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John Qi Dong
Hong Kong University of Science and Technology, dongqi@ust.hk

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HOW DOES INFORMATION TECHNOLOGY ENABLE INNOVATION IN SUPPLY CHAINS?

Completed Research Paper

John Qi Dong
School of Business and Management
Hong Kong University of Science and Technology
Clear Water Bay, Kowloon, Hong Kong
dongqi@ust.hk

Abstract

The paper explores a mechanistic understanding of IT-enabled innovation in a context of supply chain. Based on the innovation dynamics perspective and resource-based view, it links IT resources for supply chain management and IT-enabled innovation via e-business capability with supply chain partners. A conceptual model is formulated to explain how and why IT can enable product and process innovations along the supply chain, and is empirically validated by the data from 676 manufacturing firms in six countries. It was found that IT resources for supply chain management are capable of achieving IT-enabled innovation through both upstream and downstream e-business capability to collaborate with suppliers and customers. The paper contributes to the literature of digitally enabled supply chain management and IT business value. It also allows important managerial implications to firms, especially those in manufacturing sector, about how to chase IT-enabled innovation in supply chains to overcome today's depression.

Keywords: IT-enabled innovation, e-business capability, innovation dynamics perspective, resource-based view, digitally enabled supply chain management, IT business value

Introduction

"The name of the game is innovation."

– Alan George Lafley, Former Chairman, President and CEO of Proctor & Gamble

In an open economy with changing customer preferences, shifting industry boundaries, and emerging global competition, firms need to build capabilities for constant innovation (Malhotra et al. 2007). To build such innovative capabilities, contemporary enterprises need to collaborate with other enterprises, entities and institutions and leverage outside resources and knowledge (Teece 2007). Along with the innovation process from closed to chain-linked (Kline 1985) and open (Chesbrough 2003), inter-organizational collaboration has become a major way giving birth to innovation (Powell et al. 1996). Thus, collaboration with partners and innovation building are two business challenges critical for firms' success, which are not isolated with each other. In a collaborative innovation process, IT plays a more and more important role in enabling technological change and innovation development (Clemons and Row 1991). This is because IT revolutionarily facilitates inter-organizational collaboration, such as the digitally enabled integration in supply chains (Rai et al. 2006). Firms become increasingly rely on electronic interconnections to enhance competitive advantage in operational excellence, customer relationship, product and service offerings, and revenue growth (Krishnan et al. 2007).

However, there has been limited theoretical understanding as well as limited empirical grounding regarding how IT enables firms to leverage resources, manage partner and customer relationships, and explore opportunities (Krishnan et al. 2007). Nambisan (2003) suggested IS field may potentially contribute to new product development research, which can be seemed as an IT-enabled innovation process. Advanced manufacturing process and quality customer service process can also be achieved by forming capable IT capabilities (Banker et al. 2006; Ray et al. 2005). Thus, IT resources and capability may be conceptualized as an important enabler of innovation in product and process. However, no systematic investigation in IS literature has been done to study the role of IT in generating product and process innovations.

This paper contributes a model explaining IT-enabled innovation generating in product and process by e-business capability to collaborate with supply chain partners based on IT resources facilitating supply chain management (SCM), by the lenses of innovation dynamics perspective and resource-based view. It provides an understanding of this mechanism to the literature of digitally enabled SCM. It also enriches the literature of IT business valve by conceptualizing IT as an enabler of product and process innovations. The following research questions are addressed by the paper. (1) Whether and how a firm's IT resources for SCM enable product and process innovations to be derived in conjunction with its supply chain partners? (2) What mediation mechanisms lead to the creation of these innovations? (3) Do these effects vary across the supply chain for innovating with suppliers and customers?

The paper proceeds as follows. The next section reviews and extends innovation dynamics perspective and resource-based view in the digitally enabled supply chain context, followed by a section for model formulation and hypotheses development. Then, the empirical methodology used, results obtained, and robustness checks are reported. It concludes after discussion on the main findings, limitations, and managerial implications.

Theoretical Background

This section reviews the perspective of innovation dynamics in innovation literature and resource-based view in strategy literature, as well as its applications in IS. The first perspective provides us an understanding of innovation activities and the possible role of IT in this process. Resource-based view has been extensively applied in IT-performance research, which provides us another lens to link IT resources and capability to innovation outcomes.

Innovation Dynamics Perspective

Since Schumpeter (1934) provided a concept of innovation as part of economic growth, the conventional definition of innovation has been widely investigated in hopes of establishing a linear model based on the characteristics of innovation activities. With technology evolving, however, innovation activities have advanced from simple linear sequential stages to interactive process, in which various specialized participants absorb, assimilate, emit and exchange knowledge (Dodgson and Rothwell 1994; Tidd et al. 2001). In light of innovation process as a series of intra and inter unit interactions (Cohen and Levinthal 1990; Tsai and Ghoshal 1998) and knowledge combination processes (Kogut and Zander 1992), it has become apparent that the linearity depiction implicit in innovation process is insufficient, and that a more dynamic and interactive conception is required (Amesse and Cohendet 2001).

Kline and Rosenberg (1986) proposed a chain-linked model, depicting that how knowledge can be acquired from external sources like network partners (Myers and Rosenbloom 1996). In the same vein, various concepts of interactive innovation have also been put forth as means of ward to understanding the non-linear, iterative and multi-agent characteristics of innovation process (Kline 1985; von Hippel 1987). This means that innovation can be regarded as resulting from distributed inter-organizational networks, rather than from single firms (Powell et al. 1996). Organizations are reported to increasingly engage in open innovation (Chesbrough 2003). Rothwell (1994) and Dodgson and Rothwell (1994) proposed five generations of innovation model into technology push, need pull, coupling, integrated, and networking models. This typology clearly depicts a new shift of innovation activities to interactive and chain-linked dynamics.

