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Abstract

We empirically analyze the impact of SOA adoption on performance benefits of information sharing in supply chains using a dataset of 305 large 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 adoption is successful in mitigating the negative effects of process complexity. Interestingly, SOA adoption 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 adoption. 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: Service Oriented Architecture, SOA, Supply Chain Management, Information Sharing

Introduction

Advances in Information Technology (IT) have had a tremendous impact on how firms manage their supply chain. 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. 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 decrease cost and improve customer service (Magretta 1998). Essentially, 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. 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, success in achieving high supply chain performance has been far from the norm. Many companies have suffered setbacks in electronically integrating their suppliers. Most 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% (Lewis 2007). One of the main reasons for disappointing performance levels in electronic supply chains is the complexity of processes and technology involved. In this paper 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.

Information sharing in supply chains have been actively studied by both information systems as well as operations researchers. Information systems researchers have focused on business value of 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 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. Similarly, in a comparison of traditional information sharing (only order information shared) with full information sharing policy (order and inventory information shared), Cachon et al. (2000) found that full information sharing leads 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 should be achieved to seek optimal 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 adoption on the performance benefits of information sharing in supply chain. We fill the research gap in this paper 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 have considered the emerging and increasingly popular technology architecture for inter-organizational information systems – Service Oriented Architecture in this paper. SOA is a technology architecture where the basic element of design, development and use of software solutions is a service (Papazoglou et al. 2003). Applications communicate with each other in such architectures through services. 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). The client application and the service provider communicate via standard protocols (e.g. SOAP, HTTP) and exchange information using standard data formats like XML.

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. Among 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 adoption. 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 adoption, especially about impact of SOA adoption on the 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 adoption 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). We bridge this research gap in this study by empirically analyzing the impact of SOA adoption on performance of supply chains. This is one of the first broad empirical studies to provide evidence of business value of SOA adoption and to explore the mechanisms of supply chain performance improvement associated with SOA adoption.

In this paper we attempt to bring together two research streams – one belonging mainly to operations stream while the other to information systems stream. We combine the operational issue of how the degree as well as 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. Our research model looks at interactions between constructs from the two research streams and effectively integrates them.

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 paper contributes to the operations management literature by first 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, we extend the research by showing that apart from the degree of information sharing, the process of information sharing also affects performance. The paper 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, we provide IT managers not only with an assessment of the impact of information sharing and SOA adoption on supply chain performance; we show how the two interact for a given process context. 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. This is followed by formulating the research model and detailing 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. Questions used for collecting the dataset used in the paper are presented in the Appendix along with other figures and tables.

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 the traditional focus of IT investments (e.g. EDI and SCM systems) and provide 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 have framed the impact of SOA adoption on supply chain performance in terms of two main 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: production information, customer information, financial information, marketing and promotion information etc. Complexity of information sharing relationship measures "how" information is shared: custom reports, real time access, ad-hoc reporting, scheduled access etc. We first look at how these characteristics of the information sharing process impact the performance of the supply chain and then we focus on how adoption of SOA moderates their impact on supply chain performance.

Information Sharing in Supply Chain

Information sharing in supply chain has been studied in depth in both the operations management as well as information systems 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. In 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. 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. Further, 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. Similarly 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.

Overall, both operations management and information systems literature indicate that larger degree of information sharing results in improvements in supply chain performance. We define this aspect of the information sharing process 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 (Cachon et al. 2000; Lee et al. 1997; Lee et al. 2000a), etc. 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. Hence, we posit our first hypothesis:

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

While transparency effectively 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 measures increase the complexity of the information sharing process. The complex information sharing process necessitates creating dedicated IT infrastructure including IT labor to maintain these functions. Further, 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 of the information sharing process also results 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.

To understand the complexity in the information sharing process we use the categorization by Campbell (1988) to use complexity as an objective task characteristic – in this case the characteristic of the information sharing process. This is consistent with the description by March et al. (1967) that complex tasks are characterized by uncertain alternatives or consequences of action and 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 five categories based on the predeterminability of the information requirements – (i) genuine decision task (ii) known, genuine decision task (iii) normal decision task (iv) normal information processing task (v) automatic information processing task. In this context, task complexity is the degree of determinability of the task. The predeterminability of the task includes the predeterminability 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. So the knowledge about the task can be associated with the structured level of the task and hence the complexity of the task. If there is a lack of knowledge then the task becomes more complex. In our case involving the information sharing across supplier and partner, the lack of knowledge about the information format or needs then we would expect the information-sharing task to be more complex. This is consistent with the data in our dataset where the complexity is more when the need is for information sharing to produce ad hoc reports or to access real-time information.

