2005) and the square roots of the AVEs were higher than the cross-construct correlations, indicating acceptable convergent and discriminant validity. Furthermore, Cronbach's alpha for all reflective constructs exceeded 0.6, and the composite reliability of all reflective constructs exceeded 0.7, indicating a good internal consistency.

TABLE 3-11. Descriptive Statistics and Correlations

	ITCAP	COL	PROINT	KMCAP	OPER	STRAT	ENV	LTERM	NORM	PERCT	TIME	TRUST	UNPRED
ITCAP	--												
COL	0.57	--											
PROINT	0.72	0.75	--										
KMCAP	0.47	0.63	0.58	--									
OPER	0.24	0.14	0.17	0.24	--								
STRAT	0.30	0.32	0.30	0.37	0.36	--							
ENV	-0.27	-0.22	-0.20	-0.13	0.09	-0.15	--						
LTERM	0.18	0.27	0.26	0.30	0.02	0.27	-0.13	--					
NORM	0.16	0.26	0.24	0.33	0.19	0.53	-0.03	0.59	--				
PERCT	0.10	0.17	0.12	0.14	-0.09	0.02	0.04	0.05	0.08	--			
TIME	0.01	-0.09	-0.12	-0.03	0.12	0.03	-0.04	0.08	0.08	0.06	--		
TRUST	0.12	0.26	0.30	0.27	0.12	0.39	-0.21	0.59	0.62	0.15	-0.02	--	
UNPRED	-0.40	-0.31	-0.35	-0.26	-0.13	-0.24	0.11	-0.12	-0.19	-0.15	-0.10	-0.03	--
Mean (SD)	2.49 (1.13)	2.77 (1.12)	2.84 (1.17)	2.97 (1.05)	3.21 (0.49)	3.63 (0.64)	3.29 (0.97)	3.95 (0.88)	4.12 (0.75)	0.19 (0.22)	3.75 (1.41)	3.90 (0.89)	1.11 (1.94)
Cronbach's alpha	0.91	--	0.92	0.96	--	0.64	0.74	--	--	--	--	--	--
Composite reliability	0.93	--	0.94	0.96	--	0.81	0.71	--	--	--	--	--	--
AVE (Square Root of AVE)	0.61 (0.78)	--	0.75 (0.87)	0.68 (0.83)	--	0.58 (0.76)	0.48 (0.69)	--	--	--	--	--	--

Convergent validity of the reflective measures was also confirmed by the values of outer model loadings. A bootstrapping sample of 500 was used to test the statistical significance of loadings. TABLE 3-12 reports the loadings of each measurement item on its latent construct. With the exception of the measures for ENV, the loadings of the indicators either reached or exceeded the recommended level of 0.7. The loadings of the ENV indicators were not significant. Because there were only three indicators of ENV and their t-values were acceptable, those three indicators were retained.

TABLE 3-12. Outer Model Loadings

Latent Construct	Indicators	Loadings	Standard Error	t Values
ITCAP	itflex1	0.75	0.06	**12.47*** **
	itflex2	0.80	0.04	**21.79*** **
	itflex3	0.80	0.04	**20.27*** **
	itflex4	0.86	0.03	**27.53*** **
	itint1	0.76	0.05	**16.07*** **
	itint2	0.79	0.05	**17.02*** **
	itint3	0.78	0.05	**16.74*** **
	itint4	0.71	0.07	**9.50*** **
PROINT	proint1	0.85	0.03	**30.85*** **
	proint2	0.87	0.02	**35.02*** **
	proint3	0.89	0.02	**41.22*** **
	proint4	0.87	0.03	**27.19*** **
	proint5	0.85	0.03	**30.50*** **
KMCAP	appl1	0.82	0.03	**30.34*** **
	appl2	0.84	0.03	**28.18*** **
	appl3	0.80	0.04	**20.95*** **
	appl4	0.81	0.04	**22.92*** **
	creat1	0.78	0.05	**16.68*** **
	creat2	0.79	0.05	**15.17*** **
	creat3	0.81	0.04	**21.82*** **
	creat4	0.88	0.02	**39.95*** **
	reten1	0.86	0.02	**40.07*** **
	reten2	0.84	0.03	**29.14*** **
	reten3	0.79	0.04	**20.01*** **
	transf1	0.86	0.03	**31.26*** **
	transf2	0.87	0.03	**31.43*** **

TABLE 3-12 (Continued)

STRAT	strat2	0.69	0.09	**7.72*** **
	strat4	0.83	0.05	**17.04*** **
	strat5	0.76	0.06	**13.82*** **
ENV	env1	-0.53	0.42	1.27
	env2	-0.44	0.43	1.03
	env3	-0.98	0.54	**1.83***

*p< 0.1, ***p<0.01

For formative constructs, the outer model weights were examined. Four indicators did not have significant weights on their respective constructs. These four indicators were col5 (t = 1.0), oper1 (t = 0.1), unpred1 (t = 1.0), and unpred2 (t = 1.61). Because oper1 had an extremely low weight, it is not a good measure for OPER. Therefore, oper1 was dropped from the scale. col5, unpred1 and unpred2 were retained due to their relatively acceptable t values. The outer model weights and their significance levels were checked again after oper1 was dropped. This time, with the exception of col5 and unpred1, all formative indicators' outer weights were significant. TABLE 3-13 reports the outer model weights.

TABLE 3-13. Outer Model Weights

Latent Construct	**Indicators**	**Weights**	**Standard Error**	**t Values**
COL	col1	0.40	0.07	**5.38*** **
	col2	0.16	0.06	**2.52** **
	col3	0.16	0.07	**2.25** **
	col4	0.15	0.05	**2.85*** **
	col5	0.07	0.07	1.03
	col6	0.31	0.07	**4.33*** **
OPER	oper2	0.46	0.25	**1.81***
	oper3	0.57	0.17	**3.29*** **
	oper4	0.48	0.20	**2.42** **
UNPRED	unpred1	-0.56	0.54	1.03
	unpred2	1.04	0.56	**1.87***

*p<0.1, **p<0.05, ***p<0.01

Multicollinearity among indicators is problematic for formative constructs as it can result in nonsignificant items. The variance inflation factor (VIF) is a useful statistic to assess multicollinearity problem. VIF values below 3.3 are indicative of an absence of multicollinearity (Diamantopoulos and Siguaw 2006). The VIF tests were run in SPSS for this dataset. VIF values were produced for five indicators of DEPONP, five indicators of DEPOFP, four indicators of OPER, six indicators of COL, and two indicators of UNPRED. The highest VIF values for these five constructs were 2.7, 2.1, 1.9, 2.8, and 1.1, respectively. All were below the threshold value 3.3. Therefore, multicollinearity is not a problem in the formative constructs.

3.4.2 Test of Hypotheses

To test the hypotheses, a path model was created in SmartPLS. Factor scores for the first order constructs of RELCAP and SCPERF were computed as weighted composites of respective indicator values. RELCAP and SCPERF were then modeled as first-order constructs where their indicators were the composite factor scores. A bootstrapping sample of 500 was used to test the statistical significance of structural paths. The results of the path analysis for the structural model are presented in FIGURE 3-2. TABLE 3-14 is a summary of the results.

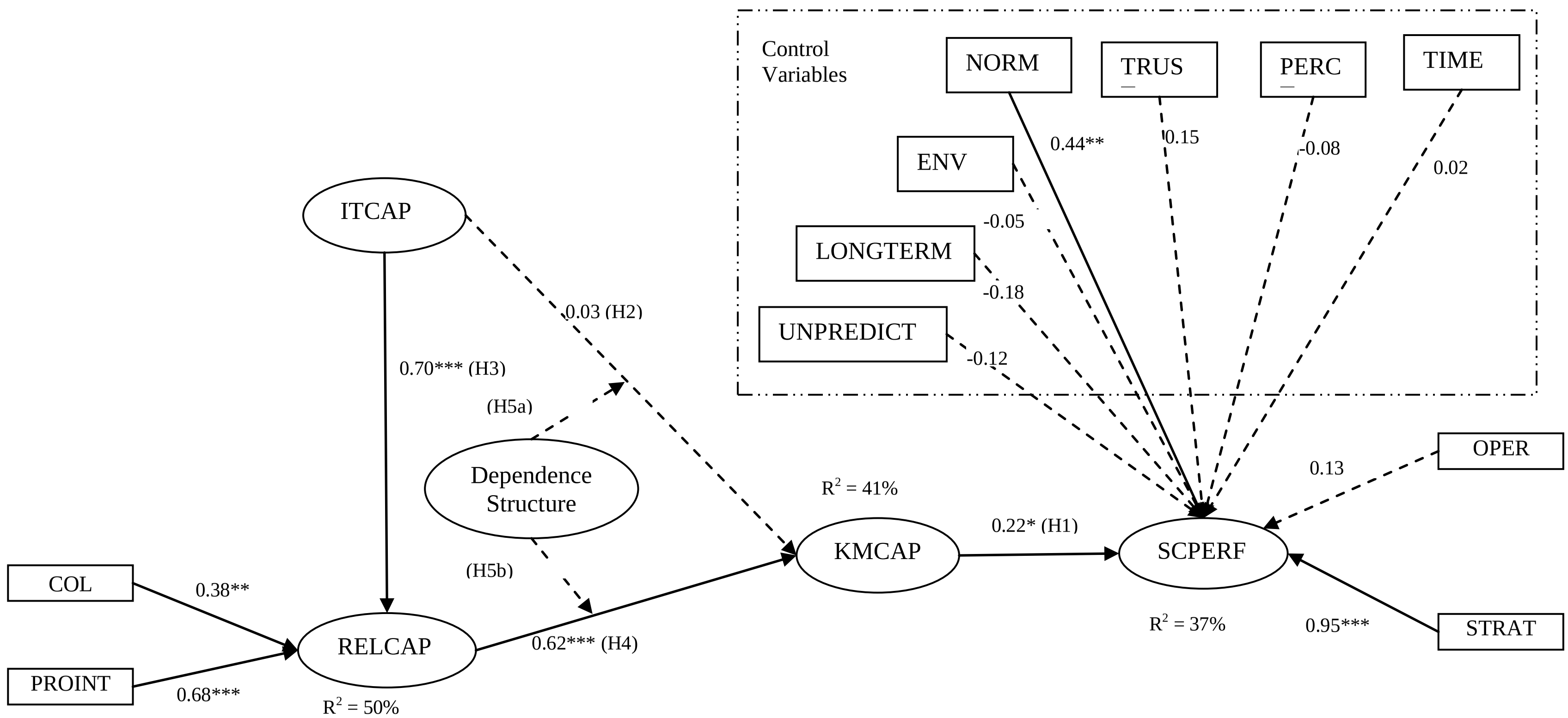

FIGURE 3-2. Path Model Results

* p< 0.1
** p<0.05
*** p< 0.01

TABLE 3-14. Path Analysis Results

	Path Coefficients	**Standard Error**	**T statistics**
	RELCAP		
PROINT	0.68	0.16	**4.44***
COL	0.38	0.17	**2.21**
ITCAP	0.70	0.06	**12.58***
R^2	*0.50*		
	KMCAP		
ITCAP	0.03	0.12	0.24
RELCAP	0.62	0.12	**5.08***
R^2	*0.41*		
	SCPERF		
OPER	0.13	0.28	0.47
STRAT	0.95	0.21	**4.44***
KMCAP	0.22	0.12	**1.87***
R^2	*0.37*		
Controls			
ENV	-0.05	0.13	0.41
LONGTERM	-0.18	0.15	1.20
NORM	0.44	0.16	**2.84***
PERCENT	-0.08	0.08	1.00
TIME	0.02	0.10	0.26
TRUST	0.15	0.15	1.00
UNPREDICAT	-0.12	0.09	1.36

* p< 0.1
** p<0.05
*** p< 0.01

The results from path analysis showed that the model accounted for 37% of variance in supply chain performance. All but one path (ITCAP → KMCAP) in the model was significant, providing support for hypotheses 1, 3, and 4. Operational performance did not load significantly on the supply chain performance construct. Finally, cooperative norm was the only control variable that was found to be significantly associated with supply chain performance.

Because the path of operational performance to SC performance was not statistically significant, operational performance cannot be considered a predictor of SC performance. This result suggested that operational performance and strategic performance should not be combined to form SC performance. Hence, a second path model was created where SC operational performance and SC strategic performance were used as two endogenous performance constructs. The relationships between KMCAP and each of the performance constructs were tested. The results are displayed in FIGURE 3-3. The results showed that KMCAP had a significant impact on SC operational performance as well as on SC strategic performance. The model explained 37% of the variance of SC strategic performance and 17% of the variance of SC operational performance.

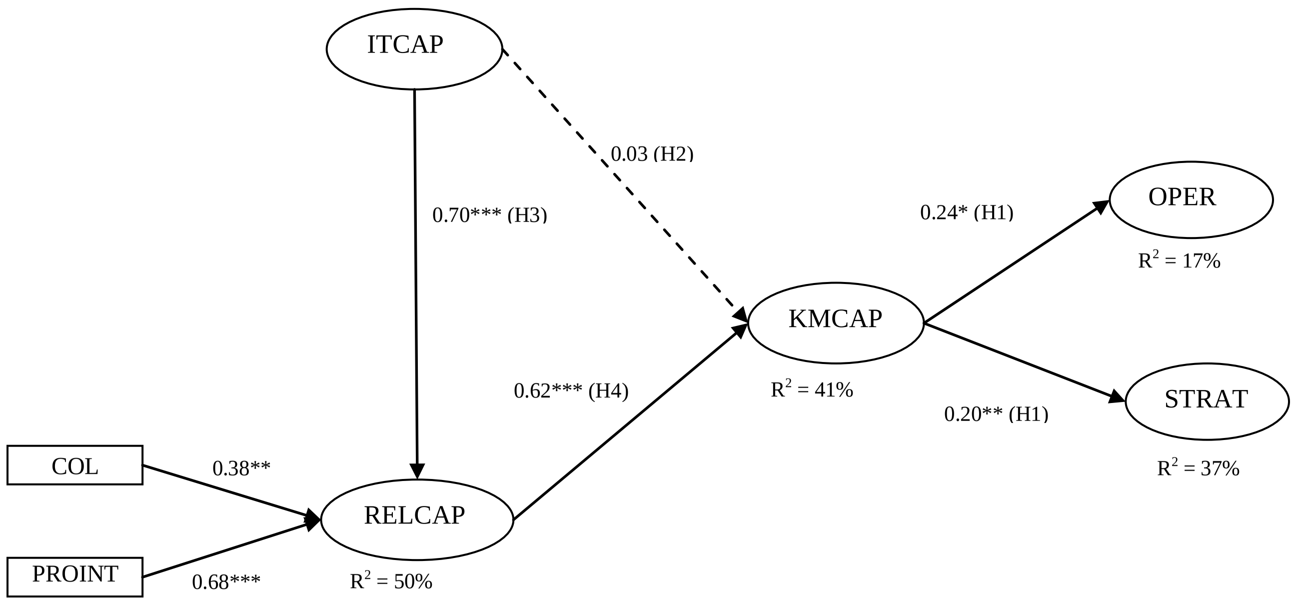

FIGURE 3-3. Path Model Results (Two Performance Constructs)

* p< 0.1
** p<0.05
*** p< 0.01

Test of Mediation

This model proposed a direct relationship between ITCAP and KMCAP. But, the results of previous path analysis examining the path coefficients of direct paths showed that the direct path from ITCAP to KMCAP was not significant. To test if RELCAP mediated the impact of ITCAP on KMCAP, two complementary methods of mediation analysis were conducted (Subramani 2004). First, the research model that proposed a partial mediation (incorporating the direct path from ITCAP to KMCAP) was compared with a competing model that proposed a full mediation. The two models were nested and the partial mediation model had one more path than the full mediation model. To assess the significance of variance added to KMCAP by the extra path from ITCAP, a technique similar to that used to test nested models in stepwise linear regression was adopted. The difference between the R^2 statistics of the two models was obtained to produce an f^2 statistic and the significance of the f^2 was assessed based on a pseudo F test[1]. The R^2 of KMCAP in the partial mediation model was 0.408, compared to the R^2 of 0.409 in the full mediation model. f^2 was 0.0017 and pseudo F (1, 153) statistic was 0.26, which was insignificant. The result suggested that the extra variance added to KMCAP by introducing the direct path from ITCAP from KMCAP was not significant for predicting the dependent variable KMCAP.

Although the comparison of the nested models showed that the path from ITCAP to KMCAP did not significantly contribute to explaining the variances in KMCAP, there was little information on the magnitude and significance of the indirect path itself. Hence, a second approach involving an analysis of individual mediated paths was conducted

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[1] f^2 is calculated as (R^2partial - R^2 full)/(1- R^2 partial). The pseudo F statistic is computed as f^2* (n-k-1), with 1, (n-k) degrees of freedom where n is the sample size and k is the number of constructs in the model.

(Hoyle and Kenny 1999; Subramani 2004). This analysis involved the path coefficients and standard errors of the direct paths between ITCAP and RELCAP, and between RELCAP and KMCAP, in the full mediation model. The magnitude of mediation was 0.45, which was computed as the product of the standardized path coefficients between ITCAP and RELCAP (0.71), and between RELCAP and KMCAP (0.64). The standard error of the mediated path was 0.058, which was calculated based on the standardized path coefficients and standard deviations of the direct paths[2]. As a result, the *z* statistic for the mediation was 7.81, which was significant at the 0.01 level. The results from the two mediation analyses suggested that there was no direct impact of ITCAP on KMCAP, and RELCAP mediated the relationship between ITCAP and KMCAP.

Although not proposed in the hypotheses, the mediation effects of KMCAP in the relationship between ITCAP and SCPERF and the relationship between RELCAP and SCPERF were tested to further examine the impact of SC capabilities on SC performance. Similar to the procedures followed in testing the mediation effect of RELCAP, comparison of partial and full mediation models and the analysis of individual mediated paths were conducted. TABLE 3-15 and 3-16 present the results of the two analyses. The results indicated that KMCAP fully mediated the impact of RELCAP on SCPERF, but only partially mediated the impact of ITCAP on SCPERF.

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[2] The standard error of the mediated path is approximated as sqrt $(p_1^2 {*} s_2^2 + p_2^2 {*} s_1^2 + s_1^2 {*} s_2^2)$, where p_1 and p_2 are the path coefficients between ITCAP and RELCAP, and between ITCAP and KMCAP, and s_1 and s_2 are the standard deviations of p_1 and p_2.

TABLE 3-15. Comparison of Nested Models

Extra Path	R^2 In Fully Mediated Model (no direct path)	R^2 In Partially Mediated Model	f^2 value	Pseudo F (1, 153)	Conclusion
ITCAP→ SCPERF	0.37	0.38	0.02	3.04	Significant at $p<0.1$
RELCAP→ SCPERF	0.3675	0.3691	0.0026	0.40	Insignificant

TABLE 3-16. Significance of Mediated Paths

Mediated Path	Direct Paths	Path Coefficients	Standard Errors	Z stat
ITCAP→ KMCAP→ SCPERF	ITCAP→ KMCAP	0.03	0.13	0.20
	KMCAP→ SCPERF	0.22	0.12	
RELCAP→ KMCAP→ SCPERF	RELCAP→ KMCAP	0.62	0.12	1.70 ($p<0.05$)
	KMCAP→ SCPERF	0.22	0.12	

Test of Moderation

This research proposed that the dependence structure of supply chains moderates the relationship between ITCAP and KMCAP, and the relationship between RELCAP and KMCAP. Specifically, when the two supply chain firms have a high interdependence and, at the same time form a symmetric relationship, the effects of ITCAP and RELCAP on KMCAP will be stronger.

To test the moderation effect, the means of the items for the two dependence constructs were calculated and used as composite scores for a firm's dependence on the partner (DEPONP) and the partner's dependence on the firm (DEPOFP). Total interdependence (TOTLD) and interdependence asymmetry (ASYMD) were then derived from DEPONP and DEPOFP. TOTLD was constructed by summing DEPONP and DEPOFP, and ASYMD was created as the absolute difference between DEPOFP and DEPONP (Kumar et al. 1998).

