**WHY IS WEB-BASED SUPPLY CHAIN MANAGEMENT POPULAR IN CHINA? A FACTOR ENDOWMENT’S PERSPECTIVE**

*Completed Research Paper*

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**Abstract**

Web-based system-to-human integration and direct system-to-system integration are alternative information technologies for supply chain management. Although the system-to-system mode is known to be more effective than the Web-based mode for data sharing, the web-based mode is dominant in the supply chain of Chinese firms. Is it a suboptimal or the most appropriate choice? We develop an analytical model to investigate how a manufacturer selects an optimal mode from competing technologies, including manual mode, Web-based mode and system-to-system mode. The contribution of this study is three-fold. First, the expected degree of information sharing influences the manufacturer’s selection. Manual mode is the optimal selection when the expected degree of information sharing is low, whereas system-to-system mode is the optimal choice when the expected degree is high. When the expected degree of information sharing is intermediate, Web-based mode is the optimal choice. Second, based on factor endowment theory, we find that labor endowment and technology endowment can influence the adoption intervals of these three modes. And third, when labor endowment is on the decline and technology endowment is on the rise in the early stage, the Web-based mode is the optimal choice than manual mode or system-to-system mode. Theoretical and practical implications of these findings are discussed.

**Keywords:** Inter-organizational systems, information sharing modes, Web-based mode, system-to-system mode, factor endowment, analytical model
Introduction

Supply chain information systems (SCIS) can be classified generally into two categories based on how data sharing is accomplished: the electronic data interchange (EDI) in direct system-to-system mode and Web-based system-to-human mode (Auramo et al. 2005; Kauremma et al. 2009; Soliman and Janz 2004). By a direct data link, EDI facilitates supply chain firms to interchange information with high efficiency and accuracy. In system-to-system mode, a firm can access its supply chain partners’ relevant data by using data format transformation techniques through an electronic interface (Auramo et al. 2005; Kauremma et al. 2009; Sanders 2008; Saraf et al. 2007; Subramani 2004). While in Web-based mode, a manufacturer provides its supply chain partners with a user name and password, and then its partners can login the manufacturer’s system to download relevant data (Soliman and Janz 2004; Subramaniam and Shaw 2002; Subramaniam and Shaw 2004). In addition to SCIS approaches, traditional manual mode such as telephone, fax and e-mail can also help supply chain firms to share information. Most research efforts have been concentrated on EDI and system-to-system mode, which have been found to bring in not only operational benefits, such as cutting inventory and logistic costs and reducing miscommunications (Auramo et al. 2005; Craighead et al. 2006; Mukhopadhyay et al. 1995; Saraf et al. 2007), but also strategic benefits, such as supporting joint R&D and rapid expanding service levels for supply chain firms (Downing 2010; Hameri and Niheitla 1997; Sanders 2008; Subramani 2004). Few researchers have paid attention to the value of Web-based mode in a manufacturer-supplier dyadic relationship, and some even suggest that Web-based mode is of little value and should be used only when a firm is under technological or budget constraints (Auramo 2005; Kauremma et al. 2009; Muffatto and Payaro 2004).

During the period 2010.07-2011.03, we investigated 7 pairs of manufacturers and suppliers with regard to their information sharing modes and found that in China many supply chain firms still use manual mode to share information. Among those firms that have implemented SCIS, including leaders in their respective industries, most choose Web-based mode instead of system-to-system mode to share information. As far as we know, firms in developed countries generally use the system-to-system mode to share supply chain information, such as Dell and its worldwide suppliers, Toyota and its suppliers. But in China firms generally use Web-based mode, even among the industry leaders such as Midea, JeansWest, Konka, Haier and Lenovo. Interestingly, international firms in China also choose to use Web-based mode to cooperate with their Chinese suppliers, such as Honda (Guangzhou), Toyota (Guangzhou), SNIFT, Nokia (China), Motorola (China). Even when a manufacturer and its supplier have high information technology capability and mature ERP systems, and when they all recognize the value of the system-to-system mode, and have large scale supply and distribution operations, they still choose Web-based mode. Thus, there comes an interesting question: why do supply chain firms in China generally choose Web-based mode but firms in developed nations usually adopt system-to-system mode? This phenomena also contradicts the generally believed view that Web-based mode will not be widely adopted because of its low value creation. Motivated by this practical difference and theoretical inconsistency, we attempt to investigate how a supply chain firm selects its information sharing mode from competing options and what the contributing factors are.

Studies on SCIS selection and adoption have flourished in recent years, and two specific areas have attracted a lot of attention. Research focusing on SCIS selection suggests that SCIS should fit with supply chain structure. For example, if the manufacturer only has one supplier for a certain material, then the SCIS between them should be an electronic monopoly (Choudhury 1997). But in these works few contextual factors have been considered. Researchers focusing on SCIS adoption intention suggest that organizational and individual factors influence the SCIS adoption. Institutional stream suggests mimetic, coercile, and normative pressures affect SCIS adoption (Liu et al. 2010; Teo et al. 2003). Technology adoption stream suggest perceived ease of use and perceived usefulness influence the intention to adopt and use information technology or information systems (Davis 1989; Davis et al. 1989; Venkatesh et al. 2003). These two streams mainly focus on the commonality of information systems adoption and provide little insights into how a firm chooses between alternative forms of inter-firm information systems. Besides these two streams, previous studies also discussed other organizational and technological factors such as knowledge sharing, trust, result demonstrability, data security, scalability and so on (Karahanna et al. 1999; Ke et al. 2009; Majchrzake et al. 2003; Soliman and Janz 2004), but an
important element -factor endowment- has not been adequately discussed (Quan et al. 2005), which is the efficiency and advantage to use labor or technology. During our investigation, we observed that factor endowment had a significant influence on the selection and adoption decisions about information sharing modes for supply chain firms in China, which motivated us to focus on factor endowment in this paper.

