ENABLING SUPPLY CHAIN AGILITY THROUGH IOS INTEGRATION AND SUPPLY CHAIN FLEXIBILITY

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Abstract

In today's turbulent environment, competitive pressures and market unpredictability have dramatically lashed business profits. Being agile is an essential ability for firms facing such an environment. However, coping with the hostile business environment requires not only the agility from individual firms but also the collaboration from their supply chain partners. Supply chain agility (SCA) therefore is vital to the competitiveness and performance of a firm and its supply chain partners. Exploring how to effectively enable SCA is significant for both practice and theory development. Recently, firms are increasingly relying on integrated information systems and analytical tools, such as business intelligent systems, and close collaboration and linkage with their supplier chain partners to enhance their responsiveness. The purpose of this paper seeks to broaden the understanding about the enabling roles of IOS integration, analytical ability of IOS, and supply chain flexibility on SCA based on the dynamic capabilities view and real options theory. With 147 matched-pair samples gathered from the top 2000 Taiwanese manufacturing firms, the results of this study support the effect of IOS integration on supply chain flexibility, including offering and sourcing flexibilities, which in turn facilitates SCA. We also propose and show the moderating effect of analytical ability of IOS on the process of enabling SCA. Our results provide the theoretical and practical implications that contribute to a better understanding in the way SCA may be achieved. The model and findings of this study should be able to serve as a basis for future research for studying SCA.

Keywords: supply chain agility, supply chain flexibility, inter-organizational system integration, and business intelligent.

1 INTRODUCTION

Globalization has resulted in a hyper-competitive business environment over the last two decades (Baramichai et al., 2007). Constant change and market unpredictability, as ubiquitous phenomena, have drastically shortened market visibility and increased uncertainty (Swafford et al., 2006). Firms, therefore, need competitive and dynamic capabilities to sustain their competitive advantages and business success. Agility, defined as the ability of the firm to cope with unexpected market opportunities and threats, has emerged as a key business imperative to seize the advantages (Swafford et al., 2008; Tallon & Pinsonneault, 2011). However, coping with market opportunities and threats requires not only individual firms' agility but also their trading partners' agile coordination and collaboration, forcing researchers and practitioners to extend the agility concept into the supply chain context. Then, supply chain agility (SCA) is proposed and defined as the capability of the firm in conjunction with its key supply chain partners to adapt or respond in a speedy manner to unexpected market changes, contributing to the agility of extended supply chain (Braunscheidel & Suresh, 2009). SCA enables a firm with its supply chain partners together to react more quickly and effectively to environment volatility and uncertainty, thereby allowing them to seize market opportunities and establish a superior competitive position in the supply chain network (Braunscheidel & Suresh, 2009; Setia et al., 2008; Swafford et al., 2006). Consequently, SCA has become one of the most essential ingredients for helping a firm and its supply chain partners survive in turbulent environments (Braunscheidel & Suresh, 2009; Ngai et al., 2011; Swafford et al., 2006). Thus, research on how to achieve SCA is both practically important and theoretically significant.

Achieving greater SCA inevitably requires a firm to maintain flexible collaboration and linkages with its upstream trading partners (Agarwal et al., 2007; Power et al., 2001) because agile response to market and customer changing needs involves unexpected changing orders and mechanisms of collaboration with the trading partners (Young-Ybarra & Wiersema, 1999). Rigidity in collaboration and linkage are likely to misguide upstream trading partners in their production decisions, inventory, and delivery, and then to cause unfulfilling orders (Lee et al., 1997), resulting in slow supply chain responses to market changes. Flexible collaboration and linkage thus becomes the key to achieving SCA. However, to achieve this is not an easy matter without the support of information technology (IT), because such flexible interactions between firms involve timely synchronization of information, automation of business processes, and sensible decision-making by management. These require integrated and intelligent information systems to support information sharing, process efficiency, and data analysis. Such a view gives rise to the important roles of supply chain flexibility (SCF) (Gosling et al., 2010; Vickery et al., 1999), integrated information system (IOS integration) and effective analytical tools of IOS (Grover & Saeed, 2007; Overby et al., 2006; Rai & Tang, 2010; Saeed et al., 2011).

Research on the relationships among these concepts, therefore, is imperative and significant to contribute to our knowledge on SCA. Although flexibility and IT have been proposed as key enablers of SCA (Braunscheidel & Suresh, 2009; Ngai et al., 2011; Swafford et al., 2006, 2008), prior studies still neglect what capabilities and characterises of IT can enable SCA. Also, existing research on SCA mainly focuses on conceptual development, still lack of empirical illustration of the cause-effect relationships (Agarwal et al., 2007; Yusuf et al., 2004; Yusuf et al., 1999); most empirical studies emphasize on internal supply (value) chain and its immediate entities due to the difficulties of extending the unit of analysis from firm to inter-firm relationship or network (Swafford et al., 2006, 2008). Thus, with regard to the emerging business value of SCA and lack of research on it, this study from the inter-firm perspective seeks to better understand how SCF facilitates SCA and how SCF is supported by IOS integration and analytical tools of IOS with greater information sharing, process efficiency, and effective decision making (Ngai et al., 2011; Sambamurthy et al., 2003). Specifically, this study aims to answer the following research questions: (1) whether and how does SCF enable SCA? (2) whether and how does integrated IOS leverage SCF and SCA? (3) whether and how does

analytical ability of IOS enhance the firm's ability to achieve SCA? This study focuses on dyadic relationships from the buyer's perspective and treats a dyad as a supply chain system responding to downstream unexpected changes. We empirically address these issues by adopting the dynamic capabilities view (Teece, 2007; Teece et al., 1997) and real option theory (Kogut & Kulatilaka, 2001). This study, involving 147 Taiwanese manufacturing firms with matched-pair samples, contributes to the literature by demonstrating the significant effects of SCF and IOS integration on SCA and showing the important moderating role of analytical ability of IOS on the processes of enabling SCA.