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. Further, complexity has been shown to impair assimilation of information and lead to larger errors in decision making (Plumlee 2003). This complexity of managing, understanding and using the information sharing process is the second dimension of information sharing in supply chain. The information sharing complexity 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 capture two different dimensions of the information sharing process. We believe that these two dimensions provide a more holistic assessment of information sharing in supply chains than just the amount of information that is shared.

Service Oriented Architecture

Proliferation of specialized software systems like ERP, SCM, CRM, EDI etc. have made integration of software systems costly and difficult. To enable information sharing across organizational departments and information systems a new breed of enterprise and web technologies (e.g. web services) and architectures (e.g. SOA) have emerged which provide a platform for integration. These integrating technologies use standardized protocols and data formats for exchanging information across enterprise applications. By supporting sharing of information and automation of underlying business processes, these integrating technologies improve performance and business agility (Subramani 2004). Malhotra et al (2005) studied the relationship configurations in supply chain relationships and the creation of new knowledge using an absorptive capacity framework. Their work provides important insight into the mechanisms in inter-organizational systems, information exchange and the role of supply chain configurations. Their research however was technology agnostic and instead focused on the interface standards. Subramani (2004) investigated the benefits of IT use in supply chains and found that relationship specific deployment of IT played a mediating role on the benefits from supply chain management systems. Chatterjee et al (2002) have also described the factors affecting the assimilation of web technologies in ecommerce firms.

There is a small but growing body of literature that describes this 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 further encourage a line of inquiry into how firms achieve this agility and what technologies lead to flexible business processes and business models. Their research, while providing solid theoretical foundations, lacked any empirical support that will enlighten managerial decisions to invest in these new technologies including web services and SOA. Chatterjee et al (2002) also 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. These studies point out the need to analyze specific phenomena involving the adoption of integrative web technologies and architecture like SOA and their impact on organizational performance.

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 organizations. It also provides a way to combine the business services across partner organizations and offer a unified service to the end user application. Recent surveys have found evidence of SOA platforms being used widely and SOA deployment growing rapidly (Iyer et al. 2003). Many large corporations have had successful implementations of web services and SOA in their ecommerce channels and supply chain. Lim et al. (2003) provide examples of Motorola (estimated benefit of about $100,000 to $150,000) and General Motors (estimated operating cost reduction of $1000 per vehicle). Several studies have suggested that adoption of SOA leads to performance benefits in supply chain (Murtaza et al. 2004).

Adoption of SOA in the supply chain can be expected to impact 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 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.*

Second, SOA is expected to make IT systems more flexible where changes can be accommodated easily (Gartner 2005). Complexity of 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). In a CIO/Computerworld survey, 77% of the respondents believed that SOA adoption will bring greater business flexibility (Koch 2006). Thus, we expect that SOA adoption will be helpful in firms and suppliers to manage the complexity of the information sharing process. SOA adoption would thus help firms mitigate the negative performance impact on information sharing complexity (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 effectively capture the process and technology level relationships between information sharing and supply chain performance.

Research Design

We can conceptualize hypotheses 1 and 2 as the main effects and hypotheses 3 and 4 as interaction effects. The research design is shown in Figure 1 in the Appendix. 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).

-- insert figure 1 around here --

Data and Methodology

Data for this study has been collected from two sources. Data used in this paper about SOA adoption and the characteristics of 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. 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).

Construct Operationalization and Variable Definitions

The variables used in the empirical model are defined below. Measures for constructs with multiple measures are mentioned in Table – 1 in the Appendix.

Variables from InformationWeek Survey:

- **Information Sharing Transparency**: This is a 11 item summative index indicating different information elements that are shared between the firm and its suppliers. The items included in the index are explained in Table – 1 in the Appendix.
- **Information Sharing Complexity**: This is a 3 item summative index indicating the complexity of information sharing process. The items that form the index include whether custom reports are provided to suppliers, frequency of data access allowed to supplier and whether the supplier is allowed access to ad-hoc reports (Table – 1).
- **SOA Adoption**: This is a 3 item summative index indicating the level of SOA and web technologies adoption in the focal firm. The items that form the index include adoption of XML, adoption of web services and broad implementation of service oriented architecture (Table - 1).
- **SCM Use**: Binary variable indicating whether the focal firm uses supply chain management systems to interact with its suppliers.

