Digital Supply Chain Integration

Abstract:
Agility is a vital factor for business success in complex industrial landscapes as it enables firms to successfully compete in a competitive market. Firms are increasing relying on information systems in achieving such agility throughout the supply chain. However, limited research has been carried out in identifying the mechanisms by which information systems and its implementation enables supply chain agility. We propose and test a model of the relationship between IS integration, supply chain agility and operational performance, using empirical data collected from OEMs and first tier suppliers in the automotive industry. Our findings show that both internal and external IS integration facilitates the achievement of supply chain agility and improves operational performance, especially, from external IS integration. The results also indicate that IS-integrated supply chain agility is better suited to efficient agility rather than customer focused agility especially in the cost-driven and build-to-forecast automotive industry. These findings reveal the mechanisms of how IS integration can facilitate greater agility in the supply chain, leading to improved operational performance.
Key words: IS integration, supply chain agility, operational performance

1 Introduction

The development of information systems (IS) has rapidly reshaped the business processes over the last decades, and supply chain agility, founded on the various integrations between supply chain partners (Christopher, 2005; van Hoek et al., 2001), has been especially influenced (Sanders, 2007). IS integration has made the sharing of information along the supply chains possible, enabling real time integration between supply chain partners through information visibility. Supply chain agility can be hampered by fragmented IS (Burua et al., 2004) as information flow and coordination of activities are fundamental for integration processes which are realized by integrated IS across network (Broadbent et al., 1999). Hence, IS integration is often referred as an essential enabler in achieving supply chain integration and agility (Gunasekaran and Ngai, 2004; Power and Sohal, 2001; Yusuf et al., 2004). Overall, studies have found integrated IS positively linked to organizational performance (Kearns and Lederer, 2003; Sanders, 2007). Today, many organizations are in the process of adopting certain types of information systems to streamline their operations. For example, United Parcel Service, one of the largest logistics service providers, adopted 'synchronized commerce' for its business. Its IS architecture enables data connectivity with customers' applications, providing real-time inventory data that is stored or in-transit to improve inventory management and market responsiveness (Rai et al., 2006).

With the current view of the unit of competition as a supply network, supply chain agility has gained significant attentions from both academics and practitioners in recent years (Elkins et al., 2004; Ismal and Sharifi, 2006), as demand and supply fluctuate more rapidly than previously. Agile supply chains can be realized through enriching customers, cooperating with partners, mastering uncertainties and leveraging the impact of information and people, a framework presented by Goldman et al. (1995). Business success can only be achieved through effective integration of all the participant companies across the supply chain (Boone et al., 2007; van Hoek et al., 2001; Wang et al., 2006) to shorten product life cycle and reduce product costs (Levary, 2000).

Studies have found the link between IS integration and operational performance, and shown that it has the potential of providing competitive advantages to firms (Kearns and Lederer, 2003;

Sanders, 2007). Similarly, supply chain agility has been shown to have a positive impact on performance (Christopher, 2005; Yusuf et al., 2004). However, IS integration in realizing supply chain agility is poorly developed (Fawcett and Magnan, 2002), especially on unravelling how IS integration may affect supply chain agility, despite the development of information technologies for collaboration and the take-up of enterprise resource planning (ERP) systems (Mabert et al., 2003).

This research explores how IS integration contributes to supply chain agility, and its operational performance. Specifically, we propose and test a model of the relationship between IS integration, supply chain agility and operational consequences. Considering that IS integration is regarded as a critical element for supply chain agility, we focus on IS integration in the context of supply chain agility to investigate operational consequences.

The next section presents a review of the relevant literature on IS integration, and supply chain agility, and specifies the relationships related to the framework. In Section 3, the research methods are presented, followed by the results of testing the framework in Section 4. Section 5 discusses survey analysis with its implications. The final section offers some concluding comments and research limitations.

2 Background

2.1 Supply chain agility and operation performance

Supply Chain Management (SCM) consists of individual functional entities with commitments to provide related resources and information to achieve the objectives of efficient management of suppliers as well as the flow of parts (Lau and Lee 2000). It recognizes that the value-adding processes should involve integrated business processes among entities of the chain (Sanders, 2007) to lead to superior performance (Frohlich and Westbrook, 2002). In market conditions of increasing levels of customization and product variety, agility is becoming important as it concerns 'customer responsiveness and mastering market turbulences' (Reichhardt and Holweg, 2007; van Hoek et al. 2001). Goldman et al. (1995) identify four basic dimensions of agility: enriching customers, cooperating to enhance competitiveness, organizing to master changes, and leveraging the impact of people and information. The definition provides a basic conceptual view on the relevant elements of agility, stressing the responses to changes and capturing changes as opportunities (Sharifi and Zhang, 1999), and it turns to a new vision for businesses.

The origin of supply chain agility as a concept lies in Flexible Manufacturing Systems (FMS). Many works present agility as a concept closely links with the manufacturing environment or as performance capabilities (Aitken el al., 2002). Tracing back these studies is the work given by van Heok et al. (2001) and Christopher (2000). They present a framework for agility in the context of supply chain by adapting the general agility framework (Goldman et al., 1995) to the supply chain settings. van Hoek et al. (2001) have identified four dimensions of agile supply chain, which are customer sensitivity, virtual integration, process integration and network integration.