During the change of innovation process, the role of IT becomes more and more important (Tidd et al. 2001; Schilling 2005). Because inter-organizational dynamic interaction and knowledge exchange can be extensively supported by IT, firms can take advantage of IT resources and capability to leverage outside resources and knowledge for innovation generating. Thus, innovation dynamics perspective essentially stresses the importance of interaction and collaboration among organizations, which is supported by IT resources and capability. For example in the supply chain context, IT resources can facilitate transactions of purchasing and ordering, and strategic information sharing with partners. Such e-business capability improves the collaboration between the focal firm and its supply chain partners, which in turn enables firm agility with a stream of new products and novel processes.

Resource-Based View

Grounded in microeconomics about firm heterogeneity and imperfect competition (Chamberlin 1933; Robinson 1933), resource-based view (RBV) explains competitive advantage by heterogeneous resource endowments (Mahoney and Pandian 1992). Penrose (1959) developed the idea and conceptualized the firm as a bundle of resources. Wernerfelt (1984) formally proposed the notion of resource position barriers and links resource attributes to firm profitability. Subsequent strategy research studied the relationship between resource attributes to competitive advantage (e.g. Amit and Schoemaker 1993; Barney 1991; Peteraf 1993; Rumelt 1984; Teece et al. 1997).

In the RBV theory, firms are suggested by the approach as follows: identify the unique resources, decide in which markets those resources can earn the highest rents, and decide whether the rents from the assets are most effectively utilized (Barney 1986; Teece 1980). Resources fulfilling the criteria of value, rareness, inimitability, and non-substitutability are strategic resources and can bring sustainable competitive advantage to firms (Barney 1991). Prior studies have examined many specific strategic resources such as entrepreneurship (Rumelt 1987), organizational culture (Barney 1986), organizational routines (Nelson and Winter 1982), invisible assets (Itami 1987), human resources (Amit and Schoemaker 1993), IT resources (Mata et al. 1995), and resources of interconnected organizations (Dovev 2002).

RBV provides a cogent framework for evaluating the strategic value of IT resources (Wade and Hulland 2004), expanding and deepening our understanding of IT business value (Melville et al. 2004). Mata et al. (1995) suggested that the extent to which an IT attribute is valuable, heterogeneous and imperfectly mobile determines sustainability of competitive advantage. Early work in IS literature derived mathematical specifications from microeconomics to examine IT inputs and productivity, consumer surplus and profitability (Brynjolfsson and Hitt 1996; Hitt and Brynjolfsson 1996), which could be seemed as initial attempts of resource-based analysis. A recent study by Oh and Pinsonneault (2007) comparing RBV with contingency-based approach also supported a stronger predictive power of RBV for IT impact on firm revenue and profitability. A number of prior studies have investigated how IT resources and capabilities enable business processes in a firm to outperform the processes of its competitors and provided supportive evidence. For example, Ray et al. (2005) applied RBV to analyzed and examined how IT resources and capabilities impact customer service process performance. Tanriverdi (2006) explained how IT resources and IT management practices impact multi-business firm performance through creating cross-unit synergy. Dong et al. (2009) provided empirical evidence that partner support improves supply chain process in upstream, internal and downstream operations. However, prior IS studies based on RBV were mainly focused on firm performance without explicit exploration of innovation outcomes, which are another form of competitive advantage for contemporary firms (Teece 2007).

It was commonly suggested in IS literature that the association between IT resources to competitive advantage is transformed by higher order IT capability. Santhanam and Hartono (2003) provided empirical evidence for positive performance effects of IT capability developed by leveraging IT investments. Sambamurthy et al. (2003) conceptualized the role of IT as a digital options generator that influences firm performance through organizational capabilities and strategic processes. Melville et al. (2004) proposed an integrative model linking IT and organizational performance via internal business processes, as well as the resources and business processes of trading partners. Bharadwaj (2000) derived a concept of IT as organizational capability impacting firm performance, which is developed by combining IT-based resources with other resources and capabilities. Similarly, Nevo and Wade (2010) described how IT-enabled assets are capable of positively affecting sustainable competitive advantage by integrating and synergizing IT resources and organizational resources. A number of studies also attributed firm performance gains to digitally enabled supply chain collaboration capabilities (e.g. Banker et al. 2006; Barua et al. 2004; Rai et al. 2006; Zhu 2004b; Zhu and Kraemer 2002; 2005; Dong et al. 2009).

Conceptual Model and Hypotheses Development

To explain how IT may generate product and process innovations, a conceptual model is formulated based on the theoretical implications of innovation dynamics perspective and resource-based view. Testable hypotheses associated with the conceptual model are developed accordingly.

Conceptual Model

The conceptual model is shown in Figure 1. IT-enabled innovation is the dependent variable to be explained. Here the definition of IT-enabled innovation in the supply chain context refers to *new or substantially improved products and services or internal producing and supplying processes, which are resulted from IT-enabled initiatives and activities*. As discussed above, higher order capabilities of combining IT resources with direct efforts toward business objectives and opportunities need to be characterized, in order to link IT resources to organizational outcomes based on RBV (Bharadwaj 2000; Santhanam and Hartono 2003; Barua et al. 2004; Rai et al. 2006). The relational view as an extension of RBV suggested that a firm's critical resources may embed in inter-organizational routines and processes (Dyer and Singh 1998), and be acquired by digitally enabled capabilities (Rai et al. 2006). In accord with this argument, our proposed model explains the mechanism of IT resources for SCM to create innovation by the capability of doing e-business with both upstream and downstream business partners. IT resources, especially the net and system infrastructure for supply chain integration, facilitate transactional processes adapting and knowledge creating and sharing in the supply chain (Galliers 1999), which in turn generate a variety of new products and business processes. With adaptive procurements and sales in addition to timely knowledge from partners, the focal firm becomes more responsive to the market needs in product development and more flexible in producing and supplying processes (Malhotra et al. 2001; 2005; 2007; Saraf et al. 2007; Zhu 2004b; Zhu and Kraemer 2002). Further, Saraf et al. (2007) argued that single focus on one type of relationship (suppliers, customers or distribution channel partners) limits the generalizability of prior studies to the reality involving all of partners. Thus, our model tends to be more realistic by incorporating both sides of supply chain.