Because DEPONP and DEPOFP both had a minimum value of 1 and a maximum value of 5, the range of ASYMD was 0 to 4 with a mean of 2 and the range of TOTLD was 2 to 10 with a mean of 6. Consequently, responses can be categorized into four groups according to the combined values of ASYMD and TOTLD. The four groups are: 1) high TOTLD and high ASYMD, 2) high TOTLD and low ASYMD, 3) low TOTLD and high ASYMD, and 4) low TOTLD and low ASYMD.

The four groups were further collapsed into two groups – (1) the high SYMTOT group where there was *both* a low asymmetric relationship between the partners *and* high total interdependence, and (2) the low SYMTOT group where there was *either* a high asymmetric relationship between the partners *or* the total interdependence was low. TABLE 3-17 illustrates the classification of dependence structure.

TABLE 3-17. Classifications of Responses Based on Dependence Structure

	Low Total Dependence (TOTLD: 2 – 6)	**High Total Dependence (TOTLD: 7 - 10)**
Low Asymmetry (ASYMD: 0 - 2)	• Low SYMTOT • The two sides of a supply chain in this category are not dependent on each other and their power is relatively the same.	• High SYMTOT • At least one firm is highly dependent on another firm (DEPONP or DEPOFP = 4, 5). Otherwise, if both DEPONP and DEPOFP are less than 4, total interdependence cannot reach 7, which is the threshold value between low and high total interdependence.
High Asymmetry (ASYMD: 3 - 4)	• Low SYMTOT • Example: DEPONP =4, DEPOFP = 1	• Low SYMTOT • Example: DEPONP = 5, DEPOFP = 2

The hypotheses proposed that the effects of ITCAP and RELCAP on KMCAP would be stronger in the high SYMTOT group than in the low SYMTOT group. A multi-group path model comparison was carried out to compare the path coefficients between the high SYMTOT and the low SYMTOT group. First, path models were built for both groups. Second, a bootstrapping sample of 500 was used to calculate the path coefficients, means and standard errors of the paths. TABLE 3-18 presents the path analysis results for both groups.

TABLE 3-18. Path Analysis Results for High SYMTOT Group and Low SYSMTOT Group

Path	Coefficients	Mean	Standard Error	t Values
highSYMTOT ***(n1 = 100)***				
ITCAP →KMCAP	-0.01	-0.01	0.12	0.06
RELCAP →KMCAP	0.61	0.62	0.13	**4.85****
ITCAP → RELCAP	0.67	0.68	0.05	**12.42****
KMCAP → SCPERF	0.27	0.26	0.10	**2.57****
lowSYMTOT ***(n2 = 64)***				
ITCAP →KMCAP	0.21	0.21	0.10	**2.02***
RELCAP →KMCAP	0.57	0.57	0.11	**5.29****
ITCAP → RELCAP	0.79	0.80	0.04	**20.48****
KMCAP → SCPERF	0.21	0.22	0.09	**2.36***

* t> 1.65
** t> 1.96
*** t> 2.58

The impact of ITCAP on KMCAP was insignificant in the highSYMTOT group but significant in the lowSYMTOT group. Consequently, it can be concluded that dependence type moderated the relationship between ITCAP and KMCAP. However, the results showed that when SC relationships were asymmetric or lack interdependence, the impact of IT on KMCAP was stronger, which was contrary to what was proposed in Hypothesis 5a. In order to determine if the significant impact of RELCAP on KMCAP was different between the two groups, path coefficients of RELCAP→ KMCAP from the two groups were compared using a *t* test[3] (Chin 2004). The *t* value of the difference between the two samples for the path between RELCAP and KMCAP was 0.23 and it was insignificant at $p< 0.1$. Hence, dependence structure did not moderate the impact of relational capability on KM capability and Hypothesis 5b was not supported.

A post-hoc power analysis

PLS models are estimated through a series of multiple regressions (Chin 1998). Hence, the power of PLS path models can be assessed in a way that is similar to calculating power in linear regression (Chin and Newsted 1999). The maximum number of predictors – formative indicators or paths from exogenous Latent Variables - should be used to calculate power. There were 9 exogenous variables to SCPERF, which had the maximum number of predictors in this model.

A post hoc power analysis was run in G*Power (Faul et al. 2009). Medium effect size of R^2 13% and a two-tail test with alpha 0.05 were specified. When the sample size was 164, the power of the test was 88%. To test the power of the multi-group comparison test, a post-hoc power analysis for independent-sample t-tests was run in G*Power. A two-tail test with alpha 0.05 was specified. A medium effect size of d 0.5 was used. When the two sample sizes were 100 and 64, the power was 87%. The results indicated that when medium effect sizes were assumed, the path analysis had an acceptable level of power to detect the effects that truly existed.

[3] $t = \frac{Path_{sample\ 1} - Path_{sample\ 2}}{\sqrt{SE_{sample\ 1}^2 + SE_{sample\ 2}^2}}$

3.5 Discussion

The results of the empirical research suggest that SC IT infrastructure capability enables SC relational capability, which in turn impacts the performance of supply chains, both strategic performance and operational performance. This section interprets the results and provides implications for practice.

A surprising result of the study is that knowledge management capability is a single dimensional construct and not a second-order construct reflected by the four dimensions – knowledge creation capability, knowledge transfer capability, knowledge retention capability, and knowledge application capability. In the factor analysis, indicators from all four knowledge management capability dimensions loaded significantly on one factor. This result implies that supply chains that have high capability in any one of the four knowledge management processes – creation, transfer, application, and retention - are likely to have high capability on the other processes also. These findings provide an empirical basis for firms to understand their supply chain knowledge management capability.

Knowledge embedded in supply chain relationships can be considered a type of complementary resource that is valuable to participating firms. According to the relational view, a collective capability in retaining, mobilizing, and utilizing the knowledge resource can contribute to sustainable growth of supply chains. The results support this relational view by showing that knowledge management capability of supply chains is positively associated with the supply chain’s performance. Supply chain performance was measured as operational performance and strategic performance. Operational performance is concerned with a supply chain’s routine functioning and was measured as a formative construct including four indicators: order fulfillment time, percentage of products meeting specifications, operating costs, and accuracy of demand forecast. Strategic performance of a supply chain relates to the supply chain's long-term competitiveness on the market. The results show that knowledge management capability of a supply chain is critical in helping the supply chain strengthen its strategically oriented relationship goals as well as in improving its routine activities.

SC IT infrastructure capability was conceptualized as two dimensions – SC IT integration and SC IT flexibility. SC IT integration allows transfer of consistent data between firms and integration of functional applications between supply chain firms. SC IT flexibility refers to the extent to which SC IT infrastructure and software applications are ready to be adapted to meet new business requirements. Although SC IT infrastructure capability was proposed as a formative second-order construct with IT integration and flexibility as its two dimensions, the results suggested that SC IT integration and flexibility were highly correlated. Essentially, the two dimensions are caused by one underlying mechanism - SC IT capability. This notion is consistent with the findings in some IS studies (e.g., Byrd and Turner 2000) that the degree to which IT infrastructure can be upgraded for modified to adapt to business changes is related to the extent to which data is transparent and consistent across multiple functions.

The results demonstrate that SC IT capability has a significant impact on the SC's relational capability, which includes supply chain process integration and supply chain collaboration. Drawing from the relational view (Dyer and Singh 1998), the relational capability of a supply chain refers to the ability of supply chain firms to collectively mobilize complementary relation-specific resources, such as human resources, information and processes. An examination of the weights for the two formative dimensions of SC relational capability suggests that although both dimensions - process integration and collaboration - are critical to the relational capability of supply chains, supply chain process integration is relatively more important than collaboration. Common data definitions and tightly coupled applications provided by SC IT integration and flexibility provide a seamless platform to support process flows across firms. Improved exchange of information as a result of integrated and flexible IT infrastructure creates opportunities for firms to identify resources or capabilities in their partner firms that may have potential for collaboration. Investments made by supply chain firms to build SC IT capability also signals the need for jointly carrying out supply chain activities.

Contrary to the proposed relationship between IT infrastructure capability and supply chain's knowledge management capability, the results show that relational capability fully mediates the impact of IT infrastructure capability on supply chain knowledge management capability, regardless of the supply chain's dependence structure. This result highlights that supply chain relational capability is an important step for supply chains to reap performance benefits from the building of knowledge management capabilities. The mediating effect of relational capability can be understood in the light of the knowledge-based view (KBV) (Grant 1991). KBV identifies knowledge management capability as a higher-order organizational capability that draws on the knowledge across individuals, groups and divisions. Because employees are the conduits of knowledge management processes, the activities or processes that mobilize employees' knowledge are likely to contribute to the creation of firms' knowledge management capability. SC process integration improves visibility of supply chain processes, which allows employees to easily understand and execute supply chain functions. Collaboration between supply chain partners, such as joint development of product specifications, permits an exchange of explicit and tacit knowledge between firms. Consequently, to materialize the benefits of using IT for managing intangible knowledge resources, supply chain firms have to first focus on building relationships grounded in process integration and collaboration.

The research identifies three types of capabilities leading to the sustainable growth of supply chains. The results demonstrate that supply chains' IT capability and relational capability can only materialize by creating a higher-order knowledge management capability. The findings are consistent with the resource-based view of firms. Substantial expertise and significant time are required for supply chain firms to put into place IT infrastructures that support integrated processes and collaborative activities. Furthermore, leveraging knowledge resources embedded in employee interactions can be highly contingent upon supply chain contexts, and thus, is unique to each supply chain. As a result, the hierarchy of supply chain capabilities makes imitation of supply chain performance by competitors difficult.

Dependence structure, as indicated by a combination of the degree of total interdependence and the asymmetry of interdependence, was found to significantly moderate the impact of IT capability on knowledge management capability. This result is contrary to what was proposed and seems a little counter intuitive. However, it provides interesting insights on how IT capabilities are viewed and used by supply chain partners. When supply chain relationships are asymmetric, the powerful parties tend to enforce an IT infrastructure on their smaller participants. It is possible that the small participants do not view their positions in the relationship as a disadvantage, but as an advantage that allows them to capitalize on the IT infrastructure for creating specialized knowledge assets in order to sustain their relationship with the larger supply chain partners. In supply chains with little interdependence, it seems that knowledge management capability is a by-product of the transactional exchanges between two independent companies.

Overall, the results corroborate the resource-based view and the relational view and show the critical role of supply chains' ability to utilize complementary resources in generating competitive supply chain performance. The study also provides useful implications for supply chain management practices. Knowledge resources in supply chains are valuable assets that, if collectively managed, will benefit their long-term competitive performance. Because firms' successes depend to a large extent on their supply chains' successes, firms in supply chains should move beyond their own boundary and pay attention in their supply chains when looking for opportunities to leverage knowledge resources. Although exchanges of products or services have been considered the primary goals of supply chains, firms should not ignore the intangible knowledge assets. Insights, know-how, interpretations, and understandings of supply chain related interactions should be systematically managed. The findings of the research suggest that supply chains that understand the importance of knowledge and engage in knowledge management are likely to thrive in the long run by quickly adapting to market changes. This research also provides empirical evidence that process integration and supply chain collaboration enabled by supply chain IT form the basis for knowledge management capability to develop. SC IT plays an important role in streamlining supply chain processes and supporting joint activities.

3.6 Limitations and Future Research

Directions for future research are discussed in view of the limitations of this study. First, subjective supply chain performance measures were used. Due to the anonymity of respondents to the survey, it is difficult for the researcher to find objective performance data to supplement the subjective measures. Future research can adopt a different strategy to include objective performance measures. Second, data were collected from only one side of the SC relationship to measure constructs at the supply chain level. To make sure that answers from the informants were representative of the supply chain, the informants were asked to identify a supply chain relationship between their firms and one of their firms' suppliers or customers that they were most familiar with. Future research can use a pair of firms as the unit of data collection so responses can be obtained from both sides of a supply chain dyad. Finally, type of supply chain IT and type of knowledge can be included in the model to extend our understanding of IT-enabled knowledge management capabilities in different contexts.

CHAPTER 4: UNDERSTANDING THE MECHANISMS OF IT-ENABLED KNOWLEDGE MANAGEMENT IN SUPPLY CHAINS– A COMPUTATIONAL SIMULATION APPROACH

4.1 Background

A supply chain refers to “a network of facilities and activities that perform the functions of product development, procurement of material from vendors, the movement of materials between facilities, the manufacturing of products, the distribution of finished goods to customers, and the after-market support for sustainment” (Mabert and Venkataramanan 1998). Traditionally, supply chains are viewed as an arrangement of activities involved in the product manufacturing and distribution processes that can help reduce transaction costs. This transaction-based view of supply chains has led to arms-length relationships between supply chain partners who primarily focus on the prices of the products exchanged. With the emergence of global markets and increasing customer demands for innovative products, the competencies needed to meet market needs are no longer easily acquirable by a single firm (Van de Ven 2005). Therefore, supply chains have increasingly become an opportunity for firms to access complementary resources and competencies from other firms (Larsson et al. 1998; Scott 2000). We have seen various examples of firms relying on each other to improve performance in areas such as product design, marketing, logistics and research & development (Dyer and Nobeoka 2000; Lincoln et al. 1998; Rai et al. 2009). Knowledge-based view (KBV) of firms suggests that competitive advantages of firms stem from their abilities to integrate knowledge from individual employees and from different functional domains (Grant 1996b). One of the important goals of a supply chain is to integrate knowledge resources existing in the supply chain in order to achieve competitive advantage for the supply chain as a whole (Lorenzoni and Lipparini 1999; Scott 2000).

Although knowledge resources play a strategic role in supply chain relationships, the impact of knowledge management (KM) strategies on supply chain performance has largely remained anecdotal. Despite studies examining impacts of KM information technologies (IT) on firm performance (e.g., Alavi and Leidner 2001; Kane and Alavi 2007), little has been done to show how the use of KM IT in a supply chain will impact the performance of a supply chain. Therefore, the purpose of this simulation-based research is to understand the role of IT-enabled inter-organizational knowledge management strategies in affecting the long-term knowledge outcome of firms in supply chains.

This research views knowledge from the capability perspective which defines knowledge as justified belief that has potential to influence future actions (Alavi and Leidner 2001). A computational simulation research method is deemed an appropriate research method because it allows the researcher to take into account the complex and dynamic contexts in interorganizational knowledge management. The simulation study supplements the empirical study presented in the previous chapter in the following ways. First, the simulation study examines the underlying mechanisms by which KM IT impacts firms' knowledge performance, adding more insights to the empirical study. Second, the simulation study allows objective measures of performance that were not possible in the empirical research. Third, the simulation study takes into consideration firms' KM or organizational learning (OL) strategies, extending the empirical research to different organizational contexts.

A seminal work in using the simulation approach to study the impact of knowledge management and organizational learning in firms is March's (1991) knowledge exploration and exploitation model. March modeled the adaptation of an organization and its employees to an external reality through the interplay of knowledge exploitation (the refinement of existing knowledge) and knowledge exploration (the search of new knowledge). To study inter-organizational knowledge management phenomena, this study extends March's model to a dyad of firms that uses IT-facilitated knowledge management mechanisms within and across firm boundaries. Specifically, this study is interested in examining the KM ITs, such as knowledge repositories and portals (KRP) and electronic communication networks (ECN), that have been shown in a number of case studies to be useful in inter-organizational relationships. It has been acknowledged that building on existing computational models is an effective approach for "validating existing work, developing a cumulative research tradition, and enabling deeper exploration of foundational ideas than would be possible through the continual creation of new models" (Kane and Alavi, 2007, p. 789).

This research contributes to IS literature in the following ways. First, the research will lay a foundation for theory building in IT-enabled inter-organizational KM. Second, using a simulation approach to model KM IT use in supply chains, the study will extend the research on the impact of IT-enabled KM from a single organization (Kane and Alavi 2007) to an inter-organizational context so that the interaction effects of using KM IT by multiple firms can be examined.

The next section highlights the important components in March (1991)'s original model of exploration and exploitation. It also reviews the extant research that builds on March (1991), with the purpose of extending the literature to consider inter-organizational knowledge management. The third section describes how IT-enabled inter-organizational knowledge management is modeled. The fourth section depicts the experimental design, investigating the impact of supply chain firms' internal learning strategies, external learning strategies, and IT use on firms' long-term knowledge levels. The fifth section presents the results of the experiments and the discussion of the results is offered in section six. Limitations of the research and future directions are pointed out in the last section.

4.2 March's Model and Its Extension

March (1991) studies the dynamics of knowledge exploration and exploitation in a single firm. Knowledge exploitation focuses on improving existing competence and knowledge exploration emphasizes finding new opportunities (March 1991). The three primary components in March's model are an external reality, an organizational code representing the organization's beliefs about reality, and individual knowledge representing the individual beliefs of reality. The organizational code refers to rules, procedures, and norms that individuals use to guide their behavior. Exploitation occurs when individuals modify their beliefs to adapt to the organizational code. Hence, the exploitation process diffuses knowledge among individuals. Exploration, on the other hand, occurs when the organizational code is modified by the individuals whose beliefs correspond better with reality. The exploration process creates new knowledge in the organization. March (1991) observes the changes in the average knowledge level of individuals and in the knowledge level of the organizational code as a result of the mutual learning between the individuals and the organizational code. The results suggest that although an emphasis on exploitation strategies can generate quick knowledge gains in the short run than can the use of exploration strategies, a sole focus on exploitation can be detrimental to organizations in the long run. March's model shows how to maintain a balance between exploration and exploitation in order to achieve sustainable growth of individual knowledge and collective knowledge.

The paradigm of knowledge exploitation and exploration has lent itself to guiding the conceptualization of organizational innovation behaviors in numerous managerial contexts, such as high-tech innovations (Lee et al. 2003), IT use by small suppliers (Subramani 2004), and interorganizational learning (Holmqvist 2004). For example, Holmqvist (2004) reports a case study on the collaboration between a software producer and its business partners, suggesting that there is interplay between exploration and exploitation occurring in inter-organizational and intra-organizational processes. Subramani (2004) argues that using IT for knowledge exploration and exploitation is especially important for suppliers who do not have power in the supply chain relationship. Although those papers have applied the concepts of exploration and exploitation to specific management domains, they do not build on March's original computational model. There is surprisingly scarce research extending the original model proposed by March (1991). It is only recently that Kane and Alavi (2007) and Bray and Prietula (2007) extend March's original model to account for the effects of IT-enabled mechanisms in organizational learning.

Kane and Alavi (2007) study the effect of IT-enabled learning mechanisms on exploration and exploitation. Exploration and exploitation are treated as two distinctive patterns of organizational knowledge growth. Exploration occurs when there is continuous increase of knowledge over time, while exploitation features a short-term increase of knowledge followed by a persistent plateau of knowledge level. Drawing on existing case studies, Kane and Alavi (2007) model three types of IT-enabled learning mechanisms used in a single organization. The three mechanisms are 1) group-based learning technologies such as team rooms, 2) individual learning technologies such as email and instant messaging, and 3) organizational portals that are used to store and disseminate organizational-wide knowledge. Kane and Alavi (2007) demonstrate both the main effects and the interaction effects of the three IT-enabled learning mechanisms on the average individual's knowledge level in an organization. They find that knowledge repositories/portals and team rooms lead to exploitative use of knowledge (knowledge increases in a short period and plateau in the long run), while individual learning mechanisms tend to show an exploratory effect on organizational knowledge (slow but continuous increase of knowledge level). Kane and Alavi (2007) also discover a number of interaction effects between the learning mechanisms. For example, the overall results of individual learning mechanisms degrade when other tools are added, and, when a team room is combined with the use of the other tools, the configuration exhibits continuous knowledge growth as an indication of exploration.

Kane and Alavi's extension to March's model can be highlighted by two main points. First, the extended model allows individuals to learn from each other. March's model assumes that individuals do not directly interact with each other, but interact indirectly through a universal organizational code. In Kane and Alavi (2007), individuals can learn from individuals or nonhuman repositories that are generally more knowledgeable. Second, Kane and Alavi's extended model organizes individuals in teams, which take into consideration the effects of organization structures on organizational learning.