Factor endowment refers to the amount of production factors such as land, labor, capital, and entrepreneurship that a country possesses and can exploit for manufacturing, which determines the cost of certain products and influences a country’s export-import patterns (Jones 1956; Leamer and Bowen 1981; Rybczynski 1955). Although researchers have used this theory to explain labor division in international trade, the factor endowment theory enlightens us by emphasizing the importance of utilizing the dominant factors to maximize the benefit in a firm or a country. In economic theories, labor and technology are two of the most important production elements, and labor endowment and technology endowment (technology is a primary investment of capital) determine the optimal input proportion for a firm or a country (Arrow et al. 1961; Solow 1956). Labor endowment is originally used to denote the labor abundance of a country. But in analytical studies, it is usually measured by labor cost for certain work or labor outcome under certain labor cost budget (Mayer 1974; Weiss 1980). So we can consider it as the necessary labor cost for certain degree of information sharing in the SCIS context. The data quoted by National Bureau of Statistics of China based on International Labor Organization shows that in 2007 the average wage of manufacture industry workers in China was $0.78/hour, while in USA it was $30.6/hour and in Germany it was $45.5/hour. Technology endowment is usually measured by the return to scale (Cobb-Douglas technology) and in essence is a description of the efficiency of production. So we can consider technology endowment as the capability to effectively use all kinds of production and management technologies in the SCIS context. Facing the problem of information technology selection and adoption, supply chain firms have to make a tradeoff between information technology and labor. This paper explores how factor endowment influences the selection and adoption of supply chain information sharing mode, focusing on the following two issues. While studies suggest that system-to-system mode is more effective than Web-based mode and should be more attractive, why do some firms still choose the Web-based mode? And why do firms in the developed countries in general choose system-to-system mode while firms in China usually choose Web-based mode? By addressing these two issues, we hope to extend the previous perspectives on IS adoption at individual and organizational levels to IS selection at the organizational and country levels.

**Analytical Model Development**

In this section, we first develop a two-stage model for information sharing mode selection, and then examine the decision variables for each specific mode. The central focus in this model is information sharing. The manufacturer would like the supplier to share information with it so as to reduce the cost of its production. But the supplier cannot get the profit of shared information directly. So the supplier wouldn’t invest in information systems or share any information unless the manufacturer gives it some kind of incentive. Then the information sharing game can be described as the following two stages: in stage 1 the manufacturer sets an incentive mechanism and in stage 2 the supplier chooses to share how much information accordingly. The optimal information sharing mode will be selected by comparing the final benefit to the manufacturer in different modes. Details are in the subsection.

**A Two Stage Model**

In this study we examine the relationship between a manufacturer and one of its suppliers. In this dyadic relationship, the manufacturer can decide the partition coefficient of information sharing benefit while the supplier can decide the degree of information sharing. The manufacturer is in a perfect competition market and pursues to maximize its individual profit when it has the right to choose information sharing mode. Let \( \rho \) denote the partition coefficient, which has a value between 0 and 1. A value of 0 represents the case in which the manufacturer does not allot any benefit to the supplier and a value of 1 represents the case in which the manufacturer allots all the benefit to the supplier. As the main purpose is to discuss the features of different information sharing modes and the effect of factor endowment in this paper, we simplify the design of incentive mechanism. Considering linear fraction is a kind of classic revenue share mechanism and is used by many studies (e.g., Cachon and Lariviere 2005; Giannoccaro and Pontrandolfo 2004), we make a linear incentive assumption. Let \( \theta \) \((0 \leq \theta \leq 1)\) denote the degree of information sharing,
including information content, level and quality. The value of \( \theta \) equals 0 when the supplier does not share any information with the manufacturer and 1 when the supplier shares all the information with the manufacturer. Let \( VC \) denote the variable cost of supply chain information sharing, including the cost of collecting and integrating data, and \( FC \) the fixed cost including the cost of IS infrastructure and other technological preparations. Detailed settings can be seen from Table 1. Let \( \pi \) denote the income created by supply chain information sharing. Without loss of generality we define \( \pi = K * \ln(\theta + 1) \), \( K > 0 \), where coefficient \( K \) represents the potential value of shared information (Ba et al. 2010; Stahl 1996).

This study examines three common information sharing modes in supply chain cooperation: 1-manual mode, 2-Web-based mode, and 3-system-to-system mode. Table 1 shows the traits of information sharing cost in the three modes. The manual mode has a trivial fixed cost but a high variable cost while system-to-system mode has a high fixed cost but a low variable cost. The fixed and variable costs of Web-based mode are in the middle. Obviously, \( FC_1 < FC_2 < FC_3 \) is always true because of the technological level. Considering variable cost function is mostly determined by labor involvement, we mainly define \( VC \) by the technology format. In manual mode, information is interchanged by phone, fax or email, and it is human labor to collect all the orders and complete transactions and financial settlement. In web-based mode, manufacturer can issue its orders via its ERP or SCM system, and the only thing the supplier has to do is to downloading the data and make replies. Drawing on previous descriptions or specifications in the literature (Holmstrom and Milgron 1991; Lee et al. 2000; Mukhopadhyay et al. 1995; Sankaranarayanan and Sundararajan 2010; Zhu 2004), we set \( VC \) as zero, linear and quadratic respectively.

<table>
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<th>Table 1. Cost Structures of Three Information Sharing Modes</th>
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<tr>
<td>Manual mode</td>
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<tr>
<td>Fixed cost of information sharing</td>
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<tr>
<td>Variable cost of information sharing</td>
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We introduce a coefficient \( \sigma \) to represent the marginal labor cost of information sharing, which mainly depends on the labor endowment of the supplier or the industry. Considering that the variable costs of all three modes should be the same if no information is shared, we set \( VC_3 = \sigma \). This technical treatment does not change the total cost of each mode.

