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VALUE CREATION ROUTE OF TRUST GOVERNANCE BASED ON SUPPLY CHAIN INFORMATION SYSTEM INVESTMENT

[1, 2]ZHAOLIN CHENG, [1]KANG XIE*

[1] Shool of business Sun Yat-Sen University, Guangzhou 510275, Guangdong, China

[2]Bussiness School of Guangdong Ocean University, Zhanjiang 524088, Guangdong, China

ABSTRACT

In supply chain relationship governance, trust is considered as an important governance mechanism to decrease opportunism. Trust provides commitment, improves transaction efficiency, and implements the supply chain information system. The paper constructs a three-stage dynamic model based on the impact of trust governance on supply chain information system investment. It analyzes supply chain overall value creation route and features based on trust governance. The results show that trust governance can make supply chain performance Pareto optimal.

Keywords: *Supply Chain Information Systems Investment, Trust Mechanism, Value Creation*

1. INTRODUCTION

Along with the development of new technology, increasingly diversified customers' demand, and higher competition, the lifespan of some products are getting shorter and shorter, while customers require for higher quality products, most organizations are facing significant pressure to make their operational, tactical, and strategic processes more efficient and effective. It makes firms to change their organization structures and forms to suit for rapid market change and uncertainty. Firms expand their organization boundaries for competition, and the competition transits from single firm to supply chain.

Under the supply chain mode, supply chain partners needs long term stability relationship. By information sharing and resource integration supply chain can decrease unnecessary waste and operation costs and improve service capability. Information technology (IT) has been become an attractive method to share information and integrate resources, and an important tool suiting for organization structure changing[1].In fact, the interorganizational systems(IOS) based on internet makes the change more rapidly by high standardization and low cost. IOS is the use of electronic means to exchange information and conduct business transactions within and across organizational boundaries. It allows organizations to identify consumers' requirements and trends and subsequently communicate the gathered information throughout the supply chain quickly. IOS permits organizations to generate electronic purchase orders, invoices, bills of lading, and a variety of other documents and sends them instantly to trading partners anywhere in the world[2]. The reduction in communications, labor, and material costs as well as the gain in competitive advantage are among the benefits of implementing IOS.

However, in firms practice, there are some obstacles to use IOS in supply chain. From previous studies, we can separate the obstacles in two parts: one part is technology obstacle, to avoid difficulties, establishing IOS between trading partners requires compatible hardware at both ends in order to have seamless processing, while, preagreed-to standards and protocols are also required. Given different standards, a company that is a member of multiple supply chains in different industries would have to deal with multiple standards of communication, resulting in costly operations and system redundancies. As technology improvement, the technical obstacle would not hinder IOS implement any more. Another part is cost and relationship obstacle, because of the significant initial and operational investments, both the customer and the supplier are typically contractually tied to a long-term relationship. Although this may be beneficial, it has some drawbacks. Over time, other suppliers may come up with higher quality, lower priced, and/or better services and products. In such cases, switching costs associated with establishing a new linkage may prevent companies from making otherwise

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prudent changes. As the trust is low, the high asset specific may make "Rip-off" problem[3], it would be the most important obstacle for supply chain information systems implement.

It can be seen in practices in China, as the market mechanisms are not regular enough, there are little trust among firms, the trust hazard is the main obstacle for establishing supply chain information systems to share information[4]. By our investigation on supply chain information systems implement in Pearl River Delta, we found that the trust hazard caused by information asymmetric and imperfect legal system hinder the supply chain relationship improvement. So we want to solve some questions followed: How does trust mechanism impact on supply chain information systems implement? What's the value created by trust mechanism?

2. LITERATURE REVIEW

In organization studies, researchers have analyzed trust from different perspectives of psychology, sociology, organizational behavior and economics, and different levels of individual level, organization level and interorganization level[5]. Mcevily draw a conclusion by generalizing different trust definitions, that trust is a multi-level concept while its identification depends on research questions[6].