Bray and Prietula (2007) extend March's model to study the effects of organizational hierarchies and the use of knowledge management systems (KMS) on the average knowledge level of individuals in a turbulent environment with potential personnel turnover. The first extension made by Bray and Prietula changes the organizational structure from a flat organization to a hierarchical organization with multiple tiers. In such an organization, managers have direct reports. The top-tier manager plays the role of the organizational code. Managers can choose to update their knowledge based on the knowledge of the experts identified from the group of direct reports. On the other hand, individuals also receive knowledge transferred to them from their managers. The rate of learning by the organizational code that is originally conceived in March's model is replaced by the learning rate of managers in Bray and Prietula's model. Bray and Prietula's second extension to March's model adds a universal KMS that all individuals have access to. They examine the effects of the possibility that KMS influence individual beliefs on the average of individual knowledge level in a multi-tier organization.

TABLE 4-1 summarizes the parameters used in March (1991), Kane and Alavi (2007), and Bray and Prietula (2007).

TABLE 4-1. Summary of Parameters Used in OL Models

Parameters	Description	March (1991)	Kane and Alavi (2007)	Bray and Prietula (2007)
Individual learning rate (p1)	The rate by which individuals change their beliefs.	x	x	x
OL learning rate (p2)	The rate by which organizational code change values based on majority of expert opinions.	x	x	x
Personnel turnover (p3)	Percentage of individuals in an organization who leave the organization and be replaced by the individuals who have different knowledge beliefs.	x	x	x
Environment turbulence (p4)	The rate by which the reality change.	x	x	x
Mechanism richness (Rct)	Percentage of knowledge in a knowledge vector that is learned by individuals.		x	
Number of teams (t)	Number of teams in a firm; for modeling firm KMS		x	
Probability of including those with shared interest in the individual learning network	It indicates the chance that one learns from someone in the same Community of Practice (COP).		x	
Probability of including those not with shared interest in the individual learning networks	It indicates the chance that an individual learns from someone who is not in the same COP.		x	
Number of hierarchical tiers	It indicates the structure of a firm.			x
Rate of learning from KMS by individuals (pKM)	Probability that an individual's belief will be changed by a firm KMS[4].			x
Percentage of individuals who are considered experts in an org (rEX)	It determines the number of individuals who can contribute knowledge to KMS.			x

[4] Similar to individual learning rate p1 in a flat organization

4.3 Research Setting and Model

In order to extend the computational models of organizational learning to inter-organizational context, this study takes into consideration not only the learning of individuals from within their organizations but also the learning from other organizations, particularly partners in a firm's supply chain. Because IT has become an important tool in organizational learning and knowledge management, IT-enabled learning mechanisms that can facilitate learning on both the individual level and the organizational level[5] are modeled. Specifically, this study examines four types of IT-facilitated learning mechanisms - internal Electronic Communication Networks (ECN), external ECN, Company Knowledge Repositories and Portals (CompKRP), and Supply Chain Knowledge Repositories and Portals (SCKRP). These IT-enabled learning mechanisms are based on established research and practitioner literature (Kane and Alavi 2007; Parise and Sasson 2002; Peli and Booteboom 1997; Scott 2000).

IT used in ECNs are in the form of information and communication technologies (ICT), such as e-mail, instant messaging, chat rooms, and social networks. These ICTs facilitate interactions between individuals in order to achieve the goal of creating and transferring knowledge. Knowledge Repositories and Portals (KRP) refer to information systems that are used by organizations to store and disseminate organizational knowledge. TABLE 4-2 provides the literature and real-world examples corroborating the identification of the four types of IT-facilitated learning tools in supply chains.

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[5] This research assumes that individuals learn from others or from organizational knowledge repositories while organizations learn from the individuals.

TABLE 4-2. Summary of IT-enabled KM Mechanisms Used in Supply Chains

IT-Enabled Knowledge Management Mechanisms	Support from Literature	Real-world examples
Company Knowledge Repositories and Portals (CompKRP)	Parise and Sasson (2002); Kane and Alavi (2007)	Employees identify best practices and share them with colleagues using Intranet
SC Knowledge Repositories and Portals (SCKRP)	Parise and Sasson (2002); Scott (2000)	Supply chain partners log onto Extranet portals to search for explicit knowledge in the FAQ section. Manufacturers keep track of suppliers' quality, on-time delivery, and other performance attributes. Manufacturers store this knowledge in the repository. Suppliers learn to improve their performance based on the knowledge created by manufacturers.
Internal Electronic Communication Network (CompECN)	Scott (2000)	Members from the same firm exchange ideas and knowledge via communication technologies such as email, videoconferences, instant messaging, or electronic bulletin boards. Product engineers log onto a group meeting room to share prototype drawings and simulation data.
SC Electronic Communications Network (SCECN)	Parise and Sasson (2002)	Groups of product engineers from both firms discuss product design specifications in an electronic meeting room. Manufacturing personnel from both firms exchange demand forecasts, and technological trends.

The four learning mechanisms studied in this research can be further characterized by the source of knowledge (internal or external) made available by the learning mechanisms and the type of knowledge (human or IS) repository used for learning. TABLE 4-3 presents the categorization of the four IT-facilitated learning mechanisms.

TABLE 4-3. Methods of Learning in a Supply Chain

		Source of Knowledge	
		Internal	**External**
Type of Knowledge Repository	**Human**	Internal ECN	External ECN
	Information Systems	CompKRP	SCKRP

4.3.1. Model Setup

This study creates a hypothetical supply chain that consists of a dyadic relationship between firm X and firm Y. Firm X and Y both face a universal reality that is composed of m dimensions. Each reality dimension assumes a value of either 1 or -1. The reality modeled in this research is a reality that is related only to the supply chain relationship between firm X and firm Y. Other reality dimensions do not concern the supply chain partnership (e.g., outsourcing payroll IT within the firms), and therefore, are not considered as part of the reality.

It is assumed that firm X and firm Y each focuses on its own core competencies and that the two firms can complement each other's core competencies by learning from each other. For example, in a supply chain between a retailer and a manufacturer, the retailer may have superior knowledge of merchandising, marketing, customer service, purchasing, and inventory management domains of reality while the manufacturer is superior at research and development, product design, order management, logistics, and manufacturing domains of reality. The retailer can gain knowledge about how the manufacturer conducts order management through their interactions. In the model, different knowledge domains are used to represent the two firms' core competencies. The number of firm X's core competency knowledge dimensions is m_x, and the number of firm Y's core competency knowledge dimensions is m_y. This study assumes that there is no overlapping of core competency knowledge dimensions between firm X and firm Y, i.e., m_x + m_y = m.

The number of employees in firm X is n_x and the number of employees in firm Y is n_y . Each individual in a firm holds beliefs (knowledge) on m dimensions, corresponding to the m dimensions of reality. Each dimension of individual beliefs is assumed to take a value of 1, 0, or -1. If an individual's belief is 0 for a particular dimension of reality, it means that the individual does not have any knowledge of that dimension. This way of coding the individual knowledge allows us the modeling of the state where an individual has correct knowledge, no knowledge or wrong knowledge on a certain dimension of reality. The individual knowledge level (KL) is determined by the proportion of reality that is correctly represented by individual beliefs. For example, if reality has 60 dimensions (m = 60) and 30 of an individual's knowledge dimensions match that of reality, that individual has a knowledge level of 0.50; and if there is a perfect match between an individual's knowledge and reality, the individual's KL is 1.00. At the beginning of each simulation run, it was assumed that the average knowledge level of all individuals on the firm's core competency knowledge dimensions was higher than the average knowledge level of the individuals on the firm's non-core competency knowledge dimensions.

The individuals in each firm are organized into a simple group structure consisting of equal sized groups. A group is similar to the notion of a functional team or a department in organizations. Choosing equal-sized groups maintains simplicity in the model while allowing the researcher to capture the way groups use knowledge management tools. Although in reality an employee may play the role of liaison that can belong to more than one group, the model assumes that an individual belongs to one and only one group. At the beginning of the simulation run, the n_x individuals in Firm X were divided into d_x groups and the n_y individuals in Firm Y were divided into d_y groups. The number of individuals in a group is n_x/d_x in firm X and n_y/d_y in firm Y.

The study assumes that each group in the firm focuses on a number of knowledge dimensions within the firm's core competency knowledge domain. These knowledge dimensions are considered as the group's *internal focus domain (IFD)*. For example, a retailing firm can consist of three groups (departments), namely customer service, purchasing, and merchandising. Each of the three groups covers a particular functional area in the firm and those functional areas are referred to as the groups' internal focus domains. Each of the d_x groups in firm X focuses on a subset of the m_x dimensions of firm X while each of the d_y groups in Firm Y focuses on a subset of the m_y dimensions of Firm Y. The model allows different groups in the same firm to have overlaps of knowledge dimensions. For example, if one group in Firm X focuses on the internal focus domain IFD_{x1}= {1, 3, 4, 5, 6, 13, 14} (the numbers in the brackets are knowledge dimension numbers) and the other group in the same firm focuses on internal focus domain IFD_{x2} = {1, 2, 3, 8, 9, 10, 11}. The dimensions that both groups cover are 1 and 3.

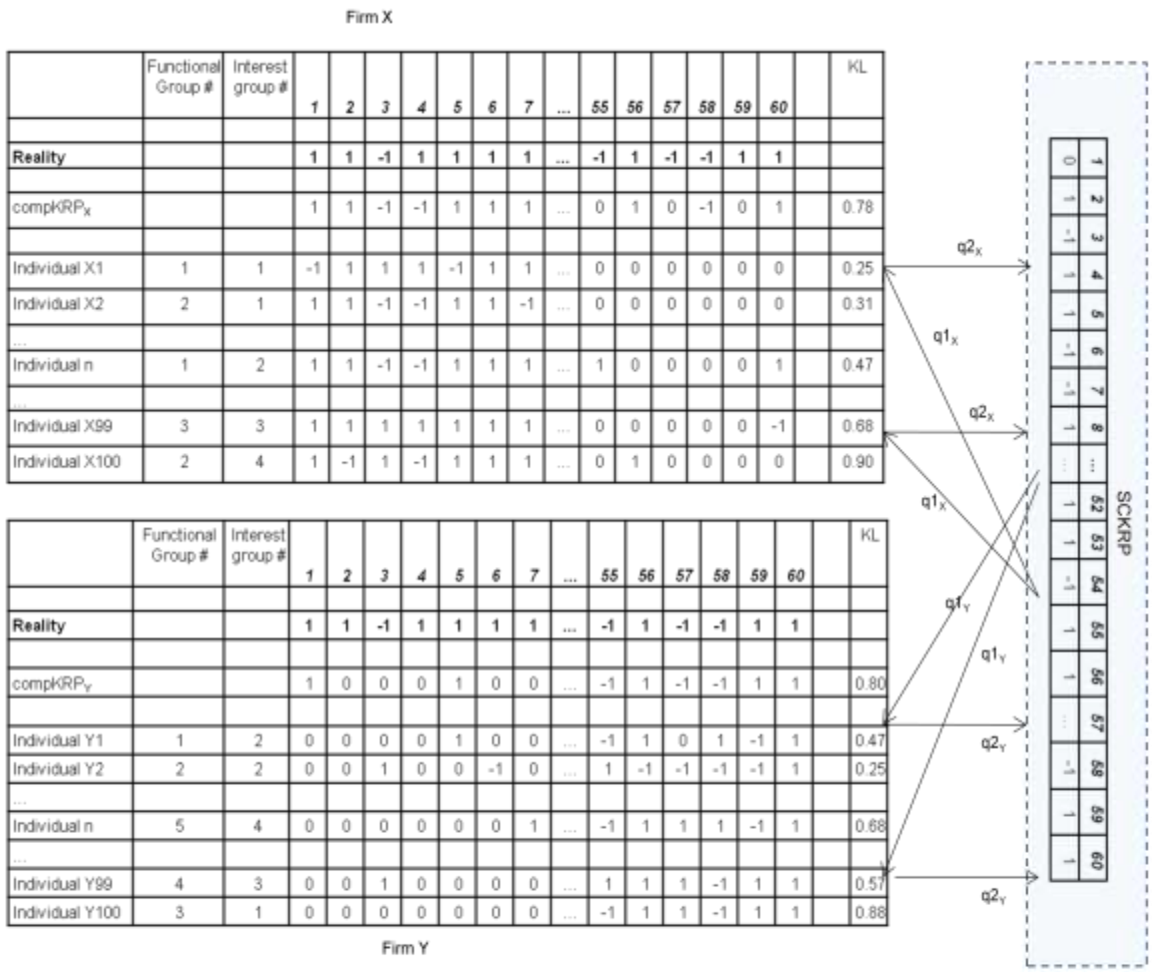
The model further assumes that a group not only focuses on the knowledge within the firm's core competency knowledge domain, it also focuses, to some extent, on the knowledge dimensions that fall in the partnering firm's core competency domain. For example, employees working in the marketing department in a fashion-clothing retailing company may pay special attention to the knowledge about product design that is part of the core competency domain of a vendor company. Although the marketing group in the retailing company may not be an expert in the area of product design, this group of employees has better knowledge in the design area than the employees working in other groups in the retailing company. The knowledge dimensions that do not fall into a firm's core competency domain, but are of special interest to a group in the firm were referred to as the group's *external focus domain (EFD).*

The number of knowledge dimensions in an IFD of a group in firm X (firm Y) is determined by K_x (K_y) - the percentage of firm X's (firm Y's) core competency that a group in firm X (firm Y) specializes in. The model assumes that each group in the same firm has an equal amount of knowledge, but on different knowledge dimensions. For instance, each group in Firm X knows about 30% of the firm's core competency domain. The number of knowledge dimensions in the internal focus domain for a group in Firm X is $K_x * m_x$ and the number of knowledge dimensions in the internal focus domain for a group in Firm Y is $K_y * m_y$. At the beginning of the simulation run, the knowledge dimensions in different internal focus domains were randomly decided.

Other than functional groups within each firm, the model also allows individuals to join one of the supply chain-wide interest groups. An interest group consists of individuals from the same firm or from the supply chain partnering firm who share similar job interests. The interest groups are modeled because individuals in a supply chain are likely to communicate with others from the same firm, or from the supply chain partnering firm, who share similar work-related interests.

4.3.2 IT-enabled KM Mechanisms

Given the setup of the supply chain consisting of two firms as described in the previous section, this section explains how the use of the four types of IT-enabled KM mechanisms– compKRP, SCKRP, internal ECN and external ECN – are modeled. FIGURE 4-1 displays a simplified illustration of the model.



Firm X

	Functional Group #	Interest group #	1	2	3	4	5	6	7	...	55	56	57	58	59	60		KL
Reality			**1**	**1**	**-1**	**1**	**1**	**1**	**1**	**...**	**-1**	**1**	**-1**	**-1**	**1**	**1**		
$compKRP_X$			1	1	-1	-1	1	1	1	...	0	1	0	-1	0	1		0.78
Individual X1	1	1	-1	1	1	1	-1	1	1	...	0	0	0	0	0	0		0.25
Individual X2	2	1	1	1	-1	-1	1	1	-1	...	0	0	0	0	0	0		0.31
...																		
Individual n	1	2	1	1	-1	-1	1	1	1	...	1	0	0	0	0	1		0.47
...																		
Individual X99	3	3	1	1	1	1	1	1	1	...	0	0	0	0	0	-1		0.68
Individual X100	2	4	1	-1	1	-1	1	1	1	...	0	1	0	0	0	0		0.90

	Functional Group #	Interest group #	1	2	3	4	5	6	7	...	55	56	57	58	59	60		KL
Reality			**1**	**1**	**-1**	**1**	**1**	**1**	**1**	**...**	**-1**	**1**	**-1**	**-1**	**1**	**1**		
$compKRP_Y$			1	0	0	0	1	0	0	...	-1	1	-1	-1	1	1		0.80
Individual Y1	1	2	0	0	0	0	1	0	0	...	-1	1	0	1	-1	1		0.47
Individual Y2	2	2	0	0	1	0	0	-1	0	...	1	-1	-1	-1	-1	1		0.25
...																		
Individual n	5	4	0	0	0	0	0	0	1	...	-1	1	1	1	-1	1		0.68
...																		
Individual Y99	4	3	0	0	1	0	0	0	0	...	1	1	1	-1	1	1		0.57
Individual Y100	3	1	0	0	0	0	0	0	0	...	-1	1	1	-1	1	1		0.88

Firm Y

Note: q_1 is the external learning probability and q_2 is the external contributing probability.

FIGURE 4-1. Simulation Model Illustration

compKRP. compKRP is a knowledge vector that has *m* dimensions, with each dimension corresponding to a dimension in reality. Firm X and firm Y each has their own compKRP. Individuals from one firm do not have access to the compKRP in the other firm. compKRP is updated by individuals with superior knowledge in the firm and it disseminates knowledge to all other individuals in the firm. In flat organizations, compKRPs serve the role of the organizational code conceived by March (1991). A similar way of modeling KRP has been adopted by Bray and Prietula (2007).

(1) Domain experts contribute to compKRP (i.e., compKRP learns): In the beginning of the simulation, the compKRP started with neutral beliefs on all the knowledge dimensions. Domain experts are defined as individuals who work in a group and have higher KL on the group's focus domains (both IFD and EFD) than the compKRP. Domain experts can only update their IFD and EFD in compKRP. In each round, the probability that a domain expert contributes to a particular knowledge dimension in compKRP is p_2 .The probability that each dimension is updated is independent. When the knowledge value on a particular knowledge dimension in compKRP is the same as the dominant belief among the domain experts, the knowledge value in compKRP remains unchanged. When the knowledge value in compKRP differs from the domain expert belief, the chance that the knowledge value in compKRP remains unchanged at the end of the period is $(1 - p_2)^t$ (t is the number of experts who hold different beliefs than compKRP minus the number of experts who hold the same beliefs as compKRP). Essentially, the knowledge values in compKRP are determined by the agreement among domain experts (represented by t) and by the individual contribution probability p_2.

(2) Individuals learn from compKRP: Individuals adopt the values in compKRP according to a learning probability p_1. In each round, there is a probability of p_1 that the

individual's belief of a particular knowledge dimension changes to the non-zero value in compKRP. (Value zero in compKRP does not affect individual beliefs.)

SCKRP: SCKRP stores knowledge in m dimensions, with each dimension corresponding to a dimension in reality. Unlike compKRP, which is an intra-organizational knowledge management system, SCKPR is inter-organizational and, therefore, can be contributed to and learned by individuals from both firm X and firm Y. A domain expert from either firm can update the knowledge dimensions that fall into the expert's internal focus domain. Meanwhile, SCKRP disseminates knowledge to all the individuals from both firms.

(1) Domain experts contribute to SCKRP: The simulation begins with a SCKRP characterized by neutral beliefs on all dimensions (no knowledge at all). In the context of SCKRP, a domain expert is defined as an individual whose knowledge in his or her internal focus domain corresponds to reality better than the SCKRP. The simulation selected the domain experts who can update SCKRP based on individuals' KL on IFD only (not IFD and EFD). An individual's EFD falls into the partnering firm's core competency. Because the SCKRP can be accessed by both sides of the supply chain, the simulation let the individuals update their own firm's core competency domain. In each round, domain experts contribute the knowledge of a particular dimension on the internal focus domain in SCKRP according to an external knowledge contributing probability q_2. The probability that each dimension is updated is independent. When a knowledge value in SCKRP is the same as the majority of expert belief, the knowledge value remains unchanged. When a knowledge value in SCKRP differs from the majority of expert belief, the probability that the knowledge value in SCKRP remains unchanged at the end of a

round is $(1 - q_2)^t$ (t is the number of experts whose beliefs differ from SCKRP minus the number of experts who agree with SCKRP).

(2) Individuals learn from SCKRP: SCKRP not only draws expertise from firm X and firm Y, it also allows each firm's expertise to be disseminated in the supply chain. The probability that an individual adopts SCKRP's knowledge value on a particular dimension is called the external learning probability q_1.

Electronic Communication Networks (ECN): Individuals in the supply chain learn from each other through ECN. ECN refers to a group of individuals, from the same firm or from different firms in the supply chain, who share common work interests and use communication technologies as the primary means to facilitate interaction and learning. An ECN allows individuals to discuss business, ask questions, or to exchange ideas. The individuals in the supply chain have their own ECN. Each employee's ECN is comprised of two types of individuals: the ones working in the same functional group as the employee and the ones belonging to the same interest group as the employee. An employee's interest group can include others from the supply chain's partnering firm. The ECN in which individuals come from the same firm as the employee's is called internal ECN, and the ECN in which individuals come from the partnering firm is called the employee's external ECN.