In this two-stage model, although the degree of information sharing can be observed by the manufacturer, the manufacturer cannot compel the supplier to share certain information. From this perspective, incentive mechanism theory is still salient in this model. Thus, we assume both the manufacturer and the supplier pursue to maximize its profit respectively. In addition, the supplier faces a participation constraint. If the allotted benefit from information sharing is greater than the benefit from the alternative use of the invested resources, then the supplier will agree to invest in the information sharing, otherwise, it will not cooperate. Incentive compatibility constraint implies that the supplier will choose a degree of information sharing so as to maximize its profit for any given value of the partition coefficient \( \rho \). Then we can set up the whole framework as follows:

Manufacturer's decision objective: \( \text{Max } U = \pi(\theta) * (1 - \rho) \) \hspace{1cm} (1)

Participation constraint: \( \pi(\theta) \rho - c(\theta) \geq c(\theta) * R \) \hspace{1cm} (2)

Incentive compatibility: \( \pi(\theta) \rho - c(\theta) > \pi(\theta') \rho - c(\theta') \) \hspace{1cm} (3)

In constraint (2), \( R \) represents the expected return coefficient of business investment, which mainly depends on the capability of the firm.
The Decision Process and Selection Variables of Manual Mode

From inequation (3), we know the supplier will choose a degree of information sharing to maximize its profit for any given value of the partition coefficient $\rho$. For the manual mode, the profit of the supplier is:

$$B = \pi(\theta)\rho - c(\theta) = K \ln(\theta + 1) - \sigma(\theta + 1)^2 - FC1$$  \hspace{1cm} (4)

$$B' = \frac{K\rho}{\theta + 1} - 2\sigma^* (\theta + 1)$$  \hspace{1cm} (5)

By setting $B' = 0$, we can obtain the corresponding $\theta^* = \frac{K\rho}{\sqrt{2\sigma}} - 1$  \hspace{1cm} (6)

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It can be shown that $B' \geq 0$, when $\theta \in [0, \frac{K\rho}{\sqrt{2\sigma}} - 1]$, and $B' \leq 0$ when $\theta \in (\frac{K\rho}{\sqrt{2\sigma}} - 1, 1]$. As a result, the value of $B$ increases first and then decreases as $\theta$ increases. Since the supplier’s decision variable $\theta^*$ is shared knowledge to the manufacturer, thus the manufacturer also know $\theta^* = \frac{K\rho}{\sqrt{2\sigma}} - 1$. Then the manufacturer can calculate its profit $U$ by combining equations (6) and (1):

$$U = K \ln(\theta + 1) * (1 - \rho) = K \ln \frac{K\rho}{\sqrt{2\sigma}} * (1 - \rho)$$

$$U' = \frac{K(1-\rho)}{2\rho} - K \ln \frac{K\rho}{\sqrt{2\sigma}}$$  \hspace{1cm} (7)

Letting $U' = 0$, then the corresponding $\rho$ must satisfy $e^{\frac{(1-\rho)}{\rho}} - \frac{K\rho}{\sqrt{2\sigma}} = 0$  \hspace{1cm} (8)

Figure 1 illustrates the approximate solution of $\rho$ for equation (8), in which $Y_1$ stands for curve $Y_1 = e^{\frac{(1-\rho)}{\rho}}$ and $Y_2$ stands for line $Y_2 = \frac{K\rho}{\sqrt{2\sigma}}$. $U(\rho)$ increases first and then decreases and achieve its maximum at $\rho^*$. The requisite condition for $K$ and $\sigma$ is $2\sigma \leq K \leq 8\sigma * \ln 4e$ (See details in Appendix A).
ρ* is the most attractive partition coefficient the manufacturer would like to choose, but only if ρ* can satisfy participation constraint of the supplier (inequation (2)), can it be the practical partition coefficient. So we define ρ* as the incentive coefficient while ρ** (in the interval [0,1]) as the constraint coefficient. If ρ* ≥ ρ**, then the manufacturer can choose ρ* as the final partition coefficient, while if ρ* < ρ**, then the manufacturer has to choose ρ** as the final partition coefficient. So, we can conclude the final partition coefficient ρ = Max (ρ*, ρ**).

**The Decision Process and Selection Variables of Web-based Mode**

The Decision process of Web-based mode is similar as manual mode, so we moderately simplify the analysis. By Web-based mode, the profit of the supplier is:

\[ B = \pi(\theta)\rho - c(\theta) = K \cdot \ln(\theta + 1) \cdot \rho - \sigma(\theta + 1) - FC2 \]

(9)

\[ B' = \frac{K\rho}{\theta + 1} - \sigma \]

(10)

If \( B' = 0 \), then the corresponding \( \theta^* = \frac{K\rho}{\sigma} - 1 \). Considering \( B' \geq 0 \), when \( \theta \in (0, \frac{K\rho}{\sigma} - 1) \) while \( B' \leq 0 \), when \( \theta \in (\frac{K\rho}{\sigma} - 1, 1] \), thus we know \( B(\theta) \) is increasing at first and decreasing in the end in his definitional domain. Supplier’s decision variable \( \theta^* \) is a shared knowledge to the manufacturer, so the manufacturer also know \( \theta^* = \frac{K\rho}{\sigma} - 1 \). Then the manufacturer can calculate his profit \( U \) by take \( \theta^* \) into equation (1):

\[ U = K \cdot \ln(\theta + 1) \cdot (1 - \rho) = K \cdot \ln \left( \frac{K\rho}{\sigma} \cdot (1 - \rho) \right) \]

\[ U' = \frac{K(1 - \rho)}{2\rho} - K \cdot \ln \frac{K\rho}{\sigma} \]

(11)

If \( U' = 0 \), then the corresponding \( \rho \) must satisfy \( e^{\frac{1}{\rho}} - \frac{K\rho}{\sigma} = 0 \)

(12)

Figure 2 illustrates the approximate solution of \( \rho \) for equation (12), in which \( Y_1 \) stands for curve \( Y_1 = e^{\frac{1}{\rho}} \) and \( Y_2 \) stands for line \( Y_2 = \frac{K\rho}{2\sigma} \) and \( Y_3 \) stands for line \( Y_3 = \frac{K\rho}{\sigma} \). \( U(\rho) \) is increasing at first and decreasing after \( \rho^* \). The requisite condition for \( K \) and \( \sigma \) is \( \sigma \leq K \leq 2\sigma*\ln^{2e} \) (See details in Appendix B). In this mode we define \( \rho^*_2 \) as the incentive coefficient while \( \rho^{**}_2 \) as the constraint coefficient. So, we can conclude the final partition coefficient \( \rho^*_2 = \text{Max}(\rho^*_2, \rho^{**}_2) \).