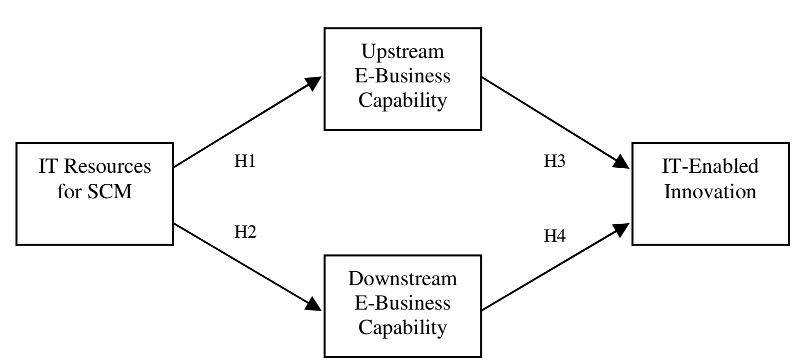

Figure 1. Conceptual Model

IT Resources for SCM and Supply Chain E-Business Capability

The most important IT resources supporting for SCM are investments in IT infrastructure facilitating connectivity, compatibility, and responsiveness (Gunasekaran and Hgai 2004). A firm's existing IT infrastructure provides the platform to launch innovative e-commerce capability faster or more effectively (Zhu 2004b). Zhu and Kraemer (2002) proposed these resources consist of net infrastructure (e.g. Internet access, LAN, and extranet), integration systems (e.g. ERP, SCM, and CRM), as well as digital data systems (e.g. CAD, and CAM) facilitating electronic exchange. They formally defined that "e-commerce capabilities reflect a company's strategic initiatives to use the Internet to share information, facilitate transactions, improve customer services, and strengthen supplier integration" (p. 279). As the dimensions of e-commerce capability, information sharing, transaction facilitating and supplier integration are highlighted, in addition to customer services on the Internet. Zhu and Kraemer (2005) suggested that the use of Internet-based e-business creates value in three ways: market expansion, transactional efficiencies, and information sharing. This study is accordingly focused on firms' e-business capability to do electronic transaction and information sharing rooted in supply chain collaboration, as not all of e-business activities investigated are necessarily launched on the Internet compared to e-commerce activities.

IT resources for SCM can enable real-time procurement and payable as well as optimal inventory holding (Rai et al. 2006). Furthermore, it also supports tight data sharing with suppliers to provide "richer, higher value-adding information exchange" (Malhotra et al. 2005, p. 10). For example, Mukhopadhyay et al. (1995) found that EDI significantly enables effective use of information between the manufacturer and its suppliers. Thus, we refer upstream e-business capability in the supply chain context to *strategic initiatives and activities of a firm to facilitate transaction and share information with its suppliers by leveraging IT resources*. Because this capability is based on the availability and use of IT resources for SCM in a firm, we propose the following hypothesis.

H1: IT resources for SCM positively affect upstream e-business capability.

We define downstream e-business capability in the supply chain context as *strategic initiatives and activities of a firm to facilitate transaction and share information with its customers and distribution channel partners by leveraging IT resources*. IT infrastructure integration for SCM leads to supply chain integration capability in account receivable and payable processes, as well as inventory and sales data sharing with downstream partners (Rai et al. 2006). Saraf et al. (2007) suggested that IS application capabilities in the context of downstream supply chain lead to two types of relational assets: inter-firm knowledge sharing and process coupling with customers and channel partners. Subramani (2004) similarly found that certain ways of use SCM systems for exploitation and exploration can generate business process specificity and domain knowledge specificity to suppliers. Therefore, IT infrastructure establishes a platform on which e-business capability can be built (Zhu and Kraemer 2005). For example, Ray et al. (2005) found that IT resources and spending can affect customer service process with shared knowledge. This leads to the following hypothesis.

H2: IT resources for SCM positively affect downstream e-business capability.

Supply Chain E-Business Capability and IT-Enabled Innovation

Nowadays, firms are leveraging inter-organizational relationships for knowledge creation (Hamel 1991; Huber 1991). By IT-enabled acquisition and assimilation of knowledge from external sources, firms can create new knowledge (Malhotra et al. 2001; 2005). It was suggested that suppliers become an important resource of innovative firms (Hull et al. 2006). As a result, focal firms could benefit from e-business activities with their suppliers from not only the high-quality and low-cost end products, but also shortened product development and production cycles (Lee 2000). Subramani (2004) suggested that the use of SCM systems for exploration leads to strategic benefits via domain knowledge specificity. By frequent electronic transactions and information sharing, suppliers are more inclined to conduct joint innovation activities such as collaborative R&D. Collaborative R&D appears to be a useful means by which strategic flexibility can be increased and access to new external knowledge can be realized (Pisano 1990; Fritsch and Lukas 2001). By analyzing a case of Boeing Rocketdyne, Malhotra et al. (2001) showed that how inter-organizational virtual team developed a radically new product. The new knowledge created through information exchange with suppliers can be not only in the arena of design of new products and services, but also in the arena of improved existing offerings and delivery through redesigned inter-organizational process (Malhotra et al. 2005). Thrafdar and Gordon (2007) illustrated how IS competencies of knowledge management and collaboration affect the conception, development and implementation of process innovation by the case of a healthcare firm. This leads to the following hypothesis.

H3: Upstream e-business capability positively affects IT-enabled innovation.