Internal ECN: An employee's internal ECN consists of individuals from the employee's functional group who are outside of the functional group but share the same interest group with the employee. When learning from the internal ECN, the employee first assembles a subnetwork of the individuals in the internal ECN to learn from, according to the probabilities of *b*. Once the subnetwork of internal ECN is assembled, the employee assesses which of these individuals have higher knowledge levels on all knowledge dimensions than the employee herself. Finally, the individual adopts the majority value of the expert group on a particular knowledge dimension according to the internal learning probability p_1.

External ECN: An employee's external ECN consists of the individuals from the supply chain partner's firm who share the same interest group number with the employee. Similar to the steps involved in learning from internal ECN, when learning from external ECN, the individual first assembles a subnetwork of the individuals in the external ECN to learn from according to the probability of *b*. Next, the individual identifies the expert group involving those individuals who have higher knowledge levels on all knowledge dimensions than the individual. Finally, the individual adopts the majority value of the expert group on a particular knowledge dimension according to the external learning probability q_1.

Combining the Learning Mode: The model allows everyone in firm X and firm Y to access the knowledge management system – KRP and SCKRP. Because of the wide availability of communication technologies (such as E-mail) in firms, individuals' access to knowledge embedded in peers, both internal and external, is also allowed.

The simulation varies the degree to which the supply chain firms use each learning mechanism. This variation enables the researcher to isolate the distinct features of each and to examine how they function in combination with each other. The simulation implements the variations of usage through a series of probabilities that represent the likelihood that an individual will choose one of the four learning methods in a given round. The choices of a learning mechanism in different rounds are independent.

An external mechanism selection probability and a KRP mechanism selection probability are set up. The external mechanism selection probability determines whether an individual will choose to learn from an external knowledge source or an internal knowledge source. The KRP mechanism selection probability determines whether the individual will choose to learn from human knowledge source or KRPs. At the beginning of the simulation, these two types of selection probabilities were used to decide which learning mode would be used by an individual. The individuals in the same firm have the same learning mode selection probabilities.

4.4 Experiment Design

C# was used to implement a computer simulation for modeling firms' IT-enabled knowledge management in a supply chain. Flowcharts depicting the simulation steps are presented in Appendix C. Because the model is an extension of March (1991), March's original model was replicated and the results obtained from this simulation were compared with March's to validate the researcher's modeling efforts. March (1991) found that higher individual learning rates and higher learning rates by the code led to quicker convergence of knowledge levels. He also found that slower individual learning accounted for higher knowledge equilibrium, especially when coupled with fast code learning. This model was able to show similar results (FIGURE 4-2).

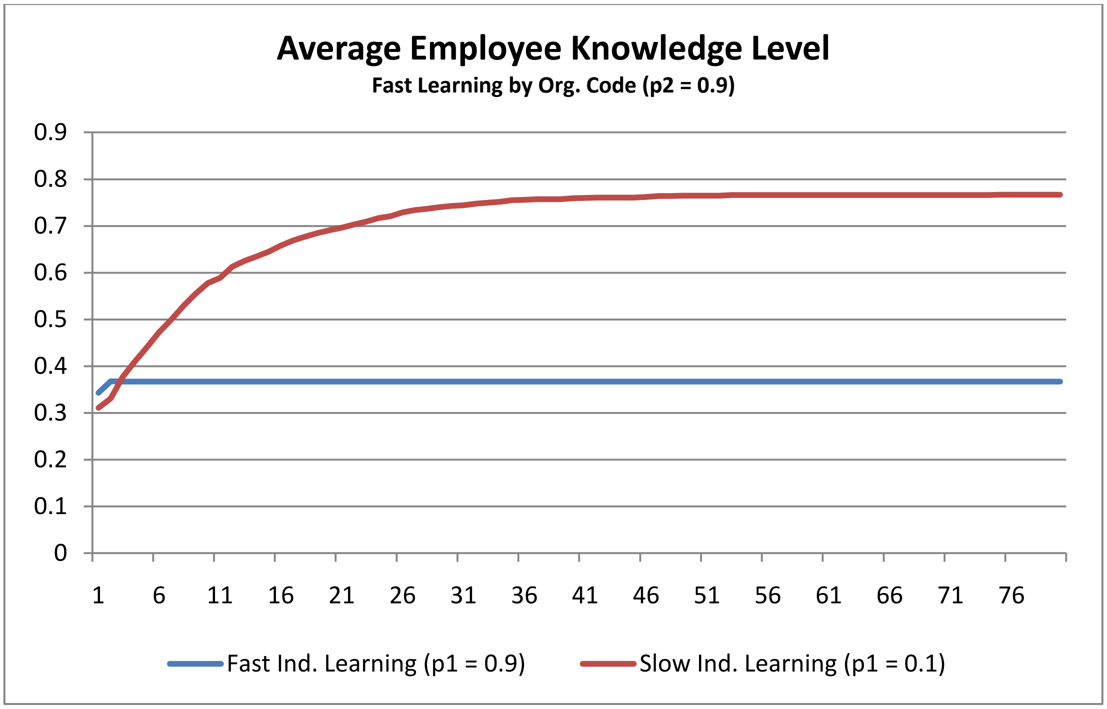


FIGURE 4-2. Effect of Individual Learning Rates on Equilibrium Knowledge Level when Organizational Code's Learning Rate is High

4.4.1 Contexts for Experiments

A set of experiments was designed with firms' organizational learning (OL) types and KRP use as the independent variables and average employee knowledge level as the dependent variable. Because employees are the conduits of a firm's knowledge, this research uses the average employee knowledge level as a proxy measure for the firm's knowledge competency. The experiments are conducted from the point of view of a focal firm that plays the role of either customer or supplier in a dyadic supply chain relationship.

The effects of the firms' OL type and the use of IT on the firms' knowledge competency were examined under three types of relationship symmetry. Existing literature (Subramani 2004; Kumar et al. 1998; Hart and Saunders 1998) and evidence from real-world cases have shown that the size of a firm as indicated by the number of employees in the firm and by the scope of a firm's business are important factors for the firm's dependence on its supply chain partners. Hence, this simulation modeled a focal firm under three types of supply chain dependence structure. First, the focal firm and its supply chain partners are similar in size. The study calls this relationship a symmetric relationship (SYM). The case of Wal-Mart and Proctor & Gamble falls into this category. Second, the focal firm is the larger firm in an asymmetric relationship (ASYMLarge). An example for this type of focal firm is GM in the relationship with one of its small auto parts suppliers. Third, the focal firm is the smaller firm in an asymmetric relationship (ASYMSmall), such as a small auto parts supplier to GM.

The factors defining the symmetry/asymmetry of a supply chain relationship in this model include the relative number of employees in the firm, the relative number of groups in the firm, and the relative number of core knowledge dimensions specialized by the firms. The parameter values used to configure these three types of relationships are listed in the table below.

TABLE 4-4. Experiment Contexts Based on Relationship Symmetry Characteristics

Experiment Number	**Relationship Symmetry**	**Firms**	**Number of individuals (*n*)**	**Number of groups (*d*)**	**Number of specialized knowledge dimensions (*m*)**	**Percentage of internal competency dimensions focused by each group ($k_{internal}$)**	**Percentage of external competency dimensions focused by each group ($k_{external}$)**
Experiment 1	SYM	Firm X (Focal firm)	50	10	30	20%	10%
		Firm Y	50	10	30	20%	10%
Experiment 2	ASYMLarge	Firm X (Focal firm)	50	10	50	20%	10%
		Firm Y	10	1	10	100%	10%
Experiment 3	ASYMSmall	Firm X (Focal firm)	10	1	10	100%	10%
		Firm Y	50	10	50	20%	10%

Five parameters were held constant across the three experiments. TABLE 4-5 displays these parameters and the values used.

TABLE 4-5. Parameters Fixed Across Three Experiments

Parameters	**Values Used in the Experiments**
Number of interest groups in the supply chain	10
Probability of learning from supply chain partners	25%
When initializing firm knowledge dimensions, probability of a core knowledge dimension equal to reality	33%
When initializing firm knowledge dimensions, probability of a non-core knowledge dimension equal to reality	20%

4.4.2 Treatments

This research considers three treatments for the focal firm: 1) the focal firm's internal OL strategy, 2) the focal firm's external OL strategy, and 3) the level of the focal firm's KRP use. The firm's KRP use has three levels: low, medium and high. Adapting from March's (1991) finding on OL, this study categorizes a firm's OL strategies as one of these four categories: 1) slow on both learning and contributing (Slow OL), 2) slow on learning, fast on contributing (Exploration), 3) fast on learning, slow on contributing (Exploitation), and 4) fast on both learning and contributing (Fast OL). These four types of OL strategies can be applied to both internal learning and external learning. Because there is no strong empirical evidence or theoretical foundation to postulate a relationship between firms' internal and external OL strategies, this research treats internal OL and external OL as independent of each other. Consequently there are a total of 16 OL strategy combinations that can be employed by the focal firm.

For each relationship asymmetry, there is a 4x4x3 factorial design. Thirty replications were made in each treatment group and 60 periods were run in each replication. Consistent with March (1991) and Kane and Alavi (2007), the 60 period run was considered a long term of firm's OL. Average employee knowledge level at the 60th period was examined. TABLE 4-6 shows the three treatments and the levels in each treatment.

TABLE 4-6. 4x4x3 Factorial Design

Treatment		**Levels**
Focal Firm's Internal OL Strategy (INTOL)	Slow OL	Internal learning probability (p_1) = 0.1 Internal contributing probability (p_2)= 0.1
	Exploration	Internal learning probability (p_1) = 0.1 Internal contributing probability (p_2)= 0.9
	Exploitation	Internal learning probability (p_1) = 0.9 Internal contributing probability (p_2)= 0.1
	Fast OL	Internal learning probability (p_1) = 0.9 Internal contributing probability (p_2)= 0.9
Focal Firm's External OL Strategy (EXTOL)	Slow OL	External learning probability (q_1) = 0.1 External contributing probability (q_2)= 0.1
	Exploration	External learning probability (q_1) = 0.1 External contributing probability (q_2)= 0.9
	Exploitation	External learning probability (q_1) = 0.9 External contributing probability (q_2)= 0.1
	Fast OL	External learning probability (q_1) = 0.9 External contributing probability (q_2)= 0.9
KRP Level in Focal Firm (KRP)	Low	Probability of learning from KRP ($p_{KRPLearning}$) = 0.1
	Medium	Probability of learning from KRP ($p_{KRPLearning}$) = 0.5
	High	Probability of learning from KRP ($p_{KRPLearning}$) = 0.9

Because OL strategies and KRP use in the partner firms were not considered the primary interest in the experiments, random values ranging from 0 to 1 were assigned to those parameters. The replications in each treatment group shared the same random numbers.

4.5 Results

Three 4x4x3 experiments were conducted and analysis of variance (ANOVA) was used to analyze the results. This section presents the results from each experiment. TABLE 4-14 at the end of the section summarizes the findings.

The simulation was also run using parameter values other than those defined for the experiments in order to check the robustness of the findings. The results showed that the general trend of knowledge level held, although the degrees of knowledge level differed depending on the values selected as input. Overall, the results regarding the impact of IT and learning strategies on average employee knowledge were robust and can be generalized to similar parameter setups.

4.5.1 Effects of OL Strategies and IT Use for Firms in Symmetric Supply Chain Relationships

Analysis of variance (ANOVA) was used to examine the main effects of firms' internal OL strategies (INTOL), external OL strategies (EXTOL), KRP use (KRP), and their interactions on firms' average employee knowledge levels. TABLE 4-7 shows the results. All three main effects and the interaction effects were significant.

TABLE 4-7. Three-way ANOVA Results (SYM)

Source	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
INTOL	0.30	3	0.10	73.36	0.00
EXTOL	3.29	3	1.10	801.98	0.00
KRP	11.69	2	5.84	4268.04	0.00
INTOL * EXTOL	1.14	9	0.13	92.15	0.00
INTOL * KRP	9.87	6	1.65	1201.85	0.00
EXTOL * KRP	2.27	6	0.38	276.57	0.00
INTOL * EXTOL * KRP	2.49	18	0.14	101.02	0.00
Error	1.91	1392	0.00		
Total	32.96	1439			

Further ANOVA tests were needed to explain the three-way interactions. Hence, four two-way ANVOAs, one for each INTOL type, were carried out to understand the effects of EXTOL and KRP. The results of four two-way interactions are reported in TABLE 4-8. The interaction between EXTOL and KRP was significant in all four cases. When interactions were present, the interpretations of main effects were meaningless. Figure SYM (1) to SYM (4) in TABLE 4-9 plotted the interactions between EXTOL and KRP under each type of INTOL to aid the interpretation.

TABLE 4-8. Effects of EXTOL and KRP under Each INTOL Type (SYM)

Internal OL Strategies	Sources	Sum of Squares	df	Mean Square	F	Sig.
Slow OL	EXTOL	1.49	3	0.50	360.87	0.00
	KRP	0.44	2	0.22	159.77	0.00
	EXTOL * KRP	0.72	6	0.12	87.39	0.00
Exploration	EXTOL	0.24	3	0.08	46.18	0.00
	KRP	0.23	2	0.12	67.16	0.00
	EXTOL * KRP	1.80	6	0.30	173.68	0.00
Exploitation	EXTOL	1.69	3	0.56	384.42	0.00
	KRP	9.71	2	4.86	3321.31	0.00
	EXTOL * KRP	1.47	6	0.25	167.56	0.00
Fast OL	EXTOL	1.02	3	0.34	371.36	0.00
	KRP	11.18	2	5.59	6128.74	0.00
	EXTOL * KRP	0.77	6	0.13	140.75	0.00

TABLE 4-9. Overview of Interactions Between EXTOL and KRP Under Each INTOL Type

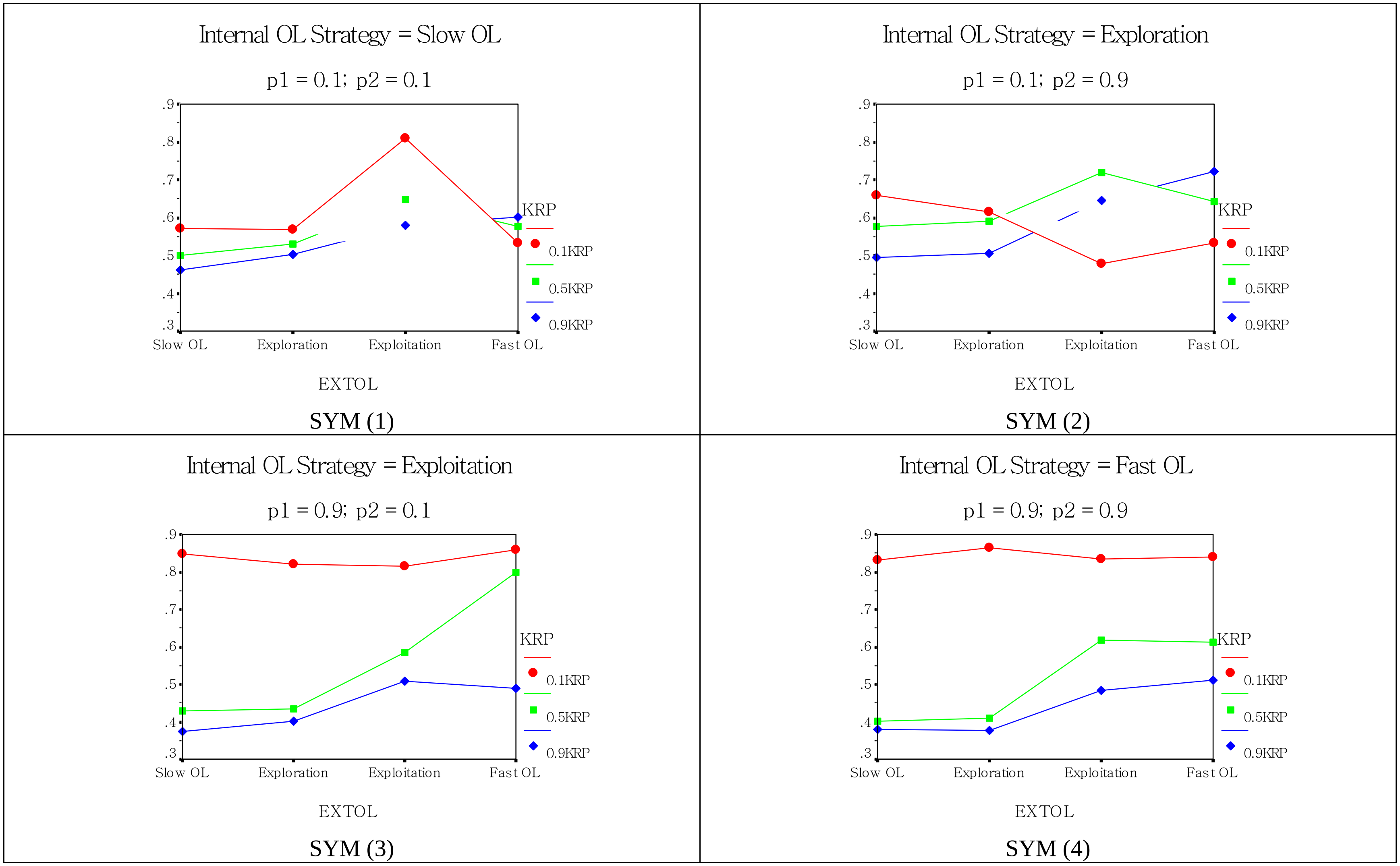
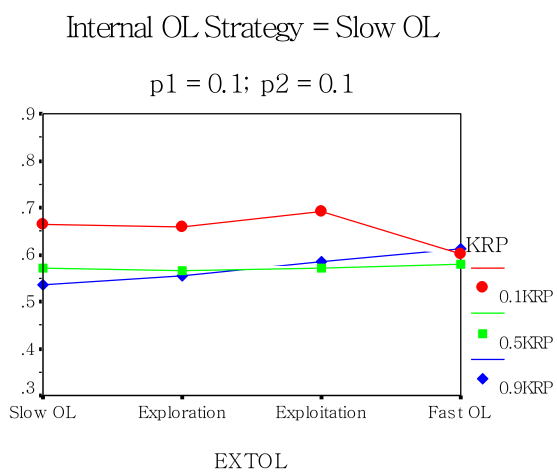
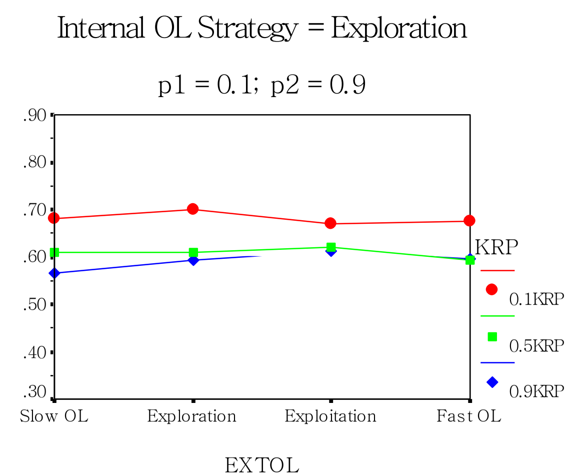


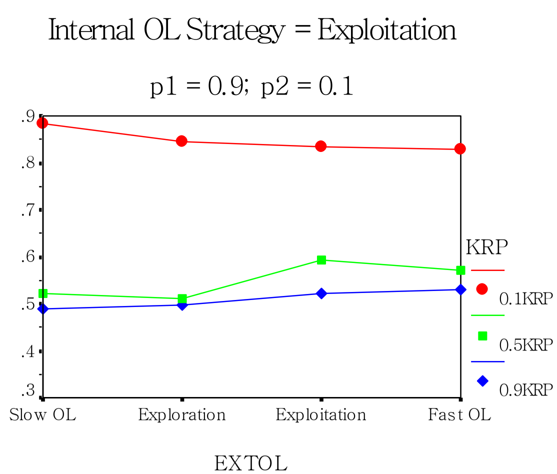
TABLE 4-9 (Continued)