2 CONCEPTUAL FRAMEWORK

Prior studies of SCA appear to lack a comprehensive and substantial theoretical foundation; most studies adopt the resource base view and develop flexibility-agility association as a competence-capability relationship (Braunscheidel & Suresh, 2009; Swafford et al., 2006, 2008). In this study, several preliminary theoretical works from strategic management provide us with new insights into how to achieve SCA, particularly the dynamic capabilities view that share many of the same concepts with agility (Overby et al., 2006; Teece, 2007; Teece et al., 1997) and real options theory that elaborates how firms to seize emergent opportunities (Kogut & Kulatilaka, 1994, 2001). Based on these two streams of research, we propose the conceptual framework as follows.

According to the dynamic capabilities view (Teece et al., 1997), winners in today's competitive environment have been firms that can demonstrate timely responsiveness and rapid and flexible product innovation. Firms need being able to integrate, build, and reconfigure internal and external competences to seize opportunities and address rapidly changing environments (Teece et al., 1997). These higher-order capabilities in the supply chain context therefore are reflected in more specific capabilities such as SCA, which reflects a firm with its key supplier being able to timely respond to a changing marketplace, wherein they need to adapt their operations and linkages based on correct and foreseen information. Based on the dynamic capabilities view (Teece, 2007), these concepts that enable SCA can be considered as seizing capability coordinated with sensing capability. Thus, we develop our conceptual framework as shown in Figure 1.

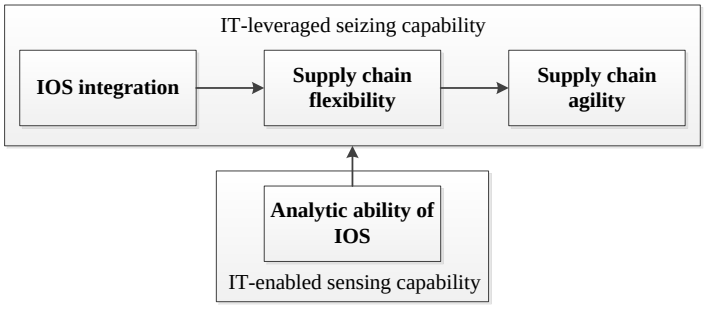

Figure 1. Conceptual framework

2.1 IT-leveraged seizing capability

To seize opportunities, firms need strategizing around investment decisions, getting the timing right and leveraging products and services from one application to another efficiently (Teece, 2007). These activities involve efficient transition from one state to another, requiring a fundamental platform as a capabilities basket, to support related complementary activities. In recent digital economics, a firm with its key supplier being successful in enabling SCA depend on their IOS competence. The competence has been considered a critical antecedent for firms to generate more competitive actions and greater action repertoire complexity (Overby et al., 2006; Sambamurthy et al., 2003). Integrated IOS (or called IOS integration) enables consistent and real-time transfer of information between applications and functions of trading partners (Rai et al., 2006). That integrated IOS can be blended with inter-firm processes permits firms to adapt to changing requirements rapidly (Sambamurthy et al.,

2003) and to develop higher-order capabilities for operations and workflow coordination (Rai et al., 2006). These capabilities expand the available collaboration and linkage options of solution space, thus enhancing the range and mobility of the capacity of SCF (Upton, 1994). These capabilities of variety are options held by the firm with its key supplier for seizing future opportunities. IOS integration therefore as an options generator provides the firm and its key supplier with a stock of options that creates a solid capability platform from which to launch agile moves (Kogut & Kulatilaka, 2001; Overby et al., 2006; Sambamurthy et al., 2003). Striking the options at appropriate time appears as the choice of capabilities that provide the appropriate flexibility for a stochastically changing environment. Thus, it is held that IOS integration can provide the flexibility to seize and to respond to opportunities (Kogut & Kulatilaka, 2001), thereby achieving SCA.

2.2 IT-enabled sensing capability

According to the microfoundations of dynamic capabilities (Teece, 2007), to identify and seize the opportunities when they emerge, firms must constantly scan, search, and explore markets. These activities involve the probing and re-probing of market trends and customer needs, which involve a understanding of latent demand, the structural evolution of industries and markets, and likely supplier and competitor responses. However, seizing a market opportunity inevitably will incur certain cost for transition from one state to another. The ability to calibrate the required transition and effectuate the needed adjustments with minimum cost is important for firms. Such an ability then depends on whether the firm can scan the environment, evaluate markets and competitors, and accomplish reconfiguration and transformation ahead of competition (Teece et al., 1997). These requirements emerge a critical role of sensing capability. Recently, most transaction and customer data are stored in large databases or data warehouses, called big data. These data must be filtered to become sensible (Teece, 2007). Potential information and knowledge, such as customer needs, market demands, and trends, are hidden within the data and must be discovered by analytical tools, such as time series analysis, optimization techniques, scenario-based planning, or other business intelligent tools (Saeed et al., 2011). Such tools can extract market opportunities from the databases by applying specific decision models to a particular situation and therefore support seizing capability. Consequently, as shown in Figure 1, three antecedent constructs are pinpointed to analyze their effects on SCA. We propose a research model and the associated hypotheses based on the conceptual framework.

