IMPACT OF SOA USE ON PERFORMANCE OUTCOMES OF INFORMATION SHARING IN SUPPLY CHAIN

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Abstract

We empirically analyze the impact of SOA use on performance benefits of information sharing in supply chains using a dataset of publicly listed US firms. We show that complexity and transparency of information sharing process significantly impact performance. Information sharing complexity has a negative effect while transparency has a positive effect. We also demonstrate that SOA use in supply chain is successful in mitigating the negative effects of process complexity. Interestingly, SOA use also leads to reduction in performance benefits of information sharing transparency. We contribute to business value of IT research by providing empirical evidence of business value of SOA. We show that both "what" information is shared and "how" it is shared affect performance and they interact differently with SOA use. Our results emphasize the interaction between process characteristics and technology architecture and provide directions for managers to orchestrate information sharing processes in supply chains and leverage SOA for optimal performance.

Keywords: Business Value of Information Sharing, Service Oriented Architecture, SOA, Supply Chain, Information Sharing

1 Introduction

Advances in Information Technology (IT) have had a significant impact on how firms manage their supply chain. Companies have used IT to connect with their suppliers and share relevant information in a timely and efficient manner for improving supply chain performance. Companies like Wal-Mart and Dell have achieved impressive improvements in supply chain performance by tightly integrating their suppliers in an electronic network.

Greater information sharing with supply chain partners is a key driver of improvements in supply chain performance. Information sharing through the supply chain reduces uncertainty, enables the channel participants to match supply and demand closely and anticipate future changes in the market, leading to improved supply chain performance. For example: Wal-Mart shares information regarding retail sales of P&G's products at Wal-Mart stores in real time with P&G. This enables P&G to better manage its production process and inventory levels in the supply chain. Dell Inc. has developed extensive capabilities to share information related to quality, relationship management, design, daily production requirements, and inventory levels even on an hourly basis with suppliers. This has enabled Dell to reduce cost and improve customer service (Magretta 1998).

Adoption of inter-organizational information systems like EDI, ERP and SCM have grown rapidly as firms realize the value of electronically integrating their supply chain and sharing information with channel partners. However, efforts to integrate supplier and improve information sharing in supply chain have not always been successful. Many companies have suffered setbacks in electronically integrating their suppliers. Prominent examples include Nike's inventory buildup in 2001, Hershey missing shipments during Halloween in 1999 and Toys-R-Us' failure to fulfill Christmas demand in 1999 (SupplyChainDigest 2006). Failure rate in supply chain management system implementations have been estimated to be as high as 70% with the complexity of processes and technology involved considered one of the main reasons for disappointing performance levels in electronic supply chains (Lewis 2007).

Information sharing in supply chain has been actively studied by both information systems as well as operations management researchers. Information systems researchers have focused on empirical studies of business value of inter-organizational systems such as EDI. In a study of EDI at Chrysler, total benefits of EDI per vehicle amounted to over $100 resulting in annual savings of $220 million for the company (Mukhopadhyay et al. 1995). In contrast, operations researchers have mainly focused on analytical studies of the impact of information sharing on parameters such as inventory and lead times. Using an analytical model of two level supply chain, Lee et al. (2000a) showed that sharing of demand information leads to lower inventory and cost levels. Similarly, Cachon et al. (2000) found that by sharing order information in addition to inventory information led to an average reduction of 2.2% in supply chain cost.

While the impact of information sharing on supply chain performance has been well studied, the extant research has focused mainly on "what" information is shared and has not given due attention to "how" the information is shared. In particular, the characteristics of the information sharing process and the technology architecture used to enable the information sharing process have not been considered. In a recent paper, Kim et al. (2006) argue that in case of electronic information sharing, more is not always better and that the fit between contextual factors and electronic information sharing is needed to achieve improved channel performance. We extend their emphasis on the context for information sharing in this paper and argue that for getting deeper insights into performance benefits of information sharing, we need to look at the process and technology level.

The current research is deficient in studies that integrate the impact of process characteristics and specific technology architecture use on the performance benefits of information sharing in supply chain. This study fills the research gap by empirically analyzing the impact of information sharing on supply chain performance while explicitly considering the impact of characteristics of the information sharing process as well as the technology architecture used to enable the process. We look at the impact of information sharing process complexity on supply chain performance and analyze whether the new generation of integrative IT architecture, Service Oriented Architecture (SOA) can help manage the complexity and hence improve supply chain performance.

This study considers the emerging and increasingly popular technology architecture for inter-organizational information systems – Service Oriented Architecture as a solution to manage complexity. SOA is a technology architecture where the basic element of design, development and use of software solutions are services (Papazoglou et al. 2003). Services are self- describing components, which can be recognized by client applications through look up from a registry (such as UDDI: Universal Description, Discovery and Integration). Applications communicate with each other in such architectures through services. The client application and the service provider communicate via standard protocols (e.g. SOAP, HTTP) and exchange information using standard data formats like XML.

There has been a rapid growth in adoption of SOA by firms. According to a recent survey by IDC (Dubie 2006), the worldwide spending on SOA is likely to reach about $9 billion by 2009. Another survey by Aberdeen group (Aberdeen 2006) indicates that 45% of companies surveyed have projects underway involving SOA in their supply chain and another 17% plan to start such projects in the next 12 months.

Amid this rapid growth in SOA deployment, IT managers are faced with concerns about net business value of their SOA investments. CIO.com (2006) reported that managers perceive the difficulty in demonstrating net business value of SOA as one of the main problems with SOA use. While IT managers have to make a decision on SOA adoption to facilitate migration to new technology platforms and to enable efficient information exchange in their supply chain, they have little information available about organizational impact of SOA use, especially about impact of SOA use on the supply chain performance. In this study, we provide empirical evidence of the impact of SOA use on supply chain performance.

