

A Coordination Mechanism of Supply Chain under Asymmetric Information Based on Supply Hub

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Abstract—The Supply Hub could be applied to the downstream in the supply chain. The research showed that Supply Hub could integrate supply chain system in the corresponding stages, strengthen information sharing and supply chain coordination. The paper studied a supply chain with multiple manufacturers and multiple retailers dealing with a single product, established models of supply chains with and without a Supply Hub in its downstream under asymmetric information environment respectively. The result showed that the information sharing taken by Supply Hub could optimize the decision-making in supply chain, which can improve the whole benefits of supply chain system as well.

Keywords- supply chain coordination; Supply Hub; asymmetric information; information sharing

I. INTRODUCTION

A Supply Hub is a location generally close to a manufacturer's facility where all or some of its supplies are warehoused with the agreement that the materials will be paid for only after consumed. Supply Hub is an innovative strategy to achieve cost reduction and improved responsiveness [1]. Supply chain is composed by different stakeholders; each of them is seeking to maximize their own interests, so the logistics, information flow, capital flow in supply chain should be coordinated, in order to maximize revenue of whole supply chain system.

In general, manufacturers are the core of the supply chain; retailers are at the end of the supply chain, so they are subjected to the market demand uncertainty more directly. In common, the retailers are weaker than the core enterprises in supply chain, and they are lack of ability to share information, in the transaction process they also have an incentive to conceal private information in order to raise their own revenue. In addition, retailers are in larger quantities so that the core enterprises are difficult to collect their information. These circumstances will lead to decline in the whole benefits of supply chain.

Supply Hub model can be applied not only to upstream, but also to downstream in the supply chain, located between manufacturers and retailers. The Supply Hub not only provides traditional vendor-managed inventory or third-party logistics services, but can be a supply chain integrator, which can

enhance information sharing, and provide overall supply chain solutions efficiency.

II. LITERATURE REVIEW

Thomas and Griffin (1996) reviewed the literature addressing coordinated planning between two or more stages of the supply chain, placing particular emphasis on models that would lend themselves to a total supply chain model, suggested directions for future research [2]. They early studied supply chain coordination systematically. Lee et al (1997) claimed that the information transferred in the form of "orders" tended to be distorted and could misguide upstream members in their inventory and production decisions [3]. They analyzed how the information transmission had impact on the supply chain performance early. Li and Liu (2008) developed an extended newsboy model and presented a coordination decision policy in a supply chain consisting of one manufacturer and one retailer [4]. Li and Zhang considered information sharing in a decentralized supply chain where one manufacturer supplied to multiple retailers competing in price, each retailer had some private information about the uncertain demand function which he may choose to disclose to the manufacturer [5].

Barnes et al (2000) proposed the concept of Supply Hub, described the dynamics of the operation of Supply Hubs, and provided case example [1]. Shah and Goh (2006) dealt with the joint management of operations at the Supply Hub for the customer and the upstream supplier, and suggested a structured hierarchical approach which can help Supply Hub in achieving balance between various parties involved in chain [6]. Ma et al (2008, 2009) carried out a systematic study of the Supply Hub. They analyzed the supply-driven supply chain collaborative operation mode based on Supply Hub to solve the problem of production and distribution collaborative decision-making in context of Supply Hub [7]; proposed the collaborative decision models between production and distribution for considering and not considering the distribution lot-sizing matching among suppliers respectively, in order to study the collaborative decision problem about suppliers' distribution lot-sizing in context of Supply Hub[8]; introduced the concept of Supply Hubs embedded BOM to establish three supply chain design models with no Supply Hub, one Supply Hub and two Supply Hubs, respectively, carried out case study [9].

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Currently, there are many researches on supply chain coordination, but few of them study the coordinating role of Supply Hub in supply chain. Existing studies of Supply Hub usually focus on inventory, replenishment, distribution and other operational aspects, and Supply Hub is generally constructed in the upstream of supply chain. This paper studies a supply chain with multiple manufacturers and multiple retailers dealing with a single product, establishes models of supply chains with and without a Supply Hub in its downstream under asymmetric information environment respectively, shows that the information sharing taken by Supply Hub could optimize the decision-making in supply chain, which can improve the whole benefits of supply chain system as well.

III. THE MODEL

Considering the downstream of a supply chain with m manufacturers and n retailers, there is no difference among the various manufactures and retailers, and they are equal and independent respectively. The market demand is nonlinear price elasticity, as $D(p) = Kp^{-\alpha}$ ($K > 0, \alpha > 1$). The cost for each manufacturer is s , the manufacturers provide a product at wholesale price w to retailers. Each retailer orders the product in the quantity q , and then sells them to end customers at retail price p .