3 RESEARCH MODEL

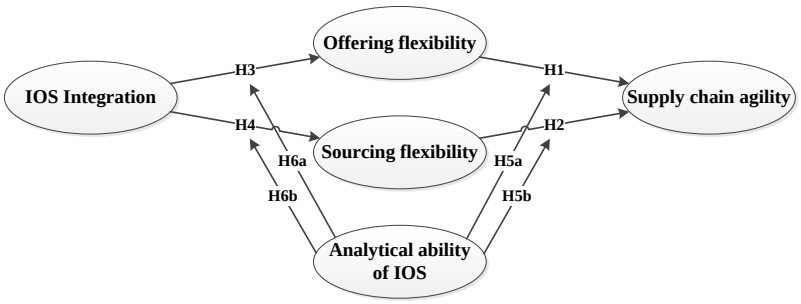

Figure 2. Research model

3.1 Supply chain agility

SCA, extended from general agility concept, provides a more practical orientation for assessing agility in the supply chain context (van Hoek et al., 2001). In the field of management information systems, SCA is a relatively new concept (Ngai et al., 2011). Recently, researchers tend to conceptualize SCA as a multi-dimensional construct. In this study, we adapt the definition proposed by Braunscheidel and Suresh (2009) and define SCA as the extent to which the capability of a firm, internally, in conjunction with its key supplier (a dyadic perspective), to adapt or respond in a speedy manner to a

changing marketplace so as to contribute to the agility of the extended supply chain. Different from the original definition of Braunscheidel and Suresh (2009), we focus on the perspective of dyadic relationship as a system to reflect SCA and model SCA as a second-order construct reflected on customer responsiveness, product responsiveness, and demand response.

3.2 Effect of Supply chain flexibility

Flexibility generally is perceived as an adaptive response to environment uncertainty (Gerwin, 1993). It reflects the ability of a system, as dyadic firms in this study, to change or react with little penalty in time, effort, cost or performance, as holding a stock of options (Upton, 1994). In the supply chain setting, flexibility usually incorporates different flexibilities to form a higher order SCF construct (Gosain et al., 2004; Gosling et al., 2010; Vickery et al., 1999). Consequently, researchers have proposed different flexibilities to form SCF, resulting in a huge and ambiguous construct that is difficult to identify and elaborate. Gosain et al. (2004), however, provide a relatively clear definition of SCF referring to the extent to which supply chain linkages are able to adapt to changing business conditions rather than being forced into committed adaptation to a given environment. We follow their definition and conceptualization and, based on the studies of Vickery et al. (1999), Gosain et al. (2004), and Gosling et al. (2010), identify offering flexibility and sourcing flexibility as the two key elements of SCF. We nevertheless do not aggregate these two flexibilities into a second-order or product construct (Gosain et al., 2004) because an aggregated construct may eliminate the nuances of each characteristic. Including these two flexibilities in our model can help us better understand the cause-effect relationships.

Offering flexibility refers to the ability of a supply chain linkage to support changes in product or service offerings produced in conjunction with the supplier, in response to changes in the business environment (Gosain et al., 2004). Offering flexibility, representing the abilities to accommodate change in production output, change delivery dates, product line, as well as the production of new product (Gosain et al., 2004; Gosling et al., 2010), provides a firm with its key supplier a set of available options waiting for timely responses to a changing marketplace without negatively impacting the cost or capability of their process (Braunscheidel & Suresh, 2009; Upton, 1994). In today's volatile business environment, market demands and customer needs are changing constantly. Staying flexibly until customer demands and needs emerge and then producing appropriate output levels as exercising options are likely to support the firm to quickly allocate resources and design appropriate services to fit the new demands (Teece, 2007). Further, a natural synergy exists in offering flexibility (Swafford et al., 2008). For example, the firm with its supplier being able to produce different combinations and volumes of products may directly promote new production schedules and new product introductions (Swafford et al., 2008). Thus, by tapping the synergies among different forms of flexibilities within offering flexibility, supply chain agility is more likely to be achieved (Agarwal et al., 2007; Swafford et al., 2008). Accordingly, we propose the following hypothesis:

Hypothesis 1: Offering flexibility is positively associated with supply chain agility.

Sourcing flexibility, defined as the ability of a supply chain linkage to re-configure the linkage through relationship modification with the supplier in response to changes in the business environment (Gosling et al., 2010; Stevenson & Spring, 2007; Young-Ybarra & Wiersema, 1999), can provide a firm and its supplier with greater ability to adapt to changes. Same as its basic definition, SCA is the capability of a supply chain to do unplanned new activities in response to unforeseen shifts in market demands or unique customer requests (Narasimhan et al., 2006). To respond to unforeseen changes, in addition to offering flexibility, a firm with its supplier may need to perform certain activities that are out of the boundaries of their extant agreement or contract, especially as the nature of agility encompassing the exploration of opportunities for market arbitrage (Sambamurthy et al., 2003). Appropriately, modifying the relationship between dyadic firms is able to lead them to be more flexible on assessing each other's assets, competencies, or knowledge not currently resident in the extant agreement or collaborative arrangement, thus providing the dyad more options to seize

unforeseen opportunities. Further, Teece (2007) argues that the capacity a firm has to adjust and reconfigure business models is foundational to dynamic capabilities. Choices around how to capture value are critical in designing a business. As his arguments, the linkage mode of the dyad should see their business model as how their collaboration and linkage can best meet what customers want. Flexible linkage provides the dyad firms more choices, or options, for best capturing the value from unforeseen changes. Thus, we expect the following hypothesis:

Hypothesis 2: Sourcing flexibility is positively associated with supply chain agility.

