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Abstract: The development of cross-border e-commerce highlights the importance of service integration and information sharing. This paper considers a cross-border B2B supply chain which consists of a local manufacturer and a foreign trade service integrator. The service integrator holds the service cost structure as private information. The optimal decisions and maximum expected profits of the manufacturer and service integrator are analyzed under two scenarios：no information sharing versus information sharing. The paper finds that information sharing always benefit the manufacturer but not for the service integrator. In the meanwhile, the value of information is increased with the manufacturer's forecast uncertainty about the service integrator's service cost. The whole supply chain can get pareto improvement through the Nash bargaining mechanism.

Keywords: Cross-border e-commerce, Supply chain management, Information sharing, Service decision

1. INTRODUCTION

Cross-border e-commerce usually refers to transactions, payments and logistics in different countries through e-commerce [1]. As a new type of e-commerce, cross-border e-commerce has been widely spread and developed rapidly under the national strategy background of "One Belt and One Road (B&R)" in China [2]. According to the data from China's cross-border e-commerce research center in May 2017, China's cross-border e-commerce import and export reached 6.6 trillion yuan in 2016, Increased by 38.7% over the same period in 2015, and B2B accounted for 88.7% of total transactions in China's cross-border e-commerce.

China's B2B cross-border e-commerce SME (small- and medium-sized enterprises) trade occurs mainly through foreign trade service integrators [3]. These all-in-one integrators (e.g., Onetouch.alibaba.com, Globalsources.com, DHgate.com) with integrated services for international logistics, cross-border payments, internet financing, multilingual services, etc. [4]. These integrated services can not only enhance the platform experience, but also bring new customers to the SME. For example, DHgate.com is rich in supporting services to10 million enterprises and individual buyers from nearly 230 countries and regions provided by specialist partners from logistics (UPS, DHL, FedEx, TNT, etc.), to payments (MasterCard, VISA, American Express, etc.), to technology innovation, to internet financing (China Construction Bank, etc.).

Due to the dynamics of resources, customers and services, these service integrators often keep some private information in order to seek more profits, which causes the information asymmetry problem[5]. The existence of asymmetric information often leads to the loss of efficiency and brings difficulties to the coordination of the supply chain system. How to collaborate with these service integrators under information asymmetry become a key issue restricting the development of china's cross-border e-commerce.

Cost information asymmetry is ubiquitous in distributed supply chain systems [6]. Kumar and Pugazhendhi[7] indicated that information sharing is one of the important tools of coordination among firms in a supply chain,

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and allow enterprises to refine their strategies of supply chain to maximize their profits. Ketzenberg et al.[8] reported that the value of information sharing can range from 0 to 30% profit increase.

Information sharing has been extensively studied in previous literature. The early research focuses on the incentives to share information with horizontal competition in oligopoly(Gal-Or[9]; Li[10]). Recent literature has been studied different types of information (e.g., demand, cost, inventory) sharing under complex competition. Some papers focused on demand information sharing. For example, Zhang [11] took the leakage effect into account and suggested that the retailers will not share private demand information with the supplier in Cournot duopoly. Li and Zhang [12] examined how the level of confidentiality influences firms information sharing decisions. Ha et al. [13] focus on vertical information sharing under two competing supply chains consider production diseconomies. Jiang and Hao [14] examined both vertical and horizontal information sharing under different channel structures. Cost-information sharing has also been studied by several scholars. For example, Yao et al. [15] explored cost information sharing in a supply chain by considering value-added costs as retailer's private information, they indicated that the retailers are not always better off with information sharing. Zhou and Zhu [16] investigated the incentive for cost-information sharing under Cournot competition. Kostamis and Duenyas [17] demonstrated the value of both cost and demand information sharing. Zhao et al. [18] considered a supply chain with two service providers competing for one client. Setak et al. [19] demonstrated that the manufacturer with cooperative advertising program can encourage the retailers to share their cost information.