As a social concept, trust was influenced by many internal and external factors. Fuehrera analyses stable and durable relationships as being the results of interaction between control and trust building, three aspects can solve the obstacles on trust, information communication technology (ICT) enabled communication capability, stable business understanding and strong commerce moral[7].Ratnasingam examines how institutional structures develop through governance mechanisms leading to technology trust derived from structural assurances for online dyadic relationships, he discussed four perspectives of trust, namely technological, economic, behavioral, and organizational perspectives, to show how technology trust evolves into relationship trust[8]. Nielsen thought trust is a computational expectation where trust in a computational entity is interpreted as the expectation of certain future behavior based on behavioral patterns of the past, he defines a mathematical measure for quantitatively comparing the effectiveness of probabilistic computational trust systems in various environments. Yan analyzes trust transfer and superposition mechanisms under different trust atmospheres based on social network theory, and constructs trust equilibrium model using network equilibrium theory and limit thought. The model was solved and the stability of the solution was analyzed. He concludes trust equilibrium is closely related to trust atmosphere and initial trust distribution; trust atmosphere acts as a hygiene factor in trust equilibrium, the stability of trust equilibrium mainly depends on key relations[10].

Previous studies have analyzed trust generation mechanism, such as formal relationship, cooperation lasting, education level, specific investment and technology support, but there are little research on the relationship between trust and IT, so, there are some research gaps. Existed studies are mostly qualitative analysis on trust effected factors and how trust improve supply chain performance and so on, little quantity analysis are less, which are mostly on trust generation and less on trust value creation. This paper build a three-stage trust model based on supply chain information system, analyzes the relationship and characteristics of supply chain information system and trust evolution, and the value creation route.

3. BASIC MODEL

Considering a simple two-echelon supply chain composed of one supplier and one manufacturer, both supplier and manufacturer are risk-neutral, supplier supplies key raw materials to manufacturer. Supplier and manufacturer are rationality, they both consider their behaviors for maximizing profits. They communicated with each other by using information systems, so we can describe the supply chain communication as a three-stage process.

3.1 Stage One, Supply Send Signal By Supply Chain Information System Investment

Basic hypothesis: (1). Trust is a probability that manufacturer thought supplier would fulfill its commitments, and do some favorable things to manufacturer (such as provide qualified products), while trust level is higher, the probability is higher, otherwise is lower. (2) As the cooperation time is longer, the trust of manufacturer on supplier is higher. (3) The trust of manufacturer on supplier is proportional to supplier's investment of supply chain information systems, the more supplier invests information systems, manufacturer's trust is higher, where trust can be seen as a capability trust. (4) The manufacturer's order to supplier is proportional to trust level, trust is higher, and supplier would get more order quantity. (5) The

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marginal order changing is increased by trust level, it means higher trust level make order increase more rapidly.

Based on the hypothesis above, we use a linear model to describe trust level as:

$$r = a t + b I + g \quad (1)$$

Where, r is the manufacturer's trust level on supplier, t is the time, I is supplier's supply chain information system investment level, it can also mean the supply chain information systems' using cost, a , b , g are parameters bigger than zero.

According to hypothesis (4)and (5), supplier's order quantity change can be described as:

$$\dot{Q} = a_0 + br \quad (2)$$

Where, Q is the order quantity, a_0 and b are parameters bigger than zero.

Substitute formula 1 to formula 2, and solve is , we can get:

$$\dot{Q} = a_0 + b(a t + b I + g)$$

$$\Rightarrow \dot{Q} = a' + b' t + cI$$

Where, $a' = a_0 + bg$, $b' = a \times b$, $c = b \times b$

$$\Rightarrow Q = (a' + cI)t + \frac{b'}{2}t^2 + e$$

It assumed that supplier's produce cost per time is C_0 , supplier's type is q , and r is supplier's trustworthiness level, q and r satisfied $f: q \to r$ is one-to-one mapping, that means supplier type q would cooperate with manufacturer at unique probability r , and it would betray manufacturer at probability 1- r , $r \in [0,1]$, it can get profits π' if it betray, for contract incomplete, we did not consider punishment. The whole cooperation duration is $[0,T]$, at time t1, supplier would face to external temptations to get profits p', then it do some opportunism behavior and betray manufacturer.

The supplier's expected profits in the whole cooperation is:

$$Ep_s = \int_0^{t1} P\left[(a' + cI)t + \frac{b'}{2}t^2\right] - C_0 - I\,dt + r\int_{t1}^{T} P\left[(a' + cI)t + \frac{b'}{2}t^2\right] - C_0 - I\,dt + (1-r)p' - I_0 \quad (3)$$

From formula (3), we can get:

$$\frac{\partial^2 Ep_s}{\partial I \partial r} = \left(\frac{P \times c}{2}t^2 - 2t\right)\Big|_{t1}^{T} \quad (4)$$

Obviously, because manufacturer can not know supplier's type, if it did not do anything, there would be "adverse selection" problem in supply chain, and it may collapse the supply chain. So supplier, especial high quality supplier, should send some signal to show its type to maintain the supply chain relationship. We assume the signal is information system investment, for the basic requirement of signal sending, which called "Spence-Morris condition", it must satisfy $\left(\frac{P \times c}{2}t^2 - 2t\right)\Big|_{t1}^{T} > 0$, the information system investment can be an effective signal.