**The Decision Process and Selection Variables of System-to-System Mode**

In this mode the profit of the supplier is:

\[ B = \pi(\theta)\rho - c(\theta) = K \cdot \ln(\theta + 1) \cdot \rho - \sigma - FC3 \text{ and } B' = \frac{K\rho}{\theta + 1} \]

While \( B' \) is always bigger than 0 when \( \theta \in [0,1] \), so \( B(\theta) \) is an increasing function and the manufacturer gets its maximal profit when \( \theta = 1 \). Then the manufacturer can calculate his profit \( U \) by take \( \theta^* = 1 \) into
equation (1): \[ U = K \ln(\theta + 1) \cdot (1 - \rho) = K \ln 2 \cdot (1 - \rho) \]. Obviously, the manufacturer achieves its ultimate profit when it chooses \( \rho = 0 \) as the partition coefficient. This is to say, there is no need for the manufacturer to motivate the supplier to share information if they are already connected by information systems. The optimal incentive coefficient \( \rho^* \) can also be found in Figure 2, but it is at origin.

**Information Sharing Mode Selection and Factor Endowment**

In this section, we firstly compare the decision variables of the manual, Web-based, and system-to-system modes, and then illustrate how a manufacturer can select from competing information sharing modes. Then in a subsection, we focus on the effects of labor endowment and technology endowment.

**Information Sharing Mode Selection and Adoption**

In the preceding section we have examined three information sharing modes individually. To clarify the similarities and differences among the three modes, we summarize the decision variables in Table 2 and Table 3. Table 2 shows the decision variables, constraints and profits of the three modes, and Table 3 shows the relationship among the decision variables of the three modes.

| Table 2. Decision Variables, Constraints and Profits of the Three Modes |
|-------------------------------------------------|-----------------|-----------------|
| Manual mode | Web-based mode | System-to-system mode |
| Incentive coefficient \( \rho^* \) | \( \rho_1^* \) | \( \rho_2^* \) | \( \rho_3^* \) |
| Constraint coefficient \( \rho^{**} \) | \( \rho_1^{**} \) | \( \rho_2^{**} \) | \( \rho_3^{**} \) |
| Final partition coefficient \( \rho \) | \( \max (\rho_1^*, \rho_2^*) \) | \( \max (\rho_2^*, \rho_3^*) \) | \( \rho_3^{**} \) |
| Information sharing degree \( \theta \) | \( \theta_1^* = \frac{\sqrt{K \rho}}{2 \sigma} - 1 \) | \( \theta_2^* = \frac{\sqrt{K \rho}}{\sigma} - 1 \) | \( \theta_3^* = 1 \) |
| Valid conditions | \( 2\sigma \leq K \leq 8\sigma \ln 4c \); \( 0 \leq \rho_1^* \leq 1 \) | \( \sigma \leq K \leq 2\sigma \ln 2c \); \( 0 \leq \rho_2^* \leq 1 \) | \( 0 \leq \rho_3^{**} \leq 1 \) |
| Profit of manufacturer \( U \) | \( U = \pi(\theta)^* \cdot (1 - \rho) \) | \( U = \pi(\theta)^* \cdot (1 - \rho) \) | \( U = \pi(\theta)^* \cdot (1 - \rho) \) |
| Profit of supplier \( B \) | \( B = \pi(\theta)\rho - c_2(\theta) \) | \( B = \pi(\theta)\rho - c_2(\theta) \) | \( B = \pi(\theta)\rho - c_2(\theta) \) |

The manual mode is similar to the Web-based mode in the following ways. (1) The greater the \( K \) is, the greater the \( \theta \) is. That is, the greater the value created by information sharing, the more willing the supplier to cooperate. (2) \( \rho \) has a positive effect on \( \theta \). That is, the greater the partition coefficient is, the more information the supplier will share. (3) \( \sigma \) has a negative effect on \( \theta \). That is, the smaller the information sharing cost, the more information the supplier will share. (4) \( K \) has a negative effect on \( \rho^* \). That is to say, the greater the value created by information sharing, the smaller partition coefficient the manufacturer will allot. (5) \( \sigma \) has a positive effect on \( \rho^* \), which means the greater the information sharing cost, the larger partition coefficient the manufacture will allot. Because we assume that information sharing can reduce the cost of the final product and bring profit merely to the manufacturer, the supplier would not like to share information with high cost but no return. So the bigger the information sharing cost is, the bigger partition coefficient should be. Although the total profit is small as the cost is large, it is still superior to non information sharing for the manufacturer and supplier. (6) If \( K \) is large or FC is small,
a certain information sharing mode becomes the choice. This finding is consistent with the practical cases, which supports the validity of our model to some extent. In essence, K presents the value of potential information sharing.