3.3 Effect of IOS integration

IOS integration reflects the extent to which a focal firm's information systems are closely linked with its supplier's information systems as a unified whole to facilitate bidirectional information access (Grover & Saeed, 2007; Rai & Tang, 2010; Saraf et al., 2007). An integrated IOS provides a firm and its supplier seamlessly linked activities and bidirectional information access and sharing. This, in turn, will help them achieve offering flexibility by two approaches. On the one hand, IOS integration can help dyadic firms to expand the range of output levels as well as available options (Upton, 1994). IOS integration as a process-oriented IOS system is designed to help dyadic firms conduct business processes, connect their stakeholders, and facilitate boundary-spanning activities (Overby et al., 2006) as IOS integration can provide timely inter-firm information sharing and coordination. Its proper applications also give the dyadic firms greater ability to manage their supply chain operations and control and coordinate with each other (Wang et al., 2006). An integrated IOS also can make the dyad more easily to track each other's variations in production schedules, product qualities, inventory levels, and delivery capability (Rai et al., 2006; Wang et al., 2006). Through bidirectional information sharing, IOS integration therefore facilitates process integration and enhance visibility, which, in turn, help the firms to plan and adjust their own operations more rapidly, allowing greater adaptability of their linked activities (Wang et al., 2006) and more rapidly adjusted processes (Overby et al., 2006; Rai et al., 2006; Rai & Tang, 2010; Saraf et al., 2007). These abilities enabled by IOS integration can expand the range of offering options for the dyadic firms. On the other hand, IOS integration reduces the transition penalties for moving the output levels within the range. IOS integration provides the firms with integrated data, applications, and processes (Rai et al., 2006). Those information channels reduce communication and collaboration costs and help the firms transit from one state to another more easily, resulting in greater mobility (Upton, 1994). Teece et al. (1997) also suggest that integration of external activities and virtual corporation are critical enablers for seizing capabilities. Similarly, Sambamurthy et al. (2003) and Overby et al. (2006) propose that an integrated IOS platform is able to promote process reach and richness, which create the digital options for achieving flexibility and thereby enhance agility. Thus, we propose:

Hypothesis 3: IOS integration is positively associated with offering flexibility.

Well-built IOS integration usually involves dyadic firms mutually making a series of linked strategic decisions and moving related resources to support the building process (Rai et al., 2006). These activities enable the dyad to understand each other's requirements, constraints and weaknesses (Kogut & Zander, 1992) which, in turn, may influence their attitudes of adapting the linkage toward positive outcomes. Intense and real-time operational information sharing enabled by IOS integration further helps managers of the dyad to identify possible problems of their operations. These problems may subvert the responding capability and competitive advantages of their relationship. Modifying their linkage to fix the problems and to meet business environment changes becomes reasonable and indispensable. Further, IOS integration may force the dyad to expend the range of the linkage. According to the relational view (Dyer & Singh, 1998), IOS integration is a type of relational-specific assets because it evolves a series of mutual adjustments on information system configurations, personnel skills, and organizational structures. These relational-specific tangible and intangible assets, though facilitating information sharing and process efficiency, may also lead to lock-in effect on the linkage (Young-Ybarra & Wiersema, 1999). Therefore, in order to protect these assets, the firms may

be more willing to remain flexible in terms of modifying their agreement and relationship so not to cause the relationship to fail (Young-Ybarra & Wiersema, 1999). Consequently, their available options can be expanded, leading to greater sourcing flexibility. Thus, we propose the following hypothesis:

Hypothesis 4: IOS integration is positively associated with sourcing flexibility.

3.4 Effect of Analytical ability of IOS

Analytic ability of IOS is defined as the extent to which the IOS provides analytical tools to support decision making with respect to the supply chain functions (Saeed et al., 2011). Analytic ability of IOS can help a firm develop rich knowledge through real-time data monitoring, pattern recognition, and strategic scenario modelling (Overby et al., 2006; Saeed et al., 2011), helping the managers identify emerging opportunities and unforeseen customer needs and decide when to exercise offering options with its supplier, and thereby supporting agility. As Overby et al. (2006) argue, analytical ability of IOS as knowledge-oriented IT supports a firm's sensing capability more directly. Analytical ability help the firm not only identify patterns and extract knowledge from data or databases but also rule out overloaded or garbage data (Overby et al., 2006). High-quality knowledge helps the firm's managers sense the opportunities, allowing them to allocate appropriate resources and output levels more rapidly than other firms without such knowledge. Teece (2007) also suggests that the ability to sense opportunities is clearly not uniformly distributed among firms; opportunity discovery by individual firms require both access to information and the ability to recognize, sense, and shape development; those depend on the capabilities and knowledge that can help seizing the opportunities. Thus, if two firms with their suppliers, respectively, had the same initial level of offering flexibility, the one dyad with higher analytical ability would have more information and knowledge to use their flexibility and offering options and could, therefore, attain a higher level of SCA. Accordingly, we propose the following hypothesis:

Hypothesis 5a: The impact of offering flexibility on supply chain agility is positively moderated by analytical ability of IOS.