Although previous IS research has focused on strategic benefits of technology adoption (Sambamurthy et al. 2003), in particular from adoption of web technologies (Chatterjee et al. 2002) and electronic supply chains (Malhotra et al. 2005; Subramani 2004), to our knowledge there has been no broad cross-sectional empirical study of supply chain performance impact of use of new web technologies or architectural paradigms. Previous research on business value of SOA have mainly focused on anecdotal or case study based evidence (Lim et al. 2003) rather than empirical studies. We bridge this research gap in this study by analyzing the impact of SOA use on performance of supply chains. This is one of the first broad empirical studies to provide evidence of business value of SOA use and to explore the mechanisms of supply chain performance improvement associated with SOA use.

This research brings together two research streams focusing on information sharing in supply chain – operations management and information systems. We combine the operational issue of how the degree and the process of information sharing can affect supply chain performance with the information systems issue of how SOA adoption can mitigate process complexity and lead to tangible business value in supply chains.

This study contributes to both research and practice. On the research side, it contributes to the literature on business value of IT by providing broad empirical evidence of business value of SOA adoption and its interaction with process characteristics. The study contributes to the operations management literature by providing empirical support to previous theoretical research (Lee et al. 2000a; Yu et al. 2001) that suggests that information sharing in supply chain leads to performance improvements. Further, it extends that research by showing that apart from the degree of information sharing, the characteristics of the process of information sharing also affects performance. The study also contributes by combining operations and information systems research streams in a broad empirical study while keeping the focus on details at process and technology level.

On the practice side, this study provides IT managers with an assessment of the impact of information sharing and SOA adoption on supply chain performance. The results show how the process characteristics and technology choice interact to result in performance improvement in supply chain. This would help managers orchestrate better information sharing processes and make informed decisions about SOA adoption for their supply chain context.

The rest of the paper is organized as follows. The next section provides a summary of previous work on information sharing in supply chain and service oriented architecture to develop the hypotheses. Section 3 formulates the research model used and details the data and methodology used to test the hypotheses. Results and their analysis are presented in Section 4 followed by a discussion of the results, limitations of the study and conclusions in Section 5.

2 Theory, Hypotheses and Research Design

We are focusing on the business value of SOA adoption and its interaction with process characteristics in the context of the supply chain relationship between firms and their suppliers. Supplier relations have been an important destination for IT investments (e.g. EDI and SCM systems). Widespread adoption of SOA systems for connecting with suppliers provides an ideal setting to study performance impact of SOA adoption.

Based on prior supply chain literature as well as potential benefits of SOA adoption, we frame the impact of SOA adoption on supply chain performance in terms of two characteristics of the information sharing process between the firm and its suppliers: transparency and complexity. Transparency of information sharing relationship refers to "what" information is shared including production information, customer information, financial information and marketing and promotion information. Complexity of information sharing relationship measures "how" information is shared: using custom reports, providing real time access, using ad-hoc reporting or allowing scheduled access.

In this study we first look at how the characteristics of the information sharing process, transparency and complexity, impact the performance of the supply chain and then we focus on how use of SOA in supply chain moderates the impact of supply chain process characteristics on supply chain performance.

2.1 Information Sharing and Supply Chain Performance

Information sharing in supply chain has been studied in depth in both the information systems and the operations management literature. In the information systems literature, Clemons et al. (1992) concluded that information transfer using IT has the unique capability of simultaneously trimming down a firm's cost of decision making and operation, and the transaction cost of its channel partners. There have been several studies on use of EDI. E.g. Mukhopadhyay et al. (1995) studied the use of EDI systems and concluded that the systems provided significant business value. In a recent study of Internet enabled business value, Barua et al. (2004) showed that electronic integration and information sharing with suppliers leads to performance improvement.

On the operations management side, in their seminal work on information distortion in supply chain, also known as the bull whip effect, Lee et al. (1997) showed that when only order information is shared through the supply chain, it misguides upstream members in their inventory and production decisions resulting in lower supply chain performance. They argue that information sharing of sell-through and inventory status data can help in mitigating the bull whip effect and improve supply chain performance. Using an analytical model of two level supply chain, Lee et al. (2000a) showed that sharing of demand information leads to lower inventory and cost. Yu et al. (2001) showed that increasing information sharing among members of a decentralized supply chain leads to Pareto improvements in the performance of the entire supply chain. Lee et al. (2000b) argued that advances in IT has allowed supply chain partners to operate in tight coordination through information sharing. They describe five types of information sharing: inventory, sales, demand forecast, order status and production schedule.

Overall, both information systems and operations management literature indicate that larger degree of information sharing results in improvements in supply chain performance. We define the level of information sharing in supply chain as “information sharing transparency”. Information sharing transparency is a measure of how much information is being shared in the supply chain. For example: a supply chain that shares demand, inventory and production data has higher information sharing transparency than a supply chain that only shares demand and inventory data. As per previous research higher transparency will provide more information to channel partners to make optimal decisions, avoid distortion of demand data through bull whip effect and lead to higher supply chain performance (Cachon et al. 2000; Lee et al. 1997; Lee et al. 2000a). Hence, we posit our first hypothesis:

Hypothesis 1: *Higher transparency of the information sharing process is associated with higher supply chain performance*

While transparency describes what information is being shared, the information can be delivered in a variety of ways. Advances in information technology have allowed firms to structure information sharing process with varying degree of customized reporting, real time access, data access frequency, access levels and software integration. However, these customization dimensions increase the complexity of the information sharing process.

To study the impact of complexity of information sharing process on supply chain performance, we follow the previous literature on task complexity and its performance impact. March et al. (1967) described complex tasks are characterized by uncertain alternatives or consequences of action. Complex tasks are characterized by the existence of a number of subtasks, which may or may not be easily factored into nearly independent parts. Bystrom and Jarvelin (1995) divide task complexity into different categories based on the pre-determinability of the task. The pre-determinability of the task includes the pre-determinability of the information requirements, process and outcome. If the task is more structured then the elements of the task are known in advance and it becomes less complex. Similarly, previous knowledge about the task and information requirements for the task makes the task less complex.