<table>
<thead>
<tr>
<th>Table 3. Relationships Among the Decision Variables of the Three Modes</th>
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<tbody>
<tr>
<td>Manual mode</td>
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<tr>
<td>K and θ</td>
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<td>ρ and θ</td>
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<td>σ and θ</td>
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<td>K and ρ*</td>
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<td>σ and ρ*</td>
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<tr>
<td>Selection Intention</td>
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<tr>
<td>Final coefficient</td>
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The difference between manual mode and Web-based mode is also significant. From the fifth row of table 2, we can conclude that in Web-based mode the supplier is more sensitive to the incentive from the manufacturer than in manual mode (K, σ, ρ have a greater effect on θ). From Figure 2 we can see that if there exists a ρ1* in the manual mode, then there must exist a ρ2* in the Web-based mode. But the opposite is not necessarily true. In other words, if there exists a ρ2* in Web-based mode, it does not mean there always exist a ρ1*. So we can conclude that web-based mode is more likely to be available than manual mode in spite of K is large or small (See details in Appendix C).

Different from manual mode and Web-based mode, system-to-system mode has two unique features, including (1) if system-to-system mode has already been implemented between the manufacturer and the supplier, the supplier has to share all information no matter how large the partition coefficient is; and (2) if the manufacturer wants the supplier to accept system-to-system mode, it only needs to set a partition coefficient which can satisfy the participation constraint of the supplier. These finds are consistent with previous literatures which take information sharing for granted in the system-to-system mode (Lee et al. 2000; Saraf et al. 2007).

When the manufacturer has to choose an information sharing mode from competing modes, it will choose the one which can bring it the maximum profit U. To simplify the analysis, we assume that the final partition coefficient equals to the constraint coefficient (ρ = ρ**) and at this time, the manufacturer's profit equals to the total income created by information sharing minus the total cost (including the opportunity cost) of information sharing. Because the income created by a given degree of information sharing is the same for all three information sharing modes, the profit of the manufacturer solely depends on the total cost of the supplier. When the supplier's cost is the lowest, that is, the benefit allocated to the supplier is the smallest, the manufacturer obtains the highest profit (see Figure 3, PC=(FC+VC)*(1+R), which denotes information sharing cost plus opportunity cost ).
From Figure 3 we can identify the optimal interval for each information sharing mode by the critical information sharing degree. When $\theta \in [0, \theta_1]$, the total cost of the manual mode is the smallest, then the manufacturer should choose manual mode if the constraints in Table 2 are satisfied. By the same token, the manufacturer should choose Web-based mode when $\theta \in [\theta_1, \theta_2]$ and system-to-system mode when $\theta \in [\theta_2, 1]$.

If the assumption is violated, then the manufacturer can gain the total surplus value by information sharing. Then the incentive coefficient is greater than the constraint coefficient ($\rho^* > \rho^{**}$), meaning that the manufacturer is willing to further motivate the supplier to share more information in order to gain more profit. From the fifth row of Table 2 we can transform the equations into other forms, and we rewrite them as $\rho_1 = \frac{\sigma \theta_{1} \left(1 + \theta_{1}\right)}{K}$, $\rho_2 = \frac{\sigma \theta_{2} \left(1 + \theta_{2}\right)}{K}$, $\rho_3$ is independent of $\theta_3$. These equations do not mean that the final partition coefficient $\rho$ is determined by the degree of information sharing $\theta$. In fact, they reveal that in the optimal situation $\rho$ is correlated with $\theta$. Obviously, the profit functions of both the manual and the Web-based modes have a turning point. The turning point $A_1$ of the manual mode is smaller than that ($A_2$) of the Web-based mode (see Figure 4, dashed line denotes the virtual case under strict assumption while solid line denotes the practical case. Details are in Appendix D). When we relax the assumption, the results in figure 4 are almost the same as it in Figure 3. Compared with Figure 3, the adoption critical point of Web-based mode changes from $\theta_1$ to $\theta_{11}$ and that of system-to-system mode changes from $\theta_2$ to $\theta_{11}$. Thus, we have Lemma 1.

**Lemma 1:** The expected degree of information sharing influences the manufacturer’s selection of information sharing mode. The optimal choice is the manual mode when the expected degree of information sharing is low, the system-to-system mode when the expected degree is high, and the Web-based mode when the degree is intermediate.

### The Effect of Labor Endowment and Technology Endowment

In our model, $\sigma$ represents the labor cost for the supplier to collect, sort out, input, and check data. If we do not consider other factors, we can deem that $\sigma$ is solely determined by the labor endowment.
In the manual mode, the lowest supplier income $I_1$ which satisfies the participation constraint equals $[FC_1 + \sigma(\theta+1)] \times (1+R)$, then in the Web-based mode $I_2$ equals $[FC_2 + \sigma(\theta+1)] \times (1+R)$ and in the system-to-system mode $I_3$ equals $[FC_3 + \sigma(\theta+1)] \times (1+R)$. In Appendix D we have deduced that the selection of information sharing mode is similar in essence (there are always optimal intervals and critical points in all modes) whether it is in the strict assumption (the surplus profit is solely appropriated by the manufacturer) or in practice (the supplier can gain more than his opportunity cost). Considering the strict assumption does not change the qualitative conclusions, we apply the strict assumption to simplify our derivation. We think it is more important to investigate how factor endowment influences the critical selection criteria than figure out the precise critical point of each information sharing mode. Under the strict assumption, the supplier’s cost equals the supplier’s income ($PC=I$), so the difference between the incomes results from the difference in cost among the three information sharing modes, which determines the final selection decision of the manufacturer. A comparative statistical analysis is showed in figure 5.

When the labor cost is low, the total cost of information sharing is the smallest in manual mode, medium in Web-based mode, and the highest in system-to-system mode. When $\sigma$ is heterogeneous in various context, Figure 5 shows that $\sigma$ has a significant impact on the optimal adoption interval. When the labor cost decreases, the selection critical points of the manual mode and Web-based mode will shift to the right ($\theta_1 \rightarrow \theta_1'$, $\theta_2 \rightarrow \theta_2'$), and the optimal selection interval for the system-to-system mode will be shortened. When the labor cost increases, the selection critical points of the Web-based mode and system-to-system mode will shift to the left ($\theta_1 \rightarrow \theta_1''$, $\theta_2 \rightarrow \theta_2''$), and the optimal selection interval for the manual mode will be shortened. When the labor cost increases, if it is in the early stages, the selection interval of the Web-based mode will move left with a considerable compensation. If it is in the later stages, the adoption interval of system-to-system mode will keep increasing and that of the Web-based mode will shrink. As a result, we have the following Lemma 2 (See details in Appendix E).