Customer sensitivity includes customer enrichment, marketing understanding and rapid response (van Hoek et al., 2001), and indicates that the supply chain should be driven by demands for high quality, high performance and low cost customer-oriented products and service(Agarwal et al., 2004; Collin and Lorenzin, 2006; Lee, 2004; Ismail and Sharifi, 2006). Process integration is concerned with the adaptive capability of mastering changes uncertainty (van Hoek, 2001). This requires that the supply chain can allocate the resource flexibly to meet different requirements, and be nimble its process of products to achieve different objectives within the same facilitates

(Gunasekaran, 1998; Jin et al., 2005; Yusuf et al., 2004). Network integration relates to cooperating to compete by making use of the strengths of partners to achieve greater responsiveness to market needs (Christopher, 2005; van Hoek et al., 2001). Virtual integration relates to leveraging information on supply chain to realize real time asynchronous coordination of inter-firm planning and execution in supply networks (Bal et al., 1999; Collin and Lorenzin, 2006; Jin et al., 2005).

As discussed before, customer responsiveness is key to success in today's market. Agility is all about creating that responsiveness (van Hoek et al., 2001). Hence, one primary target of achieving supply chain agility is to respond customers quickly (Lee, 2004), and supply chains should be customer-oriented rather than forecast-driven (Reichart and Holweg, 2007). In addition, supply chain agility is also about mastering changes and uncertainties. The supply chain should be rapid enough to reconfigure all resources (Goldman et al., 1995). In a wider context, agility postulates flexibility and responsiveness in manufacturing operations, organizations and supply chains as a key tenet of a firm's competitiveness (Reichhart and Holweg, 2007). Responsiveness is the ability to respond time-effectively based on the ability to understand market and customers (Catalan and Kotzab, 2003), while flexibility is more related to the changes in product, volume, mix and delivery (Slack, 1987).

Supply chain agility requires coordination and integration across individual firm functions and throughout supply chains. Research constantly supports that integration between firms improves firm performance (Frohlich and Westbrook, 2002; Johnson, 1999; Lee et al., 1997; Sanders, 2007). Sanders (2007) underscores that successful firms have tight collaboration with their partners, enabling the real time information to transfer across supply chains as well as coordinated inventory management. The following consequence is products can be delivered quickly and reliably (Lee et al., 1997). Devaraj et al. (2007) concludes that there is a positive relationship between suppliers integration with operational performance, especially cost, delivery performance. However, Frohlich and Westbrook (2002) address that better performance can be achieved when the firm coordinates with both customers and suppliers than with partners only from one side. Many studies tend to focus on integration from one side of the supply chain and there is little confirmatory evidence provided on simultaneous consideration of the supply and demand side collaboration and integration (Sanders, 2007).

2.2 IS integration and supply chain agility

A key characteristic of supply chain agility is the instant availability of information to manage an 'on demand' business operation (Auramo et al., 2005; Yusuf et al., 2004). There is evidence that lack of information sharing and sparse information prohibits supply chain coordination and lead to greater operational inefficiencies (Patnayakuni et al., 2006). For example, e-mail systems, expert systems, modelling and stimulation systems are identified as requirements to achieve agile enterprises (Gunneson, 1997). In general, IS integration for SCM has been studied from two different levels of analysis (Pagell, 2004). External integration examines integration between organizations, with the relationship of buyers and suppliers. For instance, Johnson et al. (2007) investigate the e-business technologies in supply chain and propose that it targets at reducing dyadic coordination costs, leading to improved performance. Rai et al. (2006) investigate cross-functional SCM application integration for supply chain integration and discover a significant correlation between cross-functional application integration and firm performance, in particular, operation excellence. Vickery et al. (2003) observe the statistical causality of integrated IS, supply chain integration, customer service and financial performance. On the other hand, internal integration investigates the integration across various functional units within one organization. For example, Ellinger et al. (1997) focus on integration between marketing and logistics departments. Coronado (2003) develops a framework to ensure that IS can delivery benefits for manufacturing agility in small and medium sized enterprises, because IS is believed to be critical and ultimately required for agile enterprises. Narasimhan and Kim (2001) show that integrating IS into the logistics can improve the performance. Lam (2005) explores the critical success factors of enterprise application integration for organizations by using case studies. Other studies have also examined IS integration into an entire organization and developed the way to help functions work more closely and efficiently (Pagell, 2004).

For exploring IS integration in the context of supply chain agility, firstly, customer sensitivity supports the customers' processes in a way that is perceived by customers to be satisfied, and emphasizes fast response to customer requirements (Christopher, 2005). IS integration within and among organizations enables them to capture data on demand, leading to customer-focused supply chains and achieving greater responsiveness (Christopher, 2000). Secondly, one dimension of agile supply chains is to thrive on change and uncertainty, which is stressed by process integration (Agarwal et al., 2006). IS integration provides real time information to reflect changes, including customer orders or market changes so that the product and volume flexibility can be improved. Thirdly, cooperation is necessary within an organization as a means of synchronizing often numerous people and organizational subunits that play a role in bringing about the actions required to continually meet ever-changing customer needs (McGaughey, 1999). Good communication is a key to realize such cooperation (Preiss et al., 1996). IS integration facilitates the implementation of communication by synchronizing information across supply chains within real time. Fourthly, virtual integration facilitates the process of achieving greater agility by encouraging the free flow of information and exchange of ideas, i.e. collaborative organizational work. System integration leverages the value of information because it spans internal and external organizational boundaries making it possible to provide the information that is needed (McGaughey, 1999).