Complexity of the information sharing process in supply chain is likely to have a negative effect on the supply chain performance. The increase in complexity makes it difficult for the information recipient to make timely and efficient decisions based on the received information as managers need to manage additional cognitive load to manage the additional task complexity. Task complexity has been shown to affect information seeking behavior of users (Bystrom et al. 1995). Complexity has been shown to impair assimilation of information and lead to larger errors in decision making (Plumlee 2003). Roberts et al. (2004) showed that complexity affected how users interacted in groups – communication, participation and group integration were found to be lower in more complex tasks. Complexity of the information sharing process can also result in delays in information sharing which can have a negative impact on performance. Bensoussan et al. (2005) showed analytically that the total inventory-related cost decreases when the length of the information delay decreases.

The complexity of the information sharing process is expected to have a negative impact on supply chain performance as higher complexity will place incremental burden on managers to get and understand the information shared. Complexity of the information sharing process may also delay access to the information by channel partners; thereby affecting the performance of the supply chain. Hence, we present our second hypothesis:

Hypothesis 2: *Higher complexity of the information sharing process is associated with lower supply chain performance*

The above two hypotheses consider two dimensions of the information sharing process that provide a more holistic assessment of information sharing in supply chains than simply the amount of information that is shared. However, the information sharing process is enabled using technology architectures that may affect the impact of process characteristics on supply chain performance. We now consider the performance impact of using service oriented architecture to enable the information sharing process.

2.2 Service Oriented Architecture

The many vendors and wide variety of specialized software systems like ERP, SCM, CRM and EDI have made integration of these software costly and difficult. To enable information sharing across systems, a new breed of enterprise and web technologies (i.e. web services) and architectures (i.e SOA) have emerged that provide a platform for integration. These integrating technologies employ standardized protocols and data formats for exchanging information across enterprise applications.

Recent surveys have found evidence of SOA platforms being used widely and SOA deployment growing rapidly (Iyer et al. 2003). The real advantage of SOA lies in its ability to provide seamless integration across business units, customers and partners (Lim et al. 2003). By exposing the business services that are available in an organization to external customers, SOA offers a way to integrate data and processes across the organization. It also provides a way to combine the business services across partner organizations and offer a unified service to the end user application.

There is a small but growing body of literature that studies the performance impact of the new technology paradigm including SOA or web services. Sambamurthy et al. (2003) provide a theoretical model for analyzing the role of information technology in business strategy and how new technologies are leading to strategic flexibility in firms. They encourage further inquiry into how firms achieve agility and what technologies lead to flexible business processes and business models. Their research provides a theoretical foundation but lacks empirical support that will enlighten managerial decisions regarding investments in these new technologies including web services and SOA. Chatterjee et al (2002) suggest that organizational assimilation of web technologies leads to very useful business process benefits and study the role of top management sponsorship, investment rationale and extent of coordination on such an assimilation of web technologies. Previous research has provided anecdotal and case-study based evidence of the positive impact of SOA adoption on organizational performance. Lim et al (2003) provide examples of benefits of SOA adoption in companies like Motorola and General Motors. However, there is a need of empirical studies that studies the adoption of integrative web technologies and architecture like SOA and their impact on organizational performance.

Impact of SOA Use on Supply Chain Performance

Adoption of SOA in the supply chain impacts the performance of the supply chain in two ways. First, SOA is an integrative architecture that has the ability to bring together disparate systems, technologies and data formats. Hence, SOA makes information sharing across silos easier. Thus, while information sharing with suppliers can be expected to be beneficial on its own (Hypothesis 1), use of SOA in the information sharing process would further enhance the benefit by making communication and information sharing easier because of SOA's inherent standards based interoperability. Hence, a firm with SOA would be in a better position to efficiently share information with its suppliers. We therefore expect that SOA will have a positive interaction effect on the benefit of information sharing transparency. We posit the following interaction effect hypothesis:

Hypothesis 3: *SOA adoption by firms increases the impact of information sharing process transparency on supply chain performance.*

The second impact of SOA on supply chain is to increase flexibility. SOA is expected to make IT systems more flexible where changes can be accommodated easily (Gartner 2005). In a CIO/Computerworld survey, 77% of the respondents believed that SOA adoption will bring greater business flexibility (Koch 2006). As complexity of business processes and IT systems has emerged as one of the major concerns especially as companies grow with mergers and acquisitions and need to merge different IT systems together; SOA, by bring flexibility to the IT architecture, is expected to help companies in managing the complexity (Carter 2007). Chung et al. (2005) analyzed the relationship between IT infrastructure flexibility, mass customization and business performance. They found that an infrastructure with increased flexibility leads to increased business performance. The flexible infrastructure is also more hospitable in supporting mass customization, which leads to higher customer satisfaction (Chung et al. 2005).

In the context of information sharing in supply chain, we previously argued that the complexity of the information sharing process will have a negative impact on supply chain performance. Use of SOA in supply chain will lead to more flexibility and will be helpful to firms and suppliers manage the complexity of the information sharing process. Therefore, we expect that SOA use will help mitigate the negative performance impact of information sharing complexity on supply chain performance (interaction with Hypothesis 2). We can formalize the argument as follows:

Hypothesis 4: *SOA adoption by firms reduces the impact of information sharing process complexity on supply chain performance.*

The four hypotheses above capture the process and technology level relationships between information sharing and supply chain performance. The hypotheses are summarized below in a research design that can be empirically tested.

2.3 Research Design

Integrating the four hypotheses described above into a combined research model, we can conceptualize hypotheses 1 and 2 as the direct effects and hypotheses 3 and 4 as interaction effects. We are controlling for factors that have been shown to affect the business value of IT systems in general and supply chain performance in particular. In accordance with previous literature, we are controlling for firm size (Dewan et al. 1998), industry affiliation (Stiroh 2002) and the use of SCM systems (Subramani 2004). When using accounts payable as the supply chain performance measure (discussed in the next section), we also use accounts receivables as the control for financial processes in the firm. The research design is shown in Figure 1 below.