In this paper, we study information asymmetry in a cross-border B2B supply chain composed of a local manufacturer and a synthesized service integrator, the actual service cost is known only to services integrator herself unless she shares it with the manufacturer. We aim to address the following problems:

a) How do supply chain members decide under complete and uncomplete information scenario?
b) Can service cost information sharing improve supply chain profitability?
c) Is it possible to induce service integrator to sharing information?

The remainder of this paper is organized as follows. In Section 2, we present the problem and the assumptions of the model. In Section 3, we present the decision under no information sharing case. In Section 4, we present the decision under complete information. In Section 5, we analyze the model and discuss a profit distribution mechanism. In Section 6, we conclude the paper and give the future research directions.

2. MODEL DESCRIPTION

We consider a cross-border B2B supply chain composed of a local manufacturer and a cross-border service integrator (SI). The SI provide service package at price p_s to foreign buyers, the service package includes pre-sales consulting, supplier selection, supplier qualification certification, logistics and route selection, financing loans, export tax rebates, etc. The manufacturer produces a single product at a unit cost c_m and sells his product to foreign buyers at a price p_m through SI, and need to pay SI a membership fee K. The assumption reflects the practice of cross-border service platforms (e.g., Globalsourse.com, Alibaba.com, Made-in-China.com,etc.) who use the membership mechanisms. We assume that the membership fee K is fixed and exogenous to our model. We note that in this paper, the fixed membership fee K does not have any effect on the results, then K is not included in our model analysis and discussion.

Let D_m, D_{si} denote the consumer demand from the manufacturer and SI, respectively. We utilize a linear demand function which is widely used in supply chain literature (Tsay and Agrawal[19] ; Dan et al.[5]). The corresponding demand functions to the manufacturer and the SI are described as follows:

$$D_{si} = a - b_1 p_s + \gamma_1 s \tag{1}$$

$$D_m = a - b_1 p_s - b_2 p_m + \gamma_1 s + \gamma_2 s \tag{2}$$

Where $a > 0$ corresponds to market potential; $b_1 > 0$ is the coefficient of service price elasticity of D_S;$b_2 > 0$ is the coefficient of price elasticity of D_m. The parameters γ_1 is the SI's services sensitivities of the service demand and γ_2 are the free-ride services sensitivities to the manufacturer $(\gamma_1 > \gamma_2 > 0)$.$s$ is the service package level determined by SI. We use the service package to represent the all forms of SI's services together which is widely used in previous literature (Li et al. [20]; Dan et al. [21]). The conditions $D_{si} \geq 0$, $D_m \geq 0$ are specified to ensure that both demand non-negative.

The SI's service cost function is generally assumed to be convex with a commonly adopted form [5], [15] as below:

$$C_{si} = \frac{1}{2}\eta s^2 \quad (3)$$

Where η is an efficiency parameter for the SI 's cost,$\frac{dC_{si}}{ds} > 0, \frac{d^2C_{si}}{ds^2} > 0$. this cost parameter is assumed to be the private information, known only to the SI. Many streams of research find that firms may protect their advantage by hiding their cost information, and they are reluctant to reveal their private information for the risk of information leakage [11], [12]. From the manufacturer's point of view, this parameter is a random variable with a known probability distribution f (η).

With the above notation, the SI's and the manufacturer's profit function are given by

$$\Pi_M = (p_m - c_m)D_m \quad (4)$$

$$\Pi_{SI} = p_s D_{si} - \frac{1}{2}\eta s^2 \quad (5)$$

There is no leader in this supply chain.The manufacturer and SI make price decisions independently of each other. Thus, the SI determines its price p_s and service level s to maximize its profit Π_{SI}. Uninformed manufacturer determines its price p_m to maximize its profit Π_M.

For ease of reference, we add super script ND, SD on the equilibrium outcomes, where ND indicates that SI neither share signals nor cooperate in decision making, SD indicates that SI share signals and independently make decisions. We will contrast the optimal policies of both channel partners in the two cases: incomplete information when the manufacturer didn't get the exact cost information (Section 3), and information sharing when the manufacturer knows η exactly (Section 4).