For achieving greater supply chain agility, supply chains require well integrated IS internally and externally to realize information visibility across the supply chain. Traditionally, supply chain agility has been investigated by operations management researchers with a focus on functional problems, such as purchasing and distribution centre design (Baker, 2008), and transportation (Geoffrion and Powers, 1995). In addition, research has suggests that integrating at all levels of analysis should lead to increased performance (Pagell, 2004). However, most of these studies have focused on integration from the viewpoint of IS integration on a narrow range in SCM context, which is either internal IS integration for functional units or external integration to connect with partners, or specific technologies, such as ERP systems (Allen, 2008), e-business technologies (Devaraj et al., 2007; Johnson et al., 2007; Sanders, 2007), e-procurement applications (Pearcy and Giunipero, 2008). Some recommendations encourage focusing investigations on the inter-organizational capabilities that integrate a firm with its supply chain partners to create value (Ho et al., 2002; Rai et al., 2006). Especially, viewed from the perspective of resource-based theory, IS resources can not by themselves create sustained performance gains for a firm (Powell and Dent-Micallef, 1997). But studies have not yet explored the impact of IS integration as a whole on the formation of supply chain agility. This study would provide a comprehensive and detailed perspective of the IS integration development processes in the context of supply chain agility. The discussion shows that integrated IS can facilitate the achievement of supply chain agility. The research framework is presented in Figure 1.

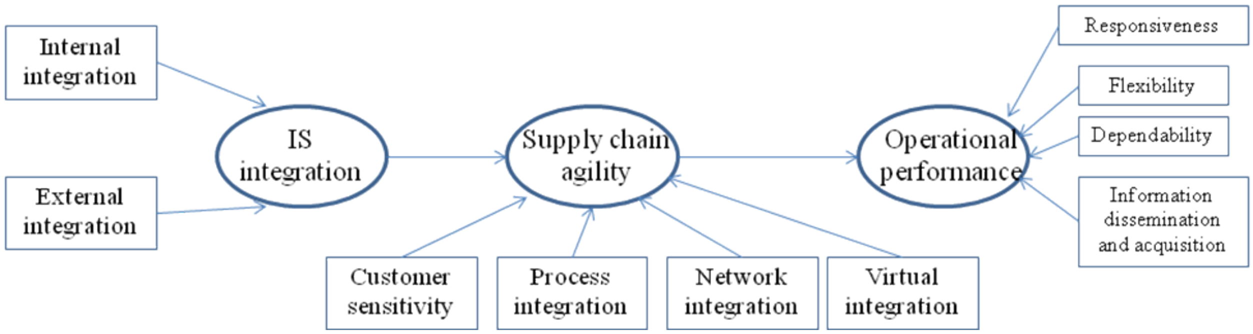

Figure 1 IS and supply chain agility framework

3 Research method

This study employed a survey method of the Chinese automotive industry supply chain. The Chinese automotive industry is suitable for this study for a number of reasons. Firstly, it is one of the leading automotive sales and production markets in the world (Gao, 2005). Secondly, the automotive industry is characterized by complexity, uncertainty and heterogeneity (Xu et al., 2003). The industry is heavily dependent on the whole supply chain, as a single manufacturing enterprise alone may find it difficult to respond rapidly to changing market requirements due to limited resource and time. Many western automotive manufacturers work in collaborative partnerships with Chinese firms to develop the market. SCM is becoming of importance as there is increasing emphasis on sourcing all production (Thru, 2006). Thirdly, Chinese automotive industry has become more information intensive (CCID, 2006). Information systems and internet reshape the process of automobiles' design, manufacturing and marketing, and facilitate the collaboration with their partners (Veloso and Kuman, 2002).

Data were collected using the survey instrument based on the examples of Rai et al. (2006) and guidelines in the literatures (Straub, 1989; Sethi and King, 1991). Five point Likert type scales were used. To ensure the minimal overlap between constructs, as well as to ensure content and face validity, literatures were reviewed to specify a set of items (Cronbach, 1971; Kerlinger, 1986). The surveys were reviewed by twelve senior managers associated with manufacturing, procurement and logistics departments from three companies to identify problems with the instruments' wording, translation, content, format and procedures. The pilot participants returned written comments about the survey instruments and further detailed discussion were carried out. As a result of the pre-test, a number of changes were made to improve clarity. All items and its constructs are presented in Table 1.