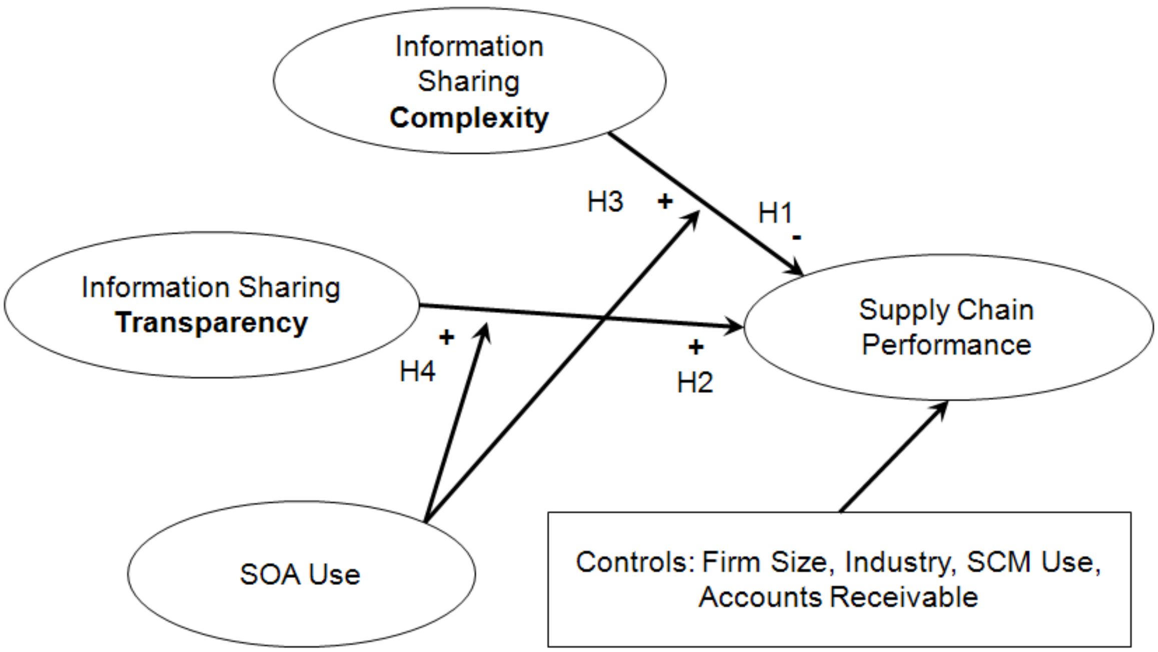

Figure 1: Research Model

Testing the research model requires data for a sample of firms on characteristics of the information sharing process, SOA use, supply chain performance and firm level controls. The research model can then be tested using multivariate regression analysis.

3 Data and Methodology

Data for this study has been collected from two sources. Data regarding SOA adoption and the information sharing process was collected through an annual survey of top IT managers of large publicly traded US based firms. We obtained the data from InformationWeek, a leading and widely circulated publication for the IT industry. The data was part of the annual InformationWeek500 ranking of the IT industry for year 2003. A practitioner oriented analysis of the data was published in InformationWeek (InformationWeek 2003). InformationWeek is considered a reliable source of IT industry related data and many academic studies have been conducted based in data provided by InformationWeek (Bharadwaj et al. 1999; Mithas et al. 2005).

The InformationWeek data was supplemented with supply chain performance, firm size and industry control data collected from Compustat. Compustat is an information service provided by Standard and Poor that includes a database of financial, statistical and market information for publicly listed companies. The combined dataset consists of 305 companies. This is an adequate sample size and is comparable with previous broad empirical studies on business value of IT (Dewan et al. 1998).

The two data sources are used to build empirical measures for the constructs used in the research model (Figure 1).

3.1 Construct Operationalization

The variables from the two data sources used in the empirical model are described below. Measures for constructs with multiple measures are mentioned in the Table 1 that follows the construct measurement details below.

Variables from InformationWeek Survey:

- **Information Sharing Transparency**: This is a 11-item summative index that represents a count of different information elements that are shared between the firm and its suppliers. The information elements include inventory information, demand information, marketing and promotion information and financial information and includes the five types of information sharing in supply chain described by Lee et al. (2000b) – inventory, sales, demand forecasting, order status and production schedule. The items included in the index are explained in Table 1 below.
- **Information Sharing Complexity**: This is a 2-item summative index that measures the complexity of information sharing process. The items that form the index include whether custom reports are provided to suppliers and whether the supplier is provided structured reports or allowed access to ad-hoc reports (Table 1).
- **SOA Use**: This is a 2-item summative index measuring the level of SOA and web technologies adoption in the focal firm. The items that form the index include use of web services and XML in the organization and broad implementation of service oriented architecture (Table 1).
- **SCM Use**: Binary variable indicating whether the firm uses supply chain management (SCM) systems to connect and interact with its suppliers.

Variables from Compustat:

- **Supply Chain Performance**: We use two measures of supply chain performance that complement each other – the operational measure of inventory and the financial measure of accounts payable. Level of inventory in supply chain is the traditional measure of supply chain performance in the operations management literature (Cachon et al. 2000; Moinzadeh 2002). We complement the primary measure of inventory with the level of accounts payable as an additional measure of supply chain performance. Inventory and accounts payable both are inverse measures of supply chain performance, i.e. lower inventory and accounts payable indicates better performance.

  Accounts payable is an unconventional measure of supply chain performance compared to more traditional measures like inventory and lead times. We have refrained from using inventory as the only dependent variable as our sample consists of different industries that have very different inventory profile. Service industries are the largest part of US economy and we want the scope of the study to include both manufacturing as well as services supplier. Accounts payable is a more inclusive measure that is relevant for both manufacturing and services industries.

  Accounts payable and inventory combine to measure benefit of supply chain performance to both sides of the supply chain relationship. A reduction in inventory benefits the firm while a reduction in accounts payable benefits the suppliers.