**Lemma 2:** When the labor cost is low, the firms will prefer manual mode and Web-based mode to system-to-system mode because the first two modes have a greater input-output ratio than the third
one. On the contrary, when the labor cost is high, Web-based mode and system-to-system mode are superior to manual mode. When the labor cost increase, in the early stage the manufacturer will still prefer the Web-based mode while in the later stage the manufacturer will prefer system-to-system mode, and manual mode will be completely obsolete.

In our model, both the value coefficient K of information sharing and the expected return coefficient R depend on the technology endowment. The higher the technology endowment is, the greater the value of K is. Thus technology endowment can influence the selection conditions of these three modes by K. As discussed in Appendix C, the larger the K is, the easier for system-to-system mode to support total information sharing. When it is in a competing context, high technology endowment can benefit system-to-system mode and Web-based mode. The interaction between technology endowment and labor endowment determines the value of R. If the technology endowment is greater than the labor endowment, R will be close to the rate of technology investment return, implying that the expected return on information sharing investment is calculated by the rate of technology investment. Because the technology endowment is high, the benefit of information sharing is great and can satisfy the participation constraint easily. Therefore, in these circumstances, the supplier would be willing to share more information and the manufacturer will use SCIS (Web-based mode or system-to-system mode) to cooperate with the supplier. On the contrary, if the technology endowment is smaller than the labor endowment, R will be close to the rate of return on labor investment, implying that the expected return on information sharing investment is calculated by the rate of labor investment. Because the supplier can gain benefits by investing in improving its labor’s welfare, information systems and information sharing may not be attractive and economical. Under such circumstances, the supplier may refuse to invest in SCIS because the income of information sharing cannot satisfy its participation constraint. Given this, the manufacturer has no choice but to select the manual mode. Combining the findings in the fifth row of Table 2, we have Lemmas 3 and 4 (See details in Appendix F).

Lemma 3: A manufacturer will gain a greater profit from all the three information sharing modes when the technology endowment is improved.

Lemma 4: The higher technology endowment a firm has, the more likely it will select Web-based mode or system-to-system mode for information sharing. The lower technology endowment a firm has, the more likely it will select manual mode for information sharing.

Discussion

This study explores the relationships between supply chain information sharing, information sharing mode selection, profit partition coefficient, and factors endowment. Previous research has suggested that system-to-system mode is more effective and attractive than Web-based mode (Muffatto & Payaro 2004; Auramo 2005; Kauremma et al. 2009). As a result, Web-based mode is generally considered as a suboptimal and constrained choice. However, the findings of our study reveal that the expected degree of information sharing determines the choice of information sharing mode. The optimal option is manual mode when the expected degree of information sharing is low, system-to-system mode when the expected degree is high, and Web-based mode when the degree is medium. Thus we conclude that the value of a specific information sharing mode is not determined merely by the technological form. As a result, system-to-system mode is not always the preferred mode for firms in supply chain. When the expected degree of information sharing is low or medium, manual mode or Web-based mode turns out to be the better choice. In practice, firms can manage to share information accurately and timely with Web-based mode, support supply chain coordination, and create operational and strategic benefits.

From Lemmas 2, 3 and 4, we can deduce that when the labor endowment is high and the technology endowment is low, it is rational for supply chain firms in China to select Web-based mode to share information. On the one hand, the labor cost in China is still relatively low. On the other hand, the technology endowment in China is also low, and the relative cost of the information technology is even greater in China than in the developed countries. As discussed above, the problem of information sharing mode selection is a tradeoff between utilizing the work forces and utilizing the technology. Consequently, although the system-to-system mode may create higher value of information sharing compared with the manual mode or the Web-based mode, it generates a lower input-output ratio for firms in China than the other two modes due to the low labor cost and high technology cost. The implications for practitioners are
that the investment in SICS is not necessarily the more the better. Factor endowment and information
demand should also be considered. We argue that not only firm size and market share but also labor and
technology endowment should be factored into the equation when manager selects a particular model for
information sharing in the supply chain. System-to-system is not the only choice for supply chain firms
when considering inter-firm IT integration. Web-based mode, cloudy computing, and SaaS mode are
more likely to be better information technologies for firms in China at present time.

We can also deduce from Lemma 2 that supply chain firms will gradually adopt Web-based mode to
replace manual mode for information sharing when the labor cost steadily increases. China is still in the
early stages of this transition process. The data quoted by National Bureau of Statistics of China based on
International Labor Organization shows that in 2005 the average wage of manufacture industry works
was $0.59/hour, and went up to $0.67/hour in 2006 and $0.78 in 2007, but there was still a huge gap to
the average level of developed nations ($30-$45/hour). So we predict that more and more firms in China
will adopt Web-based mode and phase out the manual mode. As the labor cost is unlikely to rise to the
level of the developed countries in a short time, we also predict that Web-based mode will be superior to
system-to-system mode in the foreseeable future. When the labor cost becomes fairly high and the
technology cost becomes relatively low, system-to-system mode will likely become the dominant
information sharing mode for supply chain firms in China. Thus, we conclude that Web-based mode is a
result of high labor endowment and low technology endowment in China, which is the optimal choice
rather than a suboptimal or constrained one. Similarly, system-to-system mode is a result of low labor
endowment and high technology endowment context in the developed nations. From this perspective,
labor endowment and technology endowment can explain the differences between China and those
developed nations in information sharing mode selection.