Customers and distribution channel partners are another source of co-innovators to develop new products and business processes (Mannervik and Ramirez 2006). Market-related knowledge manifests in market responsiveness and the development of innovative products and services. To unleash the potential of supply chain, a firm and its customers need to share information such as market trends, changes in customers' preferences, new product introductions, and future product plans along with transaction and coordination information. A high level of process alignment and informational capabilities with customers can increase firms' obtaining of real-time demand change, sales variation, inventory buildup, and strategic moves (Barua et al. 2004). The information delivered by e-business activities enables firms to adapt promptly product design in response to the market (Zhu 2004a). Ray et al. (2005) found that shared knowledge between IT and customer service units is a key IT capability affecting customer service process. By process coupling and knowledge sharing, customers are helping design products and services, channel partners are taking on the assembly of products, assemblers are taking on a proactive stance in marketing, and the focal firm is also emulating the internal processes of their successful partners and is redesigning its own internal processes by leveraging the knowledge from partners (Malhotra et al. 2007; Saraf et al. 2007).

The field of innovation research has suggested that customer involvement contributes to new product development for a long time (von Hippel 1986). Because lead users are familiar with conditions that lie in the future for most others and often attempt to fill the need they experience in advance, they can serve as a need forecasting laboratory for marketing research and provide new product concepts and design data (Urban and von Hippel 1988; von Hippel 2005). Customer interactions in e-business activities are also a potentially powerful tool for developing successful new services (Alam and Perry 2002). Specifically, it is seen as an effective tool for starting the idea for new services, creating value for consumers, effectively managing the overall innovation process in a firm, and enhancing the knowledge diffusion in the industry system (Magnusson et al. 2003). Thus, we propose the following hypothesis.

H4: Downstream e-business capability positively affects IT-enabled innovation.

Method

Data

To empirically examine the conceptual model and associated hypotheses, we use the data from a large-scale survey across six countries conducted in March 2009. This study chooses to focus on manufacturing sector, because manufacturing firms are usually suggested to involve more in supply chain collaboration in terms of transaction frequency and information sharing for producing and supplying (Dong et al. 2009; Subramani 2004). Empirically, concentrating on one sector helps to minimize the confounding effects of industry structure and business activities (Zhu and Kraemer 2002).

The survey was financed by the European Commission to investigate firms' use of IT and e-business activities. A sample was randomly stratified by firm size[1], based on official statistical records and widely recognized business directories from the population of firms in each country. The distribution of firm size reflects a balance of large, medium and small businesses without apparent bias across countries. The sampled firms produce a variety of goods including glass (159), refractory products (20), clay building materials (75), porcelain and ceramic products (60), cement, lime and plaster (25), and articles of concrete, cement and plaster (337).

A total number of 676 firms in France (86), Germany (180), Italy (101), Poland (120), Spain (125), and the United Kingdom (64) responded to the survey. The response rate is 13%, comparable to other cross-country studies with similar scale[2]. After pilot interviews with 25 German companies in February 2009 for the structure and

[1] The sample consists of 54% small firms with less than 50 employees, 34% medium size firms with 50-249 employees, 10% large firms with 250-999 employees, and 2% very large firms with more than 1000 employees.

[2] For example, Zhu and Kraemer (2005) studied e-business usage and value with a cross-country survey dataset including 701 firms with a response rate of 13%.

comprehensibility of the questionnaire, the survey was carried out by computer-aided telephone interview (CATI) to guarantee a high quality of response. The respondents were IT decision makers of a firm. The respondents' titles are not found to cause significant bias in the data.

Measures

Gunasekaran and Ngai (2004) suggested that IT infrastructure for SCM consists of high speed Internet services, broadband and wireless technologies, and software systems for integration. Zhu (2004b) and Zhu and Kraemer (2002) measured IT infrastructure complementary to e-commerce capability by PC, workstations, LAN, terminals, and IT intensity etc. They found that IT intensity as a general measure of IT resources is collinear with other indicators. Thus, this study selected specific indicators to measure IT resources for SCM supporting inter-organizational connectivity and data exchange in order to capture detailed information. Given a fact that all of firms in our sample use computers, we assess a firm's IT resources for SCM by two dimensions as net infrastructure and system infrastructure. This is because net infrastructure and system infrastructure are the foundations for data exchange and integration among organizations, which can be leveraged to manage supply chain operations.

Dong et al. (2009) measured IT infrastructure in the supply chain context by the number of technologies a firm has such as intranet, extranet, LAN, and wide area networks etc. We follow their way to measure net infrastructure as the number of net infrastructure a firm use including Internet access, fast speed broadband connection (2 megabits per second or more), LAN, wireless network, extranet, and remote access from field operation. System infrastructure is measured by the number of systems used to support transaction coordination and information flow integration including ERP, SCM, CRM, and supplier relationship management (SRM), as well as digitization of manufacturing data facilitating electronic exchange such as computer aided design (CAD), and computer aided manufacturing (CAM).

According to the definition of upstream and downstream e-business capability, transactional and informational activities are two characteristics of this capability. This is consistent with supply chain integration capabilities in Rai et al. (2006) incorporating digitally enabled processes and information sharing. We use two first-order constructs as electronic transaction and information sharing to measure upstream and downstream e-business capability, respectively. Specifically, e-procurement from suppliers and information sharing with suppliers are used to assess a firm's upstream e-business capability, which are aggregated by coding a set of binary indicators similar to the way of measuring e-commerce capability by Zhu and Kraemer (2005). The indicators for e-procurement from suppliers and information sharing with suppliers are developed based on the instruments for supplier connection of e-commerce capability in Zhu and Kraemer (2005) and information flow integration of supply chain process integration capability in Rai et al. (2006). Five indicators are used to assess e-procurement activities: ordering goods or services through digital networks, purchasing supplies and materials from the website of suppliers, purchasing supplies and materials from B2B marketplaces, ordering via extranets of suppliers, and purchasing activities of different units by e-procurement system are coordinated. Information sharing with suppliers is assessed by maintaining electronic data interchange with suppliers, access to the extranets of suppliers, ERP system connected with suppliers, sharing information about inventory and production plans with suppliers electronically, and having vendors further arranging inventory information with their suppliers.