  For checking the robustness of accounts payable as a measure of supply chain performance, we calculated the correlation between accounts payable and inventory levels and found the correlation to be very high (73%), indicating that accounts payable (like inventory) is a good measure of supply chain performance.

A potential problem with accounts payable as a measure of supply chain performance is that firms may consider higher accounts payable desirable since delaying payments to suppliers is similar to an inexpensive and flexible source of financing for the firm. However, previous research has shown that low levels of accounts payable is associated with better firm performance. Deloof (2003) analyzed data from more than 1,000 large Belgian firms to show that firms that take longer to pay their suppliers (indicating high accounts payable) are in fact likely to be less profitable. Mukhopadhyay et al. (2003) showed that electronic integration in supply chain leads to reduction in delays in payments to suppliers.

Late payment of invoices can be very costly if the firm is offered a discount for early payment. Deloof (2003) reports that in a survey, 75% of firms offered a discount for payment within 10 days with average discount of 3%. Even though the average contractual credit period was 41 days, the average actual payment period was 61 days with 49% of all trade credit paid late with adverse performance implications.

Even though an increase in accounts payable may lead to higher profitability in the short run – a sustained high level of accounts payable indicates clogged processes and inefficient information sharing. High level of accounts payable adds delay to completion of transaction and increases the potential for errors and late error detection leading to higher costs of fixing the errors (similar to inventory). Hence, we conclude that accounts payable is a good inverse measure of supply chain performance.

If a firm's financial processes are oriented towards maximizing working capital then the firm is likely to keep accounts payable higher and accounts receivables lower. To control for firm's financial processes, we are using levels of accounts receivable as a control in the research model for the cases when accounts payable is the dependent variable.

- **Firm Size**: Annual revenue in million USDs.
- **Industry**: Based on the first digit of the North American Industry Classification System (NAICS) code for each firm, we have divided firms into five sectors and included a binary (dummy) variable to take into account sector wise differences in performance. The five sectors are: NAICS 1 (agriculture and related industries), NAICS 2 (mining, utilities and construction), NAICS 3 (manufacturing), NAICS 4 (retail and transportation) and NAICS 5 (information technology and financial services). NAICS 1 and firms falling in the other category have been taken as the base industry sector and hence has no dummy assigned to it.
- **Accounts Receivables**: Level of accounts receivable in million USDs.

The Table 1 below details the survey questions used for constructs with multiple measures:

Construct	Measures	Scale
Information Sharing Transparency	Which applications or data types does your company give electronic access to the [suppliers]	
	Customer demographics	Binary
	Sales forecasts	Binary
	Marketing Plans	Binary
	Sales or campaign results	Binary

	Production schedules	Binary
	Accounts payable	Binary
	Customer loyalty or satisfaction metric	Binary
	Cost structure data	Binary
	Order management	Binary
	Product development specifications	Binary
	Inventory levels	Binary
Information Sharing Complexity	Please indicate how frequently is the following business practices conducted: Customized information sharing with suppliers	Scale of 1 to 4
	Do members of your electronic supply chain query your systems directly for pertinent information on an ad-hoc basis or do they obtain structured reports?	Scale of 1 to 4
SOA Adoption	Has your IT department developed and deployed a companywide services based IT architecture?	Scale of 1 to 4
	Are the following products or technologies widely deployed in your organization – Web services (applications using SOAP, UDDI, XML)?	Scale of 1 to 4

Table 1: Constructs with Multiple Measures

Dataset Validity and Descriptive Statistics

As several variables were collected from one InformationWeek survey, we assessed the potential concern of common method bias using Harman's one factor test (Podsakoff et al. 2003). Results of this test suggest that common method bias is unlikely to be a serious problem in the data. The routine tests for reliability of survey measures are not applicable because we use formative (i.e., summative) scales for our constructs. We assessed the accuracy and validity of survey responses by correlating revenue figures provided by survey respondents with the revenue figures obtained from Compustat. The correlation was found to be very high indicating that the survey responses were accurate and reliable.

Descriptive statistics of variables used in the empirical model are provided in Table 2. Table 3 presents the correlation matrix for the variables. Supply chain performance measures – inventory and accounts payable, firm size and accounts receivable control are used in the log form to account for their large variance and the resulting potential heteroskedasticity in regression results.

Variable	Mean	Std. Dev.	Min	Max
Inventory (log)	7.2081	1.5030	4.20	12.83
AP (log)	7.5263	1.6866	5.11	13.08
AR (log)	7.9273	1.8186	3.21	13.72
Firm Size (log)	9.5958	0.7979	8.52	12.46
Ind_NAICS2	0.1122	0.3165	0	1
Ind_NAICS3	0.3571	0.4804	0	1
Ind_NAICS4	0.1990	0.4003	0	1
Ind_NAICS5	0.2857	0.4529	0	1
IT Intensity	3.6433	3.4239	0	30
SCM Use	0.5738	0.4953	0	1
Transparency	3.2068	2.8202	0	11
Complexity	1.8926	0.9580	1	4
SOA Use	3.0458	0.9592	1	4

Table 2: Descriptive statistics for variables used

		1	2	3	4	5	6	7	8	9	10	11	12
1	Inventory (log)	1.00											
2	AP (log)	0.67	1.00										
3	AR (log)	0.57	0.84	1.00									
4	Firm Size (log)	0.59	0.57	0.69	1.00								
5	Ind_NAICS2	(0.19)	(0.16)	(0.03)	0.03	1.00							
6	Ind_NAICS3	0.04	(0.22)	(0.09)	(0.03)	(0.24)	1.00						
7	Ind_NAICS4	0.03	(0.09)	(0.27)	0.00	(0.15)	(0.38)	1.00					
8	Ind_NAICS5	0.16	0.47	0.40	0.02	(0.19)	(0.50)	(0.30)	1.00				
9	IT Intensity	0.19	0.11	0.13	(0.05)	(0.08)	(0.14)	(0.10)	0.32	1.00			
10	SCM Use	0.13	0.20	0.15	0.10	0.01	(0.05)	(0.07)	0.08	0.07	1.00		
11	Transparency	0.02	(0.14)	(0.06)	0.19	(0.07)	0.16	0.21	(0.33)	(0.06)	0.11	1.00	
12	Complexity	0.16	0.13	0.04	0.12	(0.13)	0.01	0.09	(0.03)	0.08	0.14	0.35	1.00
13	SOA Use	(0.09)	(0.05)	0.03	0.04	(0.02)	(0.02)	(0.04)	0.08	0.08	0.22	0.16	0.15

Table 3: Correlation coefficients for variables used

Regression Methodology

The functional form of the two regression equations is shown below in Figure 2. The empirical model contains two regression equations corresponding to two supply chain performance measures – inventory and accounts payable. The accounts receivable control is used only for estimating the regression equation with accounts payable as the dependent variable.