Table 1 Construct measurement

Latent construct	Sub-latent construct	Indicators	References

IS integration	Internal integration	IS integration within departments	Pagell (2004)
		IS integration among departments	Coronado (2003); Pagell (2004)
	External integration	IS integration with suppliers and customers	Johnson et al. (2007); Rai et al. (2006)

Supply chain agility	Customer sensitivity	Proactively seeking new emerging markets	Agarwal et al. (2006); Baker (2006); Christopher (2005); Christopher and Towill (2000); Collin and Lorenzin (2006); Goldenman et al.(1995); Gunasekaran (1998); Ismail et al. (2006); Jin et al (2005); Yusuf, et al. (2004); Van Hoek et al. (2001)
		Customer treated individually	
	Process integration	Mobility of resources to meet different requirements	
		Being nimble its processes to achieve different objectives within the same facilities	
		Being cost-effective reconfigured to respond to new production model	
	Network integration	Taking advantages of markets changes as opportunities	
		Having adaptive capabilities to be able to respond future changes	
		The ability to meet customer changes as a source of competitive advantages	
		Suppliers' involvement in the business	
		Fast response to changes in supply	
		Fast response to variations in demand	
	Virtual integration	Leveraging information to understand market and customer requirements	
		Leveraging the impact of information in everyday business	

		Leveraging information to master organizational changes	
		Leveraging information to facilitate collations with partners	
Operational performance	Responsiveness	Response to changes in product and service due to market uncertainty	Christopher et al. (2004); Gunasekaran et al. (2008); van Hoek et al.(2001)
		Process demands from downstream	Chang et al. (2004); Holweg (2005)
		Process demands from upstream	Chang et al. (2004)
	Dependability	Leverage partners' capability	Christopher et al. (2004); Van Hoek et al. (2001)
		Focus of core competence	Christopher et al. (2004)
		A single supplier for each sourced product	Martinez and Perez (2005)
		Supplier-collaborative product design	Christopher et al. (2004)
	Flexibility	Ability to handle difficult or non-standard orders	Reichhart and Holweg (2007);Vickery et al. (1997)
		Ability of increasing or decreasing product effectively	Sanders and Premus (2002); Reichhart and Holweg (2007)
	Organizational learning	Process of seeking useful information	Kohil et al. (1990); Neely et al. (1995)
		Extent to which information shared across functional units	Slater and Narver (1995)

The survey was distributed in the Shangihai Region to Original Equipment Manufacturers (OEM) and 1st tier suppliers. A total of 120 surveys were send out to the senior managers who are responsible for manufacturing, logistics and procurement departments within the firms, as a typical supply chain (Figure 2) is a network of material, information and services processing links with the characteristics of supply, transformation and demand (Chen and Paulraj, 2004).

We received of 102 responses. The response rate of 85 percent is acceptable for survey research (Rai et al., 2006). Of the respondent, 29.3 percent were from logistics/distribution function. 25.6 percent were from procurement function. 31.7 percent belonged to manufacturing function. 12.2 percent had responsibility for IS integration to the supply chain. 1.2 percent was from the supply chain function.

Figure 2 a firm's supply chain. Source: Chen and Paulraj, 2004

IS integration was operationalized as the status of internal and external integration, capturing literatures about ERP to integrate departments within organizations (Allen, 2008); and about the e-business technologies to realize the organizational collaboration (Sanders, 2007).

The dimensions of customer sensitivity, process integration, network integration and virtual integration have been identified to form supply chain agility. But the measurement of each dimension has not been well established. Hence, all items employed in the construct are extracted and summarized from literatures (Agarwal et al., 2006; Aitken et al., 2002; Baker, 2006; Christopher, 2005; Christopher and Towill, 2000; Collin and Lorenzin, 2006; Elkins et al., 2004; Gunasekaran, 1998; Goldenman et al., 1995; Ismail and Sharifi, 2006; Jin et al., 2005; Power et al., 2001; Van Hoek et al., 2001). Principle component factor analysis was used and the factor loadings use Varimax rotation to identify factors (Hair et al., 2005). All the items relating to the four dimensions of supply chain agility separate out into the four categories with factor loadings, in Table 2. A factor analysis of the constructs indicates that all indicators/items load onto a single factor with factor loadings greater than the minimum requirements of 0.40 (Nunnally and Bernstain, 1994; Gefen et al., 2000). There are releveant examples in the literature of IS and SCM supporting the method of the factor analysis in construct measures, such as Devaraj et al. (2007).

Table 2 factor analysis

	Component			
	1	2	3	4
Item 1	**.784**	.126	-.032	.311
Item2	.295	.074	.184	**.760**
Item 3	**.858**	-.008	.218	.167
Item 4	**.673**	-.120	.360	.434
Item 5	.148	.152	.138	**.826**
Item 6	**.673**	.482	.093	-.124
Item 7	.316	.110	**.769**	.204
Item 8	.068	.111	**.884**	.011
Item 9	**.574**	-.026	.415	.149
Item 10	**.797**	-.002	.315	.139

Item 11	.389	-.034	**.701**	.350
Item 12	-.063	**.872**	.051	.116
Item 13	.103	**.888**	.020	-.109
Item 14	.061	**.780**	.089	.335
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.				