Although we mainly focus on the Chinese context in this paper, the findings can be applied to other
countries as well. Every country has its unique labor and technology endowment. When a firm in a
specific country needs to choose an information sharing mode, or a new technology, it must pay attention
to the alignment between the technological form and the country’s factor endowment. Our findings that
system-to-system mode is superior with low labor endowment and manual mode is superior with high
labor endowment can also be applied at the enterprise level. We have found that some international
companies in China have various information sharing modes with their suppliers. The labor endowment
of the international companies is relatively low while the technology endowment is relatively high, but its
suppliers were manifold in labor endowment and technology endowment. As a result, the international
companies connected to its suppliers with low labor endowment and high technology endowment via
system-to-system mode, and to its supplier with high labor endowment and low technology endowment
via manual mode. When some suppliers’ factors abundance is medium, they adopted Web-based mode.
These observations provide some empirical support to our theory developed in this study.

Conclusion

This paper draws on the comparative advantage theory and factor endowment theory to explore the
decision approach and mechanism of supply chain firms when they choose an information sharing mode.
We developed an analytical model based on a game theoretical approach and derived a number of
interesting findings. First, the value of a specific information sharing mode is not merely determined by
the technological form, but the expected degree of information sharing. As a result, system-to-system
mode is not always the optimal choice for firms in a supply chain dyad. The manual mode is the optimal
selection when the expected degree of information sharing is low. In contrast, system-to-system mode is
the best choice when the expected degree is high. Between these two, the Web-based mode is optimal.
Second, factor endowment influences the expected degree of information sharing and the decision on the
selection of the information sharing mode. When the labor cost is low, firms will prefer manual mode or
Web-based mode to system-to-system mode because the first two have a greater input-output ratio than
the last one. On the other hand, when the labor cost is high, Web-based mode and system-to-system mode
are superior to the manual mode. The Web-based mode and system-to-system mode also prevail under
high technology endowment context, while manual mode is optimal when the technology endowment is
low. Last but not the least, when a country’s labor cost and technology endowment are on the rise, the
input-output ratio of the manual mode will decline while that of Web-based mode or system-to-system
will increase. If it is in the earlier stage, Web-based mode will still be superior to system-to-system mode,
while in the later stage, system-to-system mode will be preferred. These findings provide an effective explanation for why firms in the developed countries generally choose system-to-system mode while firms in China usually choose Web-based mode to share information.

Our findings from factor endowment perspective effectively address the two questions we have raised. However, we have to admit that there are various elements that can influence the selection of a particular information sharing mode. Although the final information sharing mode is not solely determined by factor endowment, our analysis shows that factor endowment is no doubt a significant factor in such decisions. Future study can collect data to test the lemmas proposed in this paper and compare the effect of factor endowment with that of other elements. Another interesting direction could be taking the legal environment and inter-organizational trust into account, which could further extend the current theory of information sharing mode selection in firms.

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Appendix A

Since \(0 \leq \theta \leq 1\), by equation \(\theta^* = \frac{K^0}{\sqrt{2\sigma}} - 1\) we know a valid value of \(\theta^*\) can be obtained only when 
\[2\sigma \leq K^0 \leq 8\sigma.\]  
Put \(2\sigma \leq K^0 \leq 8\sigma\) into equation \(e^{\left(\frac{1}{\rho}\right)} - \frac{K^0}{2\sigma} = 0\), we can get \(1 \leq \rho \leq 4\), so \(\rho\) is definitely in the interval \([-\frac{1}{\ln 4e}, 1]\). When \(\rho\) equals to its maximum, \(K^0 \geq 2\sigma\) need to be satisfied, therefore we can deduce that \(K \geq 2\sigma\). When \(\rho\) equals to its minimum, \(K^0 \leq 8\sigma\) should be satisfied, therefore we can deduce that \(K \leq 8\sigma * \ln 4e\). As a conclusion, if \(K < 2\sigma\) is true, the manufacturer is not able to incentivize the supplier to share any information not matter how large the \(\rho\) is; if \(2\sigma \leq K \leq 8\sigma * \ln 4e\) is true, the manufacturer can choose incentive coefficient by equation \(e^{\left(\frac{1}{\rho}\right)} - \frac{K^0}{2\sigma} = 0\); if \(K > 8\sigma * \ln 4e\) is true, the optimal incentive coefficient should be \(\frac{8\sigma}{K}\) (from equation \(\theta^* = \frac{K^0}{\sqrt{2\sigma}} - 1\) and the degree of shared information can achieve \(1\).

Appendix B

Since \(0 \leq \theta \leq 1\), by equation \(\theta^* = \frac{K^0}{\sigma} - 1\) we know a valid value of \(\theta^*\) can be obtained only when 
\[\sigma \leq K^0 \leq 2\sigma.\]  
Put \(\sigma \leq K^0 \leq 2\sigma\) into equation \(e^{\left(\frac{1}{\rho}\right)} - \frac{K^0}{\sigma} = 0\), we can get \(0 \leq \rho \leq \frac{1}{\ln 2e^2}\), therefore \(\rho\) is definitely in the interval \([-\frac{1}{\ln 2e^2}, 1]\). When \(\rho\) equals to its maximum, \(K^0 \geq \sigma\) need to be satisfied, therefore we can deduct that \(K \geq \sigma\). When \(\rho\) equals to its minimum, \(K^0 \leq 2\sigma\) should be satisfied, therefore we can deduce that \(K \leq 2\sigma * \ln 2e\). As a conclusion, if \(K < \sigma\) is true, the manufacturer is not able to incentivize the supplier to share any information not matter how bigger the \(\rho\) is; if \(\sigma \leq K \leq 2\sigma * \ln 2e\) is true, the
manufacturer can choose incentive coefficient by equation $e^{(\frac{1}{\rho} - 1)} - \frac{K_0}{\sigma} = \alpha$; if $K > 2\sigma^2 \ln 2e$ is true, the optimal incentive coefficient should be $\frac{2\sigma}{K}$ (from equation $\theta^* = \frac{K_0}{\sigma} - 1$) and the degree of shared information can achieve 1.