Primary Model:

$$\text{Ln(Inventory)} = \beta_0 + \beta_1 \text{ Transparency} + \beta_2 \text{ Complexity} + \beta_3 \text{ (Transparency * SOA Use)} + \beta_4 \text{ (Complexity * SOA Use)} + \beta_5 \text{ Ln(Firm Size)} + \beta_6 \text{ SCM Use} + \beta_{7\text{-}10} \text{ Industry Dummies} + \varepsilon$$

Secondary Model:

$$\text{Ln(Accounts Payable)} = \beta_0 + \beta_1 \text{ Transparency} + \beta_2 \text{ Complexity} + \beta_3 \text{ (Transparency * SOA Use)} + \beta_4 \text{ (Complexity * SOA Use)} + \beta_5 \text{ Ln(Firm Size)} + \beta_6 \text{ SCM Use} + \beta_{7\text{-}10} \text{ Industry Dummies} + \beta_6 \text{ Ln(Accounts Receivable)} + \varepsilon$$

Figure 2: Empirical Models

There are two regression equations corresponding to two supply chain performance measures. As both equations are to be estimated using the same data sample, the error terms of the two models are likely to be correlated. This implies that we cannot estimate the two models separately using two different OLS regression models since unbiased OLS estimation requires the error terms to be uncorrelated with each other (Greene 2003). Seemingly Unrelated Regression Estimation (SURE) technique allows for potential correlations between different simultaneously estimated models to obtain consistent and efficient estimates (Srivastava et al. 1987). The Breusch-Pagan test for independence of error terms across equations was rejected providing support for the appropriateness of SURE technique (Greene 2003).

4 Results and Analysis

We tested the research model using our final dataset of 116 large US companies. The two regression equations contained in the research model were tested simultaneously using SURE. Results of the SURE regression analysis are presented below in Table 4. The first part of the figure labeled "primary model" presents the results for inventory as the supply chain performance measure. The second part, labeled "secondary model", presents the results for accounts payable as the supply chain performance measure and accounts receivable as the additional control.

Variable	Primary Model (Inventory)			Hypotheses	Secondary Model (Accounts Payable)			Hypotheses
	Coeff.	p-value	Sig.		Coeff.	p-value	Sig.	
Intercept	-3.1071	0.082	*		0.0907	0.934		
Information Transparency	-0.7420	0.000	***	H1: Supported	-0.5078	0.000	***	H1: Supported
Information Complexity	0.8297	0.043	**	H2: Supported	0.1308	0.593		H2: Not Sig.
SOA Adoption	-0.2627	0.383			-0.3049	0.088	*	
Transparency * SOA Adoption	0.1895	0.001	***	H3: Not Supp'td	0.1359	0.000	****	H3: Not Supp'td
Complexity * SOA Adoption	-0.2467	0.055	*	H4: Supported	-0.0351	0.647		H4: Not Sig.
Firm Size	0.9568	0.000	****		0.2798	0.008	***	
Industry: NAICS 2	1.4800	0.038	**		0.2996	0.482		
Industry: NAICS 3	2.1570	0.002	***		0.0964	0.817		
Industry: NAICS 4	2.2882	0.003	***		1.0779	0.016	**	
Industry: NAICS 5	1.5184	0.034	**		0.5949	0.185		
SCM Use	0.1267	0.556			0.1522	0.241		
IT Intensity	0.0961	0.051	*		0.0647	0.032	**	
Accounts Receivable					0.6558	0.000	****	
Chi-Square	117.48	0.000	****		6.7700	0.000	****	
R-Square	0.5032	N = 116			0.4529	N = 116		

Signif. codes: 0.1: *, 0.05: **, 0.01: ***, 0.001: ****

Note: Supply chain performance is measured in an inverse scale. Negative coefficients mean better

Table 4: SURE Results

The results of the primary model with inventory as the supply chain performance measure support the main effects hypotheses (H1 and H2) that information sharing transparency improves supply chain performance while information sharing complexity reduces supply chain performance. This adds an important dimension to the research on information sharing in supply chain. We find that although higher degree of information sharing (information sharing transparency) does lead to higher levels of supply chain performance; it is not the only mechanism by which the information sharing process affects performance. We find that the complexity of the information sharing process is important as well in determining supply chain performance. Thus, we show that managers and researchers need to consider not only "what" information is shared in the supply chain but also "how".

Further, we find significant support for the hypothesis (Hypothesis 4) that SOA use mitigates the negative impact of information sharing complexity. This provides support for the practice assertion that SOA adds flexibility to IT system and helps combat complexity. However, the impact of SOA use on the relationship between information sharing transparency and supply chain performance (Hypothesis 3) was found to be negative and significant. This means that, in contrast to the posited effect direction in Hypothesis 3, SOA use reduces the positive impact of information sharing transparency on supply chain performance. Although this does not support our hypotheses, this is in agreement with concerns raised in practice media about governance issue associated with SOA (Coticchia 2006).

Results for the secondary model with accounts payable as the supply chain performance measure are similar to the primary model for hypotheses 1 and 3. The relationships considered in hypotheses 3 and 4 were not statistically significant in the secondary model. Thus, we find additional support for the positive relationship between information sharing transparency and supply chain performance (H1). We also find additional support for the negative interaction effect between SOA use and the relationship between information sharing transparency and supply chain performance (H2). While we did not find statistically significant support for hypotheses 2 and 4 in the secondary model, the coefficient values are in the hypothesized direction. None of the statistically significant results in the secondary model are inconsistent with the corresponding results in the primary model.