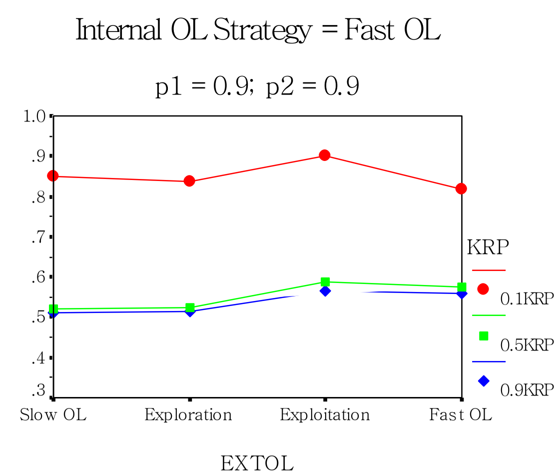
ASYMLarge (1)



ASYMLarge (2)

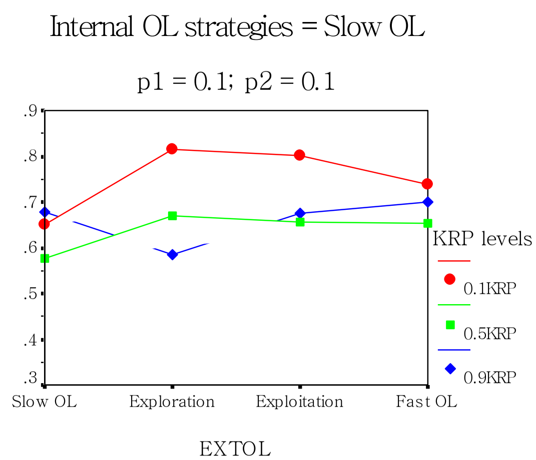


ASYMLarge (3)

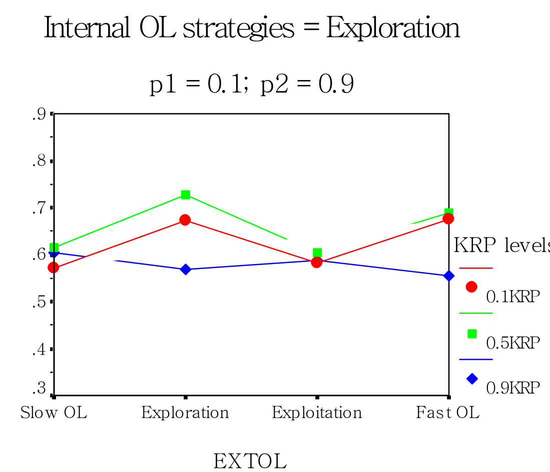


ASYMLarge (4)

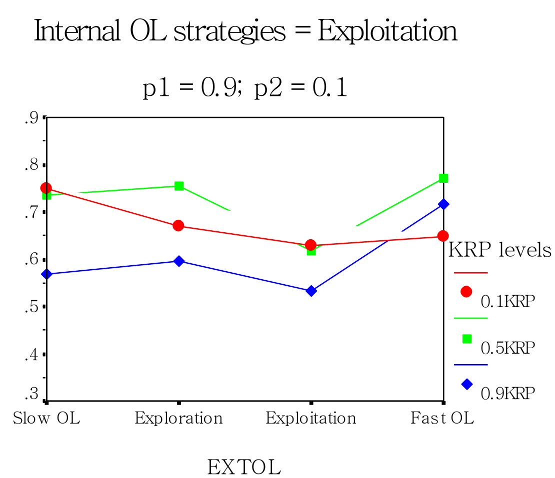
TABLE 4-9 (Continued)



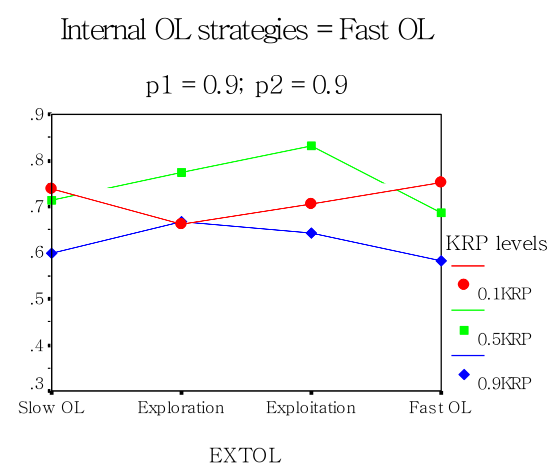
ASYMSmall (1)



ASYMSmall (2)



ASYMSmall (3)



ASYMSmall (4)

For each INTOL type, post hoc tests were used to examine the significance of the knowledge level differences between each two EXTOL types when holding KRP use constant. Depending on whether the different EXTOL groups had equal variances, Tukey tests (equal variance assumed) or Tamhane tests (unequal variance assumed) were conducted. The post hoc test results were reported in Appendix D. The impact of external OL type and firm's use of KRP on employee long-term knowledge levels was interpreted for each type of internal OL.

1) INTOL = Slow OL

When employees in focal firms are slow in learning and contributing internally, the firms' internal OL strategy is Slow OL. Overall, the Exploitation external OL strategy created better long-term average employee knowledge level the other strategies across the three KRP use levels. In particularly, the best knowledge outcome was achieved when Exploitation external OL strategy was used in combination with a low level use of KRP. The outcome was the worst when the external Slow OL was coupled with a high level of KRP use. The results indicated that because Slow OL firms were slow at acquiring new knowledge inside, to achieve a better knowledge level across all knowledge dimensions, firms had to quickly absorb the complementary knowledge from their partners to compensate for the slow learning inside. In addition, since KRP causes the knowledge to become homogenous in the long run, a low level of KRP use - or a high level of ECN - coupled with quick learning from outside can achieve the best results for internally Slow OL firms.

2) INTOL = Exploration

The internally exploratory firms are quick at contributing to their internal KRP, but slow at learning from internal KRP. The best knowledge outcome was achieved when employees used KRP or a mix of KRP and ECN to quickly learn from supply chain partners. However, when quick external learning was coupled with little KRP use, knowledge level of the firm was the lowest. The results suggested that although an Exploration internal OL strategy allowed firms to achieve higher knowledge levels of their core knowledge competencies (March 1991), this strategy was not the best strategy for external learning. An Exploitation external OL strategy was more appropriate for improving the overall knowledge level. The results also indicated that a medium or high level of KRP should be used in combination with the Exploitation external OL strategy. Because employees in internally exploratory firms are quick at contributing to internal KRP, KRP can serve as an effective technology to disseminate individuals learning to the entire firm. If low KRP is used, new knowledge learned from the external sources cannot be effectively brought into the firm. When this happened, an exploitation process could only make employees learn from the same knowledge, significantly reducing the variances in knowledge and therefore expediting the convergence of knowledge to an even lower level.

3) INTOL = Exploitation

When focal firms have high internal learning probabilities and low internal contributing probabilities, they have an Exploitation internal OL strategy. For these firms, a low level of KRP use, i.e., a high level of ECN use would generate the best result of long-term knowledge level for all four types of external OL[6]. The results indicated that when firms were learning fast internally, the external OL strategy would not matter as long as ECN was the dominant technology used to facilitate the learning. High internal learning probabilities can cause knowledge to quickly converge at a low knowledge level (March 1991). To alleviate the adverse effects of fast internal learning on knowledge outcome, a strategy that can increase the variance in knowledge should be used. High level use of ECN helps employees find diverse knowledge, and therefore, creates a higher knowledge level.

Knowledge level was the lowest when KRP was used along with a Slow OL external strategy. This is because the low external learning probabilities inherent in the Slow external OL strategy prevent the complementary knowledge from being brought into the firm and KRP further obstructs employees' opportunities to increase knowledge diversity.

4) INTOL = Fast OL

This type of firm has high internal learning probabilities and high internal contributing probabilities. Similar to the Exploitation type of firms, all four external OL strategies allowed the firms to achieve the best knowledge outcome when ECN was used.

[6] Although the post hoc test result showed that when KRP is low, the externally Fast and Slow firms better performed than the externally Exploration or Exploitation firms, but an examination of the actual knowledge levels showed that this difference did not indicate a practical significance. Therefore, the four external OL types were considered to deliver the same results under low KPR.

The slow external learning probabilities inherent in the externally Slow or Exploratory OL strategies coupled with high KRP use could cause the low knowledge level.

Summary

When firms employed a Slow OL or Exploration OL strategies internally, an Exploitation external OL strategy was the best option for the firm to reach high average employee knowledge level in the long run. The fast learning inherent in the external Exploitation strategy compensated for the slow learning inside the firms, thus increasing the overall knowledge level. However, the matching IT strategies for the internally Slow and Exploratory firms were different. Slow OL firms should use ECN as the main learning tool both internally and externally because ECN allowed the employees to be exposed to knowledge with high variability, increasing the chances of employees learning new knowledge. Because of the low contributing rate in the Slow OL firms, the use of KRP would negatively impact the chances for employees to find and learn new knowledge. The Exploration type firms, on the contrary, should focus on the use of KRP both internally and externally, because the high internal contributing probability in those firms allows KRP to effectively disseminate new knowledge learned from the supply chain partner among the employee population.

For the Exploitation and Fast OL firms, all four external OL strategies delivered the highest level of knowledge when ECN was used. So for firms that are quick learners inside, the external learning strategies do not matter as long as ECN was the dominant technology to facilitate learning.

4.5.2 Effects of OL Strategies and IT Use for Larger Firms in Asymmetric Supply Chain Relationships

Analysis of variance (ANOVA) was used to examine the main effects of firms' internal OL strategy (INTOL), external OL strategy (EXTOL), KRP use (KRP), and their interactions on firms' average employee knowledge level. TABLE 4-10 shows the ANOVA results. All three main effects and the interaction effects are significant.

TABLE 4-10. Three-way ANOVA Results (ASYMLarge)

Source	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
INTOL	0.45	3.00	0.15	121.71	0.00
EXTOL	0.20	3.00	0.07	53.27	0.00
KRP	12.49	2.00	6.24	5081.01	0.00
INTOL * EXTOL	0.11	9.00	0.01	10.24	0.00
INTOL * KRP	4.34	6.00	0.72	588.15	0.00
EXTOL * KRP	0.27	6.00	0.05	37.08	0.00
INTOL * EXTOL * KRP	0.22	18.00	0.01	10.03	0.00
Error	1.71	1392.00	0.00		
Total	19.79	1439.00			

Further ANOVA tests were needed to explain the three-way interactions. Hence, four two-way ANVOAs, one for each INTOL type, were carried out to understand the effects of EXTOL and KRP. The results of the four two-way interactions are reported in TABLE 4-11. The interaction between EXTOL and KRP was significant in all four cases. When interactions were present, the interpretations of main effects were meaningless. Figure ASYMLarge (1) to (4) in TABLE 4-9 plotted the interactions between EXTOL and KRP under each type of INTOL to aid the interpretation.

TABLE 4-11. Effects of EXTOL and KRP Under Each INTOL Type (ASYMLarge)

Internal OL Strategies		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Slow OL	EXTOL	0.04	3.00	0.01	8.38	0.00
	KRP	0.53	2.00	0.26	187.96	0.00
	EXTOL * KRP	0.19	6.00	0.03	22.93	0.00
Exploration	EXTOL	0.02	3.00	0.01	4.59	0.00
	KRP	0.54	2.00	0.27	190.91	0.00
	EXTOL * KRP	0.04	6.00	0.01	4.71	0.00
Exploitation	EXTOL	0.05	3.00	0.02	11.88	0.00
	KRP	8.21	2.00	4.11	3032.33	0.00
	EXTOL * KRP	0.18	6.00	0.03	21.64	0.00
Fast OL	EXTOL	0.21	3.00	0.07	94.63	0.00
	KRP	7.53	2.00	3.77	5184.72	0.00
	EXTOL * KRP	0.09	6.00	0.01	19.56	0.00

For the larger firms in asymmetric supply chain relationships, because their core knowledge domain is larger in scope than their complementary knowledge domain, learning from internal sources is more critical to improve their overall knowledge level than learning from supply chain partners. For each INTOL type, post hoc tests were used to examine the significance of the knowledge level differences between the two EXTOL types when holding KRP use constant. Depending on whether the different EXTOL groups had equal variances, Tukey tests (equal variance assumed) or Tamhane tests (unequal variance assumed) were conducted. The post hoc test results are reported in Appendix D. The impact of external OL type and firm's use of KRP on employee long-term knowledge levels for those firms was interpreted for each type of internal OL.

1) INTOL = Slow OL

In terms of IT choices, the use of ECN produced better results than the use of KRP. The explanation for the adverse impact of KRP on the knowledge level was that the low contributing rate inherent in Slow OL firms did not allow KRP to pick up new knowledge effectively from the employee population. Therefore, ECN was more effective for internal and external learning. When external OL strategies were considered, high external learning probabilities coupled with low external contributing probabilities (Exploitation) would produce the best average employee knowledge in the long-run. High external learning rates allowed firms to absorb complementary knowledge quickly, contributing to the improvement of the overall knowledge level. Meanwhile, low external contributing rates prevented the firms' smaller partners from mastering the firm's core knowledge domain that was larger in scope than the smaller partner's own core knowledge domain.

The knowledge level was the lowest when Slow and Exploratory external OL strategies were used in combination with high KRP level. Slow external learning inherent in Slow and Exploratory external OL strategies prevented firms from effectively learning from their partners. Moreover, KRP inhibits employees from finding diverse knowledge, further reducing the knowledge level.

2) INTOL = Exploration

For all four types of external OL strategies, a low level of KRP use generated better average employee knowledge than the high level use of KRP or a mix use of KRP and ECN[7]. Similar to the Slow internal OL strategy, the knowledge level was the lowest when Slow external OL strategy was used in combination with high KRP level.

3) INTOL = Exploitation

Similar to the firms with an Exploration internal OL strategy, high ECN use created the best knowledge level regardless of the external OL strategies. The knowledge

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[7] Although the post hoc test results indicated that Exploration *external* OL achieved the highest knowledge level when high level of ECN was used, a check of the knowledge level figures did not indicate practically significant differences between the four *external* OL strategies. Therefore, the four external strategies were considered the same in delivering the best knowledge outcome under a high ECN use.

level was the lowest when Slow and Exploration external OL strategies were used in combination with high KRP level.

4) INTOL = Fast OL

Similar to the firms with an Exploration or an Exploitation internal OL strategy, high ECN use created the best knowledge level regardless of the external OL strategies. The knowledge level was the lowest when Slow and Exploration external OL strategies were used in combination with high KRP level.

Summary

When the firm is the larger party in the supply chain, the number of dimensions of the firm's complementary knowledge domain (the supply chain partner's core knowledge domain) is less than the number of dimensions of the firm's core knowledge domain. Therefore, to improve employee knowledge levels, the focal firm should focus on improving internal knowledge as their priority. The results showed that a highly effective technology for improving internal average employee knowledge level was ECN. High level of ECN use or less KRP use by employees in the firm meant more opportunities for them to learn from their peers directly, increasing the variability in organization knowledge. The results pointed out that the larger firm in an asymmetric supply chain can always achieve the best long-term employee knowledge level when ECN was used, regardless of the firm's external OL strategy.

4.5.3 Effects of OL Strategies and IT Use for Smaller Firms in Asymmetric Supply Chain Relationships

Analysis of variance (ANOVA) was used to examine the main effects of firms' internal OL strategy (INTOL), external OL strategy (EXTOL), KRP use (KRP), and their interactions on firms' average employee knowledge levels. TABLE 4-12 shows the ANOVA results. All three main effects and the interaction effects are significant.

TABLE 4-12. Three-way ANOVA Results (ASYMSmall)

Source	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
EXTOL	0.28	3	0.09	57.18	0.00
KRP	1.82	2	0.91	561.98	0.00
INTOL	1.15	3	0.38	237.14	0.00
EXTOL * KRP	0.23	6	0.04	23.35	0.00
EXTOL * INTOL	1.14	9	0.13	78.64	0.00
KRP * INTOL	1.31	6	0.22	134.92	0.00
EXTOL * KRP * INTOL	1.82	18	0.10	62.65	0.00
Error	2.25	1392.00	0.00		
Total	9.99	1439.00			

Further ANOVA tests were needed to explain the three-way interactions. Hence, four two-way ANVOAs, one for each INTOL type, were carried out to understand the effects of EXTOL and KRP. The results of the four two-way interactions are reported in TABLE 4-13. The interaction between EXTOL and KRP was significant in all four cases. When interactions were present, the interpretations of main effects were meaningless. Figure ASYMSmall (1) to (4) in TABLE 4-9 plotted the interactions between EXTOL and KRP under each type of INTOL to aid the interpretation.

TABLE 4-13. Effects of EXTOL and KRP Under Each INTOL Type (ASYMSmall)

Internal OL Strategies		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Slow OL	EXTOL	0.30	3	0.10	59.32	0.00
	KRP	0.85	2	0.43	251.93	0.00
	EXTOL * KRP	0.61	6	0.10	60.17	0.00
Exploration	EXTOL	0.27	3	0.09	65.75	0.00
	KRP	0.39	2	0.19	140.94	0.00
	EXTOL * KRP	0.37	6	0.06	45.20	0.00
Exploitation	EXTOL	0.71	3	0.24	137.82	0.00
	KRP	0.83	2	0.41	242.64	0.00
	EXTOL * KRP	0.56	6	0.09	54.28	0.00
Fast OL	EXTOL	0.14	3	0.05	28.32	0.00
	KRP	1.06	2	0.53	312.07	0.00
	EXTOL * KRP	0.51	6	0.09	50.22	0.00

In contrast to the larger firms in the asymmetric supply chain relationships, the smaller firms should focus on learning complementary knowledge as their learning priority. The results demonstrated that there was no dominant external OL strategy that could deliver the best knowledge outcome for the smaller firms. The effect of external OL type on the knowledge outcome depended on the choice of internal OL type and the level of KRP use by the firm. For each INTOL type, post hoc tests were used to examine the significance of the knowledge level differences between the two EXTOL types when holding KRP use constant. Depending on whether the different EXTOL groups had equal variances, Tukey tests (equal variance assumed) or Tamhane tests (unequal variance assumed) were conducted. The post hoc test results were reported in Appendix D. The impact of external OL type and the firm's use of KRP on employee long-term knowledge levels were interpreted for each type of internal OL.

1) INTOL = Slow OL

When firms' external OL strategy was Exploration or Exploitation, a high level use of ECN generated the best knowledge outcome. The knowledge outcome was the worst when a Slow external OL strategy was coupled with a mixed use of ECN and KRP, and when an Exploratory external OL strategy was coupled with a high level of KRP.

2) INTOL = Exploration

Overall, a mixed use of ECN and KRP produced a better knowledge level than the other two types of IT use across all four external learning strategies. The best knowledge level was achieved when a mixed use of KRP and ECN was coupled with the Exploratory or Fast external OL strategy. The worst knowledge outcome occurred when a high level of ECN was used to aid a Slow or Exploitative external learning strategy, or when a high level of KRP was used to aid an Exploratory or Fast external learning strategy.

3) INTOL = Exploitation

Overall, a mixed use of KRP and ECN produced similar or higher knowledge levels than the other two IT use types. The best knowledge level was achieved when a mixed use of KRP and ECN was coupled with the Slow, Exploratory or Fast external OL strategy, or when a high level of ECN was coupled with a Slow external OL strategy. When a high level of KRP was used to aid the Exploitative external OL strategy, the knowledge outcome was the lowest.

4) INTOL = Fast OL

Overall, a mixed use of KRP and ECN produced similar or the best knowledge level than the other two IT use types. The best knowledge level was achieved when a mixed use of KRP and ECN was coupled with an Exploitative external OL strategy. When a high level of KRP was used to aid the Slow or Fast external learning strategy, the knowledge outcome was the lowest.

Summary

Because the firm was the smaller party in an asymmetric supply chain, the number of dimensions in the firm's core knowledge domain (the supply chain partner's complementary knowledge domain) was less than the number of dimensions in the firm's core knowledge domain. Therefore, to improve employee knowledge levels, the firm should consider improving its external knowledge as its priority. A high ECN use by the internally slow learning firms or a mix of ECN and KRP use by the internally exploratory, exploitative, and fast learning firms yielded the best knowledge outcome. As a result, choosing ECN as the dominant KM technology was an appropriate IT strategy for smaller firms in asymmetric supply chain relationships.