Variables from Compustat:

- **Supply Chain Performance**: Supply chain performance is measured as the level of accounts payable in the supply chain. Compared to the traditional measure of supply chain performance like inventory and lead times, accounts payable is an unconventional measure. However, we have refrained from using inventory as a dependent variable as our sample consists of industries as different as manufacturing and software. Different industries have very different inventory profile and some industries do not even have significant inventories. Further, services are the largest part of US economy and we want the scope of the study to include both materials as well as services supplier. Inventory does not capture service suppliers while accounts payable does. For checking the robustness of accounts payable as a measure of supply chain performance, we checked for correlation between accounts payable and inventory levels and found the correlation to be as high as 73%, indicating that accounts payable (like inventory) is a good measure of supply chain performance. For additional validity, we repeated the analysis with inventory as the dependent variable and found similar results.

  We have considered accounts payable as an inverse measure of supply chain performance – lower accounts payable indicates better supply chain performance (similar to inventory – lower inventory represents better supply chain performance). It can be argued that firms should actually look for higher accounts payable as delaying payments to suppliers is similar to an inexpensive and flexible source of financing for the firm. However, 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. 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. Even though an increase in accounts payable may lead to higher profitability – a sustained high level of accounts payable indicates clogged processes and inefficient information sharing. Information systems researchers have previously considered accounts payable as an inverse measure of supply chain performance. Mukhopadhyay et al. (2003) showed that electronic integration in supply chain leads to reduction in delays in payments to suppliers. From an entire supply chain system point of view, 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.
- **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.

Because several variables were collected from the 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 Figure 2 in the Appendix. Figure 3 in the Appendix presents the correlation matrix for the variables.

-- insert figure 2 and figure 3 around here --

The dependent variable in our empirical model is continuous, which lends itself well to ordinary least squares ("OLS") analysis. The functional form of our empirical model is as follows:

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

Results and Analysis

The research model was tested using OLS regression. We conducted the Breusch-Pagan / Cook-Weisberg test for heteroskedasticity (Hamilton 2003) on the OLS models and found that the null hypothesis of no heteroskedasticity was rejected indicating that the models suffered from significant heteroskedasticity problem. To take care of the problem we conducted OLS analysis with Huber-White robust estimates of the standard errors. We tested these regression models with robust standard errors for multicollinearity and found the variance inflation factors ("VIF") (Green 2000) to be less than 4, well below the acceptable limit. Thus, the OLS model with robust standard errors satisfies the conditions for providing unbiased, consistent and efficient estimates of regression coefficients. Results of the OLS regression analysis with robust standard errors are presented in Figure 4 in the Appendix.

-- insert figure 4 around here --

The OLS results support the main effects hypotheses (H1 and H2) that information sharing transparency improved 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 adoption 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 adoption 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 Hypothesis 3, SOA adoption 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).

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.

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 paper we have avoided the problem by directly measuring elements of information sharing and not relying on surrogate measures of electronic integration.

To counter the argument that our results may be due to short term manipulation in our dependent variable, accounts payable, we repeated the analysis with one year lagged dependent variable (accounts payable for one year after the survey) and found that all results are identical in significance and direction. Results of the lagged model are provided in Figure – 5 in the Appendix for comparison. 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. Getting similar results from both the simultaneous as well as lagged variable model suggests that the results are robust.

-- insert figure 5 around here --

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).

Research Implications

This paper 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 paper further adds to research by studying the interaction between technology adoption and process characteristics.

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 paper 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 paper 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.

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 paper, 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 paper, 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.

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.

Appendix

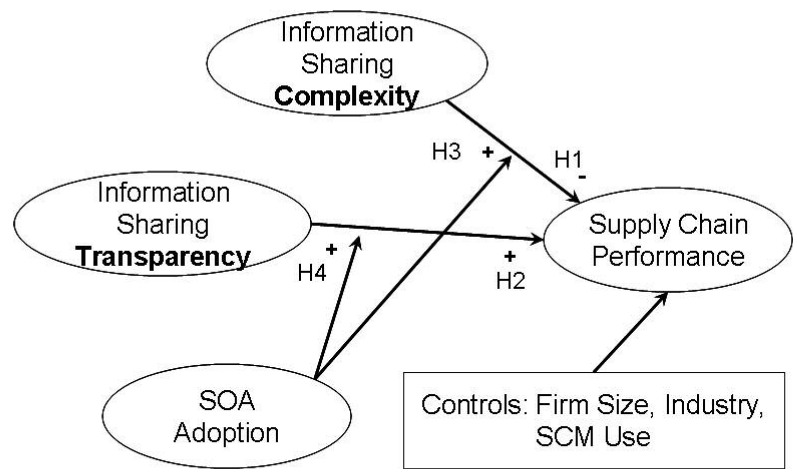

Figure 1. Research Model

Table 1. Construct Measurement (abridged)