**Appendix C**

$K < \sigma$, both manual mode and Web-based mode are invalid. $\sigma \leq K < 2\sigma$, manual mode is invalid while Web-based is valid.

$2\sigma \leq K < 2\sigma^2 \ln 2e$, both manual mode and Web-based mode are valid.

$K \geq 2\sigma^2 \ln 2e$, manual mode is valid while Web-based mode perfectly exert ($\theta - 1$).

Thus we can conclude that Web-based mode is non-strict superior to manual mode in available context aspect. And by our investigation, there is hardly complete information sharing between manufacturer and supplier, therefore it is reasonable to leave out the condition that K is very large. In fact, if K is very large it is easy for the manufacturer to incentivize the supplier to cooperate on systems integration from an economics perspective. In this paper we pay most attention on the context where incentive mechanism is necessary and significant.

**Appendix D**

By participation constraint, we can get $\rho^* = \frac{[\sigma(\theta+1)^2 + FC_1]^* (R+1)}{K \ln(\theta+1)}$. And $\rho^* = \frac{2\sigma^*(\theta+1)^2}{K}$ is already deduced. When $\rho^* > \rho^***$ is true, the manufacturer would like to share more profit with the supplier then participation constraint. Only when $[\sigma(\theta+1)^2 + FC_1]^* (R+1) = 2\sigma^*(\theta+1)^2 \ln(\theta+1)$ be satisfied, the equation $\rho^* = \rho^***$ can be true. In the same way, we can deduce $\rho^** = \frac{[\sigma(\theta+1) + FC_2]^* (R+1)}{K \ln(\theta+1)}$ and $\rho^* = \frac{\sigma^*(\theta+1)}{K}$. Only when $[\sigma(\theta+1) + FC_2]^* (R+1) = \sigma^*(\theta+1) \ln(\theta+1)$ is satisfied, the equation $\rho^* = \rho^**$ can be true. As is assumed that $FC_2 > FC_1$ and $\theta \in [0,1]$, we know for $\forall \theta$, $[\sigma(\theta+1)^2 + FC_1]^* (R+1) < 2^* [\sigma(\theta+1) + FC_2]^* (R+1)$ and $2\sigma^*(\theta+1)^2 \ln(\theta+1) > 2\sigma^*(\theta+1) \ln(\theta+1)$. So $\frac{2\sigma^*(\theta+1)^2 \ln(\theta+1)}{[\sigma(\theta+1)^2 + FC_1]^* (R+1)} > \frac{2\sigma^*(\theta+1) \ln(\theta+1)}{[\sigma(\theta+1) + FC_2]^* (R+1)}$. So $\rho^* = \rho^***$ is sure to be achieved earlier then $\rho^* = \rho^**$. In other words, $A_1$ is smaller than $A_2$.

**Appendix E**

The critical note between manual mode and Web-based mode is determined by the intersection point of $PC_1$ and $PC_2$. From $\sigma(\theta+1)^2 + FC_1 = \sigma(\theta+1) + FC_2$, we can get the solution $\theta$ satisfies $\theta(\theta+1) = \frac{FC_2 - FC_1}{\sigma}$. Combining with figure 5, we know $\theta_1(\theta+1) = \frac{FC_2 - FC_1}{\sigma_1}$ and $\theta_{11}(\theta+1) = \frac{FC_2 - FC_1}{\sigma_2}$ ($\sigma_1 < \sigma_2$).
(θ_{11} - θ_{1})/(θ_{11} + θ_{1} + 1) = \frac{FC_2 - FC_1}{σ_2} - \frac{FC_2 - FC_1}{σ_1}, \text{therefore } θ_{11} - θ_{1} = \frac{(σ_1 - σ_2)(FC_2 - FC_1)}{σ_2σ_1(θ_{11} + θ_{1} + 1)}.

When σ(θ + 1) + FC_2 = σ + FC_2, PC_2 and PC_3 will intersect, therefore the critical note between Web-based mode and system-to-system mode is \( θ = \frac{FC_3 - FC_2}{σ} \). Combining with figure 5, we know \( θ_{22} - θ_{2} = \frac{(σ_1 - σ_2)(FC_2 - FC_1)}{σ_2σ_1} \). If FC_3 - FC_2 < FC_2 - FC_1, Web-based mode won’t appear to be practical for its high implementation cost. In this circumstance, Web-based mode will be substituted by manual mode or system-to-system mode. Thus it is reasonable to assume FC_3 > FC_2 > FC_1 in this paper’s context for Web-based mode exists indeed. Obviously, \( \left| \frac{(σ_1 - σ_2)(FC_2 - FC_1)}{σ_2σ_1(θ_{11} + θ_{1} + 1)} \right| < \left| \frac{(σ_1 - σ_2)(FC_3 - FC_2)}{σ_2σ_1} \right| \).

Therefore we can conclude the optimal selection interval of system-to-system will keep increasing as the labor cost increases while the one of Web-based mode will be occupied by system-to-system mode but be partly compensated from manual mode. When the labor cost increase, in the early stage Web-based mode is likely to maintain his dominant place because the optimal adoption interval of system-to-system mode is still small. But in the later stage, system-to-system will be the most appropriate for supply chain firms.

**Appendix F**

Opportunity cost comes from same amount investment on alternative actives. The supplier can invest in technology promotion and also in labor reinforcement. We assume R=Max[Rt, Rc], in which Rt denotes technology return while Rc denotes labor return. Obviously, both \( \frac{K_ρ \cdot ln(θ_{11} + 1)}{PC_2} \) and \( \frac{K_ρ \cdot ln(θ_{11} + 1)}{PC_3} \) are positive correlated with Rt for technology endowment contains process technology, normalization capability and automation capability. When Rt<Rc, R=Rc, then it is hard for \( K_ρ \cdot ln(θ_{11} + 1) > PC*(1+Rc) \). On the other hand, only when Rt>Rc, there is a probability for the manufacturer to share the supplier a profit satisfying its participation constraint.

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