As far as the external learning strategy was concerned, there was not an overarching pattern that applies to the firms. For the internally slow learning firms, both Exploration and Exploitation external OL strategies create the highest knowledge level under condition of both high ECN use and medium ECN use. For the internally exploratory firms, an Exploration external learning strategy is the best choice under conditions of both high ECN use and medium ECN use. For the internally exploitative firms, a slow external learning strategy is the best under the condition of high ECN. A slow, exploratory, or fast external learning is the best under the condition of medium ECN use. Finally, for the internally fast learning firms, an exploitative external learning strategy is the best strategy when a mix of ECN and KRP is used. The inconsistent results regarding the best external OL strategies indicate that there may be an interaction between the external learning strategies of the small firms and their larger partners. Because the knowledge outcome of smaller firms depends highly on the firms' ability to learn from the complementary knowledge domain that is contributed to by their larger counterparts, the external OL strategy of the larger counterparts becomes important in deciding how much the smaller firms can learn. Therefore, further research is needed to uncover the mechanisms of learning for smaller firms in asymmetric supply chain relationships.

TABLE 4-14. Summary of Effects of External OL Strategies and KRP Use on Long-Term Average Employee Knowledge Level[8]

	IT	INTOL = Slow Best	INTOL = Slow Worst	INTOL = Exploratory Best	INTOL = Exploratory Worst	INTOL = Exploitative Best	INTOL = Exploitative Worst	INTOL = Fast Best	INTOL = Fast Worst
SYM	ECN	Exploitative	Fast	Slow	Exploitative	Slow Fast	Exploratory Exploitative	Exploratory	Slow Exploitative Fast
	MIX	Exploitative	Slow	Exploitative	Slow Exploratory	Fast	Slow	Exploitative Fast	Slow Exploratory
	KRP	Exploitative Fast	Slow	Fast	Slow Exploratory	Exploitative Fast	Slow OL	Fast	Slow Exploratory
ASYMLarge		*Best*	*Worst*	*Best*	*Worst*	*Best*	*Worst*	*Best*	*Worst*
	ECN	Exploitative	Slow Exploratory Fast	Exploratory	Slow Exploitative Fast	Slow	Exploratory Exploitative Fast	Exploitative	Slow Exploratory Fast
	MIX	----[9]	----	---	---	Exploitative Fast	Slow Exploratory	Exploitative Fast	Slow Exploratory
	KRP	Fast	Slow Exploratory	Exploratory Exploitative Fast	Slow	Exploitative Fast	Slow Exploratory	Exploitative Fast	Slow Exploratory
ASYMSmall		*Best*	*Worst*	*Best*	*Worst*	*Best*	*Worst*	*Best*	*Worst*
	ECN	Exploratory Exploitative	Slow	Exploratory Fast	Slow Exploitative	Slow	Exploratory Exploitative Fast	Slow Fast	Exploratory
	MIX	Exploratory Exploitative Fast	Slow	Exploratory Fast	Exploitative	Slow Exploratory Fast	Exploitative	Exploitative	Fast
	KRP	Slow Exploitative Fast	Exploratory	Slow Exploitative	Exploratory Fast	Fast	Exploitative	Exploratory Exploitative	Slow Fast

[8] Each cell presents the external OL strategy (EXTOL) type(s) that led to the best or the worst average employee knowledge level given an INTOL type and an IT type (high ECN use, a mix of ECN and KRP, and a high KRP use) in a specific relationship condition (SYM, ASYMLarge, ASYMSmall). The best EXTOL across all three IT types under each INTOL was highlighted by a dark background and the worst EXTOL was highlighted by a light grey background.

[9] Dashes mean that the four EXTOL types yielded same long-term knowledge level.

4.6 Discussion

This section discusses the findings that can be considered as general patterns. The discussion focuses on the most interesting, surprising and important outcomes of the model: the choice of IT and the choice of external learning strategies for improving a firm's knowledge competency. In addition to presenting the general findings, this section also uncovers the mechanisms behind the results. Finally, implications of the results for practitioners are discussed.

4.6.1 Choice of IT for Organizational Learning in Supply Chains

The average employee knowledge level of a firm in a supply chain is a result of internal learning and external learning. This research proposes that learning, both internal and external, is facilitated by two types of IT strategies – the IT that allows employees to learn from a common knowledge repository (KRP) and the IT that supports learning from peers (ECN). The results indicate that the choice of IT to aid organizational learning should depend on the firm's relative size in the supply chain. Smaller firms in asymmetric supply chain relationships are likely to benefit from a mixed use of ECN and KRP while larger firms in asymmetric supply chain relationships are likely to benefit from a high level use of ECN only.

KRP is similar to the organizational code in March's original model, which diffuses a common set of beliefs into individuals. When KRP is used, new knowledge can be disseminated among individuals quicker than the IT that facilitates community-based learning (Kane and Alavi 2007; Niu et al. 2009). Nonetheless, KRP hinders long-term improvement of knowledge level because it can significantly reduce variance in knowledge (Kane and Alavi 2007). When individuals frequently draw knowledge from

KRP, the knowledge among employees quickly becomes homogenous, decreasing the opportunities for new beliefs to emerge. Consequently, high levels of KRP use may result in low long-term knowledge levels. In comparison, communication technologies connecting individuals (ECN) allow individuals to establish their own human knowledge repositories. Individuals can select their own learning sources at each time using ECN so it is much more flexible than KRP. More importantly, knowledge accessed using ECN is much more diverse. Hence, although ECN was inefficient in improving knowledge in the short run (Niu et al. 2009), it preserves variance in knowledge in the long run, leading to high knowledge levels.

The results show that to improve their overall knowledge competency, firms should improve their core knowledge domain (through internal learning) as well as their complementary knowledge domain, i.e., their supply chain partners' core knowledge domain (through external learning). For larger firms, improving knowledge in the core domain is much more critical than acquiring new knowledge from their smaller supply chain partners. A high level use of ECN enables the firm to preserve variability in knowledge and therefore effectively improves knowledge level. On the contrary, for smaller firms, learning from their larger supply chain partners grants opportunities to survive and grow in the long run. But, external learning can also be challenging to the smaller firms as the scope of complementary knowledge domain is larger than their core domain. The results demonstrate that to overcome the size barrier and effectively learn from their larger partners, smaller firms should use a mix of knowledge repositories and human networks. Although there are good opportunities to find new knowledge in ECN, because knowledge learned from ECN is ad hoc, counting on it in order to acquire large amount of knowledge may be counterproductive.

4.6.2 Choice of External Learning Strategies

According to the findings of March (1991), an Exploitation learning strategy characterized by slow individual learning and fast organizational learning, does not create high long-term firm knowledge, while an Exploration learning strategy is better in generating long-term knowledge. However, when external learning and IT use are introduced into the picture, the effects of Exploitation and Exploration on firm knowledge changed. The findings from this research suggest that Exploitation dominates the Best external learning strategy category as shown in TABLE 4-14. Especially, when firms' internal learning is slow, fast external learning can compensate for the slow internal learning and help the firms achieve better overall knowledge level.

The different effects of learning strategy in a supply chain and in a single firm can be understood in light of the nature of the knowledge learned. When only one firm is involved, employees contribute to and learn from the same knowledge domain. Because wrong beliefs can be embedded among employees, quick learning signifies an unfavorable tendency among employees to learn knowledge in haste without discretion. When two firms share knowledge, however, overall knowledge is composed of two knowledge domains – the focal firm's core knowledge competency and the supply chain partner's core knowledge competency. External learning allows firms to learn from their supply chain partners on the firms' complementary knowledge dimensions. Because the focal firm has a lower knowledge level than the supply chain partners on the focal firm's complementary knowledge domain, the firms' chances of contributing to the complementary knowledge domain is low. More importantly, when supply chain partners have better knowledge of firms' complementary domains, the chances for focal firms to get the wrong knowledge are low. Hence, quick learning signifies a beneficial tendency among employees to embrace new knowledge.

Another general finding that emerged from the simulation results is that firms' relative size in supply chains is not only an important factor in determining the choice of knowledge management technologies, but also in determining the choice of the firms' external learning strategies. For larger firms in asymmetric supply chains, the four external learning strategies can yield similar knowledge outcomes. This may be because larger firms can only improve their overall knowledge competency by first improving their internal knowledge level. Therefore, the actual external learning strategies employed are less important. For the smaller firms, their best external learning strategy may be contingent upon their internal learning strategy as well as their partners' external learning strategy. Finally, for firms in symmetric relationships, the four external learning strategies yield similar results when internal learning probabilities are high, and the external strategies that allow fast external learning yield best results when internal learning probabilities are low.

The results from this research imply that firms should focus on building an IT infrastructure enabling employees' access to diverse knowledge. One type of technology that can accomplish this is communication technologies that connect employees in an electronic network. Examples include e-mails, instant messaging, and social media.

Another implication from the research is that firms may need to establish different cultures for their internal learning and external learning. For example, for smaller firms in asymmetric supply chain relationships, their long-term knowledge competency depends on their capability to learn from their partners. Depending on their internal organizational learning strategies, those smaller firms may have to develop corresponding external learning strategies in order to achieve the external learning goal in the long run. Establishing new cultures for learning can be difficult for firms as they have to overcome many barriers, such as organizational culture and propensity of learning inherent in the industry that the firms operate in. Therefore, the firm management has to be savvy in devising managerial interventions to forge an external strategy that is best for the firm's long-term survival. Examples of such managerial strategies can include supporting messages from firms' top management, monetary and non-monetary incentives to encourage learning, and policies articulating goals of learning. Most importantly, upon understanding the importance of internal learning and external learning, firm management should clearly convey to the employees the impact of internal and external learning on the firms' survival in the long-run.

4.7 Limitations and Future Research

This study improves our understanding of the mechanisms of firms' external learning from supply chains. However, the research has some limitations. First, the probability of KRP use in this research determines the probability of employees learning from both internal and external KRP. One can argue that a firm may use internal and external knowledge management systems at different rates. Nevertheless, firms' information technology infrastructure capabilities and cultures can be the overarching factors that determine both the use of internal and external knowledge management systems. For example, Microsoft implemented knowledge bases inside the company as well as outside the company for interactions with its customers and suppliers. Employees are encouraged to solve problems by resorting to the knowledge base. A second limitation is that the KRP stores employee knowledge only for a short term under the current model. In future research, the model can be modified so that the KRP can accumulate and consolidate knowledge in the long run. Another limitation of the research relates to the types of learning strategies. Based on March (1991), this research identifies four strategies for both internal learning and external learning. There may be other learning strategies characterized by different values of learning and contributing probabilities.

The research can be extended in the following ways. First, as discussed earlier, there may be interactions among firms' external OL strategies. These interactions can cause inconsistent results regarding the best and worst external OL strategies for the small firms in asymmetric supply chains. Therefore, further research is needed to investigate the effects of the interaction. Second, empirical research can be conducted to identify factors, such as organizational culture and management support, which may be the overarching factors in determining the relationship between internal and external learning strategies. Third, the model can be expanded by considering a changing external reality and employee turnover, which add variability to the closed system. Fourth, additional organizational structure and technologies supporting those structures can be modeled. For example, organizational hierarchies and technologies supporting learning from other tiers could be modeled. Fifth, the effects of supply chain partners' external learning strategies on the knowledge competency of supply chains as a whole remain an interesting topic to explore. Finally, this research studies the complex nature of supply chain learning in a dyadic supply chain context. Future research can extend the study to a network of supply chains.

CHAPTER 5: CONCLUSION

Supply chains do not only involve flows of products or services, but also flows of knowledge. Firms can access complementary knowledge resources from their supply chain partners. As supply chains become the unit of competition in today's global markets, strategies to help supply chain firms adapt and create competitive advantage at the supply chain level are imperative. This dissertation aims to understand IT-enabled knowledge management in supply chains – an increasingly important and yet substantially under-researched area in IS literature. Specifically, the dissertation focuses on the technology antecedents and performance consequences of knowledge management by supply chain firms. Taking the perspective of a supply chain dyad, the dissertation first presents a survey research that examines the relationship between the supply chain's IT capability and knowledge management capability, and the knowledge management capability's impact on supply chain performance. The results suggest that the ability of supply chain firms to collectively manage knowledge resources is an important requirement of supply chain strategic performance. In addition, supply chains' IT infrastructure capabilities facilitate supply chains in managing knowledge through the supply chains' relational capability.

A simulation model was used to further study the implications of using KM IT in managing supply chain firms' internal and external knowledge. Focusing on the focal firm in a supply chain dyad, the simulation study extends the survey research by modeling the use of KM IT – a particular type of supply chain IT - within and across firm boundaries. In addition, the simulation study enriches the context of the empirical study by taking into consideration the firms' internal and external knowledge management strategies. The simulation study puts supply chain relationships under a microscope to discover the intertwining effects of KM IT and firms' internal and external knowledge management strategies on the firms' long-term average employee knowledge level. Because employees are the conduits in knowledge management processes, the average employee knowledge level can be considered an indicator of firms' knowledge competency. The results suggest that electronic communication networks (ECN) – the KM IT that allows individuals to interact with each other - are more effective than knowledge repository and portals (KRP) in improving long-term employee knowledge level in focal firms. This finding corroborates the finding from the empirical research that supply chain IT has an impact on knowledge management capability through the mobilization and utilization of relational resources in the supply chain. This overarching result supports the theoretical perspectives of the relational view and the resource-based view. In addition, the simulation study shows that there is an interaction between firms' internal OL strategy and external OL strategy. Specifically, if the firm is in a symmetric supply chain or the firm is the larger firm in an asymmetric relationship, the positive impact of fast learning from supply chain partners is the strongest when the firm's internal learning is slow. TABLE 5-1 summarizes the research questions and the key findings of the two studies in my dissertation.

TABLE 5-1. Summary of Research Questions and Findings

	Empirical Study	Simulation Study
Research Questions	How does a supply chain's IT capability affect the supply chain's knowledge management capability? How does a supply chain's KM capability impact the supply chain's performance?	When firms learn from supply chain partners, how do KM IT and firms' organizational learning strategies affect the firms' knowledge outcome?
Main Findings	1) SC knowledge management capability positively impacts supply chain's operational and strategic performance. 2) SC IT capability positively impacts SC knowledge management capability only when supply chain relationships are asymmetric or have low interdependence. 3) SC relational capability positively affects SC knowledge management capability in supply chains of all dependence types.	1) ECN is a more effective KM IT than KRP to facilitate firms' internal and external learning. However, the appropriate level of ECN use depends on the relative size of the firms in the supply chain. a) Smaller firms in asymmetric supply chain relationships are likely to benefit from a balanced use of ECN and KRP in their internal and external learning. b) Larger firms in asymmetric supply chain relationships are likely to benefit from a high level use of ECN in their internal and external learning. 2) There is an interaction between firms' internal and external OL strategies. When firms' internal learning probability is low, a high external learning probability can help firms achieve the best knowledge level.

Overall, this dissertation contributes to our understanding of the role of supply chain IT in managing knowledge resources in supply chains. First, the empirical study articulates the role of SC IT in facilitating knowledge management, and in turn creating performance advantage. As many IS studies have found, the relationship between IT and performance is indirect (Wade and Hulland 2004). IT impacts firm and supply chain performance by enabling them to marshal other organizational resources. Taking a knowledge perspective, this dissertation shows that relational capability and knowledge management capability are critical for IT to bring performance gains to the supply chain. This insight is useful for supply chain firms to effectively implement and utilize their IT infrastructure. The empirical research also provides a new perspective in studying supply chain performance. The significance of the relationship between knowledge management capability and performance highlights the theoretical and empirical importance of knowledge in supply chains. The results can further help researchers and practitioners to develop knowledge capability measures for supply chain partnerships. The findings of the simulation study contribute to theory development in IT-enabled interorganizational learning by identifying important factors for interorganizational learning and the mechanisms by which those factors interact. A framework is developed for supply chain firms to select appropriate internal and external knowledge management strategies, and to build a knowledge management technology infrastructure for supporting those strategies. Finally, the simulation research helps improve practitioners' understanding of how to leverage firms' relationship with supply chain partners in order to achieve long-term knowledge benefits.

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APPENDIX A: KM-RELATED CONSTRUCTS AND MEASURES

TABLE A-1. KM Constructs Empirically Examined By the Literature

Constructs	References	Measures
Cross-unit knowledge creation capability	Tanriverdi 2005	To what extent does the corporate headquarters actually engage in or support the following activities? - creating customer, product and managerial knowledge that are applicable across multiple business units.
Cross-unit knowledge transfer capability	Tanriverdi 2005	To what extent does the corporate headquarters actually engage in or support the following activities? - transferring relevant customer, product and managerial knowledge among business units.
Cross-unit Knowledge integration capability	Tanriverdi 2005	To what extent does the corporate headquarters actually engage in or support the following activities? - Integrating relevant customer, product and managerial knowledge of multiple business units to gain new insights.
Cross-unit knowledge leverage capability	Tanriverdi 2005	To what extent does the corporate headquarters actually engage in or support the following activities? - Changing policies and processes of business units based on customer, product and managerial knowledge discovered/lessons learned in other departments.
Knowledge acquisition	Gold et al. 2001	My organization has processes for

process capability		1. acquiring knowledge about our customers 2. generating new knowledge from existing knowledge[10] 3. acquiring knowledge about our suppliers 4. uses feedback from projects to improve subsequent projects 5. has processes for distributing knowledge throughout the org 6. exchanging knowledge with our business partners 7. interorganizational collaboration 8. acquiring knowledge about new products/services within our industry 9. acquiring knowledge about competitors within our industry 10. benchmarking performance 11. Teams devoted to identifying best practice 12. Exchanging knowledge between individuals
Knowledge conversion process	Gold et al. 2001	My organization has processes for 1. converting knowledge into the design of new products/services 2.converting competitive intelligence into plans of action 3. filtering knowledge 4. transferring organization knowledge to individuals 5. absorbing knowledge from individuals into the organization 6. absorbing knowledge from business partners into the organization 7. distributing knowledge throughout the organization 8. integrating different sources and types of knowledge 9. organizing knowledge 10. Replacing outdated knowledge.
Knowledge acquisition process	Gold et al. 2001	My organization has processes for 1. acquiring knowledge about our customers 2. generating new knowledge from existing knowledge[11] 3. acquiring knowledge about our suppliers

[10] The gray items did not converge on the intended scale.
[11] The gray items did not converge on the intended scale.

		4. uses feedback from projects to improve subsequent projects 5. has processes for distributing knowledge throughout the org 6. exchanging knowledge with our business partners 7. interorganizational collaboration 8. acquiring knowledge about new products/services within our industry 9. acquiring knowledge about competitors within our industry 10. benchmarking performance 11. Teams devoted to identifying best practice 12. Exchanging knowledge between individuals
Socialization	Lee and Choi 2003	Our firm stresses 1. Gathering info from sales and production sites 2. sharing experience with suppliers and customers 3. engaging in dialogue with competitors 4. finding new strategies and market opportunities by wandering inside the firm 5. creating a work environment that allows peers to understand the craftsmanship and expertise
Externalization	Lee and Choi 2003	Our org stresses 1. creative and essential dialogues 2. the use of deductive and inductive thinking 3. the use of metaphors in dialogue for concept creation 4. exchanging various ideas and dialogues 5. subjective opinions
Combination	Lee and Choi 2003	Our org stresses: 1. planning strategies by using published literature, computer simulation and forecasting 2. creating manuals and documents on products and services 3. building db on products and service 4. building up materials by gathering management figures and technical info 5. transmitting newly created concepts

Internalization	Lee and Choi 2003	1. enactive liasoning activities with functional departments by cross-functional development teams 2. forming teams as a model and conducting experiments and sharing results with entire dept 3. searching and sharing new values and thoughts 4. sharing and trying to understand management visions through communications with fellows.