Let $f(t) = \frac{P \times c}{2}t^2 - 2t$

The first deviation of the formula above is $f'(t) = P \times c \times t - 2$, the Spence-Morris condition can be described as $f(t)$ is monotone increasing as $t > \frac{2}{P \times c}$, so we can get when $t1 > \frac{2}{P \times c}$, formula(4) is bigger than zero, that means the Spence-Morris condition satisfied.

By the first stage model, we can draw some conclusions:

(1) Under certain conditions, supply chain information system investment level can be the signal of suppliers' type

In supply chain communication, even the supply chain information systems investment can not improve supplier's trustworthiness level, it still can be the signal of supplier's real type send to manufacturer. Higher trustworthiness supplier would invest more on supply chain information systems, while lower trustworthiness supplier would invest less.

(2) External temptations appearing time would impact signal mechanism

When external temptations appear after specific time point, $t1 > \frac{2}{P \times c}$, the information system

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investment can be signal, if the external temptations appear early, even the high trustworthiness supplier will not invest information systems, manufacturer can not determine supplier's type. So, in supply chain cooperation, monitoring is necessary, manufacturer can use effective monitoring to control opportunism behaviors, and make IOS investment can be a significant signal.

(3) The effects of trust is stronger, signal mechanism is more effective

As $c = b \times b$ can mean order increasing coefficient of IOS investment by trust mechanism, if the effects of trust is stronger, c is bigger. When the effects of trust are very strong, even the external temptations appear early, IOS investment can still be a significant signal.

(4) Signal mechanism necessary condition

Beside the basic hypothesis, which are necessary conditions for supplier type signal mechanism, there is another condition $T > t1 > \frac{2}{P \times c}$, that is $c > \frac{2}{P \times T}$, where T is the cooperation duration.

It can be seen that if cooperation duration is longer, the condition c should satisfy is easier. So, in trust formation process, contract is necessary, it can strength the signal mechanism by providing a long cooperation period, and promotes the formation of trust. In practice, as supply chain partners tend to long-term cooperation, they will exhibit more trust, while effects of trust is stronger.

3.2 Stage Two, Supplier Select Optimal Supply Chain Information Systems Investment

We assume that manufacturer can determine supplier's type by signal after signal sending in first stage, and manufacturer will choose high trust level supplier, that is $q > m_1$, where m_1 is mean value of q, $q \sim N(m_1, s_1^2)$. In following cooperation, supplier select action a, where $a \in (-\infty, +\infty)$, $a < 0$ means supplier will harm manufacturer, such as do shoddy work and use inferior material, and we assume $a \sim N(m_2, s_2^2)$. In practice, we can see it is rare that suppliers do something extremely harmful to manufacturer or willing to benefit others, so the hypothesis is reasonable. Let $r = R(q, a)$, it means correlation coefficient of supplier's behavior and its type, obviously, supplier will benefit manufacturer with high trustworthiness level, so r>0. And r is a common knowledge.

So , we get $(q, a) \sim N(m_1, m_2, s_2^2, s_2^2, r)$

It can deduce:

$$a \mid q \sim N\left(m_2 + r\frac{s_1}{s_2}(q - m_1), s_2^2(1 - r^2)\right)$$

Let $m_2' = m_2 + r\frac{s_1}{s_2}(q - m_1), s_2'^2 = s_2^2(1 - r^2)$

As manufacturer can not determine supplier's type, the trust level is:

$$r = p(a > 0) = 1 - \int_{-\infty}^{0} \frac{1}{\sqrt{2p}s_2} e^{-\frac{(a - m_2)^2}{2s_2^2}} da$$

As manufacturer can determine supplier's type by information systems investment, the trust level is:

$$r \mid q = p(a > 0 \mid q) = 1 - \int_{-\infty}^{0} \frac{1}{\sqrt{2p}s_2} e^{-\frac{\left(a - m_2 - r\frac{s_1}{s_2}(q - m_1)\right)^2}{2s_2^2(1 - r^2)}} da \quad (5)$$