As discussed above, when the firm has greater analytical ability of IOS, its managers should have a better understanding of potential opportunities and trends in a changing market. Such knowledge should provide them the opportunity to exercise sourcing flexibility more proactively with its supplier for tackling market changes. Although sourcing flexibility provides dyadic firms greater range and mobility of linkage modification, modifying the linkage still requires a period of preparation and adaptation. By sensing the market opportunities and trends, a firm with greater analytical ability should give itself more time to modify its linkage with supplier than the others without such ability. Thus, with a more clear direction to change, the firm with analytical ability should help its linkage be better prepared for achieving SCA than others without. Accordingly, we propose the following hypothesis:

Hypothesis 5b: The impact of sourcing flexibility on supply chain agility is positively moderated by analytical ability of IOS.

Analytical ability of IOS can complement IOS integration to support a firm to expand offering options with its supplier so as to create a solid platform for enhancing offering flexibility (Overby et al., 2006). IOS integration is designed to support inter-firm business processes and product offerings. It can generate the raw data needed for the analytical tools of IOS. The tools can help the firm identify trends and patterns. These trends and patterns can be transformed into various parameters, which can then be imported into the functions of IOS integration for adjusting the automatized business processes and transactions quickly (Saeed et al., 2011). This will enhance the range and mobility of product and service offerings. These two capabilities combined can provide the firm with its supplier complementary IOS abilities. Thus, IOS integration and analytical ability of IOS are complementary, as seizing capability requires the support of sensing capability to be useful (Teece, 2007). Accordingly, we propose the following hypothesis:

Hypothesis 6a: The impact of IOS integration on offering flexibility is positively moderated by analytical ability of IOS.

Analytical ability of IOS can help trading partners understand not only trends and patterns but also to analyze performance of their collaboration and linkage (Saeed et al., 2011). This knowledge allows their managers to make effective decision of whether and when to modify their linkage in order to meet a changing market. As discussed above, although IOS integration may lead to lock-in effect on the linkage, it may also motivate and enable the dyadic firm to expand the range of their linked activities. Under such circumstances, the firm with analytical ability should have greater intelligence and capability to explore the potential options within the linkage. This would benefit the managers when they elaborate how to modify their linkage for better meeting market changes. Thus, we propose the following hypothesis:

Hypothesis 6b: The impact of IOS integration on sourcing flexibility is positively moderated by analytical ability of IOS.

4 RESEARCH METHODOLOGY

4.1 Measurement

Data were collected using a carefully developed self-report survey instrument. We developed and validated our measures using guidelines in the information systems literature (Straub, 1989). We first reviewed prior studies to develop measures that were suitable for the current study, had face validity, and had a minimal overlap between constructs. In order to establish content validity of the constructs, items were independently evaluated by each of the researchers. Then, the researchers jointly discussed each construct and its items until they had an agreement. After compiling an English version of the questionnaire, the survey items were first translated into Chinese by a bilingual researcher. The survey items were verified and refined for translation accuracy by an MIS professor and a PhD candidate. The Chinese version of the draft was then pretested with 6 senior managers (including CEO, senior business manager, procurement manager, and IS executive) for verifying face and content validity again, resulting in modification of the wording of some survey items. We operationalized all constructs using multi-item reflective measures with a seven-point scale that ranged from "strongly disagree" to "strongly agree," with its midpoint anchored as "neither agree nor disagree." Appendix A shows the instrument and the supporting literature.

4.2 Sample and data collection

A cross-sectional and matched-pair mail survey of purchasing managers and IS executives was administrated for collecting data from selected large and medium-sized manufacturing firms in Taiwan. We selected Top 2000 manufacturing firms from the Year 2012 directory of the Top 5000 Largest Firms in Taiwan, published by China Credit Information Services Ltd. After accounting for undelivered and invalid mails, the effective mailing was 1950 surveys. Survey packages were mailed to the purchasing managers of each target firm with a request that the recipient completed Part A related to SCA and SCF. The recipient needs to select an important supplier to conduct business with the recipient's firm. The recipient was asked to write down the supplier name he referred on Part B, and distributed Part B to the suitable IS executive to provide the information about IOS integration and analytical ability of IOS. Part A and B must refer to a same supplier because all of our constructs focus on the dyadic relationship as a supply chain system. Totally, 172 surveys were returned, with 147 having completed the data and available for subsequent analysis, yielding an effective response rate of 7.5%. Tables 1 and 2 exhibit the characteristics of the sample.

Non-response bias was assessed using the procedure recommended by Armstrong and Overton (Armstrong & Overton, 1977). Considering the last group of respondents as most likely to be similar to non-respondents, a comparison of the first and last quartile of respondents provides a test of

response bias. No significant differences between the first and last quartile of the respondents were found on the key research variables.

Common method variance (CMV) was tackled with three strategies. First, multiple informant approach allowed us to mitigate the CMV (Podsakoff et al., 2003). Second, we used Harmon's single-factor test to assess CMV (Podsakoff et al., 2003). Six factors with eigenvalues >1 were extracted and collectively accounted for 76% of the variances in the data, with the first factor accounting for 39.26% of the variances. These findings suggest that CMV should not be a main concern regard to our data. Third, we conducted PLS marker variable approach to diagnosing CMV (Rönkkö & Ylitalo, 2011). We compared our model including the marker variable with the baseline model. The results showed all the paths were significant in both the baseline model and the compared model. Taken together, we concluded that CMV is not significant in our data.