The Table 5 below summarizes the results of the two regression models. The relationships that are supported by both the models are labeled as strong support while the relationships that are supported by the primary model with statistically insignificant results in the secondary model are labeled as having moderate support.

No	Relationship	Support
1	Information sharing transparency improves supply chain performance	Strong
2	Information sharing complexity reduces supply chain performance	Moderate
3	SOA use reduces the positive impact of information sharing transparency on supply chain performance	Strong
4	SOA use mitigates the negative impact of information sharing complexity on supply chain performance	Moderate

Table 5: Summary of Regression Results

The results show that overall, SOA adoption leads to performance improvements. This represents the first broad empirical evidence of business value of SOA adoption using objective performance measures. Previous studies on business value of SOA had either used a case study approach (Lim et al. 2003) or used perceptual measures with potential for common method bias (Kumar et al. 2007). As the coefficient of SOA Adoption in the model with interactions is not significant, we can conclude that the entire impact of SOA adoption in supply chain performance is mediated through the two interaction effects.

Our results show that while SOA adoption does lead to tangible business value in general, its specific impact depends on the characteristics of the processes on which SOA is implemented. While we find that SOA is successful in mitigating the negative impact of process complexity. However, we also find that SOA reduces the benefits attached to a more transparent information sharing regime. This can be due to problems in governing SOA systems when a large number of information elements are being managed.

5 Discussion and Conclusion

Our goal in this paper was to study the impact of characteristics of information sharing process and SOA adoption on supply chain performance. We developed our theoretical model by integrating operations and information systems research streams. We used secondary data about characteristics of information sharing process and SOA adoption levels from InformationWeek and supply chain performance and other financial information from Compustat to build a dataset of 305 large publicly traded US companies. We used this dataset to test our research model using OLS.

We find that information sharing transparency is positively associated with supply chain performance while information sharing complexity is negatively associated with supply chain performance. Both these results support our main effects hypotheses. Our results emphasize that researchers need to study the information sharing in supply chain in the context of the process used for information sharing. While this does not invalidate conclusions from previous analytical research (Cachon et al. 2000; Lee et al. 2000a) that show positive performance benefits arising from information sharing in supply chain, it shows that actual benefits gained in practice may be lower and may depend upon the design of process and technology architectures used for information sharing.

In the case of interaction effects with SOA adoption, we find that as expected, SOA adoption reduces the negative impact of information sharing complexity. This confirms the flexibility benefit of SOA which helps in managing the complexity of the information sharing process. The interaction of SOA adoption with information sharing transparency is however negative and it reduces the performance benefits associated with information sharing transparency. The negative effect can be seen with practitioner concerns about SOA governance (Kobielus 2006). The Agile Journal, a practitioner publication, reports that "*SOA's loosely-coupled nature ... greatly increases the number of moving parts that must be managed and governed… Organizations that don't apply governance processes ... run the risk of ending up with a collection of point-to-point services that simply add another layer of technology spaghetti"* (Coticchia 2006). With high levels of information sharing transparency, SOA governance becomes even more difficult and that in turn may affect performance negatively. Previous studies have also shown that too much information can distract managers from more relevant data and reduce performance (Steckel et al. 2004).

Kim et al. (2006) note that prior research in information systems has taken the use of EDI as a surrogate measure for electronic information transfer. Venkatraman et al. (1989) argue that there is a mistaken tendency to equate electronic integration with EDI in existing electronic integration research. In this study we have avoided the problem by directly measuring elements of information sharing and not relying on surrogate measures of electronic integration.

As Subramani (2004) mentions, research in supply chain has tended to focus more on the focal firm and less on the suppliers to the focal firm. Our dependent variable, although measures a part of the operations of the focal firm, is also beneficial to the suppliers and hence is in line with the integrative supply chain research advocated by Subramani (2004).

5.1 Post-Hoc Analysis

To counter the argument that our results may be due to short term changes in our dependent variables, especially accounts payable, we repeated the analysis with one year lagged dependent variable (inventory and accounts payable for one year after the survey). In the modified regression model, we use the one year lagged values of dependent variables (inventory and accounts payable) and financial variables while keeping the hypothesized variables at the previous level. This regression, hence, shows the effect of SOA use and information sharing level in year 2002 on the supply chain performance of year 2003. Using lagged variables is an accepted practice in business value of IT literature to account for the fact that IT systems implementation precedes the benefits accruing from it by a significant time.

The lagged model is estimated using SURE, similar to the original model estimation. The results of the lagged model are provided in Table 6 below.

Variable	Lagged Primary Model (Inventory)			Hypotheses	Lagged Secondary Model (AP)			Hypotheses
	Coeff.	p-value	Sig.		Coeff.	p-value	Sig.	
Intercept	-3.8403	0.062	*		0.4482	0.686		
Information Transparency	-0.5295	0.018	**	H1: Supported	-0.5096	0.000	****	H1: Supported
Information Complexity	0.7663	0.110		H2: Not Sig.	0.2990	0.233		H2: Not Sig.
SOA Use	-0.2057	0.564			-0.2188	0.242		
Transparency * SOA Use	0.1316	0.043	**	H3: Not Supp'td	0.1364	0.000	****	H3: Not Supp'td
Complexity * SOA Use	-0.1754	0.247		H4: Not Sig	-0.0742	0.350		H4: Not Sig.
Firm Size	1.0286	0.000	****		0.1862	0.093	*	
Industry: NAICS 2	1.4296	0.081	*		0.3422	0.430		
Industry: NAICS 3	2.0824	0.009	**		0.0009	0.998		
Industry: NAICS 4	2.0445	0.019	**		0.9175	0.044	**	
Industry: NAICS 5	1.6639	0.043	**		0.4725	0.300		
SCM Use	0.0589	0.812			0.1637	0.212		
IT Intensity	-0.0602	0.284			0.0577	0.057	*	
Accounts Receivable					0.6894	0.000	****	
Chi-Square	80.08	0.000	****		660.89	0.000	****	
R-Square	0.4084	N = 116			0.8518	N = 116		

Signif. codes: 0.1: *, 0.05: **, 0.01: ***, 0.001: ****

Note: Supply chain performance is measured in an inverse scale. Negative coefficients mean better

Table 6: SURE Results for Lagged Models

Results of the lagged model are broadly similar to the main results presented in Table 4. The direction and significance of results remain consistent with the main results for the impact of information sharing transparency on supply chain performance and the negative interaction between SOA use and the relationship between information sharing transparency and supply chain performance. Thus, the two strongly supported relationships from the main analysis are also supported in the lagged variable analysis.