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
	Does your organization have the business processes in place to take advantage of real time information (instant transmission of	Scale of 1 to 4

	key data across and beyond the enterprise)	
SOA Adoption	Has your IT department developed and deployed a company wide services based IT architecture?	Binary
	How does your organization use XML?	Binary
	Are the following products or technologies widely deployed in your organization – Web services (applications using SOAP, UDDI, XML)?	Binary

Variable	Mean	Std. Dev.	Min	Max
SC Performance	8,546.51	42,543.93	3.07	414,886.00
Firm Size	10,602.19	22,381.45	791.56	245,308.00
Ind_NAICS2	0.0872	0.2825	0	1
Ind_NAICS3	0.3872	0.4877	0	1
Ind_NAICS4	0.1897	0.3926	0	1
Ind_NAICS5	0.2821	0.4506	0	1
Complexity	1.8299	0.9601	0	4
Transparency	3.0253	2.6596	0	11
SOA Adoption	0.3828	0.4865	0	1
SCM Use	0.5752	0.4948	0	1

Figure 2. Descriptive Statistics

		1	2	3	4	5	6	7	8	9	10
1	SC Performance	1.0000									
2	Firm Size	0.2771	1.0000								
3	Ind_NAICS2	-0.0576	-0.0540	1.0000							
4	Ind_NAICS3	-0.1480	0.0118	-0.2456	1.0000						
5	Ind_NAICS4	-0.0831	0.0346	-0.1496	-0.3846	1.0000					
6	Ind_NAICS5	0.3005	0.0134	-0.1937	-0.4982	-0.3033	1.0000				
7	Complexity	0.0438	0.0946	-0.1294	0.0115	0.0956	-0.0347	1.0000			
8	Transparency	-0.1784	0.1627	-0.0684	0.1618	0.2097	-0.3326	0.3465	1.0000		
9	SOA Adoption	-0.1199	-0.0391	0.0343	0.0274	-0.0624	0.0165	0.1504	0.1666	1.0000	
10	SCM Use	0.1073	0.1194	0.0127	-0.0452	-0.0695	0.0730	0.1424	0.1117	0.2181	1.0000

Figure 3. Correlation Coefficients

Variable	Supply Chain Performance			Hypotheses
	Coeff.	p-value	Sig.	
Intercept	-8072.69	0.313		
Information Sharing Transparency	-5277.02	0.010	**	H1: Supported
Information Sharing Complexity	9985.37	0.077	*	H2: Supported
SOA Adoption	-6353.32	0.346		
Transparency * SOA Adoption	4969.17	0.013	**	H3: Not Supp'td
Complexity * SOA Adoption	-10726.00	0.074	*	H4: Supported
Firm Size	0.47	0.066	*	
Industry: NAICS 2	-290.89	0.947		
Industry: NAICS 3	970.01	0.814		
Industry: NAICS 4	-189.49	0.968		
Industry: NAICS 5	24133.00	0.001		
SCM Use	10681.89	0.003	****	
F-Stat	4.21	0.000	****	
R-Square	0.14			

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

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

Figure 4. Results

Variable	Supply Chain Performance (time lagged)			Hypotheses
	Coeff.	p-value	Sig.	
Intercept	-10070.01	0.284		
Information Sharing Transparency	-6198.34	0.012	**	H1: Supported
Information Sharing Complexity	12079.86	0.071	*	H2: Supported
SOA Adoption	-5198.59	0.483		
Transparency * SOA Adoption	5852.85	0.015	**	H3: Not Supp'td
Complexity * SOA Adoption	-13537.24	0.061	*	H4: Supported
Firm Size	0.51	0.070	*	
Industry: NAICS 2	-856.65	0.868		
Industry: NAICS 3	1307.51	0.787		
Industry: NAICS 4	-528.84	0.924		
Industry: NAICS 5	27068.89	0.002		
SCM Use	12090.81	0.003		
F-Stat	4.21	0.000	****	
R-Square	0.14			

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

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

Figure 4. Results of the lagged model

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