Transform equation above into a standard normal distribution, we can get:

$$r = p(a > 0) = F\left(\frac{m_2}{s_2}\right),$$

$$r \mid q = p(a > 0 \mid q) = F\left(\frac{m_2'}{s_2'}\right) \quad (6)$$

Where $F(\times)$ is the distribution function of the standard normal distribution, while $F(\cdot)$ is monotone increasing, and $m_2' > m_2$, $s_2' < s_2$, so $r \mid q > r$, this means as manufacturer found supplier's type is higher than mean level by information system investment signal, manufacturer thought supplier would be more trustworthiness than those without signal.

As $a \mid q$ follow a normal distribution, so the formula (6) can write as:

$$0.5 + \int_{0}^{m_2 + r\frac{s_1}{s_2}(q - m_1)} \frac{1}{\sqrt{2p}s_2} e^{-\frac{\left(a - m_2 - r\frac{s_1}{s_2}(q - m_1)\right)^2}{2s_2^2(1 - r^2)}} da$$

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$$= 0.5 + \int_0^{m_2'} \frac{1}{\sqrt{2\pi}\sigma_2} e^{-\frac{(a-m_2')^2}{2\sigma_2^2}} da \qquad (7)$$

Now, manufacturer will allocate orders to suppliers by trust level, we can assume that:

$$q = \begin{cases} q_0 \times r + e & , a > 0 \\ 0 & , a \le 0 \end{cases} \qquad (8)$$

Where q_0 is parameter bigger than zero, so we can get suppliers profits function:

$$\text{Max: } p_s = P \times q - I - c_0 = P \times q_0 \times r - I - c_0' \qquad (9)$$

s.t. $p_s > 0$

To simplify question, without loss of generality, let $I = q$, from formula(5) we can get:

$$\frac{\partial r \mid q}{\partial q} = \frac{\partial r \mid q}{\partial m_2'} \times \frac{\partial m_2'}{\partial q}$$

$$= \frac{1}{\sqrt{2\pi}\sigma_2} e^{-\frac{m_2^2 \times \sigma_2^2}{2}} \times r \frac{\sigma_1}{\sigma_2} = \frac{r \times \sigma_1}{\sqrt{2\pi}\sigma_2^2} e^{-\frac{\left[m_{2+} r\frac{\sigma_1}{\sigma_2}(q - m_1)\right]^2 \times \sigma_2^2}{2}}$$

Substitute formula(5) into formula(8), and let its first derivative $\frac{\partial p_s}{\partial q} = 0$, we can get:

$$\frac{\partial \pi_s}{\partial \theta} = P \times q_0 \times \frac{\partial r \mid q}{\partial q} - 1$$

$$= \frac{P \times q_0 \times r \times \sigma_1}{\sqrt{2\pi}\sigma_2^2} e^{-\frac{\left[m_{2+} r\frac{\sigma_1}{\sigma_2}(q - m_1)\right]^2 \times \sigma_2^2}{2}} - 1 = 0$$

Solve it:

$$q^* = \frac{\sqrt{\frac{2\ln(r \times \sigma_1 \times P \times q_0) - \ln\left(\sqrt{2\pi} \times \sigma_2^2\right)}{1 - r^2}} - m_2 \times \sigma_2}{r \times \sigma_1} + m_1$$

We can find q^* is a monotonically increasing function of r, its figure is shown as Figure1:

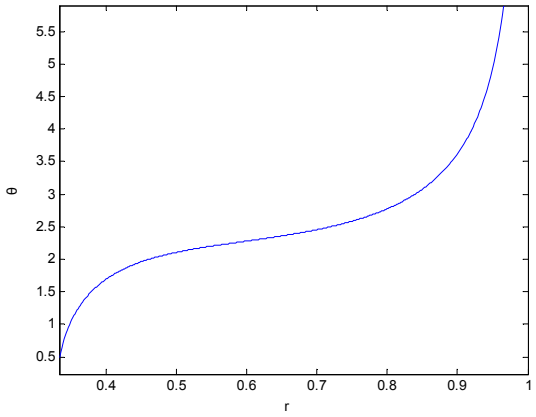

Figure 1: suppliers optimal information system investment

From Figure1, we can see that, supplier choose optimal information system investment according to manufacturer's belief, as manufacturer's belief about r increase, supplier's information system investment increase. It means that as manufacturer transfer its belief about trust to suppliers, suppliers are willing to invest information systems to send its type signal, so trust mechanism can promote IOS adoption. Supplier will change its trustworthiness level and decrease its opportunisms.