Building on prior research, four types of operational performance were assessed. They are responsiveness, flexibility, and dependability and information dissemination/acquisition of organizational learning (OL). Responsiveness is defined as responding to converting the demands to products and changes in production and service (van Hoek et al., 2001). The analysis of responsiveness is critical as it is one measurement for supply chain effectiveness (Holwg, 2005; Lee, 2002; Reichhart and Holweg, 2007). Flexibility is another important operational driver and has been widely discussed in prior research, and has various perspectives of flexibility. According to the review of the literatures, product and volume flexibility are the focus of this study. Product flexibility is the ability to handle difficult, non-standard orders to meet special customer requirements (Vickery et al., 1997), and volume flexibility is the ability to be flexible in adjusting the volume of products from peak demand and slack periods (Sanders and Premus, 2002). The third aspect of operational performance is dependability, the coordination of a firm with its partners, using the partners' strengths and focusing on the firm's core competencies (Christopher et al., 2004; Gunasekaran et al., 2008; Ismail et al., 2006)). Kohil et al. (1993) discuss orgnaizational learning impacts on SCM, and identify four aspects of organizational learning. The discussion of the impact of IS integration on supply chain agility leads to the concentration on the operaitonal outcomes of information acquisition/disseminator. Information acquisition, the process of company to seek for the usable information (Kohil et al., 1993) and information dissemination is the extent to which the information obtained by a firm is shared with its functional units (Neely et al., 1995; Slater and Narver, 1995).

Operational performance has been measured in numerous ways (Gunasekaran et al., 2008; Handfield and Nichols, 1999; Narasimhan and Das, 1999; Sanders, 2007). The measurement usually includes quality, dependability, responsiveness/speed, cost and flexibility (Ferdows and de Meyer, 1990; Slack et al., 2007). In addition, innovation and organizational learning have become added dimensions (Fitzgerald et al., 1991; Neely et al., 1995). Some researchers have suggested that manufacturers tend to simultaneously pursue multiple performance objectives rather than purely focusing on one measure (Roth and Miller, 1990; Sanders, 2007). Following the approach of multiple performance objectives, taken in previous research (Devaraj et al., 2007; Narasimhan and Das, 2001; Sanders, 2007), and the discussion of the relationship between IS integration and four dimensions of supply chain agility, the operational performance in this research focuses on responsiveness, flexibility, dependability and organizational learning (information dissemination and acquisition).

4 Data analysis

Partial Least Square (PLS) was used to test the research framework. It is well suited for highly complex predictive models (Wold and Joreskog, 1982) and theory development (Gefen et al., 2000). Given that there have been very few empirical studies in this research context and little established theory, this research focuses on theory development. In addition, PLS has other strengths that made it appropriate for this study. First, it is able to handle formative constructs (Chin and Newsted, 1999). According to Jarvis et al. (2003) and Chin (1998), the constructs in this research should be formative, which is suitable for PLS. Second, it can handle small sample size requirements (Chin, 1998; Gefen et al., 2000).

The test of the measurement model includes the estimation of internal consistency and convergent and discriminant validity of the sub-constructs and constructs. We assessed the convergent and discriminant validity by factor analyzing all indicator grouped under second-order constructs which are IS integration, supply chain agility and operational performance. The expected factor structure was shown in Appendix A with its factor loadings and Cronbach's alpha. In order to provide further evidence of discriminant validity, another suggested principle validity is adopted, illustrated by Hair et al. (2005). Table 3 provides the correlation matrix, with correlation among constructs and the square root of average variance extracted on the diagonal, indicating that the variance shared by a construct with its indicators is greater than the variance shared with other constructs in the framework.

To further examine the pattern of association between indicators, internal consistency of sub-constructs was assessed using Cronbach's alpha and composite reliability suggested by Fornell and Larcker (1981), with 0.60 considered acceptable for exploratory purposes, 0.70 considered adequate for confirmatory purposes, and .80 considered good for confirmatory purposes (Nunnally and Berstain, 1994; Hair et al., 2005). While the constructs meet tests of internal consistency and convergent validity in the empirical context, it should be noted that they are not necessary requirements for formative constructs (Chin, 1998; Jarvis et al., 2003). The tests suggest that the constructs demonstrate good measurement properties.

Table 3 Assessment of discriminant validity

Constructs	CS	PI	NI	VI	RES	DEP	FLEX	OL	ISINT	ISE
CS	**.869**									
PI	.443	**.861**								
NI	.496	.574	**.792**							
VI	.237	.152	.186	**.849**						
RES	.346	.287	.198	.562	**.872**					
DEP	.368	.170	.223	.502	.645	**.872**				
FLEX	.333	.089	.231	.475	.681	.533	**.866**			
OL	.227	.200	.288	.557	.426	.665	.684	**.912**		
ISINTE	.368	.357	.388	.494	.524	.417	.248	.475	**.869**	
ISE	.275	.374	.404	.529	.540	.348	.374	.552	.857	N/A

The test of the structural model in this research includes estimating the path coefficients and R^2. In this research, second order latent constructs are formative constructs consisting of its sub-constructs as indicators. The PLS method usually does not directly provide significant tests and confidence interval estimates of path coefficients in the research model (Gefen et al., 2000; Rai et al., 2006). In order to estimate the significance of path coefficients, bootstrapping analysis was adopted with 100 subsamples and all path coefficients were estimated using this technique. This approach is consistent with recommended practices for estimating the significance of path coefficients and indicators loadings (Lohmoeller, 1984), and has been adopted in prior research (Howell and Higgins, 1990; Rai et al., 2006; Wixon and Waston, 2001). No minimum threshold values for the weights have been established (Rai et al., 2006). The statistical significance of weights can be used to determine how important the indicators are for forming the constructs. The test of the structural model also indicates R^2 value which represents the amount of variance explained by the independent variables. Together the R^2 and the path coefficients can indicate how well the model fits. The result of the analysis for the structural model is presented in Figure 3.