TABLE A-2. Classifications of KM Measurement Items[12]

Knowledge creation process capability	
1. Acquiring knowledge about customers (activities are not clear) 2. **Acquiring** knowledge about new products/services within our industry (activities are not clear) 3. identifying best practices (Gold et al. 2001) 4. engaging in dialogue with competitors (not appropriate for inter-firm level) 5. finding new strategies and market opportunities by wandering inside the firm 6. creating a work environment that allows peers to understand the craftsmanship and expertise (too detailed) 7. creative and essential dialogues (too detailed) 8. the use of **deductive** and **inductive** thinking (too detailed) 9. the use of **metaphors** in **dialogue** for **concept creation** (too detailed) 10. enactive **liasoning** activities with functional departments by **cross-functional** development teams 11. forming teams as a model and conducting **experiments** and **sharing** (same aspects covered by other questions, such as 10 and 23) 12. if something goes **wrong**, we try hard to figure out **why** 13. we quickly try to identify our **mistakes** so that they are not repeated (same as 12) 14. if a program is **successful**, we try to **understand** what makes it work well	Gold et al. 2001; Lee and Choi 2003; Johnson et al. 2004; Hult et al. 2004

[12] The gray items were dropped from our scale development due to one of the four reasons: 1) the new measures do not overlap with each other, 2) the new measures are as inclusive as possible to cover all the aspects indicated in the existing KM process measures; 3) the new measures are appropriate to the inter-firm level; and 4) the new measures are at the same detail level.

15. if we see a **mistake** has been made, we retrace our actions to understand what happened (same as 12) 16. we **meet** to find out **product needed** in the future 17. we do a lot of **in-house research** on products 18. we **poll** participants once a year to **assess quality** of sc 19. we **review effects of change** in environment 20. Formal routines exist to **uncover faulty assumptions** 21. Participate in **special interest groups** (similar to 24) 22. I obtain useful info and suggestions from **brainstorming meetings** without spending too much time (similar to 24) 23. **Team work** is promoted by utilizing organization-wide info and knowledge (similar to 10) 24. **Drawing expertise** from each other to develop new knowledge 25. Derive inferences from **past events** (process exceptions, patterns of demand shifts, effects of different company responses)	
Knowledge transfer process capability	
1. has processes for distributing knowledge throughout the org 2. **exchanging** knowledge between individuals (not appropriate for inter-firm level) 3. **sharing experience** with suppliers and customers 4. **exchanging** various ideas and dialogues 5. **transmitting** newly created **concepts (similar to 4)** 6. **searching** and **sharing** new values and thoughts 7. **sharing** and trying to understand **management visions** through communications with fellows (not appropriate for inter-firm context) 8. We frequently have **interdepartmental meetings** to discuss trends in our supply chain 9. We **spend time** discussing future supply chain needs 10. We **share** data on **participant satisfaction** in the supply chain on a regular basis. 11. We **alert participants** when something important happens in the supply chain. 12. We frequently **share knowledge about our business environment** (e.g., other business relationships) with our customers/ channel partners. 13. Knowledge about all of our channel partners, competitors, etc., is **shared** with our other customers/channel partners. 14. Business insights are **exchanged** between us and our other customers and channel partners (similar to	Lee and Choi 2003 Hult et al. 2004; Saraf et al. 2007

4) 15. Participate in **special interest groups**	
Knowledge retention process capability	
1. Gathering info from sales and production sites (adapt to "gathering info along every process of supply chain") 2. creating **manuals** and **documents** on products and services (similar to 14) 3. building **db** on products and service (technical component) 4. building up **materials** by gathering **management** figures and **technical** info 5. Ability to **retain experiences** through people's memory, IS, organization routines about sc events 6. **Replacing** outdated knowledge (same as 8) 7. **Capturing** knowledge (same as 1) 8. **Evaluating** and updating accuracy and currency of knowledge 9. **Categorizing** knowledge 10. Is the knowledge that is indispensable for performing routine task documented? (same aspects covered by question 14) 11. We try to **store expertise** on new tasks design and development (similar to 1) 12. We try to **store** legal guidelines and policies related to tasks. 13. We extensively **search** through customer and task-related databases to obtain knowledge necessary for the tasks 14. We **document** such knowledge needed for the 15. transferring organization knowledge to **individuals** (not appropriate for inter-firm) 16. **absorbing** knowledge from individuals into the organization (not appropriate for inter-firm)	Gold et al. 2001; Gosain et al. 2004; Kulkarni and Freeze 2004
Knowledge application process capability	
1. use **feedback** from projects to improve subsequent projects 2. has processes for **exchanging** knowledge with our business partners 3. planning strategies by **using published** literature, computer **simulation** and **forecasting** 4. has processes for applying knowledge **learned from mistakes** 5. has processes for using knowledge to solve new problems 6. matches sources of knowledge to problems and challenges 7. uses knowledge to improve efficiency (confused with outcome variable) 8. is able to locate and apply knowledge to changing competitive conditions (similar to 6)	Gold et al. 2001; Johnson et al. 2004

9. quickly applies knowledge to critical competitive needs 10. quickly links sources of knowledge in solving problems (similar to 6) 11. converting competitive intelligence into plans of action 12. integrating different sources and types of knowledge 13. we constantly **assess** and **analyze** the effects of our **decisions** so that we know what adjustments to make 14. adapting the supply chain to the changing business environment by using knowledge obtained from each other	
Technological tools	
1. Analytical tools (similar to 12) 2. Collaboration tools 3. Virtual teams (similar to 2) 4. Expertise locating technologies 5. Modeling tools used in product design and manufacturing (such as CAD and CAM software) 6. Taxonomy 7. Extranet 8. Databases 9. Knowledge repositories 10. Search tools 11. Employee registering and profiling system 12. Decision support tools (e.g., analyzing past events, drawing inferences, generating predictions to aid future decision making) 13. Presentation format (does not have convergent validity with the other measures) 14. Electronic bulletin board (similar to 2) 15. Workflow diagrams (e.g., specification of roles, activities, and process interfaces) 16. Standardized forms (not adaptable to context, does not have convergent validity with the other measures) 17. Generate inferences (goes into 2) 18. **Communication** among organization members (included by 2) 19. Monitoring tools (similar to 13) 20. **Simulation** and **prediction** (similar to 12)	Kulkarni and Freeze 2004; Lee et al. 2005; Scott 2000; Im and Rai, 2008

Organizational culture	
1. Is organizational knowledge recognized as **essential** for the long term success of the organization? 2. Is KM recognized as a key **organizational competence**? 3. Employees are **ready and willing** to give advice or help on request from anyone else within the company 4. Is there any incentive-system in place to encourage the knowledge sharing among employees? (similar to 14) 5. Are there any **KM training programs or awareness campaigns**? e.g. Introductory/Specific workshops for contributors, users, facilitators, champions. 6. Is KM incorporated into the overall organizational strategy? (not adaptable to interfirm context) 7. Is there any form of benchmarking, measure, or assessment of the state of KM in the organization? (not adaptable to interfirm context) 8. Can the existing **KM processes** is easily **adapted** to meet new business requirements? 9. There exist **incentive** and benefit policies for **new idea suggestions** in utilizing existing knowledge (similar to 11) 10. **High levels** of participation are expected in capturing and transferring knowledge (similar to 3) 11. Employees are **encouraged** to explore and experiment. 12. On-the-job **training** and **learning** are valued. 13. Employees are **encouraged** to **ask** others for assistance when needed. 14. Employees are **encouraged** to **interact** with other groups. 15. Employees are **encouraged** to **discuss** their work with people in **other workgroups** (similar to 14) 16. Stressing subjective opinions (similar to 11) 17. We **promote** sharing of info and knowledge with other teams (similar to 14)	Pee et al. 2009

APPENDIX B: SURVEY INSTRUMENT

I. Welcome Message
Thank you for logging onto this URL to participate in my survey!

The objective of the survey is to understand the mechanisms by which supply chain information systems create value for firms. This research will identify critical capabilities of a supply chain information system and examine how the use of supply chain information systems impacts the collaborative capabilities and business performances of firms in different types of supply chain relationships. As a practicing manager in the supply chain area, your input is very valuable to my dissertation research and is highly appreciated.

Your participation in the study is voluntary and you are free to discontinue this survey at any time by closing the browser window. There is a progress indicator at the top of each page indicating how much of the survey you have left to answer. The survey should take you 10 to 20 minutes to complete. The information collected will be kept confidential and private and will NOT be used to identify any individual respondent. All analyses and reports will be done in the aggregate.

The aggregate results and general findings from the survey will be shared with the Institute for Supply Management (ISM) and the Association for Operations Management (APICS) for benchmarking purposes, and to be made available to their members. I am also more than happy to send a copy of the final report directly to the interested individuals upon request. The results of the survey will be published in academic and professional journals in the Information Systems and Supply Chain Management areas.
As a token of my appreciation for your time, all participants who complete the survey will have an option to enter their e-mails into a random drawing to receive one of five $50 Amazon.com gift certificates.

If you have any questions or comments regarding this survey, please contact me at **704-687-7592**or **yniu@uncc.edu**. The survey has been approved by the Compliance Office in the Office of Research Services at the University of North Carolina at Charlotte. For any questions regarding subject rights, please contact **the Compliance Office, Office of Research Services** at **704-687-3309** or **research@uncc.edu**.

Sincerely,
Yuan Niu
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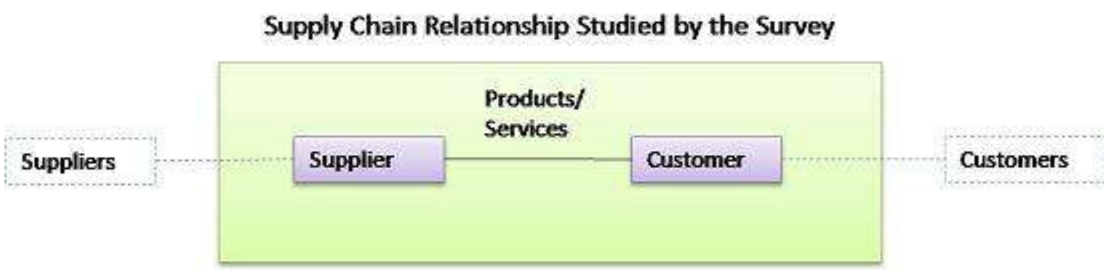
II. Survey Introduction

For the purpose of this survey, we define a supply chain relationship as the business-to-business relationship between two firms when one firm purchases products/services from the other firm in order to create offerings for a downstream market. In other words, this survey is interested in the supply chains that exchange production-related products/services. Business exchange relationships involving non-production products/services (e.g., office supplies for internal consumption) are excluded from this survey.

The figure below helps illustrate the supply chain relationship that this survey focuses on.



Please think of a product line/service you are most familiar with in a supply chain between your firm and another firm (i.e., the product line/service about which you have the most information or have direct responsibility).

With respect to the supply chain for the identified product line/service:

If your firm is the **customer** (your firm purchases the product line/service from the supplier firm), please click this link **[URL of the customer version of the survey]** to continue.

If your firm is the **supplier** (your firm sells the product line/service to the customer firm), please click this link **[URL of the supplier version of the survey]** to continue.

III. Measures

SC KM Capabilities

Please indicate the extent to which your firm and the [SC Partner Firm] *collectively* engage in each of the following processes.

1. Promoting cross-functional dialogues and activities
2. Drawing expertise from the supply chain partner to develop new knowledge
3. Stimulating discussion encompassing a variety of opinions (e.g., conducting brainstorming meetings, establishing joint teams, formation of special interest groups)
4. Integrating different sources and types of knowledge in the supply chain
5. Sharing experience with the supply chain partner
6. Exchanging ideas and concepts with the supply chain partner
7. Documenting expertise, ideas and experiences in the supply chain
8. Maintaining accuracy and currency of our understanding about the supply chain
9. Retaining past experiences and events (e.g., price changes, demand shifts, supply chain partner responses to policy changes)
10. Using past feedback from the supply chain partner to improve current interactions
11. Matching sources of knowledge to problems and challenges
12. Converting new understanding about customers, technologies and supply chain processes into plans of action
13. Evaluating the supply chain relationship and, if needed, adjusting the way the relationship is managed

Scale: 1 = 0% - 20% of the time; 2 = 21% - 40% of the time; 3 = 41% - 60% of the time; 4 = 61% - 80% of the time; 5 = 81% - 100% of the time

Operational SC Performance (Except item 5)

Please evaluate the following performance measures (compared with the industry average) for the supply chain between your firm and the [SC Partner Firm] for the product line/service identified earlier.

1. The order fulfillment cycle time
2. Percentage of delivered products/services meeting specifications
3. Operating costs of the supply chain
4. Accuracy in demand forecast for the product line/service
5. Business volume increase over the past year

Scale: 1 = Significantly Lower than Industry Average; 2 = Lower than Industry Average; 3 = Same as Industry Average; 4 = Higher than Industry Average; 5 = Significantly Higher than Industry Average

Strategic SC Performance

Please indicate the degree to which you agree or disagree with each of the following statements describing the supply chain between your firm and the [SC Partner Firm].

1. New products/services can be quickly introduced into the supply chain.
2. It is difficult for the supply chain to make adjustments to cope with changes in the business environment.

3. The supply chain has allowed our firm to become more competitive in the market. (For customers)
4. The supply chain has allowed the [SC Partner Firm] to become more competitive in the market. (For suppliers)
5. The supply chain has achieved its set goals.

Scale: 1=Strongly Disagree; 3 = Neutral; 5 = Strongly Agree

SC IT Infrastructure Capabilities

Please indicate the extent to which each of the following statements applies to the use of information technologies in the identified supply chain.

1. Data are entered only once to be retrieved by both firms.
2. The supply chain applications (e.g., supply chain planning applications, supply chain transaction applications) in our firm and the [SC Partner Firm] communicate in real time.
3. Most of the software applications used in the supply chain have been integrated between the firms.
4. Software applications on multiple platforms are interoperable with each other across the supply chain.
5. The supply chain applications are scalable.
6. The supply chain applications are designed to accommodate changes in business requirements (e.g., product specification changes, transaction volume changes).
7. The supply chain applications can be easily upgraded to support new functions in the supply chain.
8. The manner in which the components of the supply chain applications are organized allows for rapid technological changes.

Scale: 1 = 0% - 20% of the time; 2 = 21% - 40% of the time; 3 = 41% - 60% of the time; 4 = 61% - 80% of the time; 5 = 81% - 100% of the time

SC Relational Capabilities

Please indicate the extent to which the supply chain between your firm and the [SC Partner Firm] can be described by each of the following statements.

1. Supply chain procedures and routines are shared between the firms.
2. Supply chain procedures and routines are formalized consistently so that the firms can interact without misunderstanding.
3. The flow of material and information is optimized across the supply chain.
4. The supply chain procedures and routines between the firms are highly connected.
5. Each firm's way of doing business in the supply chain is closely linked with the other firm.
6. Supply chain–wide logistics is jointly managed between our firm and the [SC Partner Firm].
7. Our firm and the [SC Partner Firm] work together to develop production and delivery schedules.
8. Our firm and the [SC Partner Firm] work together to develop performance metrics.
9. Our firm and the [SC Partner Firm] work together in arriving at demand forecasts.
10. Our firm and the [SC Partner Firm] work together to develop new products/services for the relationship.

11. Our firm and the [SC Partner Firm] work together to perform competitive analysis and formulate strategies.

Scale: 1 = 0% - 20% of the time; 2 = 21% - 40% of the time; 3 = 41% - 60% of the time; 4 = 61% - 80% of the time; 5 = 81% - 100% of the time

Buyer-Supplier Dependence (For Customers)

Please indicate the extent to which you agree or disagree with the following statements.

1. The [SC Partner Firm] is a key supplier of the product line/service to our firm.
2. Our firm's relationship with the [SC Partner Firm] is very important to the achievement of our performance goals.
3. There are potential suppliers who could replace the [SC Partner Firm] to supply this product line/service to our firm.
4. We would incur minimal costs in switching to another supplier's product line/service.
5. If our relationship with the [SC Partner Firm] was discontinued, we would have difficulty in making up the sales and profits that were affected.
6. The [SC Partner Firm] considers our firm a key customer for the product line/service.
7. The [SC Partner Firm]'s relationship with us is very important to the achievement of the [SC Partner Firm]'s performance goals.
8. There are other firms that could replace our firm as the customer for the [SC Partner Firm]'s product line/service.
9. The [SC Partner Firm] would incur minimal costs in replacing our firm with another firm as the customer for the product line/service.
10. If the [SC Partner Firm]'s relationship with us was discontinued, it would be difficult for the [SC Partner Firm] to make up the sales and profits that our firm generated.

Scale: 1=Strongly Disagree; 3 = Neutral; 5 = Strongly Agree

Buyer-Supplier Dependence (For Suppliers)

1. The [SC Partner Firm] is a key customer for the product line/service.
2. Our relationship with the [SC Partner Firm] is very important to the achievement of our performance goals.
3. There are potential customers who could replace the [SC Partner Firm] to buy this product line/service.
4. We would incur minimal costs in replacing the [SC Partner Firm] with another firm as the customer for the product line/service.
5. If our relationship with the [SC Partner Firm] was discontinued, we would have difficulty in making up the sales and profits that the [SC Partner Firm] generated.
6. Our firm is a key supplier of the product line/service to the [SC Partner Firm].
7. The [SC Partner Firm]'s relationship with our firm is important to the [SC Partner Firm]'s achievement of their performance goals.
8. There are other firms that could replace our firm to supply the product line/service to the [SC Partner Firm].
9. The [SC Partner Firm] would incur minimal costs in switching to another supplier for the product line/service.

10. If the [SC Partner Firm]'s relationship with our firm was discontinued, it would be difficult for the [SC Partner Firm] to make up the sales and profits that were affected.

Scale: 1=Strongly Disagree; 3 = Neutral; 5 = Strongly Agree

Control Measures

Transaction Volume

1. Last year, what was the total transaction volume (in dollars) between your firm and the [SC Partner Firm] for the product line/service identified earlier?
2. Last year, what percentage of your firm's overall purchase value was accounted for by the product line/service from the [SC Partner Firm]?

Relationship Time

1. How long has your firm had a business relationship with the [SC Partner Firm]? ___Years

Cooperative Norms

1. Our relationship with the [SC Partner Firm] can be described as cooperative.

Scale: 1=Strongly Disagree; 3 = Neutral; 5 = Strongly Agree

Long-term orientation

1. The [SC Partner Firm] and our firm have long-term relationship goals.

Scale: 1=Strongly Disagree; 3 = Neutral; 5 = Strongly Agree

Trust

1. Our firm considers the relationship with the [SC partner firm] as built on trust.

Scale: 1=Strongly Disagree; 3 = Neutral; 5 = Strongly Agree

Environmental Uncertainty

How would you describe the market environment of the product line/service exchanged between your firm and the [SC Partner Firm]?

1. Customer needs and preferences change rapidly.
2. The competitors in the market frequently make aggressive moves to capture market share.
3. Major innovations to the product/service have constantly emerged in this market in recent years.