3. THE CASE OF NO INFORMATION SHARING (ND)

In this section, we solve the game-theoretic problem for the case of no information sharing. The actual service cost is known only to SI herself unless she shares it with the manufacturer. The manufacturer does not know the exact value of η, but knows its distribution. According to Yao et al. [15], we assume that η is uniformly distributed, i.e., $\eta \sim U[\bar{\eta} - \varepsilon, \bar{\eta} + \varepsilon]$. $\bar{\eta}$ and ε are the average and deviation of the service cost efficiency, respectively.

The manufacturer and the SI make their decisions to maximize their own profit respectively. The model in no information sharing case is presented as follows:

$$\begin{cases} \max\limits_{p_m} E(\Pi_M^{ND}) = \int_{\bar{\eta}-\varepsilon}^{\bar{\eta}+\varepsilon} (a - b_1 p_s + \gamma_1 s - b_2 p_m + \gamma_2 s)(p_m - c_m) f(\eta) d\eta \\ \quad = \frac{1}{2\varepsilon} \int_{\bar{\eta}-\varepsilon}^{\bar{\eta}+\varepsilon} (a - b_1 p_s + \gamma_1 s - b_2 p_m + \gamma_2 s)(p_m - c_m) d\eta \\ \max\limits_{p_s,\ s} \Pi_{SI}^{ND} = p_s D_{si} - \frac{1}{2}\eta s^2 \\ s.t.\ \ D_{si} > 0, D_m > 0 \end{cases} \quad (6)$$

Proposition1: Under the no information sharing case, the manufacturer's optimal prices, SI's optimal service price and optimal service level can be given as:

$$p_m^{ND} = \frac{a(\gamma_1{}^2+2\gamma_1\gamma_2)\, ln\, [\frac{2b_1(\bar{\eta}+\mathcal{E})-\gamma_1{}^2}{2b_1(\bar{\eta}-\mathcal{E})-\gamma_1{}^2}]+4b_1(2c_m b_2+a)\varepsilon}{16b_1b_2\varepsilon} \tag{7}$$

$$p_s^{ND} = \frac{\eta a}{2b_1\eta-\gamma_1{}^2} \tag{8}$$

$$s^{ND} = \frac{\gamma_1 a}{2b_1\eta-\gamma_1{}^2} \tag{9}$$

Where $2b_1(\bar{\eta}-\mathcal{E})-\gamma_1{}^2>0$

Proof:

Suppose the condition $2b_1(\bar{\eta}-\mathcal{E})-\gamma_1{}^2>0$ satisfy, since $\bar{\eta}-\mathcal{E}<\eta<\bar{\eta}+\mathcal{E}$,which indicates that $2b_1\eta-\gamma_1{}^2>0$.

The hessian matrix $H=\begin{bmatrix}-2b_1 & \gamma_1\\ \gamma_1 & -\eta\end{bmatrix}$ is negative definite when the conditions $2b_1\eta-\gamma_1{}^2>0$ satisfy, so Π_{SI}^{ND} is jointly concave with p_s, s.

The optimal decisions for SI are obtained by solving the first-order conditions:

$$\begin{cases}\frac{\partial}{\partial s}\Pi_{SI}^{ND} = -\eta s+p_s\gamma_1 = 0\\ \frac{\partial}{\partial p_s}\Pi_{SI}^{ND} = -2b_1p_s+\gamma_1 s+a = 0\end{cases} \tag{10}$$

Further substituting p_s^{ND} and s^{ND} into the manufacturers' profit functions in Eqs. (6), we get $\frac{d\Pi_M^{ND^2}}{dp_m^2}=-2b_2<0$, by solving the first-order conditions, we can obtain the manufacturers' optimal prices p_m^{ND}.