A. Supply chain under asymmetric information

We assume that c is the cost of each retails, and the asymmetric information exists between retailers and manufacturers, retails know their own cost information, while manufacturers do not know it. But the manufacturers know that the retailers' demand distribution range of c is $[\underline{c}, \bar{c}]$, and $0 \leq \underline{c} \leq \bar{c} \leq \infty$, its distribution function is $F(c)$ with density function $f(c)$, the mathematical expectation is μ , $F(c)$ is differentiable and strictly increasing.

The total order quantity of retailers is $Q = nq$, and should be equal to the market demand:

$$Q = D = Kp^{-\alpha} \quad (1)$$

The profit of single retailer is:

$$\begin{aligned} \pi_r(p, q) &= q(p - w - c) = \frac{Q}{n}(p - w - c) \\ &= \frac{Kp^{-\alpha}}{n}(p - w - c) \end{aligned} \quad (2)$$

Because retailers know their own cost, by optimizing first-order condition $\frac{\partial \pi_r}{\partial p} = 0$, we have the optimal retail price:

$$p_1^* = \frac{\alpha(w + c)}{\alpha - 1} \quad (3)$$

Thus, the optimal order quantity is got by:

$$Q_1^* = K \left[\frac{\alpha - 1}{\alpha(w + c)} \right]^\alpha \quad (4)$$

$\pi_p(w)$ in equation 5 represents the profit for a single manufacturer. So for the manufactures would try to maximize $E[\pi_p(w)]$. Meanwhile, retailers may select an order quantity to maximize their own expected profit, represented by Q_1^* in equation 5, so:

$$\begin{aligned} E[\pi_p(w)] &= E \left[\frac{Q^*(w)(w - s)}{m} \right] \\ &= \int_{\underline{c}}^{\bar{c}} \left\{ \frac{K}{m} \left[\frac{\alpha - 1}{\alpha(w + c)} \right]^\alpha (w - s) \right\} f(c) dc \end{aligned} \quad (5)$$

Thus, optimal wholesale price can be obtained by max $E[\pi_p(w)]$:

$$w^* = \frac{\alpha s + \mu}{\alpha - 1} \quad (6)$$

Manufacturers don't know the cost of retails, so take it as its mathematical expectation. We get the optimal retail price from (3) and (6):

$$p_2^* = \left(\frac{\alpha}{\alpha - 1} \right)^2 (s + \mu) \quad (7)$$

Combining (7) and (1), the optimal order quantity can be expressed as:

$$Q_2^* = \frac{K}{(s + \mu)^\alpha} \left(\frac{\alpha - 1}{\alpha} \right)^{2\alpha} \quad (8)$$

The expected profit of each retailer is given from (2), (6), (7):

$$\pi_r = \frac{K}{n(s + \mu)^{\alpha-1}} \frac{(\alpha - 1)^{2\alpha-2}}{\alpha^{2\alpha-1}} \quad (9)$$

The expected profit of each manufacturer is:

$$\pi_p = \frac{Q^*(w)(w + s)}{m} = \frac{K}{m(s + \mu)^{\alpha-1}} \frac{(\alpha - 1)^{2\alpha-1}}{\alpha^{2\alpha}} \quad (10)$$

Finally, the whole supply chain profits would be:

$$\Pi_1 = m\pi_p + n\pi_r = \frac{K}{(s + \mu)^{\alpha-1}} \left[\frac{(2\alpha - 1)(\alpha - 1)^{2\alpha-2}}{\alpha^{2\alpha}} \right] \quad (11)$$

B. Supply chain with Supply Hub

The total profit of supply chain system is given by:

$$\Pi = Q(p - s - c) = Kp^{-\alpha} (p - s - c) \quad (12)$$

Supply Hub has the business advantage, so it helps retailers to conduct forecasting, ordering, purchase and distribution, even more, provides financial support by its own capability. Manufacturers produce in accordance with the requirements of Supply Hub, thus achieve time-to-order production. Since Supply Hub participate the purchase, production, sales of the relevant supply chain members, it can obtain information comprehensively, so it can share information in supply chain, and eliminate the asymmetric information on the cost of retailers. As an integrator in supply chain, even more, Supply Hub can play a controlling role in the corresponding stage of supply chain, achieve the centralized optimal decision-making.

So we get the optimal retail price maximizing the total profit for the whole supply chain by $\frac{\partial \Pi}{\partial p} = 0$:

$$p_3^* = \frac{\alpha(s+c)}{\alpha-1} \quad (13)$$

Thus, the total profit for whole supply chain due to Supply Hub's centralized optimal decision-making is given by:

$$\Pi_2 = K\alpha^{-\alpha} \left(\frac{\alpha-1}{s+c} \right)^{\alpha-1} \quad (14)$$

C. The case study

We assume that there are $m=3$ manufacturers, $n=5$ retailers, demand factor is $K = 1.0 \times 10^6$, elasticity factor is $\alpha = 3$, the cost of each manufacturer is $s = 10$, the cost of each retailers is $c = 4$. Under asymmetric information, manufacturers think that c obey uniform distribution on the $[1, 9]$, the mathematical expectation is $\mu = \frac{c + \bar{c}}{2} = 5$.