3.3 Stage Three, Supply Chain Trust Mechanism Value Creation

According to conclusions before, we can see what behaviors would supplier and manufacturer select, manufacturer choose trust level and order quantity according to supplier's information systems investment, supplier choose the optimal information systems investment to maximize its profits.

Under supply chain trust governance mechanism, manufacturer's profits function is:

$$Ep_m \mid q^* = \int_0^{+\infty} (p \times q \mid q^* - P \times q \mid q^*) f(a \mid q^*) da$$

$$+ \int_{-\infty}^{+\infty} g(a) \times f(a \mid q^*) da$$

Manufacturer's profits function without trust is:

$$Ep_m = \int_0^{+\infty} (p \times q - P \times q) f(a) da + \int_{-\infty}^{+\infty} g(a) \times f(a) da$$

$$\because r \mid q^* > r \Rightarrow q \mid q^* > q$$

$$\therefore Ep_m \mid q^* = (p - P) q \mid q^* \times r \mid q + Eg(a \mid q^*)$$

$$> Ep_m = (p - P) q \times r + Eg(a)$$

Where g(a) is the function supplier's behavior affect manufacturer's profits, its a monotonically increasing function of variable a.

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Obviously, supply chain cooperation is stronger with trust mechanism than that without trust, and manufacturer's expected profits is bigger, this increased profits can seen as the value created by trust. We can get the similar conclusion for supplier.

Then, we can draw a conclusion that, with trust mechanism, the supply chain whole profits is Pareto optimal, and trust create values.

4. CONCLUSION

The paper builds a three-stage supply chain model, analyzes how trust governance mechanism effects supply chain value creation. Under certain conditions, supplier can send trustworthiness signal by invest information system, manufacturer's beliefs about supplier determine supplier's signal cost, then manufacturer choose optimal trust level based on supplier's behavior, at last supply chain performance was determined. Supply chain information system investment's signal effect can incentive supply chain members to build up the information system, and get the whole supply chain Pareto optimal. In the game, participants' dominant position and negotiating capacity effects first-mover advantage, how would negotiating capacity effects on supply chain members' profits is future work.

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REFERENCES:

[1] G P. Huber, "A theory of the effects of advanced information technologies on organizational design, intelligence, and decision making", *Academy of Management Review*, Vol. 15, No 1, 1990, pp. 47-71.

[2] K S. Soliman, B D. Janz, "An exploratory study to identify the critical factors affecting the decision to establish Internet-based interorganizational information systems", *Information & Management*, Vol 41, No 6, 2004, pp. 697-706.

[3] B. Klein, "Fisher-General Motors and the nature of the firm", *Journal of Law and Economics*, Vol. 43, No 1, 2000, pp. 105-141.

[4] S J. Xu,Shi-hua Ma, "A Study on Trust Crisis between Inter-Firm in Supply Chain in China", *Computer Integrated Manufacturing Systems*, Vol. 8, No 1, 2002, pp. 51-53.

[5] D M.Rousseau, S B.Sitkin, R S Burt, "Not so different after all: A cross-discipline view of trust", *Academy of Management Review*, Vol. 23, No 3, 1998, pp. 393-404.

[6] B. Mcevily, V. Perrone, A. Zaheer, "Trust as an Organizing Principle", *Organization Science*, Vol. 14, No 1, 2003, pp. 91-103.

[7] E C. Kasper-Fuehrera, N M. Ashkanasy, "Communicating trustworthiness and building trust in interorganizational virtual organizations", *Journal of Management*, Vol. 27, No 3, 2001, pp. 235.

[8] P. Ratnasingam. "Trust in inter-organizational exchanges: a case study in business to business electronic commerce", *Decision Support Systems*, Vol. 39, No 3, 2005, pp. 525-544.

[9] M. Nielsen, K. Krukow, V Sassone, "A Bayesian Model for Event-based Trust", *Electronic Notes in Theoretical Computer Science*. Vol. 172, No 1, 2007, pp. 499-521.

[10] Z H.Yan, C X. Teng, L. Liu, "Transfer Mechanism of Supply Chain Trust and Its Equilibrium", *Journal of Management Science*, Vol. 23, No 6, 2010, pp. 64-71.