Corollary 1. The optimal profits of the manufacturer and SI are:

$$\Pi_M^{ND} = \frac{(a(\gamma_1{}^2h+2\gamma_1\gamma_2h+4b_1\varepsilon)-8b_1b_2c_m\varepsilon)g}{256b_1{}^2b_2(b_1\eta-\frac{\gamma_1{}^2}{2})\varepsilon^2} \tag{11}$$

$$\Pi_{SI}^{ND} = \frac{\eta a^2}{4b_1\eta-2\gamma_1{}^2} \tag{12}$$

Where $g=a[\frac{h\gamma_1{}^4}{2}+h\,\gamma_1{}^3\gamma_2-b_1(h\eta-2\varepsilon)\gamma_1{}^2-2\,b_1\,\gamma_1\gamma_2(h\eta-4\varepsilon)+4b_1{}^2\eta\varepsilon]+4b_1b_2c_m\varepsilon(2b_1\eta-\gamma_1{}^2)$

$h=\ln[\frac{2b_1(\bar{\eta}+\mathcal{E})-\gamma_1{}^2}{2b_1(\bar{\eta}-\mathcal{E})-\gamma_1{}^2}]$

4. THE CASE OF INFORMATION SHARING (SD)

In this section, we solve the game-theoretic problem for the case where the manufacturer has complete information about the SI's service cost parameter η. The model in information sharing case is presented as follows:

$$\begin{cases}max_{p_m}\, E(\Pi_M^{SD}) = (a-b_1p_s+\gamma_1 s-b_2p_m+\gamma_2 s)(p_m-c_m)\\ max_{p_s,s}\, \Pi_{SI}^{SD} = p_sD_{si}-\frac{1}{2}\eta s^2\\ s.t.\ \ D_{si}>0, D_m>0\end{cases} \tag{13}$$

Proposition2: Under the information sharing case, the manufacturer's optimal prices, the SI's optimal service price and optimal service level can be given as:

$$p_m^{SD} = \frac{a(b_1\eta+\gamma_1\gamma_2)+c_m b_2(2b_1\eta-\gamma_1{}^2)}{2b_2(2b_1\eta-\gamma_1{}^2)} \tag{14}$$

$$p_s^{SD} = \frac{\eta a}{2b_1\eta-\gamma_1{}^2} \tag{15}$$

$$s^{SD} = \frac{\gamma_1 a}{2b_1\eta-\gamma_1{}^2} \tag{16}$$

Proof:

Following the same procedure as what is done in the proof of Proposition1, we have the result.

Corollary 2. The optimal profits of the manufacturer and SI are:

$$\Pi_M^{SD} = \frac{(a(b_1\eta+\gamma_1\gamma_2)+c_m b_2(\gamma_1{}^2-2b_1\eta))^2}{4b_2(2b_1\eta-\gamma_1{}^2)^2} \tag{17}$$

$$\Pi_{SI}^{SD} = \frac{\eta a^2}{4b_1\eta-2\gamma_1{}^2} \tag{18}$$

Above, we have obtained closed form solutions for all decision variables and the respective profits of both parties in terms of the market parameters. The difference in profits in these two cases will give us the value of the information to the manufacturer. We will discuss these models in more detail in the next section.

5. DISCUSSION

5.1 The value of information sharing

In this subsection, we study the interesting question of how the profit of each channel partner changes from the incomplete information case to the complete information case.

Proposition 3. (i)The manufacturer's profit will always increase when the information about the SI's service cost structure is shared with him. The amount of increase $\Delta\Pi_m$ is given by:

$$\Delta\Pi_M = \frac{a^2\gamma_1{}^2(\gamma_1+2\gamma_2)^2\left((2b_1\eta-\gamma_1{}^2)h-4b_1\varepsilon\right)^2}{256b_1{}^2b_2(2b_1\eta-\gamma_1{}^2)^2\varepsilon^2} > 0 \tag{19}$$

(ii) The SI does not benefit from the information sharing, her profit is the same as SD and ND scenario, $\Delta\Pi_{SI} = \Pi_{SI}^{SD} - \Pi_{SI}^{ND} = 0$.