Two relationships that were moderately supported by the main regression results are found to be not statistically significant in the lagged model even though their coefficients are in the hypothesized direction. However, this is not inconsistent with the main results as some loss of power is expected with the lagged variable analysis. As no statistically significant relationship in the lagged variable regression is inconsistent with a corresponding relationship in the main regression analysis, we can consider the lagged results to be in alignment with the main results.

5.2 Research Implications

This research adds to the business value of IT literature by empirically demonstrating business value of specific technology architecture in a specific process context. The literature on business value of IT has progressed from overall studies of productivity with several mixed results (Brynjolfsson 1993; Brynjolfsson et al. 1998) to more process oriented studies that capture the business value of IT at the process stage (Mukhopadhyay et al. 1997). In addition, overall firm level measures of business value of IT tends to under-measure the benefit as productivity benefits are competed away in the form of consumer surplus (Hitt et al. 1996). We continue the movement towards process level studies by basing this research in a specific process context and measuring business value using objective process level measures. We also show how SOA interacts with process characteristics which can provide a base for future studies that integrate process and technology elements in a unified model.

Operations management researchers have studied the impact of information sharing on supply chain performance mainly through analytical models and have not considered technology issues. We extend this research by bringing an empirical dimension and integrating with information systems research. This is in line with recent trends in operations research. As Pannirselvam et al. (1999) noted in their survey of operations management research: "*OM research shows a trend toward more integrative research … with other business disciplines …*

this kind of integrative research may require us to me more innovative in the future in our selection of methodologies used." This study further adds to research by studying the interaction between technology adoption and process characteristics.

5.3 Managerial Implications

There has been a din of vendor supported publicity about SOA. Firms like IBM and Oracle are supporting SOA and have produced several reports or white papers suggesting significant benefits of SOA adoption. It is difficult for managers of user firms to get unbiased opinions about potential benefits and pitfalls of SOA. In this paper we present an academic investigation of SOA adoption and uncover both positive and negative impact of SOA adoption on supply chain performance. We believe that our results will help managers in getting a holistic picture of SOA and its performance impact.

There has been a rich theoretical literature about information sharing in supply chains. However, the managerial utility of the theoretical works have been questioned. As Li et al. (2006b) mentioned: "*while information sharing is important, the significance of its impact on the performance of a supply chain depends on what information is shared, when and how it is shared, and with whom.*" This study analyzed the how part of information sharing and provides managers with more tangible directions to implement information sharing and SOA adoption in supply chains for improving supply chain performance. This study shows that managers need to strike a balance between sharing information in the supply chain and controlling the complexity of the information sharing process. Our results also show that managers can control the negative impact of process complexity by adopting SOA for managing their processes. However, this approach is only likely to be productive if the level of transparency in information sharing process is controlled as well.

Our study has important implications for SOA vendors like IBM, Sun and Oracle. Our results emphasize that even though there are substantial flexibility benefits to SOA, which helps counter complexity, the governance issues related to efficient management of an SOA environment when information sharing transparency is high deserves their attention. Otherwise governance problems could have an adverse impact on the scale of SOA adoption and companies that have high levels of process transparency but low process complexity would not be able to derive significant benefits from SOA adoption.

5.4 Limitations and Future Research

Empirical studies are naturally constrained by the availability and granularity of data. Although we have tried to go into process and technology level details in this research, our measure of SOA adoption is still coarse and does not take into account individual SOA standard elements being adopted by firms. Further, the data for the study was collected in 2003 and it can be argued that much development has taken place in SOA design, development and adoption since then. However, the basic nature and fundamental principles behind SOA remain the same and hence we believe that the results are still valid and relevant for current practice.

In this study, information sharing transparency only considers the amount (how many information elements – inventory, demand, promotion etc.) of information sharing. We do not consider different types of information to have different main effect on supply chain performance and different interaction effects with SOA adoption. Previous research has classified information sharing in supply chain in three categories: transactional, operational and strategic (Li et al. 2006a). Our research can be extended to study whether different categories of information sharing have different impact on supply chain performance.

Our selection of accounts payable as a dependent variable can be considered a limitation as accounts payable is not a traditional measure of supply chain performance. However, as we have conducted several robustness checks including running the model with inventory data as well, we are confident of our selection of accounts payable as a measure of supply chain performance. Our research can be extended by using other process level indicators of supply chain performance as well.

5.5 Conclusions

In spite of the billions of dollars being invested by firms every year in developing and deploying SOA, there has been no broad based empirical investigation of the performance impact of SOA adoption. This study contributes to a better understanding of the impact of SOA adoption through an empirical study of SOA adoption and information sharing in supply chain for a cross section of large US firms. We found that adoption of SOA leads to better performance. While SOA adoption helps to mitigate the negative effects of the complexity of the information sharing process, it also reduces the positive impact of information sharing transparency. Our findings extend the business value of IT as well as operations management research into supply chain and SOA. The results also provide insights for IT managers to make informed decisions about SOA adoption and information sharing process design. Although this study has certain limitations, we believe it provides a strong base for future research to further explore the information sharing process in supply chain and organizational impact of SOA adoption.

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