Scale: 1=Strongly Disagree; 3 = Neutral; 5 = Strongly Agree

Product Unpredictability

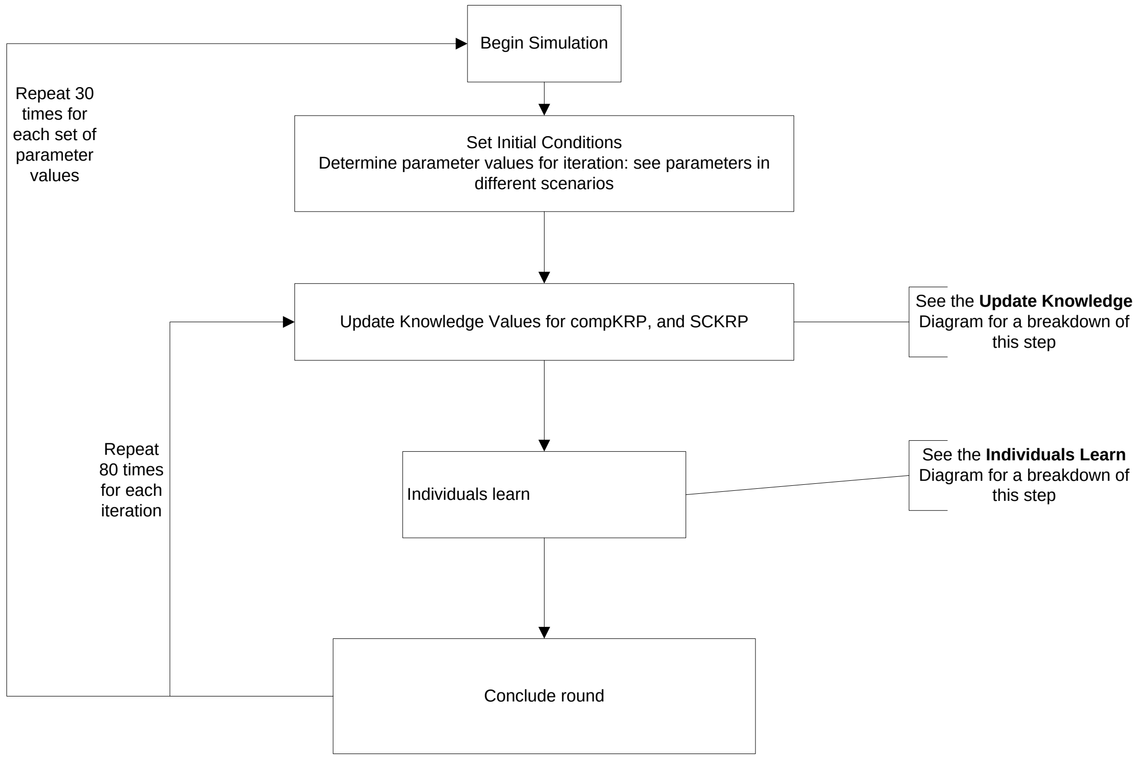
How would you describe the product line/service exchanged between your firm and the [SC Partner Firm]?

1. The product line/service is generally very complex.
2. The specifications of the product line/service are stable.

Scale: 1=Strongly Disagree; 3 = Neutral; 5 = Strongly Agree

APPENDIX C: SIMULATION FLOWCHARTS

Flowchart 1 – One Simulation Iteration



Flowchart 2 – Update Knowledge

Update compKRP

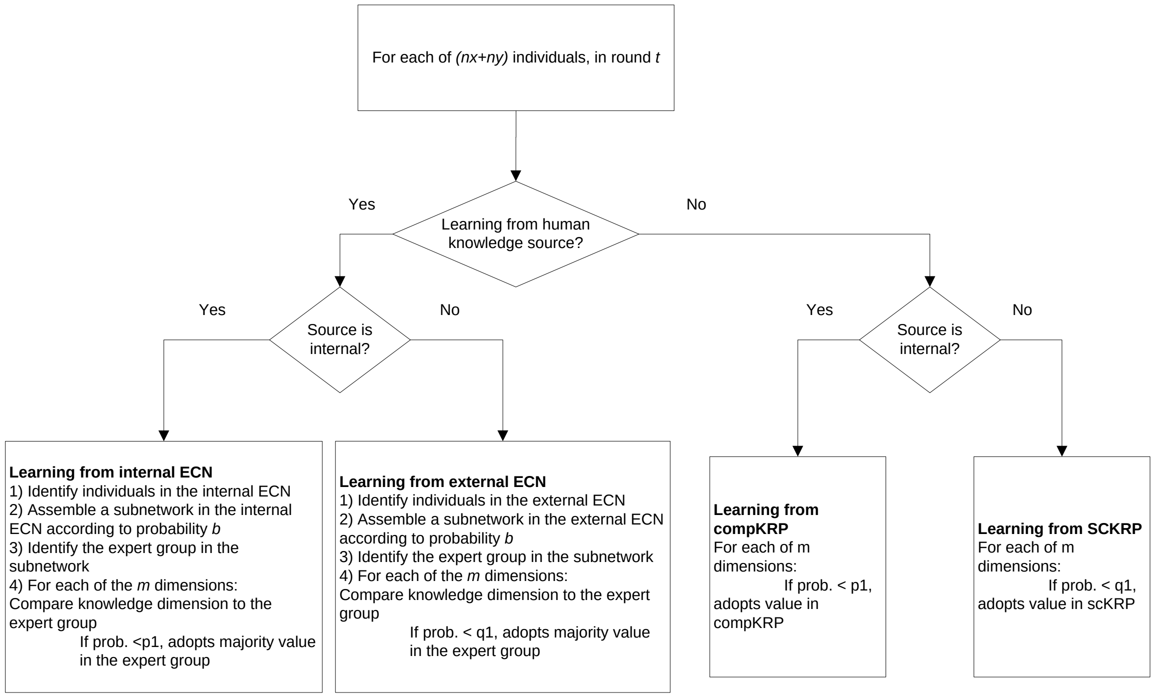
For each group in a firm
Identify domain experts on IFD and EFD (higher KL than compKRP)
For each knowledge dimension on IFD and EFD
Find majority of expert belief (0 doesn't count)
If the majority belief is same as compKRP
Do no change compKRP;
If the majority belief is different from compKRP
If compKRP is 0,
change compKRP to majority of expert value
If compKRP is not 0
k=#of majority belief - #of non-majority belief (0 doesn't count)
if random number < $(1-p2)^k$
do not change compKRP
otherwise
change compKRP value to majority value

↓

Update SCKRP

For each group in supply chain
Identify domain experts on IFD (higher KL than SCKRP)
For each knowledge dimension on IFD
Find majority of expert belief (0 doesn't count)
If the majority belief is same as SCKRP
Do no change SCKRP;
If the majority belief is different from SCKRP
If SCKRP is 0,
change SCKRP to majority of expert value
If SCKRP is not 0
k=#of majority belief - #of non-majority belief (0 doesn't count)
if random number < $(1-q2)^k$
do not change SCKRP
otherwise
change SCKRP to majority value

Flowchart 3 – Individuals Learn



APPENDIX D: RESULTS OF POST HOC TESTS COMPARING EMPLOYEE KNOWLEDGE LEVELS ACROSS FOUR *EXTOL* TYPES AT EACH *KRP* LEVEL[13]

1. SYM

		INTOL											
		Slow OL						**Exploration**					
		KRP = 0.1		KRP = 0.5		KRP = 0.9		KRP = 0.1		KRP = 0.5		KRP = 0.9	
(I) EXTOL	(J) EXTOL	(I-J)	Sig.	(I-J)	Sig.	(I-J)	Sig.	(I-J)	Sig.	(I-J)	Sig.	(I-J)	Sig.
Slow OL	Exploration	0.00	1.00	-0.03	**0.01**	-0.04	**0.00**	0.04	**0.00**	-0.01	0.58	-0.01	**0.01**
	Exploitation	-0.24	**0.00**	-0.15	**0.00**	-0.12	**0.00**	0.18	**0.00**	-0.14	**0.00**	-0.15	**0.01**
	Fast OL	0.04	**0.01**	-0.08	**0.00**	-0.14	**0.00**	0.12	**0.00**	-0.07	**0.00**	-0.23	**0.01**
Exploration	Slow OL	0.00	1.00	0.03	**0.01**	0.04	**0.00**	-0.04	**0.00**	0.01	0.58	0.01	**0.01**
	Exploitation	-0.24	**0.00**	-0.12	**0.00**	-0.07	**0.00**	0.14	**0.00**	-0.13	**0.00**	-0.14	**0.01**
	Fast OL	0.04	**0.01**	-0.05	**0.00**	-0.10	**0.00**	0.08	**0.00**	-0.05	**0.00**	-0.22	**0.01**
Exploitation	Slow OL	0.24	**0.00**	0.15	**0.00**	0.12	**0.00**	-0.18	**0.00**	0.14	**0.00**	0.15	**0.01**
	Exploration	0.24	**0.00**	0.12	**0.00**	0.07	**0.00**	-0.14	**0.00**	0.13	**0.00**	0.14	**0.01**
	Fast OL	0.28	**0.00**	0.07	**0.00**	-0.02	0.09	-0.05	**0.00**	0.07	**0.00**	-0.08	**0.01**
Fast OL	Slow OL	-0.04	**0.01**	0.08	**0.00**	0.14	**0.00**	-0.12	**0.00**	0.07	**0.00**	0.23	**0.01**
	Exploration	-0.04	**0.01**	0.05	**0.00**	0.10	**0.00**	-0.08	**0.00**	0.05	**0.00**	0.22	**0.01**
	Exploitation	-0.28	**0.00**	-0.07	**0.00**	0.02	0.09	0.05	**0.00**	-0.07	**0.00**	0.08	**0.01**
		Exploitation						**Fast**					
		KRP = 0.1		KRP = 0.5		KRP = 0.9		KRP = 0.1		KRP = 0.5		KRP = 0.9	
(I) EXTOL	(J) EXTOL	(I-J)	Sig.	(I-J)	Sig.	(I-J)	Sig.	(I-J)	Sig.	(I-J)	Sig.	(I-J)	Sig.
Slow OL	Exploration	0.03	**0.01**	-0.01	**0.01**	-0.03	**0.01**	-0.03	**0.01**	-0.01	**0.01**	0.00	**0.01**
	Exploitation	0.03	**0.01**	-0.16	**0.01**	-0.13	**0.01**	0.00	**0.01**	-0.22	**0.01**	-0.10	**0.01**
	Fast OL	-0.01	**0.01**	-0.37	**0.01**	-0.12	**0.01**	-0.01	**0.01**	-0.21	**0.01**	-0.13	**0.01**
Exploration	Slow OL	-0.03	**0.01**	0.01	**0.01**	0.03	**0.01**	0.03	**0.01**	0.01	**0.01**	0.00	**0.01**

[13] Bolded numbers indicate $p < 0.05$.

	Exploitation	0.00	**0.01**	-0.15	**0.01**	-0.11	**0.01**	0.03	**0.01**	-0.21	**0.01**	-0.11	**0.01**
	Fast OL	-0.04	**0.01**	-0.36	**0.01**	-0.09	**0.01**	0.03	**0.01**	-0.20	**0.01**	-0.13	**0.01**
Exploitation	Slow OL	-0.03	**0.01**	0.16	**0.01**	0.13	**0.01**	0.00	**0.01**	0.22	**0.01**	0.10	**0.01**
	Exploration	0.00	**0.01**	0.15	**0.01**	0.11	**0.01**	-0.03	**0.01**	0.21	**0.01**	0.11	**0.01**
	Fast OL	-0.04	**0.01**	-0.22	**0.01**	0.02	**0.01**	0.00	**0.01**	0.01	**0.01**	-0.03	**0.01**
Fast OL	Slow OL	0.01	**0.01**	0.37	**0.01**	0.12	**0.01**	0.01	**0.01**	0.21	**0.01**	0.13	**0.01**
	Exploration	0.04	**0.01**	0.36	**0.01**	0.09	**0.01**	-0.03	**0.01**	0.20	**0.01**	0.13	**0.01**
	Exploitation	0.04	**0.01**	0.22	**0.01**	-0.02	**0.01**	0.00	**0.01**	-0.01	**0.01**	0.03	**0.01**

2. ASYMLarge

		INTOL											
		Slow OL						**Exploration**					
		KRP = 0.1		KRP = 0.5		KRP = 0.9		KRP = 0.1		KRP = 0.5		KRP = 0.9	
(I) EXTOL	(J) EXTOL	(I-J)	Sig.	(I-J)	Sig.	(I-J)	Sig.	(I-J)	Sig.	(I-J)	Sig.	(I-J)	Sig.
Slow OL	Exploration	0.01	0.92	0.00	0.99	-0.02	0.20	-0.02	0.06	0.00	1.00	-0.03	**0.02**
	Exploitation	-0.03	**0.01**	0.00	1.00	-0.05	**0.00**	0.01	0.78	-0.01	0.81	-0.05	**0.00**
	Fast OL	0.06	**0.00**	-0.01	0.79	-0.07	**0.00**	0.01	0.97	0.02	0.46	-0.03	**0.01**
Exploration	Slow OL	-0.01	0.92	0.00	0.99	0.02	0.20	0.02	0.06	0.00	1.00	0.03	**0.02**
	Exploitation	-0.03	**0.00**	0.00	0.97	-0.03	**0.01**	0.03	**0.01**	-0.01	0.83	-0.02	0.14
	Fast OL	0.06	**0.00**	-0.01	0.60	-0.06	**0.00**	0.03	**0.04**	0.02	0.44	0.00	1.00
Exploitation	Slow OL	0.03	**0.01**	0.00	1.00	0.05	**0.00**	-0.01	0.78	0.01	0.81	0.05	**0.00**
	Exploration	0.03	**0.00**	0.00	0.97	0.03	**0.01**	-0.03	**0.01**	0.01	0.83	0.02	0.14
	Fast OL	0.09	**0.00**	-0.01	0.85	-0.03	**0.04**	0.00	1.00	0.03	0.09	0.02	0.20
Fast OL	Slow OL	-0.06	**0.00**	0.01	0.79	0.07	**0.00**	-0.01	0.97	-0.02	0.46	0.03	**0.01**
	Exploration	-0.06	**0.00**	0.01	0.60	0.06	**0.00**	-0.03	**0.04**	-0.02	0.44	0.00	1.00
	Exploitation	-0.09	**0.00**	0.01	0.85	0.03	**0.04**	0.00	1.00	-0.03	0.09	-0.02	0.20
		Exploitation						**Fast**					
		KRP = 0.1		KRP = 0.5		KRP = 0.9		KRP = 0.1		KRP = 0.5		KRP = 0.9	

(I) EXTOL	(J) EXTOL	(I-J)	Sig.	(I-J)	Sig.	(I-J)	Sig.	(I-J)	Sig.	(I-J)	Sig.	(I-J)	Sig.
Slow OL	Exploration	0.04	**0.00**	0.01	0.80	-0.01	0.81	0.01	0.34	0.00	0.94	0.00	1.00
	Exploitation	0.05	**0.00**	-0.07	**0.00**	-0.03	**0.00**	-0.05	**0.00**	-0.07	**0.00**	-0.05	**0.00**
	Fast OL	0.06	**0.00**	-0.05	**0.00**	-0.04	**0.00**	0.03	**0.00**	-0.05	**0.00**	-0.05	**0.00**
Exploration	Slow OL	-0.04	**0.00**	-0.01	0.80	0.01	0.81	-0.01	0.34	0.00	0.94	0.00	1.00
	Exploitation	0.01	0.63	-0.08	**0.00**	-0.02	0.06	-0.07	**0.00**	-0.06	**0.00**	-0.05	**0.00**
	Fast OL	0.02	0.23	-0.06	**0.00**	-0.03	**0.00**	0.02	0.18	-0.05	**0.00**	-0.05	**0.00**
Exploitation	Slow OL	-0.05	**0.00**	0.07	**0.00**	0.03	**0.00**	0.05	**0.00**	0.07	**0.00**	0.05	**0.00**
	Exploration	-0.01	0.63	0.08	**0.00**	0.02	0.06	0.07	**0.00**	0.06	**0.00**	0.05	**0.00**
	Fast OL	0.01	0.89	0.02	0.19	-0.01	0.76	0.08	**0.00**	0.01	0.10	0.01	0.81
Fast OL	Slow OL	-0.06	**0.00**	0.05	**0.00**	0.04	**0.00**	-0.03	**0.00**	0.05	**0.00**	0.05	**0.00**
	Exploration	-0.02	0.23	0.06	**0.00**	0.03	**0.00**	-0.02	0.18	0.05	**0.00**	0.05	**0.00**
	Exploitation	-0.01	0.89	-0.02	0.19	0.01	0.76	-0.08	**0.00**	-0.01	0.10	-0.01	0.81

3. ASYMSmall

		INTOL											
		Slow OL						**Exploration**					
		KRP = 0.1		KRP = 0.5		KRP = 0.9		KRP = 0.1		KRP = 0.5		KRP = 0.9	
(I) EXTOL	(J) EXTOL	(I-J)	Sig.	(I-J)	Sig.	(I-J)	Sig.	(I-J)	Sig.	(I-J)	Sig.	(I-J)	Sig.
Slow OL	Exploration	-0.17	**0.00**	-0.09	**0.00**	0.09	**0.00**	-0.10	**0.00**	-0.11	**0.00**	0.04	**0.00**
	Exploitation	-0.15	**0.00**	-0.08	**0.00**	0.00	1.00	-0.01	0.59	0.01	0.76	0.02	0.33
	Fast OL	-0.09	**0.00**	-0.08	**0.00**	-0.02	0.23	-0.10	**0.00**	-0.08	**0.00**	0.05	**0.00**
Exploration	Slow OL	0.17	**0.00**	0.09	**0.00**	-0.09	**0.00**	0.10	**0.00**	0.11	**0.00**	-0.04	**0.00**
	Exploitation	0.01	0.50	0.01	0.71	-0.09	**0.00**	0.09	**0.00**	0.12	**0.00**	-0.02	0.06
	Fast OL	0.08	**0.00**	0.02	0.43	-0.12	**0.00**	0.00	0.97	0.04	**0.00**	0.01	0.67
Exploitation	Slow OL	0.15	**0.00**	0.08	**0.00**	0.00	1.00	0.01	0.59	-0.01	0.76	-0.02	0.33
	Exploration	-0.01	0.50	-0.01	0.71	0.09	**0.00**	-0.09	**0.00**	-0.12	**0.00**	0.02	0.06
	Fast OL	0.06	**0.00**	0.00	1.00	-0.02	0.14	-0.09	**0.00**	-0.08	**0.00**	0.03	**0.00**

Fast OL	Slow OL	0.09	**0.00**	0.08	**0.00**	0.02	0.23	0.10	**0.00**	0.08	**0.00**	-0.05	**0.00**
	Exploration	-0.08	**0.00**	-0.02	0.43	0.12	**0.00**	0.00	0.97	-0.04	**0.00**	-0.01	0.67
	Exploitation	-0.06	**0.00**	0.00	1.00	0.02	0.14	0.09	**0.00**	0.08	**0.00**	-0.03	**0.00**
		Exploitation						**Fast**					
		KRP = 0.1		KRP = 0.5		KRP = 0.9		KRP = 0.1		KRP = 0.5		KRP = 0.9	
(I) EXTOL	(J) EXTOL	(I-J)	Sig.	(I-J)	Sig.	(I-J)	Sig.	(I-J)	Sig.	(I-J)	Sig.	(I-J)	Sig.
Slow OL	Exploration	0.08	**0.00**	-0.02	0.31	-0.03	**0.04**	0.08	**0.00**	-0.06	**0.00**	-0.07	**0.00**
	Exploitation	0.12	**0.00**	0.12	**0.00**	0.04	**0.00**	0.03	**0.02**	-0.12	**0.00**	-0.04	**0.01**
	Fast OL	0.10	**0.00**	-0.04	**0.00**	-0.15	**0.00**	-0.01	0.54	0.03	**0.04**	0.02	0.40
Exploration	Slow OL	-0.08	**0.00**	0.02	0.31	0.03	**0.04**	-0.08	**0.00**	0.06	**0.00**	0.07	**0.00**
	Exploitation	0.04	**0.00**	0.14	**0.00**	0.06	**0.00**	-0.04	**0.00**	-0.06	**0.00**	0.03	0.17
	Fast OL	0.02	0.38	-0.02	0.34	-0.12	**0.00**	-0.09	**0.00**	0.09	**0.00**	0.09	**0.00**
Exploitation	Slow OL	-0.12	**0.00**	-0.12	**0.00**	-0.04	**0.00**	-0.03	**0.02**	0.12	**0.00**	0.04	**0.01**
	Exploration	-0.04	**0.00**	-0.14	**0.00**	-0.06	**0.00**	0.04	**0.00**	0.06	**0.00**	-0.03	0.17
	Fast OL	-0.02	0.50	-0.15	**0.00**	-0.18	**0.00**	-0.05	**0.00**	0.14	**0.00**	0.06	**0.00**
Fast OL	Slow OL	-0.10	**0.00**	0.04	**0.00**	0.15	**0.00**	0.01	0.54	-0.03	**0.04**	-0.02	0.40
	Exploration	-0.02	0.38	0.02	0.34	0.12	**0.00**	0.09	**0.00**	-0.09	**0.00**	-0.09	**0.00**
	Exploitation	0.02	0.50	0.15	**0.00**	0.18	**0.00**	0.05	**0.00**	-0.14	**0.00**	-0.06	**0.00**