(iii) Service cost information sharing can improve the whole supply chain profitability, $\Delta\Pi = \Delta\Pi_M$>0.

Proof:

By the equilibrium results given in Corollary1 and Corollary 2, we have

$\Delta\Pi_M = \Pi_M^{SD} - \Pi_M^{ND} = \frac{a^2(2b_1\eta h-h\gamma_1{}^2-4b_1\varepsilon)^2\gamma_1{}^2(\gamma_1+2\gamma_2)}{256b_1{}^2b_2(2b_1\eta-\gamma_1{}^2)^2\varepsilon^2}$, It is easy to verify that $\Delta\Pi_M$>0.

Obviously, $\Delta\Pi_{SI} = \Pi_{SI}^{SD} - \Pi_{SI}^{ND} = 0$,then the amount of total supply chain profit increase is $\Delta\Pi = \Delta\Pi_M > 0$. Hence the claim.

To examine the effects of service uncertainty ε on the supply members optimal decisions, we take the first-order partial derivatives of $\Delta\Pi$ with respect to ε, and obtain the following proposition.

Proposition 4. The amount of manufacturer's profit increase $\Delta\Pi_m$ is increased with the manufacturer's estimate uncertainty ε.

Proof:

We rewrite the equation (19) as follows: $\Delta\Pi_M = [\frac{a^2\gamma_1^2(\gamma_1+2\gamma_2)^2}{256b_1^2b_2(2b_1\eta-\gamma_1^2)^2}][\frac{(2b_1\eta-\gamma_1^2)h-4b_1\varepsilon}{\varepsilon}]^2$.

let $g = (2b_1\bar{\eta} - \gamma_1^2), k = (2b_1\eta - \gamma_1^2), l = (\frac{(2b_1\eta-\gamma_1^2)h-4b_1\varepsilon}{\varepsilon})^2 = (\frac{kh-4b_1\varepsilon}{\varepsilon})^2$,we can obtain $\frac{\partial\Delta\Pi}{\partial\varepsilon}$ by solve$\frac{\partial l}{\partial\varepsilon}$.

$\frac{\partial l}{\partial\varepsilon} = \frac{2k}{\varepsilon^2}\left[\frac{kh-4b_1\varepsilon}{\varepsilon}\right]\left[\frac{(4b_1^2\varepsilon^2-g^2)h+4b_1g\varepsilon)}{(g+2b_1\varepsilon)(g-2b_1\varepsilon)}\right]$.

When $\varepsilon = 0, h = \ln[\frac{2b_1(\bar{\eta}+\varepsilon)-\gamma_1^2}{2b_1(\bar{\eta}-\varepsilon)-\gamma_1^2}] = \ln[\frac{g+2b_1\varepsilon}{g-2b_1\varepsilon}] = \frac{4b_1\varepsilon}{g}=0$

When$0 < \varepsilon < \bar{\eta}, h = \ln[\frac{2b_1(\bar{\eta}+\varepsilon)-\gamma_1^2}{2b_1(\bar{\eta}-\varepsilon)-\gamma_1^2}] > \frac{4b_1\varepsilon}{g} > 0, \ln[\frac{2b_1(\eta+\varepsilon)-\gamma_1^2}{2b_1(\eta-\varepsilon)-\gamma_1^2}] > \frac{4b_1\varepsilon}{k} > 0$

It can be shown that $\frac{kh-4b_1\varepsilon}{\varepsilon} > \frac{\frac{k4b_1\varepsilon}{k}-4b_1\varepsilon}{\varepsilon} > 0$, $\frac{(4b_1^2\varepsilon^2-g^2)h+4b_1g\varepsilon)}{(g+2b_1\varepsilon)(g-2b_1\varepsilon)} = \left[\frac{4b_1g\varepsilon}{(g+2b_1\varepsilon)(g-2b_1\varepsilon)} - h\right] > 0$,thus $\frac{\partial l}{\partial\varepsilon} > 0$.