4 Results

The result provides supports for the research framework. It indicates that the internal integration and external integration both are significantly associated with IS integration with the weight .437 (t=17.3642) and .600 (t=28.1821) respectively. Internal IS has a more significant weight on IS integration than external one. Customer sensitivity, process integration, network integration and virtual integration have significant weight on supply chain agility, which are .159 (t=4.4162), .193 (t=4.0016), .190 (t=4.4479) and .799 (t=15.2938) correspondingly. Operational performance consists of responsiveness, flexibility, dependability and information dissemination/acquisition with the weight .471 (t=12.1630), .047 (t= 6.3679), .232 (t= 7.7759), and .388 (t= 14.1152) in that order. The results also show the predictive power of path model, indicating that the model explains 42.7 percent of the variance in operational performance. The value is discussed in the following analysis section. Moreover, 39.9 percent of the variance in supply chain agility was explained by the degree of IS integration. In addition, the path coefficient from IS integration to supply chain agility is .632 (t=8.5758), and from supply chain agility to operational performance is .654 (t=9.7226). The magnitude and significance of the path coefficients provide additional evidence in supporting the research framework.

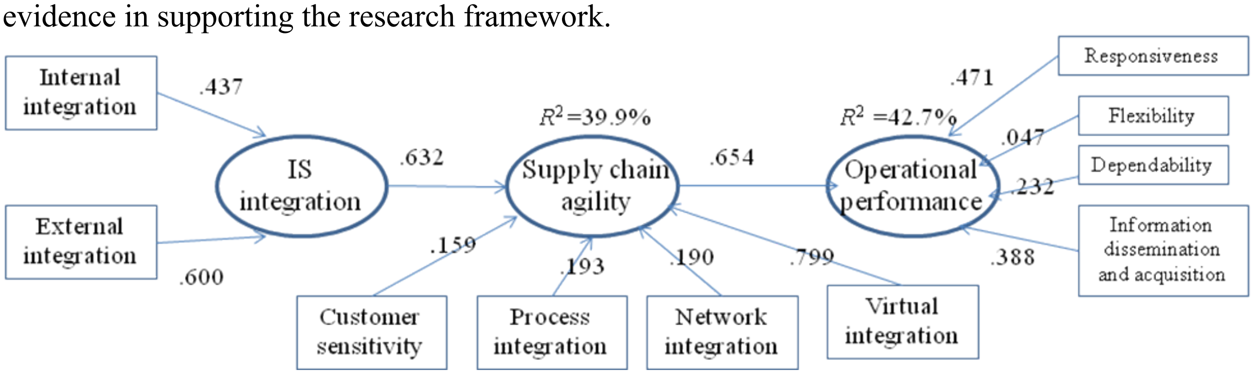

Figure 3 Results

4 Analysis and implications

The results show that IS integration enables and facilitates the process of supply chain agility, which in turn yields greater operational performance except responsiveness. These findings have significant implications for IS management in the context of the supply chain. The findings are discussed here in term of IS integration, supply chain agility and operation performance.

4.1 Integrated IS for supply chain agility

Past framings of IS integration either focus on internal integration such as ERP systems or external integration such as e-procurement (Auramo et al., 2005; Devaraj et al., 2007; Pearcy and Giunipero, 2008). In the context of supply chain agility, previous research indicates the importance of realizing internal or external integration to enable the real-time connectivity across a range of functional units and a range of applications from ERP to customer/supplier relationship management. Such IS integration not only realizes connectivity cross the entire supply chain, but also enables the information visibility or exchange between supply chain partners.

Our findings provide evidence to support the existing research on the importance of internal and external integration to transform the fragmented, functional, silo-oriented supply chain processes to integrated cross-firm supply chain process (Rai et al., 2006). Both internal and external integration play an important role in the achievement of supply chain agility. Elmuti et al. (2008) argue that integration and coordination of the functions can lead to positive and substantial improvements in overall performance. Hence, the result suggests the importance of both IS integrations in managing supply chains.