Table 1. Profile of the respondents (N=147)

Purchasing title	No.	%	MIS title	No.	%
Director/Manager/Assistant Manager/Section Manager of Purchasing	60	41	Section Manager/Manager/Assistant manager/Administrator/Consultant of MIS	33	22
Management (with purchasing responsibility)	62	42	Engineer of MIS	33	22
Top management	7	5	Management (with MIS responsibility)	49	33
Others	10	7	Top management	3	2
Missing	8	5	Others	7	5

Table 2. Profile of the responding firms (N=147)

Industry	No.	%	Number of employees	No.	%
Automobile	13	9	1-250	76	52
Chemical	17	12	251-500	29	20
Computer and electronics	55	37	501-1,000	17	12
Food	6	4	1,001-2,000	11	7
Machine and tool	10	7	>2,000	14	10
Metals and materials	27	18			
Textile	7	5			
Others	12	8			

5 RESULTS

A partial least squares (PLS) structural equation model was constructed for validating the measures and testing the hypotheses. We used SmartPLS 2.0 M3 (Ringle et al., 2005) to estimate the parameters in the outer model with a factor weighting scheme and the inner model with a path weighting scheme (Hair et al., 2012; Henseler, 2010). We used non-parametric bootstrapping with 5,000 replications and individual changes to obtain the estimates (Hair et al., 2012). Following the guidelines for second-order construct suggested by Wetzels et al. (2009), SCA was set up through the repeated use of the manifest variables of the first-order constructs.

5.1 Outer model (measurement model)

The mean, range, and standard deviation for each construct are reported in Table 3. Path loadings of all items are significant at 0.1% level, indicating individual item reliability. The composite reliability (CR) estimates are above 0.9 for all constructs, indicating good internal consistency and reliability of our scales (Hair et al., 2012). Although the item loadings and their significance appear to demonstrate convergent validity, we also assess the convergent validity of our first-order constructs using average variance extracted (AVE) criterion. The AVE of each construct exceeds the minimum threshold value of 0.50 (Fornell & Larcker, 1981; Hair et al., 2012; Henseler et al., 2009). The combined results

demonstrate convergent validity of our first-order constructs. Discriminant validity is established when the square root of the AVE by each construct is larger than the inter-construct correlations. Our results support the discriminant validity of our measures. In Table 4, we include the CR and AVE of SCA, showing the CR greater than 0.9 and the AVE greater than 0.5, which provide the evidence of reliability. The loadings of all the first-order constructs on SCA exceed 0.9 and are significant ($p < 0.01$).

Table 3. Inter-construct correlations and reliability measures for first-order constructs (N=147)

						Correlations of among constructs						
Construct	Items	Mean	Std.	CR.	AVE	1	2	3	4	5	6	7
1. Customer responsiveness	3	5.28	1.06	0.88	0.76	**0.87**						
2. Product responsiveness	4	5.01	1.21	0.86	0.78	0.79	**0.88**					
3. Demand response	3	5.07	1.08	0.82	0.74	0.83	0.72	**0.86**				
4. Offering flexibility	4	5.20	1.12	0.90	0.69	0.70	0.64	0.64	**0.83**			
5. Sourcing flexibility	3	5.19	1.23	0.92	0.80	0.52	0.47	0.53	0.57	**0.89**		
6. IOS integration	10	3.52	1.96	0.96	0.69	0.38	0.34	0.30	0.41	0.21	**0.83**	
7. Analytic ability of IOS	3	4.30	1.66	0.96	0.88	0.30	0.18	0.29	0.33	0.14	0.40	**0.94**

Note: Square roots of average variance extracted are shown on the diagonal.

Table 4. Second-order constructs and its association with first-order constructs (N=147)

Construct	**CR.**	**AVE**	**First-order constructs**	**Loadings**	**R^2**
1. Supply chain agility	0.95	0.65	Customer responsiveness	0.94	88.0%
			Product responsiveness	0.93	85.8%
			Demand response	0.91	82.1%

5.2 Inner model (structural model)

We estimate three models. Model 1 is a baseline model that predicts SCA using control variables. Model 2 builds on model 1 by including all paths in the model, but excluding the moderating effects of analytical ability of IOS. Model 3 includes analytical ability of IOS as a moderator. The results of these three models are shown in Table 5. The full model (model 3) has an R^2 of 58.5% for SCA. R^2 for offering flexibility and sourcing flexibility are 24.2% and 14.3%, respectively. In the full mode, we create product constructs with the mean-centering approach, suggested by Chin et al. (2003), for testing the moderating effects. With omission distance equal to 5, that all the cross-validated redundancy Q^2 values of the endogenous constructs are larger than zero indicates that the exogenous constructs have predictive relevance for the endogenous constructs (Chin, 2010). Finally, absolute GOF is 0.49.