According to equation (11), we get the expected profit of whole supply chain under asymmetric information:

$$\begin{aligned} \Pi_1 &= \frac{K}{(s+\mu)^{\alpha-1}} \left[\frac{(2\alpha-1)(\alpha-1)^{2\alpha-2}}{\alpha^{2\alpha}} \right] \\ &= \frac{1 \times 10^6}{(10+5)^{(3-1)}} \left[\frac{(2 \times 3 - 1)(3-1)^{(2 \times 3 - 2)}}{3^{2 \times 3}} \right] = 487.74 \end{aligned}$$

Also due to equation (14), we can get the total profit for whole supply chain with Supply Hub's centralized optimal decision-making:

$$\begin{aligned} \Pi_2 &= K\alpha^{-\alpha} \left(\frac{\alpha-1}{s+c} \right)^{\alpha-1} \\ &= 1 \times 10^6 \times 3^{(-3)} \left(\frac{3-1}{10+4} \right)^{(3-1)} = 756.31 \end{aligned}$$

$\Pi_2 > \Pi_1$, the total profit of supply chain system rose by 55.06% by centralized optimal decision-making based on Supply hub.

For different cost of retailers, the corresponding expectation is estimated by manufacturers. We compare the profit for the

whole supply chain under asymmetric information and the profit for the whole supply chain with Supply Hub; the result is showed in Figure 1.

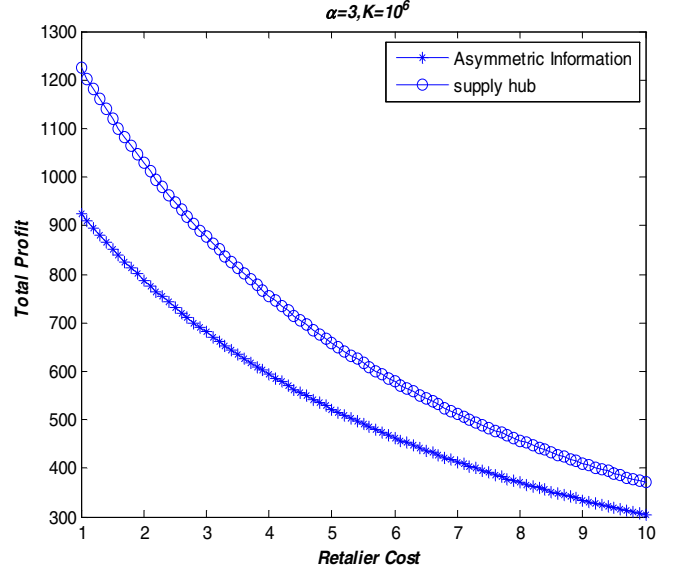


Figure 1. Total Profit Comparison for two models (I)

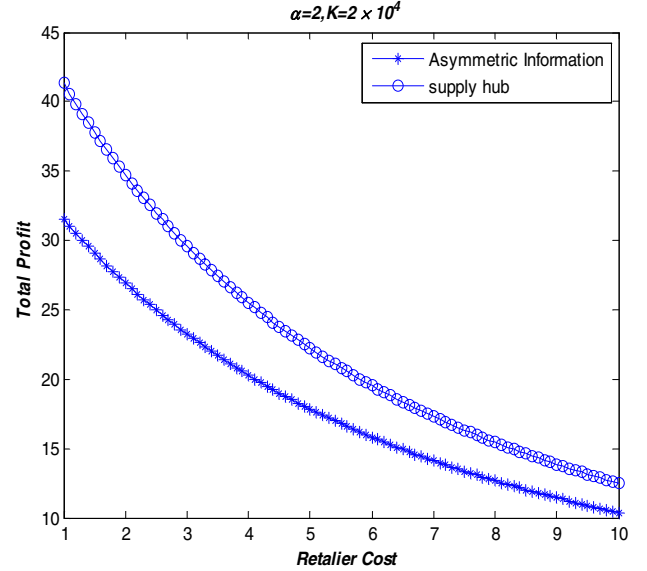


Figure 2. Total Profit Comparison for two models (II)

The above comparisons indicate that the total profit of supply chain with Supply Hub centralized optimal decision-making is always superior to the total profit of supply chain without Supply Hub under asymmetric information.

IV. CONCLUSION

Supply Hub is established in the upstream of supply chain generally, the research shows that Supply Hub can also affect the downstream performance (profit) of supply chain, not only provide third-party logistics services, but also promote the optimization of the whole supply chain. Supply Hub can grasp

the relevant supply chain members' operations, should be the controller in appropriate stage of the supply chain. It provides the necessary support to various members, which can facilitate information sharing in supply chain. Model and case study show that, due to the centralized optimal decision-making under information-sharing based on Supply Hub, the total profit of supply chain system is improved.

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