Therefore $\frac{\partial\Delta\Pi}{\partial\varepsilon} > 0$.

Proposition 4 shows that the more uncertain the manufacturer's estimate about the SI's service cost structure, the higher the value of information. It would be profitable for the manufacturer if he can encourage the SI to share her service cost information, $\Delta\Pi_M$ would be the maximum amount the manufacturer would be willing to spend for the information. Notice that the SI's profit is the same as SD and ND scenario because her optimal service price and service level only depend on her own cost structure, so the SI has no incentives to share her service cost information to the manufacturer. The willingness of SI to share her cost information can be achieved by a profit allocation mechanism. Next section we will use a Nash bargaining model to solve this problem.

5.2 Nash bargaining solution

In this subsection, we want to figure out how to align benefits between members and create motivation to induce service integrator to sharing information.

Let $\Delta\Pi_M{}^*, \Delta\Pi_{SI}{}^*$ respresent the portion of the extra-profit the manufacturer and the SI received at the information sharing scenario, respectively. In order to ensure the success of the information sharing, an optimal profit scheme is acceptable to both the manufacturer and the SI only if $\Delta\Pi_M{}^* > 0, \Delta\Pi_{SI}{}^* > 0$.

According to Nash[23],We assume that both the manufacturer and the retailer have the following utility functions:

$$U_M = (\Delta\Pi_M{}^*)^{\varphi_1} \quad (20)$$

$$U_{SI} = (\Delta\Pi_{SI}{}^*)^{\varphi_2} \quad (21)$$

.

Where $\Delta\Pi_M{}^* + \Delta\Pi_{SI}{}^* = \Delta\Pi. \varphi_1, \varphi_2$ are the bargaining power for manufacturer and SI, respectively. Bargaining power is determined by negotiation skills, risk tolerance and bargaining tactics, etc.

The optimal bargaining profit scheme is obtained by maximizing the system utility function:

$$\begin{cases} \text{Max } U_M U_{SI} = (\Delta\Pi_M{}^*)^{\varphi_1}(\Delta\Pi_{SI}{}^*)^{\varphi_2} \\ \text{s.t. } \Delta\Pi_M{}^* + \Delta\Pi_{SI}{}^* = \Delta\Pi \end{cases} \quad (22)$$

The optimal solution of this problem is $\Delta\Pi_M{}^* = \frac{\varphi_1}{\varphi_1+\varphi_2}\Delta\Pi, \Delta\Pi_{SI}{}^* = \frac{\varphi_2}{\varphi_1+\varphi_2}\Delta\Pi$.

Where $\Delta\Pi = \frac{a^2\gamma_1{}^2(\gamma_1+2\gamma_2)^2\left((2b_1\eta-\gamma_1{}^2)h-4b_1\varepsilon\right)^2}{256b_1{}^2b_2(2b_1\eta-\gamma_1{}^2)^2\varepsilon^2}$. Thus, both the manufacturer and the SI can gain from information sharing, which leads to a win-win solution for the whole cross-border B2B supply chain.

6. CONCLUSIONS

In this paper, we present a cross-border B2B supply chain composed of a local manufacturer and a service integrator who face a demand sensitive to product price, service price, and service level. We assume only services integrator has private information about her service cost to reflect the information asymmetry between supply members. The manufacturer is assumed to be the Stackelberg leader, and two scenarios are analyzed: no information sharing case and the complete information case. Our results indicate that information sharing always has a positive impact on the manufacturer's performance but not for the service integrator. The service integrator would be motivated to share its private information with the manufacturer under some profits allocation mechanisms.

Our research can be extended in many two directions. First, we can figure out what kind of contracts can coordinate the supply chain. Second, we can consider the competition among several manufacturers and service integrators.

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