Symmetrically, we measure downstream e-business capability by two first-order constructs as e-sales to customers and information sharing with customers. The indicators for e-sales to customers and information sharing with customers are developed based on the instruments for transaction of e-commerce capability in Zhu and Kraemer (2005) and information flow integration of supply chain process integration capability in Rai et al. (2006). Five indicators are used to assess e-sales activities: customers and distribution channel partners can order goods or services through digital networks, selling products and services on the company website, selling products and services in B2B marketplaces, customers and distribution channel partners can place order via extranets with the firm, and purchasing activities of different units by e-sales system are coordinated. Information sharing with customers is assessed by maintaining electronic data interchange with customers and distribution channel partners, access to the extranets of customers and distribution channel partners, ERP system connected with customers and distribution channel partners, sharing information about inventory and production plans with customers and distribution channel partners electronically, and having electronic catalogues for products description as a basis for data exchanges with customers and distribution channel partners.

We measure IT-enabled innovation by two dimensions as product innovation and process innovation. Following the design of performance measures for net-enabled business transformation in Barua et al. (2004), we clean our innovation measures to be attributable to IT-enabled initiatives and activities only in order to mitigate a concern of confounding factors. We assess IT-enabled product innovation by the degree to which the innovative products or services includes IT components, is resulted from IT-enabled research and development, and is benefited from IT-enabled market launch. For IT-enabled process innovation, we assess the degree to which the innovative processes are supported by IT-enabled initiatives and activities; is resulted from IT-enabled process design, and is implemented by IT-enabled initiatives and activities. Note that these measures for innovation do not reflect the overall innovation outcomes of the firm, but only the innovations enabled by IT. We use three-level interval scale (fully, partly, or not at all) for each indicator. Furthermore, we control the effects of firm size and industry, which have been suggested to affect innovation outcomes (Bughin and Jacques 1994; Peneder 2010)[3]. The number of employees is used as a measure of firm size (Brynjolfsson et al. 1994). Industry is coded by three categories according to firms' NACE Rev. 2 codes (23.1 glass and glass products; 23.2, 23.3, 23.4 ceramic and ceramic products; 23.5, 23.6 cement and cement products).

Analysis

Structural equation modeling (SEM) has been extensively used for modeling multiple interdependent relationships and latent constructs (Anderson and Gerbing 1988). Petter et al. (2007) found that a number of IS studies using SEM suffered from a problem of reflective construct specification, which essentially should be formative. To avoid the problem, the decision rules suggested by Jarvis et al. (2003) for identifying construct as formative or reflective are carefully checked in this study[4]. Because our first-order constructs define the characteristics of second-order constructs in the conceptual model, do not have the same or similar content, do not necessarily co-vary with each other, and do not require the same antecedents and consequences, formative specification is a proper way to specify our second-order constructs. Table 1 describes the measurements for second-order constructs. We use partial least squares (PLS), because the research model is exploratory in nature and has formative latent variables with mixed scales. PLS is component-based SEM and was suggested to be flexible to deal with formative indicators and mixed scales without distribution assumptions, compared to covariance-based SEM (Chin 1998). SmartPLS 2.0 M3 was used to analyze the data.

Table 1. Construct Measurements

Second-Order Construct	Type	First-Order Construct	Loadings	Scale
IT Resources for SCM	Formative	Net Infrastructure	0.813	7-Point
		System Infrastructure	0.886	7-Point
Upstream E-Business Capability	Formative	E-Procurement from Suppliers	0.795	6-Point
		Information Sharing with Suppliers	0.846	6-Point
Downstream E-Business Capability	Formative	E-Sales to Customers	0.630	6-Point
		Information Sharing with Customers	0.956	6-Point
IT-Enabled Innovation	Formative	IT-Enabled Product Innovation	0.746	7-Point
		IT-Enabled Process Innovation	0.921	7-Point

Note. All of the loadings are significant at the 0.01 level.

[3] A model incorporating another control variable for country was estimated, resulting in similar results. Because country is not the interest of this study, the paper is focused on the parsimonious model.

[4] The four decision rules in Jarvis et al. (2003) are: (1) Are the indicators defining characteristics or manifestations of the construct? (2) Should the indicators have the same or similar content? (3) Should a change in one of the indicators be associated with changes in the other indicators? (4) Are the indicators expected to have the same antecedents and consequences?

Results

Measurement Model

Because our latent constructs are formative, internal consistency or reliability is not required (Chin 1998; Petter et al. 2007) [5]. We follow the guidelines by Fornell and Larcker (1981) to assess discriminant validity of the measurements by average variance extracted (AVE) approach. A construct is considered to be distinct from the others, if its square root of AVE is greater than its correlations with other constructs (Barclay et al. 1995). Thus, Table 2 shows that the measurements for the constructs in our conceptual model demonstrate good discriminant validity.

Table 2. Correlation and Discriminant Validity

Variable	ITR	UEBC	DEBC	ITI	Industry	Size
IT Resources for SCM (ITR)	(0.852)					
Upstream E-Business Capability (UEBC)	0.498 [0.446]	(0.821)				
Downstream E-Business Capability (DEBC)	0.393 [0.330]	0.547 [0.500]	(0.825)			
IT-Enabled Innovation (ITI)	0.446 [0.389]	0.398 [0.336]	0.349 [0.282]	(0.844)		
Industry	-0.063	-0.112	-0.140	-0.068		
Size	0.375	0.275	0.301	0.335	-0.073	
Marker Variable	0.119	0.094	0.126	0.180	0.033	0.155

Note. The diagonal figures in parentheses are the square roots of AVE. The figures in brackets are corrected correlations partial out common method variance.