In addition, the results of the path coefficients suggest that external IS integration is relatively more important than internal integration, indicating the significance of electronic communication among firms. As Smeltzer (2002) noted that, to obtain the maximum overall benefits from a supply chain, all companies involved should be linked electronically. Although both Frohlich (2002) and Hausman and Stock (2003) discuss high costs, potential threats of losing confidential information among the firms and the difficulties of integrating multiple technology platforms, Internet technology provides an efficient and cost-effective solution to realize digital connection (McGaughey, 1999). Archer et al. (2008) discover that e-business is used quite extensively by the companies with Internet access to communicate and collaborate with their business partners. Sander (2007) also notices that e-business, the Internet and web-based technologies, have a greater impact on intra-firm collaboration which leader to a greater firm performance. Therefore, one possible explanation is that with Internet technology and availability of application service providers, the firms can easily be connected with each other by e.g. web Portal, web EDI (Howard, 2005).

4.2 IS-integrated supply chain agility

The results suggest that IS integration has a substantial effect on achieving an supply chain agile capability and the effect is embedded into the process of customer sensitivity, process integration, network integration and virtual integration since IS integration has a significant path coefficient on supply chain agility. However, IS integration only explains 39.9 percent of the variance in supply chain agility, indicating that factors not included in the research model affect the agile capability across supply chains. Further research is needed to understand factors that affect it. The results reveal that IS integration is a necessary factor of achieving supply chain agility, but not sufficient on its own. Hence, other factors may also have strong influence on achieving greater agility across supply chains. For instance, Archer et al. (2008) argue for the need for education for the SME management on using e-business solutions. Fawcett et al. (2008) discover that the people issues such as trust, culture, and willingness to collaborate are also important barriers to successful supply chain collaboration.

The results also give suggestions of the impacts of customer sensitivity, process integration, network integration and virtual integration on the formation of supply chain agility. Virtual integration has the strongest effect, followed by process integration, network integration and then customer sensitivity which ahs the weakest impact on supply chain agility. This result provides further evidence to support the theory that supply chain agility should be information-based (Christopher, 2005). Virtual integration and process integration have a relatively stronger impact than network integration and customer sensitivity, indicating that for achieving greater agility, the companies might focus on the internal process of improving the responses to changes and the role of information first so that the capabilities can be effectively applied to develop such agility with their customers or suppliers.

This study suggests that a successful deployment of IS involves not only the technology to connect other functional units, but also the identification of the context in which IS will be applied. As Swanson (1994) suggests, managers should identify the appropriate context related to IS and reconfigure the organizational processes in a way that can realize the values of IS. In this research, four dimensions have different weights on supply chain agility, providing the hierarchy of the context for the employment of IS integration. That is, instead of applying IS integration simultaneously in supply chain agility, IS integration can be applied to achieve process and virtual integration, and then to customer sensitivity and network integration. Furthermore, this research implies that supply chain agility is not equivalent with IS integration among supply chain partners. Rather, IS integration is a separate construct that promotes four dimensions of supply chain agility. As noted by Sanders (2007), occasionally companies presume that having information technology in place means that collaboration with partners exists. Based on the findings, the effort to IS integration that particularly facilitates supply chain agility progress, should be given great consideration, but other factors should also be considered.

4.3 Operational performance gained through digitally enabled supply chain agility

On operational performance, the results indicate that the digitally enabled supply chain agility can have a substantial impact, as identified from the significant weight and R^2. Responsiveness has a strong and significant weight on operational performance, indicating that IS integrated supply chain agility improves firm responsiveness. This supports existing research. We also note that a limited focus on the level and status of operational costs may have damaging consequences on firm responsive ability (Lee, 2002; Neely et al., 1995). As Elmuti et al. (2008) argue, customer responsiveness significantly correlates with net income and ROI. Hence the balancing point of cost-efficiency and responsiveness is important for companies to realize great operational performance (Boyer and Lewis, 1992; Reichhart and Holweg, 2007).

Dependability and information dissemination/acquisition both have strong impacts on operational performance, indicating the importance of working with partners. Information visibility should be realized in departments as well as among organizations. Flexibility within organizations has the weakest weight on operation performance, showing the inability of handling non-standard orders and volume changes in the companies attempting to achieve greater supply chain agility. One explanation is that integrated IS computerizes and standardises business processes, and reduces the capability to handle non-standard orders. Another explanation is that the companies tend to maximise production run. This leads to orders being brought forward in order to maintain the same production run, proposed by Levy and Phillip (1998), as their research results also suggest that IS does not provide flexibility for companies.

Furthermore, as Dasgupta et al. (1999) reveal, productivity in the service and manufacturing sectors appears to lag when increasing IS investment occurs.

The results support the notion of theories on supply chain agility concentrating on responsiveness and flexibility (Aitken et al., 2002; Ismail and Sharifi, 2006; Christopher, 2005; van Hoek et al., 2001). Responsiveness is mainly achieved through rapid, short time response while flexibility focuses on managing product variety and volume. The relatively stronger weight of responsiveness than flexibility shows that IS-integrated supply chain agility is more capable of shortening response times rather than handling product and volume flexibility. This implies that efficient agility, which is fast responding, is the goal for the studied automotive firms, rather than customer responsive agility, which is customer orientated. As Holweg and Pil (2008) argue, although many firms adopt build-to-order strategy to improve performance of customization, they do not embrace the strategy as a significant goal. More importantly, their research also identifies the inability of IS to meet the responsiveness goals placed on the overall system. Hence, as shown in this research, firms focus on shortening lead times to satisfy customers rather than extensive customer interaction to enrich the customer experience and improve responsiveness. One explanation is that the automotive industry is still cost-driven (Childhouse et al., 2003) and many firms still apply build-to-forecast models (Holweg et al., 2008). Furthermore, as the results stresses on working efficiency, the study suggest that the use of IS integration may be more conductive to activities that involve process automation and task efficiency, supporting the findings of Pagell (2004) and Sanders (2008). Pagell (2004) finds that IS systems by themselves do not play a critical role in integration, rather the use of IS is more for communication and work efficiency. Sanders (2008) proposes that the use of IS in integration supports more on automation tasks than innovation or new ideas development.