In terms of the full model, we first note that offering flexibility has a strong effect on SCA ($p<0.001$), supporting H1. Similarly, the results also support H2 ($p<0.01$), indicating the effect of sourcing flexibility on SCA. Our analysis reveals that analytical ability of IOS moderates the link between offering flexibility and SCA ($p<0.01$; H5a is supported) but fails to moderate the link between sourcing flexibility and SCA ($p>0.05$; H5b is not supported). So firms should not expect greater SCA from sourcing flexibility in the presence of utilizing analytical tools. IOS integration is positively related to both offering flexibility ($p<0.01$; H3 is supported) and sourcing flexibility ($p<0.01$; H4 is supported), suggesting that IOS integration can create various options for firms to increase SCF. As expected, analytical ability of IOS moderates the link between IOS integration and offering flexibility ($p<0.05$; H6a is supported). Perhaps most interesting of all, our analysis presents that analytical ability of IOS has a negative and significant moderating effect on the link between IOS integration and sourcing flexibility (H6b is no supported).

Further, considering offering and sourcing flexibilities as two mediators in our model, we tested the magnitude and significance of individual mediated paths with the multiple mediator model proposed

by Preacher and Hayes (2008). We performed percentile bootstrap to estimate indirect effects with 5,000 re-sampling. The results indicate that offering and sourcing flexibilities fully mediate the link between IOS integration and SCA because the direct effect of IOS integration on SCA turns from significant (t=4.74) to insignificant (t=1.63) when adding the mediators. Based on Sobel's test (Sobel, 1982) and the bootstrap results, the two indirect paths are significant (the indirect path through offering flexibility is significant at 0.05 level; through sourcing flexibility is significant at 0.1 level).

Table 5. Model results

	Model 1 Controls Only	**Model 2 Excluding Analytic Abi.**	**Model 3 Full Model**
Controls	Firm size ^{NS} Sales ^{NS} Purchasing ^{NS} Association. ^{NS} Frequency ^{NS}	Firm size ^{NS} Sales ^{NS} Purchasing ^{NS} Association. ^{NS} Frequency ^{NS}	Firm size ^{NS} Sales ^{NS} Purchasing ^{NS} Association. ^{NS} Frequency ^{NS}
Offering Flex. → SCA		0.607***	0.600***
H1 (+) Supported		*0.073*	*0.083*
Analytic Abi. → SCA			0.052 ^{NS}
Main effect			*0.091*
(Offering Flex. × Analytic Abi.) → SCA			0.239**
Moderating effect: **H5a (+) Supported**			*0.144*
Sourcing Flex. → SCA		0.198*	0.219**
H2 (+) Supported		*0.086*	*0.085*
(Sourcing Flex. × Analytic Abi. → SCA			-0.083 ^{NS}
Moderating effect: **H5b (+) Not supported**			*0.087*
IOS Int.→ Offering Flex.		0.408***	0.270**
H3 (+) Supported		*0.069*	*0.087*
Analytic Abi. → Offering Flex.			0.249**
Main effect			*0.098*
(IOS Int. × Analytic Abi. → Offering Flex.			0.217*
Moderating effect: **H6a (+) Supported**			*0.235*
IOS Int.→ Sourcing Flex.		0.207*	0.238**
H4 (+) Supported		*0.084*	*0.094*
Analytic Abi. → Sourcing Flex.			-0.012 ^{NS}
Main effect			*0.103*
(IOS Int. × Analytic Abi. → Sourcing Flex.			-0.320**
Moderating effect: **H6b (+) Not supported**			*0.306*
Explained Variance: R^2			
SCA	2%	54.1%	58.5%
Offering Flex.		16.7%	24.2%
Sourcing Flex.		4.3%	14.3%

*Note: *** p < 0.001; ** p < 0.01; * p < 0.05; NS: not significant; standard error terms are shown in italics. We report the main effect of analytic ability of IOS on each endogenous construct for reference. These paths are added to the model in order to model analytic ability of IOS as a moderator. While not ordinarily interpreted as part of a moderation test, the main effect is still open to interpretation on its own merits.*

6 DISCUSSION AND CONCLUSIONS

6.1 Summary of results

Overall, our results show that IOS integration enables SCF, which, in turn, facilitates SCA. Consistent with prior studies in demonstrating the flexibility-agility relationship (Braunscheidel & Suresh, 2009; Swafford et al., 2006, 2008), we find support for the proposition that offering flexibility and sourcing flexibility, though they represent different aspects of SCF, can help dyadic firms achieving greater SCA. We further compare the effects of these two flexibilities and find that the effect of offering

flexibility (β=0.6) is stronger than that of sourcing flexibility (β=0.219) on SCA. This result appears reasonable because offering flexibility, which focuses on flexible product and service offerings, should allow the supply chain to meet unexpected market demands and customer needs, thereby enabling greater supply chain agility. Sourcing flexibility, on the other hand, focuses on relationship modification of dyadic firms, which may only provide a foundation for their supply chain to operate flexibly and speedily without the restriction of agreements or contracts. Thus, although both of the capabilities are significant on facilitating SCA, they engage in different dimensions of supply chain management.

This study shows that both offering and sourcing flexibilities fully mediate the effect of IOS integration on SCA. The results are consistent with the conceptual frameworks of Sambamurthy et al. (2003) and Overby et al. (2006). They propose that, through IT competence, firms can generate digital options, which in turn enable agility. In this study, we not only extend their framework but also empirically demonstrate similar relationships in the supply chain context.