While PLS does not provide significance tests, bootstrapping technique can help to solve the problem. To obtain stable results of bootstrapping, we bootstrap 10000 subsamples to get the distribution of loadings, weights and path coefficients. As shown in Table 1, all of the loadings of our first-order variable were significant ($p < 0.01$). The PLS results are presented in Figure 2. Similar to beta coefficients in regression model, weights usually have lower absolute value compared to loadings (Rai et al. 2006). Nevertheless, all of our first-order variables had significant weights ($p < 0.01$), indicating appropriate formation for the second-order constructs.

Structural Model

The overall model can explain 22.7 percent variation of IT-enabled innovation. IT resources for SCM can explain 24.8 percent variation of upstream e-business capability and 15.4 percent variation of downstream e-business capability. The path coefficients from IT resources for SCM to upstream e-business capability and downstream e-business capability were 0.498 ($p < 0.01$) and 0.393 ($p < 0.01$). The path coefficients from upstream e-business capability and downstream e-business capability to IT-enabled innovation were 0.260 ($p < 0.01$) and 0.140 ($p < 0.05$). Our conceptual model and all of the hypotheses were supported.

Moreover, firm size demonstrated a significantly positive path to IT-enabled innovation, as bigger firms are more likely to have IT-enabled innovation than smaller firms. Industry was not significant, which may be caused by firms in our sample similarly characterized by manufacturing non-metallic mineral products.

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[5] While it is not required for formative construct specification, we examine the composite reliability of our second-order constructs. All of the constructs had composite reliability above 0.8. Specifically, the composite reliability of IT resources for SCM, upstream e-business capability, downstream e-business capability, and IT-enabled innovation was 0.841, 0.806, 0.814, and 0.832.

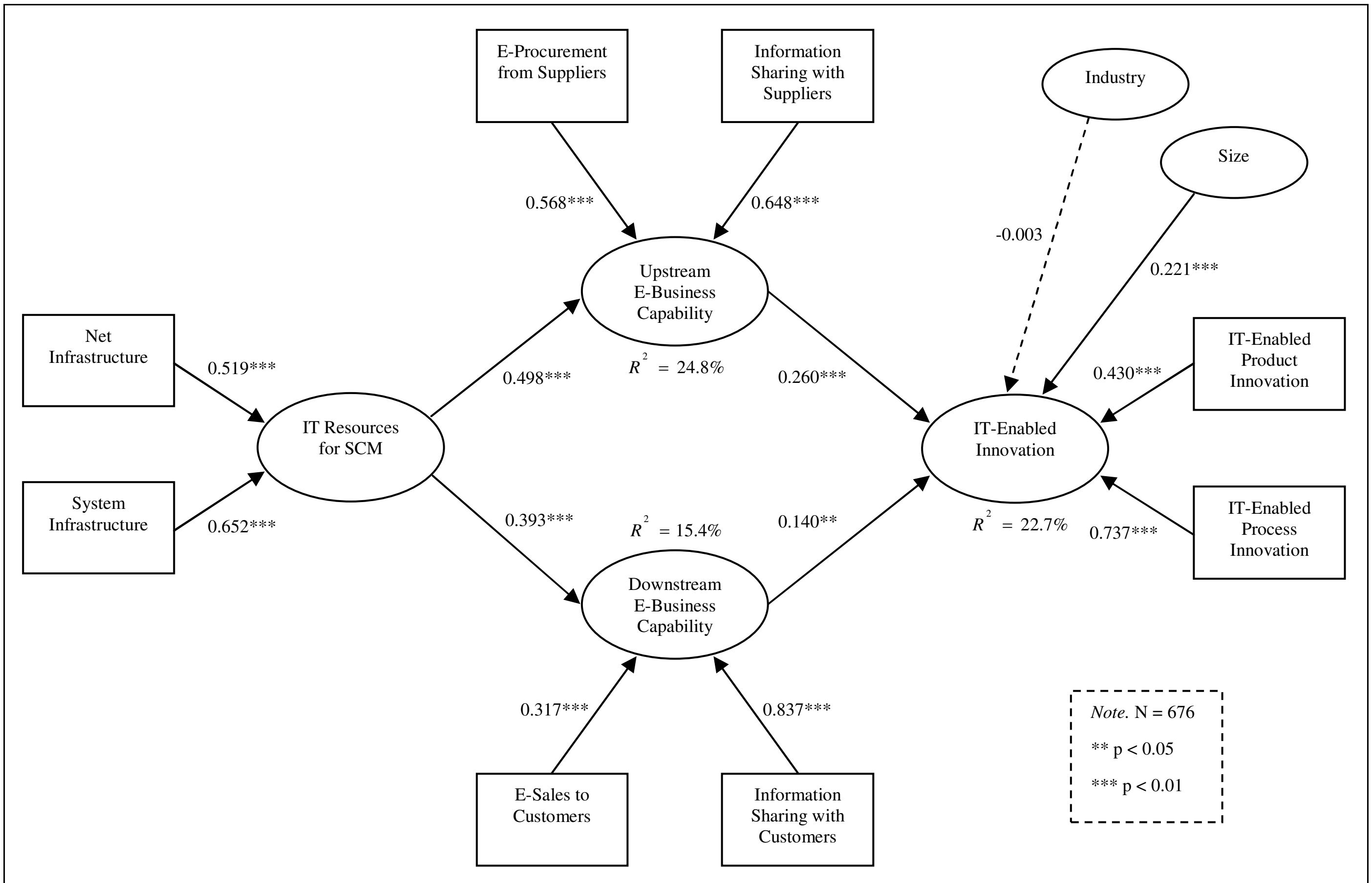

Figure 2. PLS Results

Robustness Checks

Confounding Factors

Besides clean measures for innovation attributable to IT-enabled initiatives and activities, we formally examine potential confounding factors. The commitment to e-business may affect the results. For example, some innovative firms recognizing the importance of e-business may tend to invest more in IT resources and do e-business activities. Thus, firms in which IT decision makers think that e-business has an influence on the industry competition (N = 187, 27.7%) are excluded in a re-estimation of the research model. The results were consistent with the estimation in Figure 2. The path coefficients from IT resources for SCM to upstream e-business capability and downstream e-business capability were 0.424 ($p < 0.01$) and 0.292 ($p < 0.01$). The path coefficients from upstream e-business capability and downstream e-business capability to IT-enabled innovation were 0.241 ($p < 0.01$) and 0.111 ($p < 0.1$).