The result of 42.7 percent explanation of operation performance also indicates that supply chain agility is a suitable approach to leverage operational performance, in particular when this approach is facilitated by IS integration. The results may indicate that the different dimensions of supply chain agility are hierarchical and interrelated, which might be similar to the sandcone model presented by Ferdow and de Meyer (1990). The deployment and investment of IS integration needs to be coordinated through the four agility dimensions in order to realize its full potential of such digitally-enabled supply chain agility. The result also indicate that other factors affect operational performance, especially as Mondragon et al. (2004) claim, agility is a continuous process rather than a static state and the factors such as training, employees' skills are important to enhance agile manufacturing.

5 Conclusions

The study's agility framework provides an integrated perspective of IS integration, supply chain agility and operational performance. The research revealed that the development of supply chain agility positions firms to realize improvements in their performance, in particular, on cutting down the response times so that customer waiting times are reduced. The study also shows the difficulty of greater improvements on product flexibility and volume flexibility, indicating that the current manufacturing is still modularity-based mass production rather than order-based customer-focused manufacturing. Especially with a cost-driven and build-to-forecast automotive industry, IS-integrated supply chain agility is better suited to efficient agility rather than customer focused agility. Furthermore, supply chain agility has four dimensions which are hierarchical, from virtual integration, process integration, to network integration to customer sensitivity. These facilitate the process towards an information-based supply chain. But to leverage supply chains agility, IS integration, with both internal and external integration important to the supply chain agility dimensions, should automate business processes, as well as support decision making and flexible business processes.

The study focuses on the automotive industry in the Shanghai Region, so future research may consider variables such as culture or development. Also, the data only includes OEMs and 1st tier suppliers. This may be expanded to include 2nd or 3rd tiers of suppliers to capture the role of IS along the entire supply chain. Future research may address the issue of how deep the IS integration should penetrate for optimal performance. Finally, in cost-driven supply chains customer orientation may be a minor management objective. Future research may explore the differences of the use of IS integration and operation performance consequence when the supply chain is customer-oriented.

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Appendix A. Analysis of the measurement model

Measurement Items		**Factor Structure and Loadings**	
IS integration		**Internal IS integration**	**External IS integration**
ISE1	IS integration within departments	.870	
ISE2	IS integration among departments	.870	
ISX1	IS integration with suppliers		n/a
Average Variance Extracted		.756	
Cronbach's Alpha/Composite reliability		.826/.861	n/a
Measurement Items		**Factor Structure and Loadings**	

Supply Chain Agility		Customer sensitivity (CS)	Process Integration(P
CS1	Proactively seeking new emerging markets	.841	
CS2	Customer treated individually	.795	
PI1	Mobility of resources to meet different requirements		.752
PI2	Being nimble its processes to achieve different objectives within the same facilities		.877
PI3	Being cost-effective reconfigured to respond to new production model		.715
NI1	Taking advantages of markets changes as opportunities		
NI2	Having adaptive capabilities to be able to respond future changes		
NI3	The ability to meet customer changes as a source of competitive advantages		
NI4	Suppliers' involvement in the business		
NI5	Fast response to changes in supply		
NI6	Fast response to variations in demand		
VI1	Leveraging information to understand market and customer requirements		
.833			
VI2	Facilitating the collaborative work with partners e.g. suppliers		
.854			
.774			
VI3	Leveraging information to master organizational changes		

VI4	Leveraging information to facilitate collations with partners		
Average Variance Extracted		.756	.742
Cronbach's Alpha/Composite reliability		.678/ .861	.820/ .896
Measurement Items		**Factor Structure and Loadings**	
Operational Performance		**Responsiveness**	**Dependability**
RE1	Response to changes in product and service due to market uncertainty	.792	
RE2	Process of demands from downstream	.816	
RE3	Process of demands from upstream	.866	
DE1	Leverage partners' capability		.764
DE2	Focus of core competence		.764
DE3	A single supplier for each sourced product		.673
DE4	Supplier-collaborative product design		.863
FL1	Ability to handle difficult or non-standard orders		
FL2	Flexibility of increasing or decreasing product effectively		.878
OL1	Process of seeking useful information		
OL2	Extent to which information shared across functional units		
Average Variance Extracted		.760	.760
Cronbach's Alpha/Composite reliability		.764/.904	.820/ .904

1 Rotated factor solution based on principal component analysis with varimax rotation.
2 internal consistency uses Cronbach's alpha and a measure of composite reiability proposed by Fornel and Larcker (1981).