More interesting results are the moderating effect of analytical ability of IOS on each direct path. We show that analytical ability of IOS significantly and positively moderates the path from IOS integration to offering flexibility, and from offering flexibility to SCA. These findings suggest that mining potential market trends and demand patterns can enhance the ability of a firm with its supplier to change product or service offerings and thus react to a changing market more rapidly. This result also demonstrates the importance of business intelligent systems. However, our findings show that analytical ability of IOS negatively moderates the relationship between IOS integration and sourcing flexibility, completely opposite to our hypothesis (H6b). One plausible reason is that analytical ability of IOS provides sufficient information and knowledge for the managers of dyadic firms to help them understand potential uncertainty in the future and then lead them to negotiate a more flexible contract prepared for future changes, thus reducing their needs to modify their relationship in the future. Another plausible reason is that firms may choose loose coupling with or de-selection of its supplier to meet future changes. Under such circumstances, they will have less need to maintain a long-term relationship and build an integrated IOS with their suppliers, for avoiding the lock-in effect and the difficulty of modifying the relationship.

6.2 Implications for research and practice

For academic, we develop and examine a model that (1) deliberates the IOS integration as a key enabler of SCF, which in turn facilitates SCA; (2) proposes analytical ability of IOS as a key moderator that strengthens the effect of offering flexibility on SCA; (3) adopts the dynamic capabilities view to provide a new approach in explaining the flexibility-agility relationship. We expand the prior research on SCA to focus on the relationship with upstream trading partners. For practice, our findings suggest that SCA as a seizing capability is facilitated through offering and sourcing flexibilities. Establishing an integrated IOS with trading partners should be helpful in enabling overall seizing capability, wherein information about market trends and demand patterns provided by the analytical tools is critical in enhancing flexible and speedy product and service offerings.

6.3 Limitations

This study has several limitations. First, the response rate of the survey appears relatively low. This may be caused by our survey that requires multiple informants. The approach, however, reduces the threat of common method bias. Second, even though the possibility of non-response bias was checked and ruled out statistically, the representativeness of the sample, and thus the generalizability of our results, could still be limited. Third, the cross-sectional nature of the study only provides us with evidence for the associations among the research variables. The theoretical foundations employed to support the hypotheses nevertheless provide justification for our proposed model. Finally, the respondents were asked to select a major supplier as the target supplier for answering the survey on

which our results were based. However, assuming that the choices of the relationship were randomly distributed across the sample, the choices may have minimal effects on the results.

Appendix A. Measurement Items

Scale indicators	References
Supply chain agility	Braunscheidel and Suresh (2009)
Demand response	Khan and Pillania (2008)
We are able to respond to changes in demand without overstocks or lost sales in conjunction with this supplier. (DR1)	Swafford et al. (2006)
We are capable of forecasting market demand in conjunction with this supplier. (DR2)	van Hoek et al. (2001)
We are capable of responding to real market demand in conjunction with this supplier. (DR3)	
Customer responsiveness	
We are capable of rapidly improving customer service in conjunction with this supplier. (CR1)	
We are capable of rapidly improving responsiveness to changing market needs in conjunction with this supplier. (CR2)	
We are capable of rapidly reducing order-to-delivery cycle time in conjunction with this supplier. (CR3)	
Product responsiveness	
We are capable of rapidly increasing levels of product customization in conjunction with this supplier. (PR1)	
We are capable of rapidly reducing manufacturing lead time in conjunction with this supplier. (PR2)	
We are capable of rapidly reducing product development cycle time in conjunction with this supplier. (PR3)	
We are capable of rapidly increasing frequencies of new product introductions in conjunction with this supplier. (PR4)	
Supply chain flexibility	Gosain et al. (2004)
Offering flexibility	Swafford et al. (2008)
We are able to efficiently respond to change in demanded product volumes in conjunction with this supplier. (OF1)	Young-Ybarra and Wiersema (1999)
We are able to efficiently alter deliver schedules to meet customer requirement in conjunction with this supplier. (OF2)	Zhang et al. (2003)
We are able to efficiently produce different combinations of products in conjunction with this supplier. (OF3)	
We are able to efficiently phase out old products and introduce new ones in conjunction with this supplier. (OF4)	
Sourcing flexibility	
When business environment changes, we and this supplier are able to modify the agreement rather than hold each other to the original terms. (SF1)	
Flexibility in response to requests for changes is a characteristic of the conjunction between us and this supplier. (SF2)	
Our company and this supplier expect to be make adjustments in the ongoing relationship to cope with changing circumstances. (SF3)	
IOS integration	Grover and Saeed (2007)
Data are entered only once to be retrieved by this supplier's system. (IOSI1)	Rai et al. (2006)
Our system can access data from this supplier's system. (IOSI2)	Rai and Tang (2010)
Our system can aggregate relevant information from this supplier's databases. (IOSI3)	Saraf et al. (2007)
Our company shares databases with each other. (IOSI4)	Saeed et al. (2011)
We have successfully integrated relevant applications of our system with this supplier's applications. (IOSI5)	
Our applications work seamlessly with this supplier's applications. (IOSI6)	
Our applications can share real time information with this supplier's applications. (IOSI7)	
We have synchronized data formats and standards with this supplier. (IOSI8)	
The data formats and standards used in the systems of our firm and this supplier are based on a common standard. (IOSI9)	
Definitions of key data elements (e.g., order and part numbers) are common between ours and this supplier's system. (IOSI10)	
Analytic ability of IOS	Saeed et al. (2011)
Our systems offer various decision making tools (such as optimization, scenario analysis, etc.) for managing our relationship with this supplier. (AA1)	
Our systems offer various tools that can enable us to examine trends in the data for managing our interaction with this supplier. (AA2)	
Our systems offer various statistical tools for supporting our interactions with this supplier. (AA3)	

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