Multiple locations may cause a firm to rely more on digital connectivity and e-business activities to overcome geographic restriction. Meanwhile, firms growing across regions are usually more successful, which may be due to stronger innovative ability for some reasons other than e-business capability. A re-estimation with the data excluding firms with plants in different locations (N = 208, 30.8%) was conducted. Still, similar results were obtained. The path coefficients from IT resources for SCM to upstream e-business capability and downstream e-business capability were 0.451 ($p < 0.01$) and 0.343 ($p < 0.01$). The path coefficients from upstream e-business capability and downstream e-business capability to IT-enabled innovation were 0.204 ($p < 0.01$) and 0.209 ($p < 0.01$).

Common Method Bias

Because common method bias is a typical concern for self-reported data, we take multiple steps to safeguard against it. We use different types of scale to measure the constructs, which is helpful to mitigate the influence of common method bias (Klein and Rai 2009). Specifically, we utilize 7-point scale to measure the first-order constructs forming independent variable (IT resources for SCM) and dependent variable (IT-enabled innovation). The first-order constructs for two mediators (upstream e-business capability and downstream e-business capability) are measured by 6-point scale (see Table 1). In addition to using binary indicators to aggregate the first-order variables for IT-enabled resources for SCM, upstream e-business capability, and downstream e-business capability (see similar procedure used by Zhu and Kraemer 2002), we use three-level interval scale to measure the indicators of IT-enabled product innovation and IT-enabled process innovation (see similar procedure used by Klein and Rai 2009). A continuous variable for firm size is also incorporated in the model.

Malhotra et al. (2006) suggested that marker variable technique is a more effective tool for accounting for common method bias, compared to the traditionally used multitrait-multimethod matrix (MTMM) approach and Harman's single-factor test. Thus, we formally correct common method bias by using a market variable. We select a marker variable that is theoretically unrelated to the latent variables: the importance of environmental protection regulation related to the EU Emission Trading Scheme for each firm. It is measured by three-level interval scale (very important, somewhat important, or unimportant). Following the guidelines by Lindell and Whitney (2001), the smallest correlation between marker variable and latent variable (i.e. upstream e-business capability; $r = 0.094$) is used as a proxy for common method variance (CMV). By using a marker variable, correlations among latent variables are partial out CMV. There is not material change in the corrected correlations, indicating that CMV can not substantially explain the relationships in our research model (see Table 2).

As far as a feasible extent, we compare firm size data from survey and other sources. We utilize the information about the number of employees from Dun & Bradstreet database for firms in France, Italy, Spain and the United Kingdom, Heins und Partner Business Pool database for firms in Germany, and Hoppenstedt Bonnier database for firms in Poland. The self-reported number of employees was found to be significantly related to the data from the databases ($r = 0.268$; $p < 0.01$). Only the data for a very small number of observations from two sources are considerably different, while a high correlation was found after winsorization at 1% ($r = 0.702$; $p < 0.01$). Anyway, the significant correlation of the data from different sources provides evidence for consistency and mitigates a concern of common method bias.

Discussion

This section discusses the main findings based on empirical results, by answering the research questions proposed earlier. Limitations and possible extensions are addressed with respect to data and methodology used, as well as the generalizability of the findings. Implications from this study are placed to managers.

Main Findings

First, whether and how a firm's IT resources for SCM enable product and process innovations to be derived in conjunction with its supply chain partners? The empirical evidence fully supports the conceptual model from a firm's IT resources for SCM to innovation outcomes in product and process, via upstream and downstream e-business capability. Thus, it contributes to digitally enabled SCM literature by showing that IT resources for SCM can create product and process innovations by facilitating transaction and sharing information with suppliers and customers. This finding is consistent with prior research that suggested process coupling and integration as well as collaborative information exchange and knowledge sharing are important for firms to achieve business goals in the supply chain context (Malhotra et al. 2005; 2007; Rai et al. 2006; Saraf et al. 2007). However, this study extends the literature by adopting a novel angle of innovation outcomes rather than performance, and links IT resources and capability in supply chains to new product development and novel process design. The paper also enriches IT business value literature by conceptualizing IT as an enabler of product and process innovations. While IT itself is commodity-like (Carr 2003), higher order capability rooted in IT can gain strategic payoffs by fitting the pieces together (Barua et al. 2004; Bharadwaj 2000; Mata et al. 1995; Melville et al. 2004; Nevo and Wade 2010; Zhu and Kraemer 2002; 2005). With regards to innovation is crucial to sustainable superior performance (Teece 2007), we found that IT is a strategic resource and contributes significant business value to firms in a form of innovation.

Second, what mediation mechanisms lead to the creation of these innovations? This study found that IT resources for SCM enable innovation outcomes by higher order capabilities of doing e-business. As electronic transaction closely couples the supply chain processes between the focal firm and its business partners, it may in turn shorten turnover and financial cycles, facilitate receivables and payables, acquire and analyze consumer need data efficiently, and respond to the market timely. These capabilities can help a firm to design and launch new product, as well as coordinate and promote the efficiency of producing and supplying processes (Zhu and Kraemer 2005). Furthermore, information sharing demonstrated greater weights than electronic transaction reflects their relative importance in forming e-business capability. The reason may be that information sharing is close to knowledge generating and assimilating which is more curtail to innovative capabilities (Malhotra et al. 2005; 2007). Information sharing integrates information and psychical flows among firms, minimizes inventory holdings, coordinates production and distribution plans, and especially supports knowledge transfer from suppliers and customers to the focal firm about potential future business. Thus, information sharing with suppliers and customers can leverage knowledge from inter-organizational collaboration to enable new product development (Malhotra et al. 2002) and revolutionary synergy integrating supply chain processes (Rai et al. 2006).

Third, do these effects vary across the supply chain for innovating with suppliers and customers? The mediation paths from IT resources for SCM to IT-enabled innovation through upstream and downstream e-business capability are $0.409 \times 0.260 = 0.106$ and $0.393 \times 0.140 = 0.055$. It indicates that upstream e-business capability is more important for generating IT-enabled innovation than downstream e-business capability. It enriches innovation research traditionally focused on customer side (e.g. von Hippel 1986; 2005; Urban and von Hippel 1988), by showing the importance of suppler side as an innovation source. Furthermore, the PLS results showed different magnitudes of electronic transaction and information sharing in terms of upstream and downstream e-business capability. While e-procurement from suppliers and information sharing with suppliers contribute almost equally to upstream e-business capability, downstream e-business capability heavily relies on information sharing with customers compared to e-sales to customers. There may be two reasons lead to the unbalanced weights for downstream e-business capability. In the context of manufacturing supply chain, the nature of e-business capability for upstream and downstream may be different. Upstream e-business capability with suppliers is usually centered on coordinating and synergizing manufacturing operations. However, downstream e-business capability relies on conveying richer knowledge about market (Ray et al. 2005). In addition, e-sales have been widely diffused in electronic marketplaces for a long time (Soh et al. 2006), compared to e-procurement. Therefore, it may not be as central as information sharing for developing downstream e-business capability today.

Limitations

While multiple steps against common method bias have been taken, single data source is still a limitation of the study. Multiple data sources may be used in future study, such as measuring innovation by objective number of patents. However, it should be noted that patents are usually inaccurate to capture process innovation. Another limitation of our data is the cross-sectional feature. Some innovations may be developed across years, suggesting a longitudinal design of data collection if possible. Furthermore, the data used in this study are collected from manufacturing sector, which restricts our findings to be extended to service sector or other settings. However, the large sample size coming with multiple national contexts lead to great confidence to generalize our findings, especially to the manufacturing supply chain context. The richness of our data also has potential to support additional research in the future.

This study responds to a call to refine measures in the supply chain context by separating upstream and downstream of supply chain (Dong et al. 2009). Nevertheless, it still leaves room for the improvement in measures. For example, some of our first-order constructs are measured by aggregation of binary indicators. It relies on an assumption that the more IT infrastructure and strategic activities a firm has, the higher IT resources and capability of the firm will be. While prior research has employed this procedure to measure IT infrastructure and e-commerce capability (e.g. Dong et al. 2009; Zhu and Kraemer 2002), the variation in technology adoption and the depth of e-business activities may be considered by future study. Moreover, dichotomous indicators provide less information than multi-point items, which may be used by future study.

Managerial Implications

This paper allows timely suggestions for managers to overcome today's depression by IT-enabled innovation. The data were collected in recent year of 2009 after financial crisis. Based on the main findings of the study, this paper sheds light on chasing of innovation in an IT-enabled way. Firms, especially those in manufacturing sector, may leverage IT resources to develop higher order e-business capability to work closely with their suppliers and customers. This approach was found to come with innovation outcomes in new products and business processes. By facilitating transaction and sharing information in the supply chain, e-business capability can integrate external resources which a single firm does not have to generate process synergy and market knowledge giving birth to product and process innovations.

Dell is a good example to elaborate how electronic transaction in the supply chain can help innovation generating. By real-time e-procurement with suppliers, Dell is able to produce in a just-in-time (JIT) manner, which generates a much lower level of inventory and production cost than the industry. In addition, its manufacturing line is flexible for mass-customization production of new products. Dell is also capable to build to order and sale directly to consumers by downstream e-business capability. This capability creates new products with consumers and gets rid of channel cost. The case of Proctor & Gamble shows the value of information sharing for innovation generating. By IT-enabled "connect + develop", Proctor & Gamble is capable to access intellectual properties externally developed by suppliers and customers in its own business. With digitally enabled information sharing with business partners, hundreds of innovations are obtained every year across the spectrums in product, marketing, manufacturing, and distribution, over 50% of which come from the outside.

Concluding Remarks

This paper investigates how IT enables product and process innovations through e-business capability in the supply chain, especially in manufacturing sector. It was found that IT resources for SCM can build upstream and downstream e-business capability, which facilitates transaction and information sharing of the focal firm with its supply chain partners, and in turn generate innovation outcomes in product and process. The results are robust after ruling out potential confounding factors and partial out common method variance. It contributes an initial attempt to link IT resources to IT-enabled innovation by high order IT capability. By uncovering the mechanism of this process based on innovation dynamics perspective and resource-based view, this study enriches IS literature of digitally enabled SCM and IT business value.

Some avenues for future study can be provided based on this study. While innovation has been found to be crucial to sustainable superior performance (Teece 2007), the relationship between IT-enabled innovation and firm performance sustainability may be examined by future study. In particular, the differences in performance impacts of IT-enabled innovation compared with other types of innovation are interesting. Related to this, developing IT skills of employees is another stream of IT resources, which may be incorporated into the model later.

Another direction for future study is to explore IT-enabled innovation in other contexts besides supply chains. It should be noted that this study is in an early stage of exploring the mechanism of IT-enabled innovation. In today's digital era, IT plays an important role in nearly all of business activities. Various mechanisms of IT-enabled innovation are widely open. Even in a context of supply chain, this study has a focus of manufacturing sector, which may be distinct with service sector. Future study may investigate IT-enabled innovation in different contexts and extend our understanding about the role of IT in contemporary enterprises.

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